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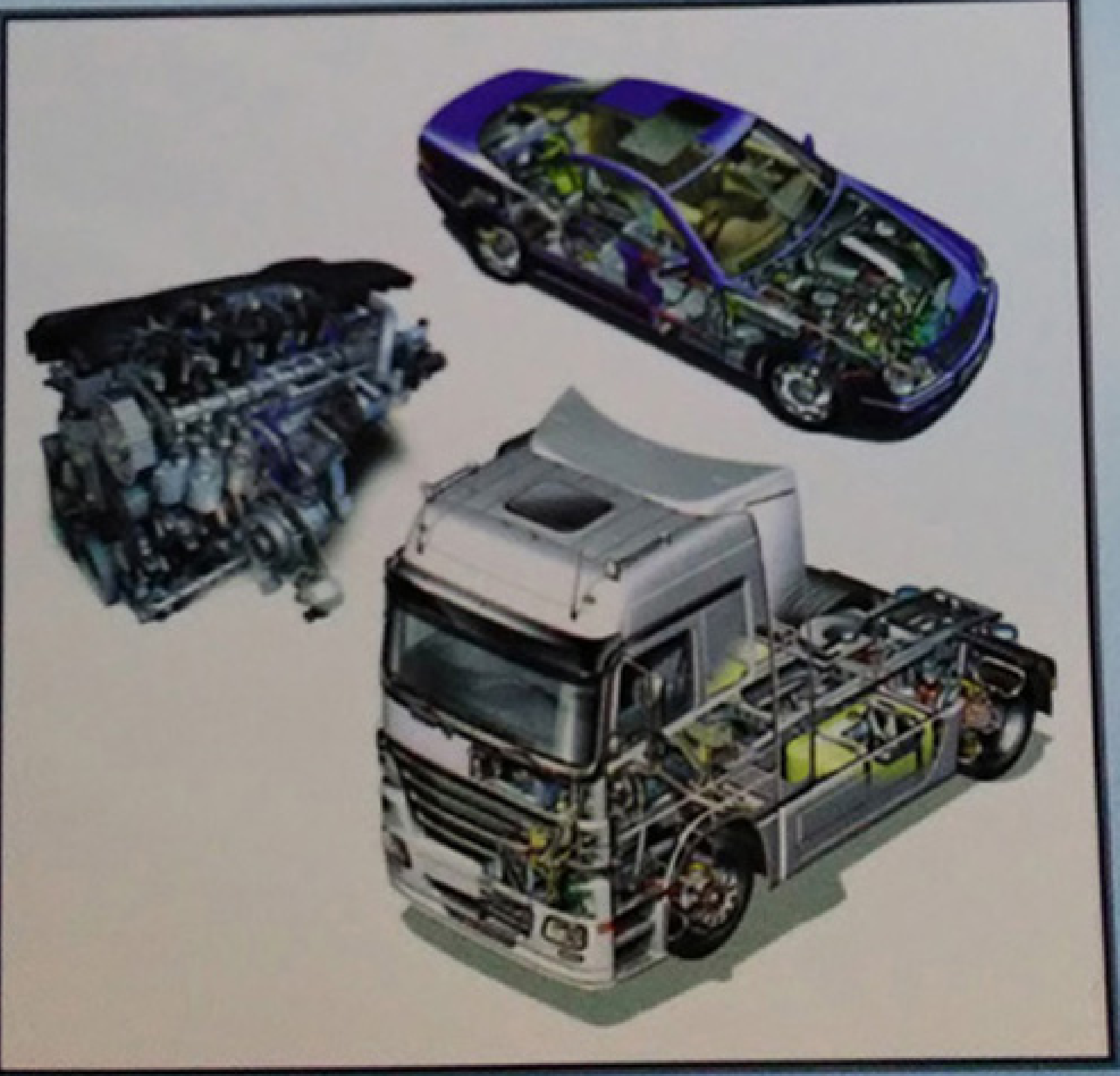
Study guide



Ministry of education and science of Ukraine
Kharkiv national automobile and highway university

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This publication describes the design and operation of mechanisms, units and systems of cars and internal combustion engines for the purpose of teaching and self-training of university students in the direction of "mechanical engineering" and "transport" in the scope of the curriculum.

У даному виданні описані будова та робота механізмів, агрегатів і систем автомобілів і двигунів внутрішнього згоряння з метою навчання та самопідготовки студентів ЗВО з напрямку «механічна інженерія» та «транспорт» у обсязі навчального плану.

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INTRODUCTION

Automobile (or automobile) is a symbol of the 20^{th} century and is an integral part of human life. It was created due to the talented and enterprising people, engineers for a state of mind or education, production organizers and investors who saw a car as a way to get profit. The development of the car is closely associated with its integral part – the internal combustion engine (ICE).

The concept "automobile" includes vehicles intended for the transportation of passengers (cars and buses), cargo and transport equipment. Special attention is paid to cars and buses, since the life and rights of citizens are protected by the legislation of leading world countries.

Car creation is divided into three stages: draft design, engineering and design study. At each stage, technical solutions are thought out, thanks to which the car becomes attractive and arouses the interest of consumers.

For two hundred years of its existence, the car has practically not changed. Despite a number of fundamental structural differences between multiple cars, they have a lot in common: an internal combustion engine (ICE); body; chassis. Therefore, cars are classified and joined into groups; categories and types.

As the design of the car is improved and thanks to the development of electronics, today the automobile has become safer, faster, more economical, more comfortable and more reliable than its first models, therefore, studying the design of a car will allow students to become more educated in the automotive industry.

Studying such disciplines as "Automobiles", "Layout of automobile", "Layout of machinery with ICE" and the like, students should familiarize themselves with the device and the principle of operation of the main elements and units of the car, as well as understand the structure of the formation of a car as a single machine, which a man directly controls.

The material given in this compendium of lectures will provide the student with an understanding of special technical disciplines for the operation, repair and design of a car, and will also give a general idea of the structure of units, elements, assemblies, mechanisms and systems installed on a car.

The use of compendium of lectures in the educational process will allow students, while studying in specialized disciplines, to acquire the necessary basic knowledge on the design of cars and machinery with an internal combustion engine.

The authors of this publication express their gratitude to the team of the Department of Automobiles of the Kharkiv National Automobile and Highway University for their support in the preparation of the study guide "Construction and layout of automobiles and internal-combustion engines".

1 CONCEPTUAL MODULE

The history of development of automotive industry. Classification of cars and internal combustion engines. General layout of the car

1.1. Subject and content of the course.
1.2. Stages of automotive industry development in CIS countries.
1.3. Classification of automobiles.
1.4. General layout of automobile.
1.5. Classification of car internal-combustion engines.

1.1. *Subject and content of the course*

This lecture course is aimed at studying such disciplines as “Automobiles” and “Layout of machinery with internal combustion engines” and is the first course of lectures on the study of a car, a tractor and other machinery. This lecture course is the main one in the study of other subjects of a special cycle, providing the training of highly qualified specialists in the maintenance, repair and design of cars and engines. After studying this lecture course, an educational practice is carried out, on which the acquired knowledge is consolidated. The main objective of the course is to gain solid knowledge of the design and operation of the main units, mechanisms and systems of the car.

1.2. *Stages of automotive industry development in the CIS*

The only enterprise that produced cars in Russia was the Russian-Baltic Carriage Works (Riga). At this plant, as a rule, cars were assembled from imported spare parts. From 1908 to 1915, the plant produced 451 passenger cars and a small number of trucks and special vehicles. Evacuated to Moscow during World War I, the Russian-Baltic plant ceased to exist in 1915. The automobile industry had to be practically recreated. There are several main stages in the development of the automotive industry.

The first stage (1924–1930) was characterized by small-scale production of cars. The first Soviet cars AMO-15 with a carrying capacity of 1.5 tons were produced in 1924 in Moscow at the AMO plant (now PO ZIL) in the amount of 10 pieces. In 1925, the production of YaZ trucks (Yaroslavl automobile plant) began.

At the second stage (1931–1946), the main attention was paid to the creation of a material base for the mass production of cars, personnel were trained. During this period, a plant in Moscow was reconstructed and an automobile plant was built in the city of Gorky. GAZ entered service in January 1932 and produced GAZ-AA and GAZ-MM trucks, as well as GAZ-A and M-1 cars, and the Moscow plant produced ZIS-5 trucks and ZIS-101 cars. Then, in 1943, the GAZ-67B off-road passenger car was produced, and in 1946 the GAZ-51 truck and the M-20 Pobeda passenger car. At the third stage (1947–1958), vehicles of new designs were developed. GAZ in 1948 began production of GAZ-63, Moscow plant - ZIS-150 and ZIS-110. In 1947, the production of Moskvich-400 vehicles began.

In connection with the commissioning of new plants: Minsk, Pavlovsk, Kutaisi, Kremenchuh and Lviv plant, the type of trucks and cars has expanded even more, as well as of the buses.

The fourth stage (1959–1965) was characterized by an increase in the number of cars produced, an increase in their quality, as well as the specialization and cooperation of automobile plants. New car models appear: Zaporizhzhia Automobile Plant (ZAZ), Ulianovsk Automobile Plant, Ural Automobile Plant, etc. Specialization of plants of Yaroslavl, Kremenchuh, Zhodinsky (BelAZ) was taking place.

The fifth stage (1966–1970) was characterized by the reconstruction and technical re-equipment of existing plants (GAZ, ZIL, AZLK, MAZ, BelAZ, etc.) and the construction of new plants in Izhevsk and Volzhsk.

The sixth stage (1971-1980). The automotive industry developed especially intensively during this decade. The Kamsk automobile plant was built. The main result of this period is the creation of an industrial basis for the dieselization of trucks.

The seventh stage (from 1981 to 1992) is characterized by further development of the automotive industry, improvement of economic and environmental performance of engines. Since 1992 - a plant in Ukraine.

1.3. *Classification of automobiles*

The automotive industry produces different types of cars depending on the purpose and adaptability to road conditions.

By purpose, cars are divided into:

- passenger cars (cars and buses);
- trucks (Am. Eng.) or lorries (Br. Eng.):

Car accommodating less than 8 people are called ***passenger cars***; those accommodating more than 8 people are called ***buses***.

Special vehicles mainly perform non-transport work. These include utility vehicles for cleaning and watering streets, firefighters, truck cranes, car dealerships, etc.

Specialized vehicles transport goods according to specific qualities or characteristics: bulk, liquid, large-sized timber, pipes, etc.

According to their adaptability to road conditions, we distinguish the cars of normal and increased cross-country ability.

All cars, depending on the type and purpose, are divided into classes, according to which they are marked.

Each car model has its own designation, depending on whether it is a basic or modification. The basic model is the car model, on the basis of which its modifications are produced. This is the main car model produced in large quantities.

The base car model is assigned a four-digit numeric code, in which the first two digits represent the class, and the next two represent the car model. In this case, the letter designation of the manufacturer is placed in front of the digital index.

A modification is a car model that differs from the baseline in some indicators (structural and operational) that meet certain requirements and operating conditions. For example, modifications may differ from the base model in the engine used, bodywork, interior trim, etc.

Modifications have a five-digit numeric index, in which the fifth digit means the modification number of the base model.

Passenger cars are divided into five classes depending on the capacity of the cylinders (tank capacity) of the engine (Table 1.1).

Buses are also divided into five classes depending on their length (Table 1.1).

Trucks are divided into seven classes depending on their gross weight (Table 1.1).

Table 1.1 - **The designation system of the rolling stock of road transport (first 2 digits)**

Rolling stock	Index						
Passenger cars	With capacity, l:						
	Up to 1.2	1.3…1.8	1.9…3.5	Over 3.5			
	11	21	31	41			
Buses							
	Up to 5	6…7.5	8…9.5	10.5…12	Over 16.5		
	22	32	42	52	62		
Trucks	With gross weight, t:						
	Up to 1.2	1.3...2	2.1…8	8.1…14	14.1…20	20.1…40	Over 40
With onboard platform	13	23	33	43	53	63	73
Semitrailer tractors	14	24	34	44	54	64	74
Dump trucks	15	25	35	45	55	65	75
Tanks	16	26	36	46	56	66	76
Vans	17	27	37	47	57	67	77
Special	19	29	39	49	59	69	79

Trailers and semitrailers are marked with a four-digit numeric index (Table 1.2), preceded by the letter designation of the manufacturer. The second two digits of the index (Table 1.3) out of four for trailers and semitrailers are assigned depending on their total mass, according to which trailers and semitrailers are divided into five groups.

Table 1.2 - **Designation system of the trailer train of road transport (first 2 digits)**

Type of trailers and semitrailers	Index		Type of trailers and semitrailers	Index	
	For trailers	For semitrailers (pole-trailers)		For trailers	For semitrailers and pole-trailers
Passenger	81	91	Dump trucks	85	95
Bus	82	92	Tanks	86	96
Trucks (sided)	83	93	Vans	87	97
			Special	89	99

Table 1.3 - **The designation system of the trailer train of road transport (last 2 digits)**

Group	Index	Gross weight, t	
		Trailers and semitrailers	Pole-trailers
1	01…24	До 4	До 6
2	25…49	4…10	6…10
3	50…69	10…16	10…16
4	70…84	16…24	16…24
5	85…99	over 24	over 24

An example of a car designation: VAZ - 21099i

VAZ is a manufacturer (Volzhsk Automobile Plant); 2 – car class (engine capacity from 1.3–1.8); 1 – type of car (passenger); 09 – car model (this is the difference between cars of the same manufacturer); 9 – modification of the car (out-of-hay some kind of novelty in the existing model); i – version of execution (it can be either a number or a letter, in this example the modification of the car has an injection engine)

In accordance with the UNECE Regulations, vehicles are classified into the following categories and subcategories (Table 1.4).

Table 1.4 - **Classification according to UNECE Regulations**

Category of the vehicle	Subcategory of the vehicle	Type of the vehicle	Gross weight, t	Maximum speed	Engine capacity, cm^3	Notes
L	L_1	Two-wheel	----	Up to 50	Up to 50 cm^3 Up to 4 kWh	Mopeds
	L_2	Three-wheel	----	Up to 50	Up to 50 cm^3 Up to 4 kWh	Mopeds
	L_3	Two-wheel	----	Over 50	Unlimited	Motorcycles
	L_4	Three-wheel	----	Over 50	Unlimited	Scooters
	L_5	Three-wheeled	----	Over 50	Unlimited	Tricycles
	L_6	Four-wheel	Up to 0.35	Up to 50	Up to 50 cm^3 Up to 4 kWh	Light quadricycle
	L_7	Four-wheel	Up to 0.55	Over 50	Up to 15 kWh	Quadricycle

M	M_1	Having at least 4 wheels and carrying no more than 8 people (except for the driver)	----	----	Unlimited	Passenger cars
	M_2	Having at least 4 wheels and carrying more than 8 people (except for the driver)	Up to 5	----	Unlimited	Buses
	M_3	Having at least 4 wheels and carrying no more than 8 people (except for the driver)	Over 5	----	Unlimited	Buses, including articulated buses
N	N_1	Having at least 4 wheels and carrying loads	Up to 3.5	----	Unlimited	Trucks and special
	N_2	Having at least 4 wheels and carrying loads	From 3.5 to 12	----	Unlimited	Trucks, special vehicles, towing vehicles
	N_3	Having at least 4 wheels and carrying loads	Over 12	----	Unlimited	Trucks, special vehicles, towing vehicles
O	O_1	Powerless vehicle	Up to 0.75	----	----	Trailers and semitrailers
	O_2	Powerless vehicle	From 0.75 to 3.5	----	----	Trailers and semitrailers
	O_3	Powerless vehicle	From 3.5 to 10	----	----	Trailers and semitrailers
	O_4	Powerless vehicle	Over 10	----	----	Trailers and semitrailers
T	***T***	Four-wheel	----	----	----	Tractors and forestry equipment

Vehicles of categories M, N and *O* can be classified as special-purpose vehicles, which are intended for passenger and cargo transportation associated with the performance of special functions, which require a special body and (or) special equipment. The designation of the special purpose vehicle category must be supplemented with the symbol "***C***". For example, a medical aid vehicle of category M_2 must have the designation $\boldsymbol{M_2C}$.

The designations of off-road vehicles of categories *M* and *N* are supplemented with the letter "***G***". Certain requirements are imposed on such vehicles for wheel drive, ground clearance, maximum climb, entry and exit angles, the presence of differential lock mechanisms and some others. For example, an N_1 vehicle that meets the requirements for off-road vehicles should be designated $\boldsymbol{N_1G}$.

Agricultural and forestry tractors, wheeled or tracked, are mainly intended for towing, pushing, transporting or driving certain devices, mechanisms or trailers intended for use in agriculture or forestry. Such a tractor can be adapted to transport goods and service personnel.

In addition to the classification in accordance with the UNECE Regulations, in Europe there is still an unofficial classification of passenger cars by dimensions (Table 1.5).

Table 1.5 - **European classification of passenger cars by dimensions**

Class	A	B	C	D	E	F
Length, m	Up to 3.6	3.6–3.9	3.9–4.4	4.4–4.7	4.6–4.8	Over 4.8
Width, m	Up to 1.6	1.5–1.7	1.6–1.75	1.7–1.8	Over 1.8	Over 1.8

1.4. *General layout of automobile*

An automobile (or a car) is a self-propelled vehicle driven by an engine and intended for the carriage of passengers, cargo or transport equipment. A car is a complex machine, consisting of parts, assemblies, mechanisms, assemblies and systems.

A part is a product made of a homogeneous material (by name and brand), without the use of assembly operations. The part with which the assembly of a unit, mechanism or an assembly begins is called base.

A unit is a series of parts connected to each other by means of threaded, riveted, welded and other connections.

A mechanism is movably interconnected parts or units that transform motion and speed.

An assembly is several mechanisms connected into one whole.

A system is a set of mechanisms, units and assemblies that are in relationships and connections with each other, perform certain functions during operation.

All mechanisms, assemblies and systems form three main parts that make up the car: engine, body and chassis.

Since the designs of cars are very diverse, we will consider the general device using the example of a car with a piston-type internal combustion engine (ICE) and a classic arrangement (engine in front, driving wheels at the rear.

Engine is a power plant that converts any type of energy into mechanical work. The engine consists of 2 mechanisms (crank and gas distribution) and 5 systems (*lubrication system, cooling* system, power supply system, ignition system and engine starting system).

Body serves to accommodate the driver, passengers and cargo, and to protect them from external actions. The engine is also located within the body.

Chassis is a set of mechanisms, assemblies and systems that provide movement and control of the vehicle. The chassis consists of a transmission, undercarriage and control systems (steering and brake).

Transmission is used to transmit and convert the torque from the engine to the drive wheels. The transmission consists of a clutch, gearbox, cardan gear (for a rear-wheel drive vehicle), main gear, differential and semi-axles.

Undercarriage contains elements that ensure the integrity of the vehicle and the possibility of its movement. It consists of the bearing system, suspension, axles and propellers (wheeled or caterpillar type).

Steering is used to change the trajectory of the vehicle.

Brake control has the following functions:

- reducing the speed of the car including its stop;
- maintaining a constant vehicle speed on long descents;
- keeping a stationary car in place.

1.5. *Classification of automobile ICE*

Most modern cars are equipped with piston internal combustion engines (ICE)

Internal combustion engines are classified according to the following criteria:

1) designation - transport and stationary;

2) the way of carrying out the working cycle – four-stroke and two-stroke;

3) the method of mixture formation – with external mixture formation – carburetor and gas and with internal mixture formation – diesel engines;

4) the method of ignition of the working mixture – with forced ignition from an electric spark (carburetor, gas, etc.); with compression ignition (self-ignition) – diesel engines;

5) the type of fuel used – gasoline-powered; heavy fuel diesel engines; internal-combustion engines running on gas;

6) the number of cylinders;

7) arrangement of cylinders – single-row: with vertical arrangement of cylinders, with a skew of the cylinders' axis from the vertical; 2-row: *V* – shaped with different camber angles, opposed;

8) the method of filling the cylinders with a fresh charge – naturally aspirated engines, with supercharging;

9) the type of cooling – with liquid or air cooling.

The following designations are adopted for marking engines:

Ch - four-stroke; D - two-stroke; R - reversible; C - shipboard with reversible clutch; P - with a reduction gear; K - crosshead; N - supercharged.

The numbers indicate: the first is the number of cylinders; the number in front of the line is the diameter of the cylinder in cm; the number after the slash – piston stroke in cm; the last figure is modernization.

Example: diesel 8ChN 12/14 - eight-cylinder, four-stroke, non-reversible, supercharged, cylinder diameter 140 mm, piston stroke 140 mm.

References

1. Кисликов В.Ф., В.В. Лущик. Будова й експлуатація автомобілів. Київ: Либідь, 2018. – 400 с.

2. Омеличев А.А. Підручник з будови автомобіля. – Дніпро: Моноліт, 2019. – 288 с.

Test questions

?

1. What car is called a passenger car?
2. How long is the small bus?
3. What does the second digit in the classification of passenger cars VAZ 21099 mean?
4. Decipher the designation of KamAZ-740 diesel engine according to the classification.
5. What is a car and what is its purpose?
6. What is an internal combustion engine?
7. What is a transmission and what is its purpose?

2 CONCEPTUAL MODULE

General layout of internal combustion engine. Operating principle of piston, gas turbine and jet ICE

2.1. The layout and basic concepts of ICE.
2.2. Operating principle of piston ICE.
2.3. Operating principle of gas turbine and jet engines.

2.1. *Layout and basic concepts of ICE*

ICEs belong to the most common type of heat engines, i.e., those in which the heat released during the combustion of the working fluid is converted into mechanical energy. Heat engines can be divided into two main groups:

- engines with external heat supply, EEHS (external combustion: steam, Stirling, etc.)
- internal combustion engines ICE (piston, combined, gas turbines, reactive).

The schematic diagram of the internal combustion engine consists of the following parts: crankcase 1, cylinder 2, exhaust 3 and intake 4 valves, cover (cylinder head) 5, piston 6, connecting rod 7, crankshaft 8 (Fig.2.1).

The base of the engine body is crankcase 9, it houses the crankshaft 7. Cylinder 1 and other parts are attached to it.

Designation of the main parts of the internal combustion engine.

Crankcase is made by casting and reinforced with stiffening ribs. It has two parts. The lower part of the crankcase is cast or it is made in the form of a stamped pallet 8.

Cylinder 1 houses piston 5, which has the shape of a glass, with the bottom turned towards the cylinder head. In the inner cavity of the cylinder, the piston moves back and forth. The piston is sealed by piston rings.

The volume between the head 5 and the piston 6 at top dead center (TDC) forms a *combustion chamber*. The movement of the piston in the

cylinder is transmitted to the shaft 7 by means of the attached *connecting rod* 6, which is in the form of a profile rod with two heads.
The connecting rod head, which unites the connecting rod with the shaft journal, is called the lower head.

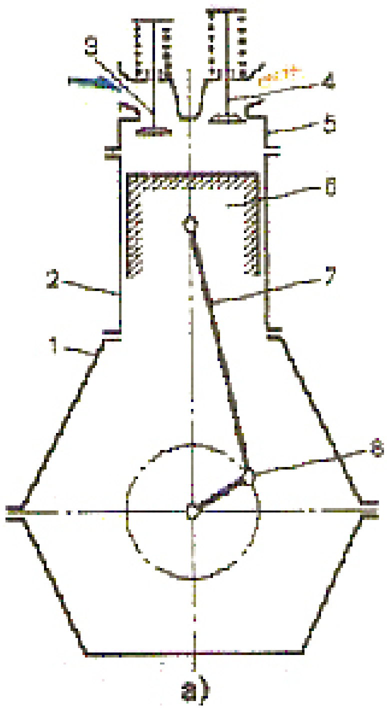

Fig. 2.1. **Schematic diagram of a piston internal combustion engine**

The connecting rod head, which pivots the connecting rod to the piston through the piston pin, is called the upper head.

The distance *L* between the axes of the upper and lower heads is the length of the connecting rod.

The size (crank) of the *crankshaft* throw is indicated by the radius R.

In an internal combustion engine with a split crankshaft crankcase, it is located in support bearings (liners).

To bring the mechanism out of the dead center, a *flywheel* made in the form of a cast (or stamped) disk with a massive rim is installed on the crankshaft flange.

2.2. *Operating principle piston ICE*

The operation of the internal combustion engine is based on the use of the force of gas pressure on piston 6, when they expand during combustion in the cylinder. A mixture of fuel vapors and air entering cylinder 2 through valves 3 is ignited at a certain moment by an electric spark. During combustion, the working fluid expands and presses on the walls of the combustion chamber and piston 6. The piston moves and transfers the force to the crankshaft crank 8.

Thus, **four** main processes take place in the engine cylinder: **intake**, **compression**, (the working stroke of the combustion of the mixture and **expansion** of combustion products, as a result of which the released thermal energy is partially converted into mechanical work), and **release**.

Through the valves, the working fluid is inlet and the exhaust gases are released.

The set of the processes (cycles) repeated in cylinders is called a working cycle.

Engine performance depends on the following design parameters:

Top dead center (TDC) is the extreme upper position of the piston.

Bottom dead center (BDC) is the lowest position of the piston.

Crank radius (R) is the distance from the crankshaft main journal axis to the connecting rod journal axis.

Piston stroke (S) is the distance between the extreme positions of the piston equal to twice the radius of the crankshaft crank.

Stroke is a part of a working cycle that occurs in one piston stroke.

Capacity of the cylinder (V_h) is the volume of space freed by the piston when it is moved to TDC, to BDC.

Combustion chamber volume (V_c) is the volume of space above the piston at its position from TDC.

Total volume of the cylinder (V_a) is the volume of the space above the piston when it is in BDC.

Obviously, the total volume is the amount

$$V_a = V_h + V_c.$$

Engine capacity V_l (l) in multi-cylinder engines is the sum of the capacities of the cylinders or

$$V_л = V_h \cdot i = \frac{\pi \cdot D^2 \cdot S}{4} \cdot i. \qquad (1)$$

where i is the number of cylinders (usually written on the trunk of light cars).

Compression ratio ε is the ratio of the total volume V_a of the cylinder to the volume V_c of the combustion chamber

$$\varepsilon = V_a / V_c = (V_h + V_c) / V_c = V_h / V_c + 1$$

The compression ratio shows how many times the total volume of the engine cylinder decreases when the piston moves from BDC to TDC. The compression ratio is dimensionless.

For gasoline internal combustion engines ε = 6,5 – 10

diesel engine ε = 14 – 21

With increasing compression ratio ε the engine power increases.

Piston stroke *S* and cylinder diameter *D* determine the dimensions of the engine.

If the *S/D* ratio is 1, then the engine is called *short-stroke*.

If S/D> 1 – then the internal combustion engine is called *long-stroke*.

2.3. O*perating principle of a gas turbine engine, jet engines and combined*

Fuel combustion in a gas turbine engine (GTE) takes place directly in the combustion chamber 10. Fuel is supplied to it by a fuel pump through a nozzle. The air required for combustion is pumped by a compressor 13 mounted on the same shaft with the impeller of the gas turbine 12. The combustion products enter the impeller of the turbine 12 through the guide vane 11 under high pressure and rotate it (Fig. 2.2).

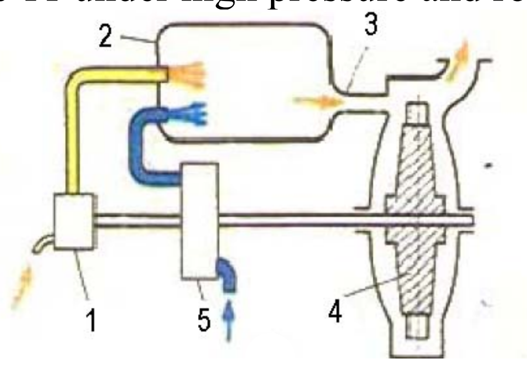

Fig. 2.2. Gas turbine engine: 1 - fuel pump;
2 - combustion chamber; 3 - guiding device; 4 - gas turbine; 5 - compressor

The gas turbine operates at a high speed; however, it is inferior to the piston internal combustion engine in terms of efficiency.

In *jet* internal combustion engines (Fig. 2.3), liquid fuel and oxidizer, found in tanks 14 and 15, in one way or another (for example, with the help of pumps 3) get into the combustion chamber 10. Combustion products expand. Under high pressure, they flow out of the nozzle 17. The outflow of gases from the nozzle is the cause of the engine's jet thrust.

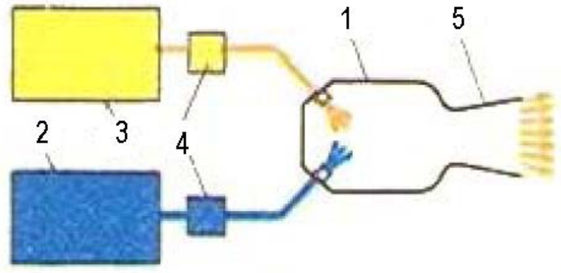

Fig. 2.3. Liquid jet engine:
1 - combustion chamber; 2, 3 - fuel tanks; 4 - pumps; 5 - nozzle;

Combined engines are those that consist of a piston part and several compressor and expansion machines, as well as of devices for supplying and removing heat, united by a common working fluid.

For example: Piston ICE + GTE.

References

1. Кисликов В.Ф., В.В. Лущик. Будова й експлуатація автомобілів. Київ: Либідь, 2018. – 400 с.
2. Скляров В.М., Волков В.П., Скляров М.В. Автомобільні двигуни. Особливості конструкції: навч. посібник – Харків: ХНАДУ, 2012. – 405с.

Test questions

?

1. Which ICE design includes: liquid fuel tank, oxidizer tank, pump, combustion chamber, nozzle?
2. Which ICE layout includes: fuel system, combustion chamber, guide vanes, compressor?
3. What is dead center?
4. What is a piston stroke?
5. What is the capacity of a cylinder?
6. What is a combustion chamber?
7. What is the total volume of a cylinder?

3 CONCEPTUAL MODULE

Methods for preparing air-fuel mixture and regulation of its composition. Working cycle of a four-stroke and two-stroke ICE

3.1. Methods for preparing air-fuel mixture and regulating its composition.
3.2. Working cycle of a four-stroke engine.
3.3. Working cycle of a two-stroke engine.
3.4. Indicator and effective values.

3.1. *Methods for preparing air fuel mixture and regulation of its composition*

Internal combustion engines operate in wide speed and load modes, depending on its purpose. The crankshaft speed *n* in the internal combustion engine can vary over a wide range (min^{-1});

n_{max} = 800 – marine diesel engines;
5000 – automobile diesel engines;
2000 – tractor diesel engines;
4000 – cargo gasoline engines;
7000 – passenger gasoline engines;

One cycle takes 0.15–0.02s, two-stroke *t* is two times less.

This time is enough for intake, compression, evaporation, mixing, combustion and exhaust gas discharge. The processes are heterogeneous in different types of internal combustion engines (gasoline and diesel).

In an internal combustion engine with *spark ignition*, the mixture formation process begins in advance. The quality of mixture formation depends on the speed of air passing through the carburetor. The combustion process takes place only in the *gas phase*. The air is heated at the inlet. Mixing in such an engine is called *external*.

In *gas* engines, mixing fuel and air is even easier. Gas leaving the evaporator (heater) turns into a gaseous state, mixes with air and turns into a homogeneous working mixture. Mixing is *external.*

The rational (stoichiometric) ratio of air and gas in gas internal combustion engines is 1: 9, and in gasoline and diesel engines it is 1:15.

With such mixture ratios, the combustion process in an internal combustion engine is very efficient and economical.

In a diesel engine, the mixture is formed in a shorter time (20-30 times less than in gasoline engines). Fuel is injected 20-28^0 before TDC. High injection pressure provides a finely dispersed medium, which quickly turns into a vapor state.

One of the features of ignition in engines with external mixture formation is the limit of possible mixture depletion. As the load increases, the mixture has to be enriched, i.e., supply an additional amount of fuel, and such regulation is called *quantitative*.

In ICE with internal mixture formation, a heterogeneous mixture is formed in the cylinder. At the beginning, the most prepared zones burn out, and then the others, with the help of diffusion. Such regulation of the mixture is called *qualitative*.

Mixture control can be *combined* (for example, in gas diesels). Part of the diesel fuel is fed through the nozzle, and part of the gas – through the diffuser – the mixer.

3.2. *Working cycle of a four-stroke engine*

The working cycle of an internal combustion engine is a set of processes occurring in the engine, which are repeated in a certain sequence (Table 3.1) in each cylinder, as a result of which the internal combustion engine is continuously working (Fig. 3.1).

Table 3.1 - **The value of the parameters of the working fluid at different cycle times**

Crankshaft rotation angle	Stroke	Piston movement	ICE		Diesel	
			P, MPa	*T*, °C	*P, MPa*	*T*, °C
0–180	intake	down *r-a*	0.07–0.095	80–130	0.08–0.09	50–80
180–360	compression	up *a-c*	1.0–1.5	300–400	4–5	450–650
360–540	working stroke	down *c-z-b*	4–5.5	2200–2500	8–12	1600–2000
540–570	exhaust	up *b-r*	0.1–0.12	700–900	0.1–0.12	600–700

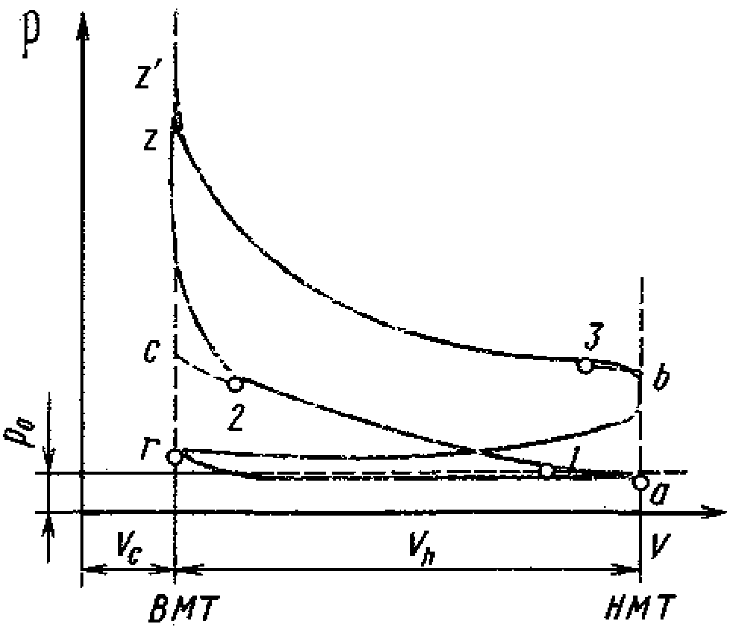

Рис. 3.1. **Indicator diagram of a 4-stroke internal combustion engine**

Depending on the ongoing processes, the working cycle is conventionally divided into strokes.

A stroke is a part of a working cycle that occurs in one piston stroke.

The working cycle of a four-stroke engine consists of the following processes: intake, compression, working stroke and exhaust, which are carried out in two revolutions of the crankshaft.

3.3. *Working cycle of a two-stroke engine*

From a consideration of a four-stroke engine, it follows that a four-stroke engine operates as a heat engine for only half of the time spent on a cycle (compression and expansion strokes). The second half of the time (intake and exhaust strokes), the engine operates as a pump.

In two-stroke engines, in which the working cycle is completed in two cycles (one revolution of the crankshaft) the time allotted for the working cycle is used better. Unlike four-stroke engines, two-stroke engines clean the working cylinder from combustion products and fill it with a fresh charge, i.e., gas exchange processes occur only when the piston moves near the BDC.

In this case, the cleaning of the cylinder from exhaust gases is carried out by displacing them not by a piston, but by air or a combustible mixture previously compressed to a certain pressure. The preliminary compression of air or mixture is carried out in a special purge pump or compressor, made in the form of a separate unit. In small engines, the internal cavity of the crankcase (curved-spike chamber) and the engine piston are sometimes used as a purge pump.

In the process of gas exchange in two-stroke engines, some of the air or combustible mixture is inevitably removed from the cylinder along with the exhaust gases through the exhaust bodies. This leakage of air or combustible mixture is taken into account when choosing the flow rate of the blowing pump or compressor.

Fig. 3.2 shows a diagram of the operation of a two-stroke engine with internal mixture formation and a direct-flow valve-slotted gas exchange scheme. The main features of this type of engine layout are:

- intake ports 8 are located in the lower part of the cylinder, whose height is about 10 ... 20% of the piston stroke; the opening and closing of the intake ports is performed by the piston when it moves in the cylinder;
- exhaust valves 4 are located in the cylinder cover, driven by a camshaft, whose rotation speed ensures that the valves open once per revolution of the crankshaft;
- a purge pump 2 forces air under pressure into the receiver 7 to clean the cylinder from combustion products and fill it with a fresh charge.

The working cycle in the engine is carried out as follows.

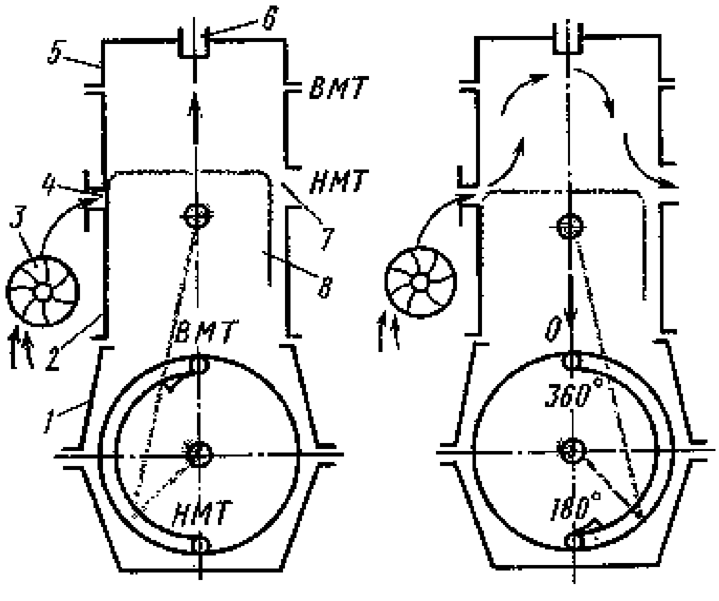

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Fig. 3.2. **Two-stroke internal combustion engine**: 1 - crankcase; 2 - cylinder; 3 - pump; 4.7 - purge windows; 5 - head; 6 - spark plug; 8 – piston

The first stroke corresponds to the piston stroke from TDC to BDC (fig. 3.3). Combustion has just occurred in the cylinder (line *cz*) and the process of gas expansion has begun, i.e., the working stroke is carried out. Somewhat earlier than the moment the piston approaches the intake ports, the exhaust valves 4 in the cylinder cover open, and the combustion products begin to flow out of the cylinder into the exhaust pipe; in this case, the pressure in the cylinder drops sharply (line *zn*). The inlet ports 8 are opened by the piston when the pressure in the cylinder becomes approximately equal to the pressure of the pre-compressed air in the receiver or slightly higher than it. Air entering the cylinder through the intake ports displaces the combustion products remaining in the cylinder through the exhaust valves and fills the cylinder (purging), i.e., gas exchange is carried out (section *na* on the indicator diagram).

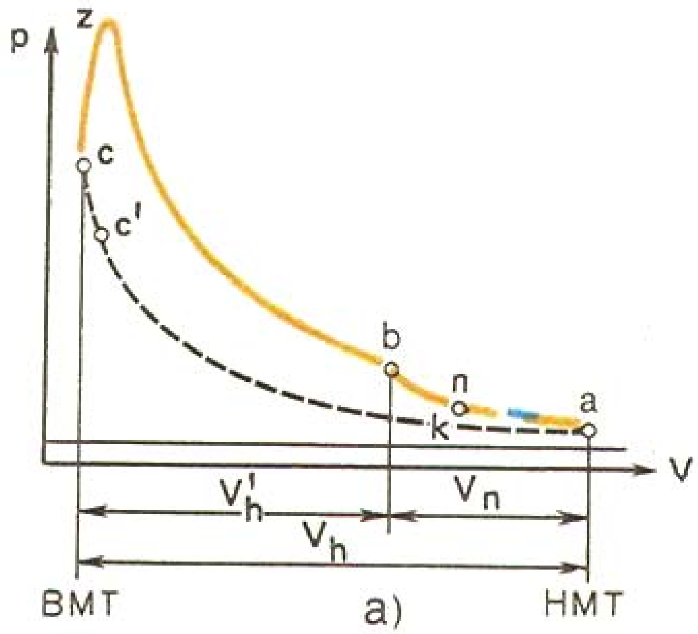

Fig. 3.3. **2-stroke ICE indicator diagram**

Thus, during the first stroke combustion of fuel, expansion of gases, release of gases, purging and filling of the cylinder take place in the cylinder.

The second stroke corresponds to the piston stroke from BDC to TDC (fig. 3.3). At the beginning of the piston stroke, the processes of removing exhaust gases, purging and filling the cylinder with a fresh charge continue. The end of cylinder purging (line *ak*) is determined by the timing of the closing of the intake ports and exhaust valves. The latter are closed either simultaneously with the inlet ports, or somewhat earlier. The pressure in the cylinder towards the end of the gas exchange in two-stroke engines is slightly higher than atmospheric pressure and depends on the air pressure in the receiver. From the moment the gas exchange ends and the piston completely closes the intake ports, the process of air compression begins. When the piston does not reach 10 ... 30 ° in the angle of rotation of the crankshaft to TDC (point *c′*), the fuel starts to flow into the cylinder through the nozzle.

Consequently, during the second stroke in the cylinder, the end of exhaust occurs, the cylinder is purged and filled at the beginning of the piston stroke and compressed during its further stroke.

In addition to the above-considered direct-flow valve-slotted scheme (Fig. 3.4, a) of gas exchange in two-stroke engines, other schemes are also used.

The loop gas exchange scheme (Fig. 3.4, b) greatly simplifies the design of the engine in comparison with the valve-slotted one, but at the same time the quality of gas exchange deteriorates and air or mixture losses occur during filling. The loop gas exchange scheme is distinguished by a wide variety of design options and is used in engines for various purposes (from low-power for mopeds and up to large ones with a capacity of several tens of thousands of kilowatts for ships).

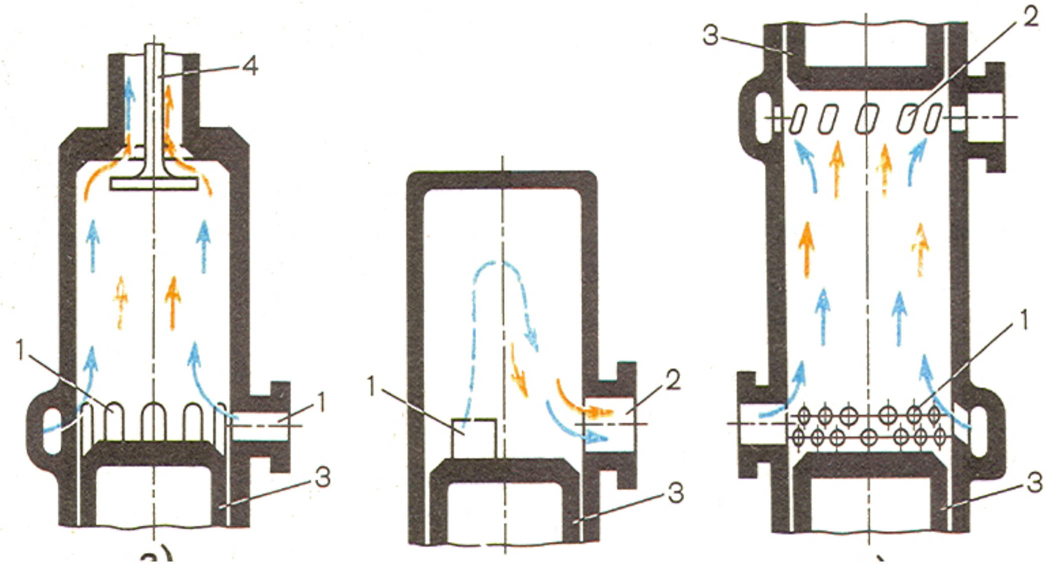

Fig. 3.4. **Gas exchange schemes in two-stroke engines**:
a - straight valve-crevice; b - loop;
c - straight-through with oppositely moving pistons.
1 - inlet window; 2 - outlet window; 3 - piston;
4 - outlet valve

The direct-flow gas exchange scheme from the opposite moving pistons (Fig. 3.4, c), in which one piston controls the inlet ports, and the other – the outlet ports, ensures high quality of gas exchange.

3.4. *Indicative and effective values*

The power that the gases develop in the engine cylinder is called the *indicator power* N_i. It characterizes the work performed by gases in the engine cylinder in one cycle, and is a parameter for assessing the cycle perfection. The area bounded by the curve shown in Figure 3.1 is equivalent to the indicator work L_i.

The *average indicator pressure* is the value P_i, which is such a conditionally permanently acting excess pressure, at which the work of gases performed during one piston stroke, equals to the *indicator work* for 1 cycle, kJ.

$$L_i = P_i \cdot V_h,$$

Knowing the indicator work, you can determine the indicator power kW.

$$N_i = P_i \cdot V_h \cdot i \cdot n/30 \cdot \tau,$$

where i is the number of cylinders;

n is the frequency of rotation of the motor shaft;

τ is engine strokes.

Indicative fuel consumption (g / kWh) is.

$$g_i = G_T \cdot 1000/N_i,$$

where *GT* is fuel consumption per hour (kg / h).

The degree of fuel use in the operating cycle, i.e., the economic efficiency of the engine is estimated by the indicator efficiency η_i, which is the ratio of the heat equivalent to the indicator work to all the heat released with the fuel when it is completely burned (Table 3.2)

$$\eta_i = L_i/22{,}4 \cdot H_u$$

Engine power N_e taken from the crankshaft is called *effective*, kW

$$N_e = N_i - N_m,$$

where N_m is the power of mechanical losses, which includes the costs of friction, gas exchange and the drive of auxiliary mechanisms.

Table 3.2 - **Technical and economic indicators of the internal combustion engine**

Engines	η_{ib}	η_e	g_i, g / kWh	g_e, g / kWh
Gasoline	0.28–0.39	0.25–0.33	245–300	250–325
Diesel	0.42–0.48	0.35–0.4	175–205	200–238
Gas	0.28–0.33	0.23–0.28	–	–

Effective efficiency

$$\eta_e = \eta_i \cdot \eta_m$$

where η_m is the mechanical efficiency.

Specific effective fuel consumption g_e estimates the amount of fuel consumed per unit of power g/kWh.

$$g_e = G_T \cdot 1000/N_e.$$

References

1. Кисликов В.Ф., В.В. Лущик. Будова й експлуатація автомобілів. Київ: Либідь, 2018. – 400 с.
2. Скляров В.М., Волков В.П., Скляров М.В. Автомобільні двигуни. Особливості конструкції: навч. посібник – Харків: ХНАДУ, 2012. – 405с.

Test questions

?

1. What is power?
2. What is effective power?
3. What is indicative power?
4. What is torque?
5. What does a cylinder capacity depend on?
6. What does the compression degree in cylinders depend on?
7. What is called a stroke in engine operation?
8. What is a working cycle of an engine?
9. What stroke occurs in the cylinder of a carburetor engine when the piston moves upwards with closed valves?
10. What stroke occurs in the cylinder of a carburetor engine when the piston moves down with one closed and the other open?
11. What stroke occurs in the cylinder of a carburetor engine when the piston moves upwards with one valve open and the other closed?
12. What stroke occurs in the cylinder of a carburetor engine when the piston moves down with valves closed?

4 CONCEPTUAL MODULE

Development of ICE power. Increasing efficiency and decreasing toxicity of piston internal combustion engines

4.1. Engine boost (pressurization).
4.2. Compressors (blowers).
4.3. Gas-dynamic boost (pressurization).
4.4. Turbo-compressors (turbochargers).
4.5. Air coolers.
4.6. Neutralization of exhaust gases.

4.1. *Engine boost*

ICE boost can be achieved in two ways

- By increasing the engine speed **n**
  - diesel - 4000 - 4500 min-1 Further increase is not advisable.
  - ICE - 5000 - 7000 min-1 Limited by the condition of durability
- By increasing the compression ratio **ε**
  - diesel 14 – 22
  - ICE 10 – 12

3. By a more modern method of mixture formation in the combustion chamber (CC) of the engine.

4. By the use of supercharging, which is usually widely used both in diesel engines and in engines equipped with gasoline injection. (R_e forcing).

5. By reducing mechanical loss N_m.

ICE boost is a process that increases the weight filling of the cylinders with air, including with the help of a compressor.

By the value of the generated pressure, the boost is divided into:

- low $R_{изб}$ up to 0.15 MPa;
- average $R_{изб}$ up to 0.2 MPa;

- high $R_{изб}$ over 0.2 MPa.

By to the method used to increase pressure, there are:

- supercharging with superchargers;
- boost using wave phenomena (gas-dynamic boost);

By drive type:

- with a mechanical drive;
- gas turbine supercharging;
- combined boost.

4.2. *Compressors (blowers)*

Compressors serve to compress air to a certain consumer pressure. ***Compressors are called volumetric*** if compression occurs in them when the closed volume decreases.

4.2.1. ***Rotary-gear compressors*** (Roots type) are characterized by a comparatively simple design, long service life, balanced rotor, high frequency of air supply and favorable dependence of the pressure change behind the compressor on the rotational speed of the rotors (for variable ICE modes). A diagram of such a compressor is shown in Fig.4.1

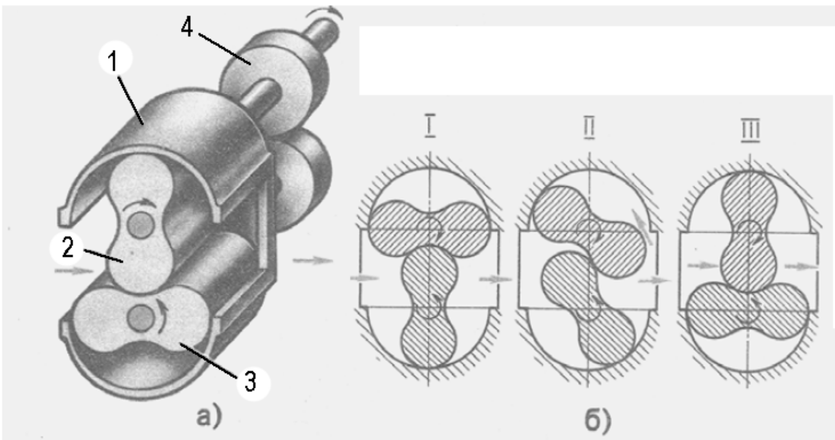

Fig. 4.1. Rotary gear compressor:
a - rotary gear compressor assembly;
1 - fixed body; 2 and 3 - rotors; 4 - drive gears;
I, II and III - positions of the rotors when turning

Compressor with a screw rotor (Lisholm type) is characterized by a high degree of pressure increase (up to 7), high speed (12000 min-1), high reliability and balance (Fig. 4.2). The complexity of the rotor shape, their massiveness, housing cooling, noise, high frequency, pressure pulsations – all this complicates their operation on automotive ICE.

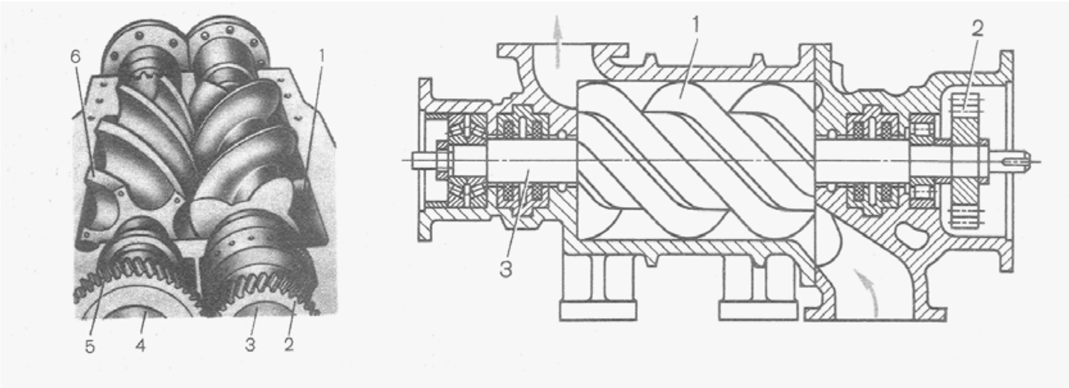

Fig. 4.2. **Screw rotor**:
1 - leading rotor; 2 and 5 - synchronizing
gear wheels; 3 and 4 - shafts; 6 - the driven rotor

4.2.2. ***The piston compressor*** is characterized by high efficiency, reliability, smooth pressure change. Complexity and high cost, imbalance, large mass, significant oil consumption.

4.2.3. ***Rotary vane compressors*** are similar to oil pumps.

4.2.4. ***Centrifugal compressors*** are based on the principle of interaction of a high-speed gas flow with the impeller blades and the blades of the stationary elements of the machine. A diagram of centrifugal compressors is shown in Fig. 4.3.

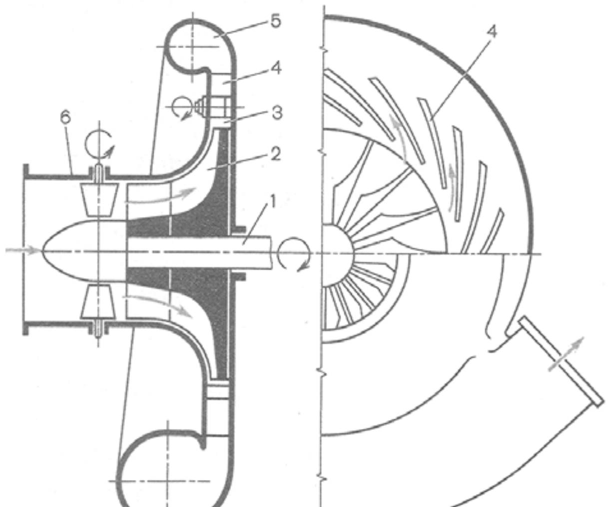

Fig. 4.3. **Schematic diagram of a single-stage centrifugal compressor**: 1 - smooth shaft; 2 - impeller; 3 - diffuser; 4 - blades; 5 - air collector; 6 - input device

Due to the variable cross-section of the diffuser, the flow rate decreases and the pressure increases.

The degree of pressure increase is limited to 3.5-4.0. The peripheral wheel speeds reach 450 m/s, the rotation frequency is 5000 to 20,000 min $^{-1}$.

4.2.5. ***Axial compressors.*** They have a higher efficiency than the centrifugal ones, since there is no change in the direction of the flow. Their work is unstable in the flow path, as it is characterized by a change in the speed and direction of the air flow – this phenomenon is called *surge.*

4.3. *Gas-dynamic boost (pressurization)*

Gas-dynamic boost (pressurization) is characterized by the fact that it allows increasing the weight filling of cylinders without blowers, by using the high-speed pressure of the flow (inertial blowing), the suction action of the flow (ejection), phenomena associated with its oscillatory motion in the pipeline, and other phenomena.

4.4. *Turbo-compressor*

4.4.1. *Turbo-compressor (turbocharger)* is a unit consisting of a compressor and a gas turbine, whose impellers sit on the same shaft. The principle of operation is based on the use of the turbine wheel energy.

Turbocharger diagrams are shown in Fig. 4.4.

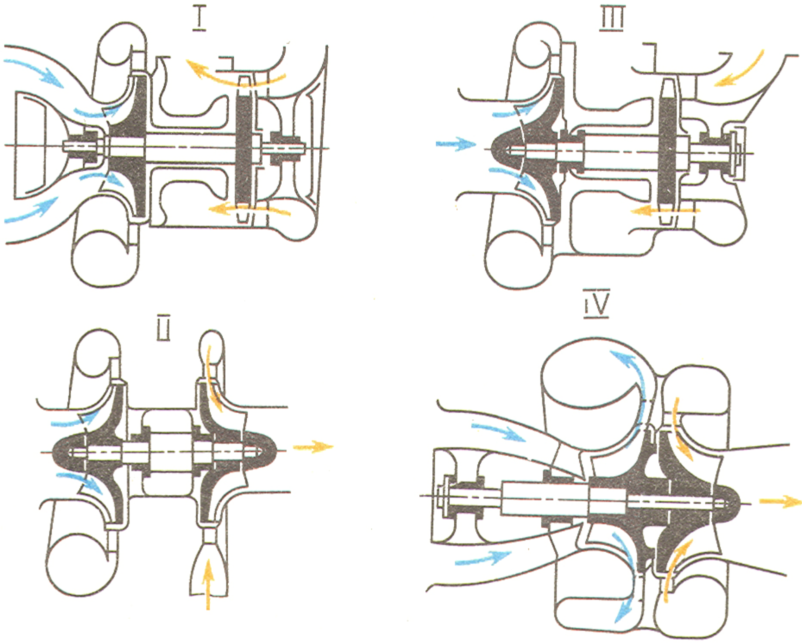

Рис. 4.4. **Structural diagrams of turbochargers of combined engines**

I. The scheme with supports located at the ends of the turbocharger (TC) rotor:

Disadvantages of the TC scheme are:

- increased length of the unit;
- the complexity of the input device.

II. Two-cantilever scheme: with supports located between the compressor and turbine discs.

Advantages:

- minimum dimensions and weight.

Disadvantages:

- impossibility to inspect bearings without removing the rotor;
- enhanced bearing cooling.

III. The scheme: the compressor wheel is cantilevered, and the rotor supports are on both sides of the turbine disk.

Advantages of the scheme:

- minimum input losses;
- general compactness.

Disadvantages:

- access to the bearing.

IV. The scheme: the minimum temperature of the bearings is ensured, with the small dimensions of the unit.

Advantages of the scheme:

- minimum T bearings;
- minimum dimensions.

Disadvantages:

- the mono-rotor heats the intake air

Example of designation TCR - 7

TC - turbocharger; $\pi = 1.6 - 2.5$

R - radial turbine;

7 - compressor wheel diameter in cm.

TKR – 7 are installed on internal combustion engines for trucks (KamAZ, KAZ, ZIL, GAZ).

4.4.2. *Comprex* (wave pressure exchanger). Pressure exchanger circuit is given in (Fig. 4.5).

Its operating principles are as follows:

When the rotor, in which the atmospheric air is located, rotates, the exhaust gases flow directly into the trapezoidal channel of the rotor. Gas compresses air at sound speed.

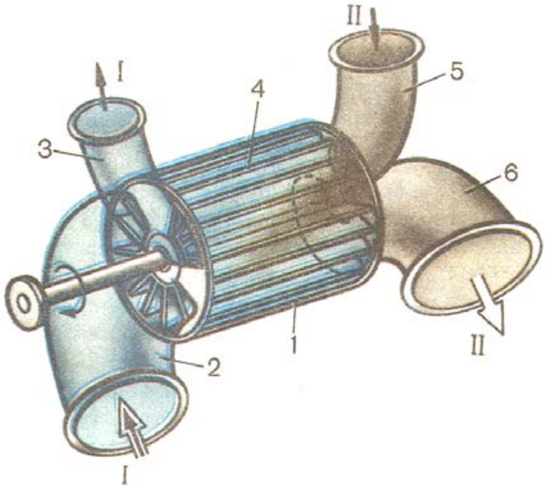

Fig. 4.5. **Pressure wave exchanger diagram**:
1 - case; 2 and 3 - respectively inlet and outlet
air filters; 4 - rotor; 5 and 6 - inlet
and outlet gas pipelines; I - air; II – gas

The length of the channel and the frequency of rotation of the rotor are selected in such a way that by the end of the air compression process the channel reaches the outlet port.

A sudden shutdown of the gas flow at the right edge of the rotor cell causes a rarefaction wave, where fresh air enters. The number of channels reaches 70, η = 75%

4.5. *Air coolers*

Due to the increase in air pressure, the temperature in the intake manifold also rises, which reduces η_v and increases the thermal stress of the parts. Therefore, charge air coolers are used in the internal combustion engine.

Recuperative coolers (with a dividing surface) are most often used in internal combustion engines.

There is a classification:

1) by the type of cooling medium
- water-air;
- air-air;
- freon-air (currently not produced);

2) by the design of the heat transfer surface:
- tubular;
- laminar;

3) by the direction of flows of working media:
- direct-flow (or counter-flow);
- cross type;
- riveted.

4.6. *Exhaust gas neutralization*

The reduction of exhaust gas toxicity is achieved in several ways:
- impact on R_e (internal combustion engine workflow);
- the use of alternative fuels;
- installation of neutralization systems;

Chemical and mechanical means of exhaust gas purification are used.

Chemical methods:
- thermal neutralizers;
- catalytic converters;

Thermal neutralizer is a combustion chamber located in the exhaust duct of the internal combustion engine, this chamber is used for afterburning products of incomplete combustion.

Catalytic oxidation converters provide the transition of CO products into CO_2 at low temperatures (250 - 300) due to the use of expensive metals - platinum, palladium, radium. To increase the contact surface, the catalyst is applied in a thin layer on the surface of silicon earth or clay earth, in the form of balls or a monolithic carrier with cells. The catalytic converter is installed in the muffler.

Additional device with fresh air supply, reducing media catalytic converters provide the transfer of products

$$2NO + 2CO \longleftrightarrow N_2 + 2CO_2.$$

For this, plate rhodium catalysis is used.

References

1. Кисликов В.Ф., В.В. Лущик. Будова й експлуатація автомобілів. Київ: Либідь, 2018. – 400 с.

2. Скляров В.М., Волков В.П., Скляров М.В. Автомобільні двигуни. Особливості конструкції: навч. посібник – Харків: ХНАДУ, 2012. – 405с.

3. Омеличев А.А. Підручник з будови автомобіля. – Дніпро: Моноліт, 2019. – 288 с.

Test questions

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1. What is pressurization (charge) of an internal combustion engine?
2. What types of compressors are there?
3. What is the efficiency of axial compressors?
4. What is comprex?
5. How are air coolers classified?
6. What is exhaust gas neutralization

5 CONCEPTUAL MODULE

Fuel classification. Composition of fuels. Alternative fuels.

5.1. Fuel classification.
5.2. The composition of the fuels.
5.3. Fuel properties.
5.4. Gaseous fuel.
5.5. Alternative fuels

5.1. *Fuel classification*

Fuels for internal combustion engines are distinguished:
- by engine type (gasoline (petrol), diesel);
- by state of aggregation (liquid, gaseous, solid);
- by chemical composition (hydrocarbon, non-hydrocarbon);
- by type of feedstock (oil, synthetic).

The primary process of separating oil into fractions is called *direct distillation* or *distillation* (Figure 5.1).

In addition to direct distillation, there is a task of processing high-boiling oil products by splitting (destruction) of heavy hydrocarbon molecules into lighter ones. This process is called *cracking*.

Cracking is high-temperature processing of oil and its fractions in order to obtain, as a rule, products of lower molecular weight - motor fuel, lubricating oils, etc., as well as raw materials for the chemical and petrochemical industries.

Cracking can be *thermal* and *catalytic.* Thermal occurs without air access, and catalytic - with a catalyst at a pressure of 2–10 MPa. Cracking is one of the most important processes ensuring deep oil refining.

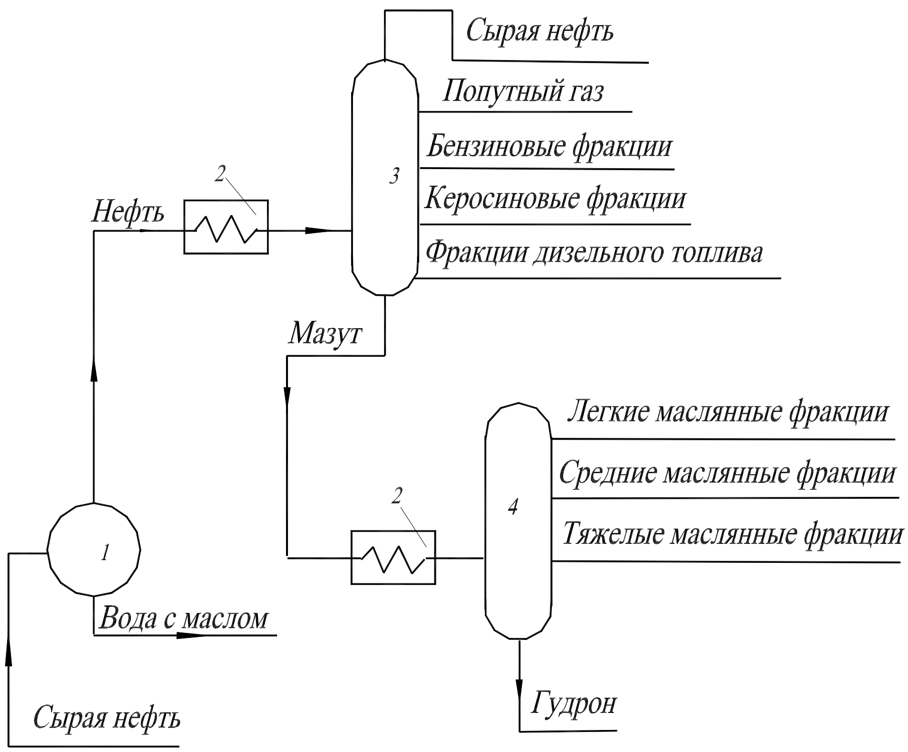


Fig. 5.1. **Primary oil refining**:
1 - apparatus for electrical desalination; 2 - oven; 3 - atmospheric distillation column; 4 - vacuum rectification column

5.2. *Fuel composition*

Elemental composition shows the content of individual elements in the fuel. Petroleum liquid fuel consists mainly of carbon C (85–87%); hydrogen H (12.5-14.7%) and a relatively small volume of oxygen O (0-0.5%), sulfur S (2-5%) and nitrogen N (Table 5.1).

Table 5.1 - **Elemental composition of fuel**

Fuel	Elemental composition of fuel mass			Molar mass M_t, kg/kmol	Net calorific value H_i MJ/kg
	C	H	O		
Oil:					
Petrol	0.885	0.145	–	110 – 120	44
Diesel	0.870	0.126	0.004	180 – 200	42.5
Heavy. diesel	0.870	0.125	0.005	220 – 280	41.8
Alcohol					
Methanol CH3OH	0.375	0.125	0.5	32	19.95
Ethanol C2H5OH	0.520	0.130	0.35	46	27.72

Knowing the elemental composition of the fuel, it is possible to make a thermal calculation of the working process of the internal combustion engine.

Fractional composition of the fuel is the volume fraction in the oil product of hydrocarbons flowing out within certain temperature limits.

Fraction is a part of the fuel that boils away in a certain temperature range.

Usually, the temperature is recorded as $t_{н.\ кипен}$, $t_{10\%}$, $t_{50\%}$, $t_{90\%}$, $t_{к.\ кипен}$.

The group composition of fuels characterizes the percentage of hydrocarbons of various groups in the fuel.

The composition of the fuel includes all major groups of hydrocarbons (alkanes, cyclanes, aromatic), as well as unsaturated hydrocarbons obtained during cracking (olefins and diolefins). The group composition determines the allowable compression ratio of the engine.

In fuels, the most common are hydrocarbon impurities, water and mechanical impurities.

The *heat of combustion of fuel* is the amount of heat released during the complete combustion of the fuel. The highest H_B and the lowest $H_н$ are distinguished. When determining the highest H_B, the heat that is released during the condensation of water contained in the combustion products is taken into account.

5.3. *Fuel properties*

Fuel properties affecting atomization are:

- spray is understood as the process of disintegration of a jet into droplets and further crushing of droplets into smaller particles;
- the average droplet diameter characterizes the fineness of the spray;
- dissimilation depends on external (aerodynamic) and internal (viscosity, surface tension) forces.

Volatility of fuels:

- the volatility of fuels characterizes the rate of its transition from the liquid phase to vapor;
- the rate of evaporation is characterized by the amount of vapor generated from a unit of liquid surface per unit of time.

To improve engine performance, the following is used:

- heating of the combustible mixture during the operation of the internal combustion engine;

- volatility of fuel when starting a cold internal combustion engine (heating, starting fluids: "Kholod D-40" – for diesel, "Arktika" – for gasoline;

- the effect of volatility on the operation of the fuel supply system (formation of steam plugs, icing of the carburetor);

- the effect of volatility on the heating and throttle response of the internal combustion engine;

- *the effect of volatility on wear, formation of deposits and toxicity of internal combustion engines*.

The detonation resistance of fuels is characterized by the combustion of fuel in gasoline internal combustion engines without detonation.

Detonation is explosive combustion at a speed of 1400–2500 m/s.

The resulting consequences are *glow ignition*.

Octane number (RON) is a conventional unit for measuring the detonation resistance of a fuel, numerically equal to the percentage of isooctane (100 units) n – C_8H_{18} in its mixture with normal heptane (0 units) C_7H_{17}. For example, if the reference mixture contains 76% isooctane and 24% heptane by volume, then the RON of this mixture is 76.

Depending on the tests, a distinction is made between motor (RONM) and research methods (RONR).

The difference between RONM and RONR is called the *sensitivity* of the gasoline. The higher the sensitivity, the higher its detonation resistance. A-76, AI-93, AI-98. A is automobile gasoline.

Antiknock agents are inorganic compounds of various metals (lead (tetraethyl lead $P_b(C_2H_5)_4$)), manganese, chromium, etc.).

Self-ignition of fuels characterizes its ability to self-ignite in a diesel engine and is estimated by the cetane number (CN).

The cetane number is a conventional unit for measuring the self-ignitability of fuel, numerically equal to the percentage (by volume) content of cetane (100%) $C_{16}H_{34}$ in its mixture with alphamethylnaphthalene (0%) $C_{11}H_{10}$.

Example: L(S)- 0.2 -40, (summer fuel, with a mass fraction of sulfur 0.2%, flash point 40).

The higher the CN, the better the self-igniting properties of the fuel. Fuels are: L(S) - summer, Z (W)- winter, A - arctic.

Stability of fuels is the ability to maintain their properties under specified operating conditions.

They are subdivided into:

- *physical stability - preservation of fractional composition*;
- *chemical stability - preservation of the chemical composition.*

The influence of fuel on corrosive wear of parts should be minimal.

The influence of the fuel on the formation of deposits should also be minimal.

5.4. *Gaseous fuel*

As a gaseous fuel in the internal combustion engine, natural gases are used, associated gases emitted during the extraction and processing of oil, associated industrial and sewage gases, as well as gases obtained from solid fuels by their gasification.

Gaseous fuels (GF) have the same performance properties as gasolines.

The mixture formation process is more perfect than in a gasoline engine, due to the homogeneity of the mixture.

Gaseous fuels have a high detonation resistance (RONM 80 - 110), which allows them to be used with a higher compression ratio. GFs have a lower volumetric heat than fuel oils. In this regard, to ensure the specified mileage, the gas is stored in a compressed or liquefied state.

Gaseous fuels are divided into:

- natural gas;
- industrial;
- gas generator.

According to the state of aggregation, they are divided into:

- compressed (methane CH_4, H_2, CO, etc.),
- liquefied (ethane C_2H_6, propane C_3H_8, butane C_4H_{10}, ethylene C_2H_4, propylene C_3H_6, butylene C_4H_8, etc.)

5.5. *Alternative fuels*

One of the promising types of fuel is liquid hydrogen H_2, obtained from water using nuclear energy. It is currently used as an additive to hydrocarbon fuels.

Alcohols (ethanol - C_2H_5OH, methanol - CH_3OH). Methanol is produced from natural gas and coal. Ethanol - from vegetable raw materials.

Alcohols have a lower calorific value

Ethanol $H_и$ = 27.72 MJ / kg.

Methanol $H_и$ = 19.95 MJ / kg.

They are used in internal combustion engines with high detonation ability.

Biogas - the fractional composition of gas contains up to 70% of methane, the rest consists of inert gases.

References

1. Кисликов В.Ф., В.В. Лущик. Будова й експлуатація автомобілів. Київ: Либідь, 2018. – 400 с.
2. Скляров В.М., Волков В.П., Скляров М.В. Автомобільні двигуни. Особливості конструкції: навч. посібник – Харків: ХНАДУ, 2012. – 405с.
3. Омеличев А.А. Підручник з будови автомобіля. – Дніпро: Моноліт, 2019. – 288 с.

Test questions

?

1. How are fuels classified?
2. What property of fuel is determined by the specific weight of one cubic centimeter of fuel?
3. What property of fuel is determined by the amount of heat released during the complete combustion of 1 kg of fuel?
4. What property of fuel is determined by numbers in fuel manipulation?
5. What quality of gasoline provides easy start of the engine and the greatest economy in its work?
6. What is detonation?
7. For what purpose is ethyl liquid introduced into motor gasoline?

6 CONCEPTUAL MODULE

Oils and lubricants for ICE

6.1. *Engine oils*

Engine oils serve to reduce wear and tear on moving parts and friction power loss in them; they perform the function of a sealing medium (in the area of the piston rings) and heat dissipation.

In the internal combustion engine, the oils of petroleum origin are mainly used (distillate, mixed and synthetic).

With regard to the specific operating conditions of oil in the engine, the separation of friction in rubbing pairs (into hydrodynamic, boundary, semi-dry, dry) is conditional due to a sharp change in operating conditions.

Temperature has the greatest influence on oil performance.

6.2. *Properties of oils*

Lubricity is a combination of anti-friction, anti-wear and anti-scuffing properties.

To enhance these properties, additives are used:

- *antifriction (vegetable and animal fats, oleic and stearic acids, esters, etc.)*

- antiwear and anti-scuffing (organic compounds of phosphorus, sulfur, forming strong films on the friction surface).

Viscous and depressant properties. *Viscosity determines energy consumption to overcome frictional forces. In the calculations, use is* *made of kinematic viscosity, which is the ratio of dynamic viscosity and density. The oil marking indicates the kinematic viscosity mm/s at a temperature of 100 ° C.*

The oil viscosity increases with decreasing temperature. There is a distinguishing between *structural* solidification, in which the mobility of the oil decreases due to *crystallization and viscous solidification*, in which the mobility of the oil decreases due to an increase in viscosity.

The temperature at which the oil loses its mobility is called the *pour point.*

The ability of the oil not to lose mobility up to certain temperatures is determined by its *depressant properties*.

To reduce (depress) the temperature, substances called *depressants* are added to the oil. Depressants use the products of polymerization of hydrocarbons and oxygen-containing compounds.

For gasoline internal combustion engines, engine oil of various effects is used – O - 6, 8, 10, 12 mm^2 / s.

For a diesel engine, O of 8, 10, 12, 14, 16, 20 mm^2 / s is used

Thermal oxidative and radiation stability of oils. When oils are heated in the presence of air, oxidation and thermal decomposition processes take place. The ability of the oil to resist oxidation at elevated temperatures is characterized by its *thermo-oxidative stability*.

Antioxidant additives are classified as:

- *additives - inhibitors (slowing down the oxidation of oil in a thick layer (volume)), (DP-1 of barium dialkyldithiophosphate*).

- thermooxidizing additives (in a thin layer of zinc alkylthiophosphate).

The ability of an oil to withstand radiation exposure is characterized by its *radiation stability*.

Anti-radiation additives (iodine, benzene, thiazines, etc.).

Anti-corrosion and conservation properties. *Protection of surfaces with oil* against temperature and pressure R.

Acid number (KOH) - 0.04 - 0.1 mg KOH/ g. assesses the corrosiveness of the oil.

The alkaline properties of the oil (neutralization of acidic products) are characterized by the *base number* (mg KOH / 1 g of oil).

For long-term storage, preservatives are used with additives of fatty acids, esters, metal sulfanates, etc.

Varnish-forming and detergent have *dispersing properties. The deposited film with a thickness of 20 - 30 microns, due to the similarity with lacquer coatings, is called varnish deposits. They negatively affect the operation of the engine, collect carbon deposits, mechanical particles, "burn" rings.*

To create adsorbent films on the surface that prevent the deposition of varnishes, detergents (ash and ashless) are introduced into the oil.

Antifoam and demulsification properties. Saturation with gas oil is called aeration (up to 25% by volume). The gas can be in the following state:

- soluble form;
- gas-oil dispersion (gas bubbles in oil);
- foam (characterized by foaming).

Antifoam additives are made on the basis of organic silicon compounds. When water enters the oil, it forms an emulsion.

Demulsification -is separation of water from the oil, reduced by special substances demulsifiers.

Flushing properties. For flushing from deposits, special flushing oils are used.

Physical and chemical stability of oils is the ability to maintain their fractional composition.

Run-in properties. *When using special oils, the run-in is reduced by 2 times.*

Aging of oils is a complex foam-functional and multi-stage process of physical and chemical transformations occurring due to two main reasons: internal - caused by the violation of oil stability (evaporation, oxidation, decomposition, polymerization) and external - caused by contamination of the oil by mechanical impurities, water and fuel.

Oil burnout is caused by its combustion by evaporation, leaks and emission through the crankcase ventilation system (determined by the% ratio of fuel consumption).

6.3. *Classification of oils*

Engine oils, depending on the country of manufacture, have a different classification.

6.3.1. Oils made in the CIS

Groups of engine oils are given in table. 6.1 according to the purpose and viscosity in accordance with the standard GOST 17479.1-85 adopted in the CIS countries.

Table 6.1 - **Classification of oils**

<table>
<tr><td colspan="2">Oil group</td><td colspan="3">Recommended area of usage</td></tr>
<tr><td colspan="2">A</td><td colspan="3">Gasoline, non-powered automobile ICE</td></tr>
<tr><td rowspan="2">Б</td><td>$Б_1$</td><td colspan="2">Carburetor</td><td rowspan="2">Low-powered engines 3.5% additives</td></tr>
<tr><td>$Б_2$</td><td colspan="2">Diesel</td></tr>
<tr><td rowspan="2">В</td><td>$В_1$</td><td colspan="2">Carburetor</td><td rowspan="2">Medium-powered engines 4-7% additives</td></tr>
<tr><td>$В_2$</td><td colspan="2">Diesel</td></tr>
<tr><td rowspan="2">Г</td><td>$Г_1$</td><td colspan="2">Carburetor</td><td rowspan="2">Highly forced engines 7-12% additives</td></tr>
<tr><td>$Г_2$</td><td colspan="2">Diesel</td></tr>
<tr><td colspan="2">Д</td><td colspan="3">Highly powered diesel engines operating in difficult conditions 18-25% of additives</td></tr>
<tr><td colspan="2">Е</td><td colspan="3">Low-speed diesels running on heavy fuel with sulfur up to 3.5%</td></tr>
<tr><td rowspan="2">Class of viscosity</td><td colspan="2">Viscosity at 255 K (mm^2 / s)</td><td colspan="2">Viscosity at 373 K (mm^2 / s)</td></tr>
<tr><td>not less than</td><td>not more than</td><td>not less than</td><td>not more than</td></tr>
<tr><td>4з</td><td>1300</td><td>2600</td><td>3.8</td><td>–</td></tr>
<tr><td>6з</td><td>2600</td><td>10400</td><td>3.8</td><td>–</td></tr>
<tr><td>6</td><td>–</td><td>–</td><td>5</td><td>7</td></tr>
<tr><td>8</td><td>–</td><td>–</td><td>7</td><td>9</td></tr>
<tr><td>10</td><td>–</td><td>–</td><td>9</td><td>11</td></tr>
<tr><td>12</td><td>–</td><td>–</td><td>11</td><td>13</td></tr>
<tr><td>14</td><td>–</td><td>–</td><td>13</td><td>15</td></tr>
<tr><td>16</td><td>–</td><td>–</td><td>15</td><td>16</td></tr>
<tr><td>20</td><td>–</td><td>–</td><td>18</td><td>22</td></tr>
<tr><td>4з/6</td><td>1300</td><td>2600</td><td>5.5</td><td>6.5</td></tr>
<tr><td>4з/8</td><td>1300</td><td>2600</td><td>7.5</td><td>9.5</td></tr>
<tr><td>4з/10</td><td>1300</td><td>2600</td><td>9.5</td><td>10.5</td></tr>
<tr><td>6з/10</td><td>2600</td><td>2600</td><td>9.5</td><td>10.5</td></tr>
</table>

M is engine oil;
З – this index means thickened.
n is the presence of additives;
Б - barium additive (M - 14 GB);
И - imported additives (M - 8 GI).
Example: M - 6s / 10G 1.

Old markings.
А - automobile;
К - acid cleaning;
С - selective cleaning;
Digit - viscosity at 373 K (100°C);
З - thickened;
Д - for diesel engines;
М - 8А (АС - 8);
М - 4з/6В1 (АСЗп – 6);
М - 8Б (ДС – 8).
Synthetic oils are classified into:
- hydrocarbon;
- diester;
- polyalkylene glycol;
- polyethylene;
- diakylbenzene;
- organophosphorus;
- fatty;
- halogenated;
- organosilicon;

The engine oil type designation is a combination of letters and numbers that is not easy to understand. Therefore, we will give their decoding below.

6.3.2. Imported oils

6.3.2.1. Classification of engine oils by purpose and API performance levels

The API (American Petroleum Institute) classification is the most well-known international classification of engine oils by application and performance level.

API classification divides engine oils into two categories (tables 6.2, 6.3):

S (Service) is for gasoline engines of passenger cars, vans and light trucks;

C (Commercial) is for diesel engines of commercial vehicles (trucks), industrial and agricultural tractors, road construction equipment.

The oil class designation consists of two letters of the Latin alphabet: the first (S or C) indicates the oil category, the second indicates the level of performance properties. The further the second letter from the beginning of the alphabet, the higher the level of properties (i.e. oil quality).

Table 6.2 - **API Specification for Gasoline Engines**

Class	Status	Purpose
SM	Active	For engines produced after 2004
SL	Active	For engines produced before 2004
SJ	Active	For engines produced before 2001
SH	Outdated	For engines produced before 1996
SG	Outdated	For engines produced before 1993
SF	Outdated	For engines produced before 1988
SE	Outdated	For engines produced before 1979
SD	Outdated	For engines produced before 1971
SC	Outdated	For engines produced before 1967
SB	Outdated	For engines produced before 1951
SA	Outdated	For engines produced before 1930

Table 6.3 - **API Specification for Diesel Engines**

Class	Status	Purpose
1	2	3
CJ-4	Active	For engines produced after 2006. Replace the oils of classes CI-4, CH-4, CG-4 и CF-4
CI-4	Active	For engines produced after 2002. Replace the oils of classes CD, CE, CF-4, CG-4 и CH-4
CH-4	Active	For engines produced after 1998. Replace the oils of classes CD, CE, CF-4 и CG-4
CG-4	Outdated	For engines produced before 2009.
CF-4	Outdated	For engines produced before 1995
CF-2	Active	For engines produced after 1994
CF	Active	For engines produced after 1994
CE	Outdated	For engines produced before 1994
CD-II	Outdated	For engines produced before 1994
CD	Outdated	For engines produced before 1985
CC	Outdated	For engines produced before 1990
CB	Outdated	For engines produced before 1961
CA	Outdated	For engines produced before 1959

The classes of diesel oil are additionally subdivided for two-stroke (CD-2, CF-2) and four-stroke diesel engines (CF-4, CG-4, CH-4). Most foreign engine oils are universal - they are used in both gasoline and diesel engines. Such oils have a double designation, for example: SF / CC, CD / SF, etc. The main purpose of the oil is indicated by the first letters, i.e. SF / CC - "more gasoline", CD / SF - "more diesel". Energy-saving oils for gasoline engines are additionally designated with the abbreviation EC (Energy Conserving).

The API classification contains 3 valid classes of category "S" and 6 valid classes of category "C". However, many manufacturers continue to release oils of the classes excluded from the specification, as cars with old engines continue to operate.

6.3.2.2. Classification of engine oils by purpose and levels of performance properties CCMC

The company Comite des Constructeurs d'Automobiles du Mars Commun determines the quality of oils in accordance with European requirements. The CCMC classification (later ACEA) includes all API tests and prescribes additional, more stringent testing on European test engines. G stands for petrol (gas) engines, D stands for diesel engines for commercial vehicles and PD stands for diesel engines for passenger cars. The letters represent the current numbering and reflect the growth in the capabilities of the respective engine oil in line with technical progress.

6.3.2.3. Classification of engine oils by purpose and ACEA performance levels (table 6.4)

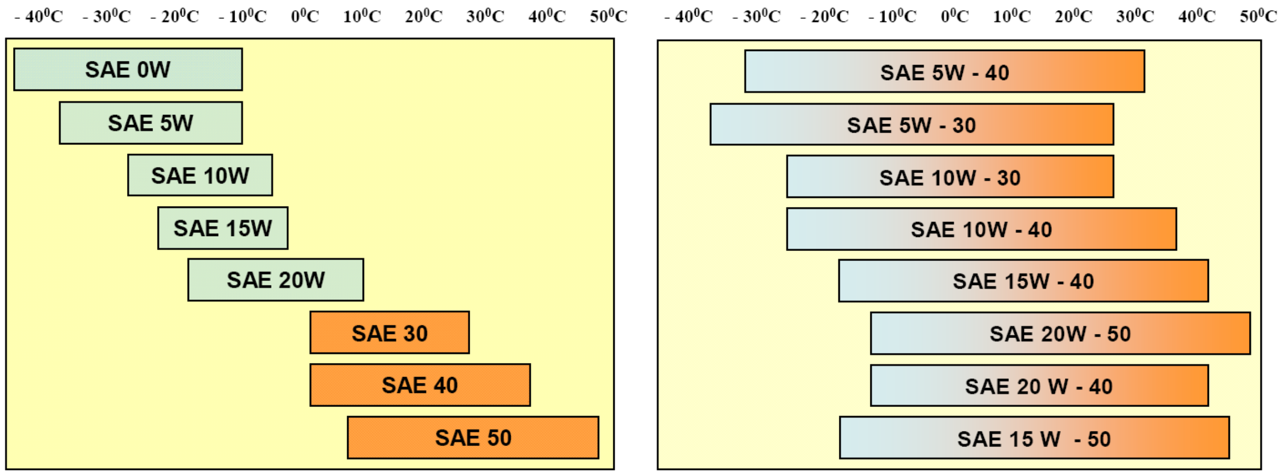
Table 6.4 - **Classification of ACEA engine oils**

"A" – gasoline engines		
Category	Use and features	Characteristics
A1-96	Preventing the formation of depositing on the piston and sludge formation, high-temperature oxidation resistance, wear protection.	Oil with maximum fuel saving effect. New standard for low viscosity engine oils at 150 нC (non-turbocharged).
A2-96	Same as A1-96, but with better bearing protection.	The standard class for engines of modern and future cars used on highways (with and without turbocharging).

A3-96	Same as A2-96, but with better resistance to high-temperature oxidation than A1-96 and A2-96.	Extra class for engines of high-speed cars with special requirements for antioxidant, viscous and anti-altered properties of oil (with and without turbocharging).
"B" - diesel engines of passenger cars		
B1-96	Preventing the formation of deposits on the piston, dispersing soot (thickened oils), protecting the camshaft cams from wear.	Oil with maximum fuel-saving effect. New standard for low viscosity motor oils at 150 нS (non-turbocharged).
B2-У6	The same as B1-96, but with better bearing protection.	Standard grade, passenger car engines, turbocharged and non-turbocharged.
B3-У6	The same as B2-96, but with better protection of the Sh-96 camshaft cams from wear, the ability to disperse soot and maintain a viscosity characteristic.	Extra class, turbo-bonded engines for passenger cars
"E" - diesel engines of trucks		
E1-96	Preventing the formation of deposits on the piston, polishing the cylinders, protecting the camshaft cams from wear.	Standard class, highly supercharged engines, working in difficult conditions.
E2-96	Better characteristics than for E1-96, for the same indicators	The standard class, engines with high pressure and without overflow, operating in easy and difficult conditions, in terms of properties (cleanliness and wear) are better than E1-96.
E3-96	Better characteristics than for E2-96, for the same indicators. The ability to disperse soot and maintain a viscosity characteristic is additionally monitored.	Extra class, with excellent soot dispersing ability, engines with high supercharging, operating in especially severe conditions.
(E4...)	On development stage	The newest class for a new generation of truck engines with extended drain intervals.

6.3.2.4. SAE viscosity classification of engine oils

The SAE J300 specification, depending on the temperature range, describes three types of engine oils: **winter, summer and multigrade** (Fig. 6.1).



а б

Fig. 6.1. **Types of engine oils depending on from ambient temperature:**
a - winter and summer oils; b - multigrade

Winter oils: SAE 0W, SAE 5W, SAE 10W, SAE 15W, SAE 20W, SAE 25W are designated by a number (SAE viscosity grade) and the letter "W" (Winter). For winter oils, two parameters of low-temperature dynamic viscosity (cranking and pumpability) and one parameter (minimum kinematic viscosity), which characterize the high-temperature properties of winter motor oils, have been established.

Cranking characterizes the dynamic viscosity of the engine oil and the temperature at which the oil remains sufficiently liquid and stable engine start is ensured.

Pumpability characterizes the dynamic viscosity of the oil, at which it can be pumped through the engine lubrication system, protecting its rubbing parts from working in dry friction mode.

Minimum kinematic viscosity at 100 ° C is an indicator that determines the minimum viscosity of the engine oil when the engine is warm.

Summer oils: SAE 20, SAE 30, SAE 40, SAE 50, SAE 60 are designated by a number without letter designation (SAE viscosity grade).

The main properties of summer oils are determined by:

- minimum and maximum kinematic viscosities at 100 ° C;
- minimum viscosity at 150 ° C and a shear rate of 106 s-1.

Multigrade oils are SAE 0W-20, SAE 0W-30, SAE 0W-40, SAE 0W-50, SAE 0W-60, SAE 5W-20, SAE 5W-30, SAE 5W-40, SAE 5W-50, SAE 5W -60, SAE 10W-20, SAE 10W-30, SAE 10W-40, SAE 10W-

50, SAE 10W-60, SAE 15W-30, SAE 15W-40, SAE 15W-50, SAE 15W-60, SAE 20W -30, SAE 20W-40, SAE 20W-50, SAE 20W-60. The designation consists of a combination of winter and summer oils, separated by a dash. Multigrade oils must meet the criteria for both winter and summer oils at the same time. The lower the number in front of the letter W, the lower the viscosity of the oil at low temperatures, easier cold start of the engine with a starter and better pumpability of the oil through the lubrication system. The larger the number after the letter W, the higher the viscosity of the oil at high temperatures and the more reliable engine lubrication in hot weather.

The scope of oil 5 W-40 usage is: this engine oil can be used in winter at temperatures down to –30°C and in summer at temperatures above 35°C.

6.3.2.5. Additives

Additives are chemically active substances. They are added to oil to improve its performance or impart new properties. Antioxidants, for example, increase the oil's resistance to aging, anti-wear additives protect the engine from increased wear, detergents give the oil flushing properties. Depending on the field of application and the required load properties, various additives are added to the oil in different amounts. In modern oils, the number of additives is 15-25%.

6.3.2.6. Mineral engine oils

Traditional engine oils are made from mineral oils. However, they no longer meet the increased demands for extended drain intervals and anti-friction properties required for high power engines. Typical viscosity values: 15 W-40 or 20 W-50.

6.3.2.7. Semi-synthetic engine oils

These are mineral oils with the addition of synthetic components. They improve cold starting conditions, effectively clean the engine and provide good wear protection. Typical viscosity: 10 W -40.

6.3.2.8. Synthetic engine oils

Synthetic base oils serve as the basis for the production of engine oils with significantly improved properties. Synthetic oils, suitable for gasoline and diesel engines, provide optimal wear protection, very good lubrication when starting a cold engine, reduce engine friction and clean it perfectly. They often meet the highest requirements of the API, CCMC (ACEA) and automotive companies. These oils provide long drain intervals. Typical viscosity value: 5W-40.

6.3.2.9. Diesel engine oils

Currently, the highest requirements for oils for diesel engines of passenger cars and diesel engines with turbocharging are set by Volkswagen classification PD2 CCMC (ACEA) and standard 505.00. These oils are suitable for naturally aspirated and turbocharged engines with or without charge air cooling.

6.3.2.10. Oils with good anti-friction properties

They have the best fluidity at low temperatures, are distinguished by low pumping work and high heat capacity. Therefore, they provide a reduction in fuel consumption. Typical viscosity: 5 W -40, 10 W-40.

6.3.2.11. Multigrade oils

They do not thicken too much in winter and do not liquefy in summer at high engine temperatures. For example. 5 W-40, 10W-40, 15W-40, 20 W-50.

6.3.2.12. Transmission oils

When choosing a transmission oil, the conditions of use and the manufacturer's recommendations must be taken into account. Requirements for oil quality must be checked in the vehicle operating manual, at a car service station of this brand, or in the recommendations of the oil supplier. Requirements for the quality of oils for **manual transmissions** vary from API GL1 to API GL5.

6.3.2.13. Group scope of usage

GL-1 - Cylindrical, worm and spiral bevel gears for low speed and low load conditions. Mineral oils without additives or with antioxidant and antifoam additives without extreme pressure components.

GL-2 - Worm gears operating in GL -1 conditions, but with higher requirements for antifriction properties. May contain anti-friction components.

GL-3 - Conventional spiral bevel gear transmissions operating in moderately severe conditions in terms of speed and load. They have better anti-wear properties than GL-2.

GL-4 - Automotive hypoid transmissions operating at high speeds at low torques and low speeds at high torques.

The presence of highly effective anti-seize additives is obligatory.

GL-5 - Automotive hypoid gears operating at high speeds and low torques, under the action of GL-5 shock loads on the gear teeth and high sliding speeds. Should have a large amount of serophosphate-containing anti-seize additive.

GL-6 - Automotive hypoid gears with increased vertical offset of the gear axes, i.e., operating at higher GL-6 speeds, shock loads and high torques. They have a greater amount of serophosphorus-containing anti-seize additive than GL-5 oils.

For manual transmissions, any of the above or engine oil may be used. It should be remembered that API GL 5 is a quality requirement for **the main gear**. Oil for **automatic transmissions** does not obey the API classification. The gearbox manufacturer sets its own requirements for these oils. Different types of oils cannot be mixed with each other.

6.4. *Solid and grease lubricants*

Solid layered lubricants (SLL) are crystalline substances with lubricating properties - (graphite, vermiculite, molybdenum disulfides MoS2 and tungsten WS2, boron nitrite, etc.)

In addition, the following are used:

- chemically active coatings (sulfur, chlorine, phosphorus)

- *soft metals (lead, indium, tin, cadmium, nylon, polyethylene).*

Composite lubricants (CL) are a combination of certain types of solid lubricants that provide optimal properties (lubricity, hardness).

Greases (G) are liquid oils specially thickened to impart specific properties.

Classification of greases:

- anti-friction grease;
- conservation grease;
- sealing grease (sealing of gaps).

Depending on the type of thickener:

1 - soap grease:

1.1 - calcium (grease);

- УС - 1 fatty grease;
- УС - 2 fatty grease;
- С - synthetic grease;

1.2 - sodium (constalins) 1–13, АМ, ЯНЗ – 2, КСБ;

1.3 - lithium: lithol - 24, cyatim - 201, fiol - 1, ЛС – 15;

1.4 - barium: ШРБ–4;

1.5 - lead.

The flaw is that they cannot be reused.

2 - hydrocarbon КС, ПВК - conservation grease;

3 - organic grease;

4 - inorganic grease;

Depending on operating temperatures, they are divided into: low medium, refractory.

6.5. *Coolants*

Water. Advantages: high specific heat capacity, safety, non-toxicity. Disadvantages: scale, dense cemented deposits (sludge, silt-like formations).

Antifreezes are low freezing liquids. The most common are ethylene glycol (CH2OH). Their characteristics:

- when heated, the volume increases to 6 - 8%;
- thermal conductivity and heat capacity are lower than that of water;
- only water evaporates during operation (add water);
- have increased permeability and mobility;
- when freezing do not break the cooling system;
- destructive effect on rubber.

The characteristics of the coolants are given in Table. 6.5.

Table 6.5 - **Technical characteristics of coolants**

Brand	Temperature of freezing	Density	Colour	Content of ethylene glycerol
40	233	1.0675	–	53
65	208	1.085	–	66
Tosol A-40	233	1.078	light blue	53.7
Tosol A-65	208	1.085	red	62.4

High boiling coolants consist of a mixture of high molecular weight alcohols, glycols and ethers boiling at 350 - 480 K.

References

1. Кисликов В.Ф., В.В. Лущик. Будова й експлуатація автомобілів. Київ: Либідь, 2018. – 400 с.
2. Скляров В.М., Волков В.П., Скляров М.В. Автомобільні двигуни. Особливості конструкції: навч. посібник – Харків: ХНАДУ, 2012. – 405с.
3. Омеличев А.А. Підручник з будови автомобіля. – Дніпро: Моноліт, 2019. – 288 с.

Test questions

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1. From what and in what way are mineral oils for engines obtained?
2. What are the names of the oils (taking into account their physical properties) obtained from crude oil and used for lubricating the parts of crankshaft mechanism and valve train?
3. What does the last letter on the marking of M6A oil for gasoline engines indicate?
4. What does the last letter in the marking of M10B oil for gasoline engines indicate?

7 CONCEPTUAL MODULE

General layout of ICE. Configuration of crankshaft mechanism (CSM). Forces and moments in CSM. ICE framework, Cylinders and heads.

7.1. General layout of the internal combustion engine.
7.2. Placement of the internal combustion engine on the frame.
7.3. Configuration of CSM.
7.4. Forces and moments in CSM.
7.5. Engine framework.
7.6. Cylinders.
7.7. Heads.
7.8. Gaskets and seals.

7.1. *General layout of the internal combustion engine*

Modern internal combustion engines are complex units, which include the following systems and mechanisms:

The body (framework) of the engine serves as the basis for the installation of stationary and moving parts (CSM), (valve train) and other systems.

CSM consists of moving parts that perceive the pressure of gases and convert the reciprocating movement of a piston into a rotational movement of a crankshaft.

Valve train serves to perform a certain sequence of the release of combustion products and the intake of a fresh charge into the cylinder.

Lubrication system is designed to clean and supply oil to all parts of the internal combustion engine that are subject to friction, as well as their partial cooling.

Fuel system provides cleaning and supply of fuel and air to the engine cylinders in an appropriate amount and at a certain point in time, as well as the removal of exhaust gases.

Cooling system is designed to maintain a constant temperature regime of the internal combustion engine and remove heat from engine parts.

Starting system provides the minimum crankshaft speed required to start the internal combustion engine in any operating conditions.

Ignition system is designed for the timely and stable supply of a spark discharge to the engine cylinders to ignite the air-fuel mixture.

7.2. *Placement of ICE on a frame*

Internal combustion engines are installed in the front, middle and rear of the car. There are longitudinal and transverse installation of the engine relative to the vehicle axis.

In accordance with the requirements of passive safety in the event of a collision of a car with an obstacle, the power unit must come off the supports so as not to limit the deformation of body parts, whose rigidity is specially calculated to create a given level of collisions. At the same time, the engine and transmission parts must not enter the passenger compartment.

Usually, the internal combustion engine is attached at 3-4 points, while it is the load-bearing element of the chassis.

The most rational is fastening at 3 points, since in this case the deformation of the frame acts less on the internal combustion engine.

Spring fasteners are used in the form of rectangular, cylindrical or other rubber gaskets with metal plates or cups vulcanized to them. For massive engines of tractors and cars with increased carrying capacity, such an attachment is insufficient, therefore, jet rods are introduced, which are also equipped with spring elements.

7.3. *Configuration of crankshaft mechanism*

In modern piston internal combustion engines, two types of CSM are used: trunk and crosshead, Figs. 7.1, 7.2. Trunk-type ICSMs are used in tractor ICE.

Crossheads are used for heavy engines (marine).

The most common CSM confugurations can have a different layout: in-line, V-shaped, which are shown in Fig. 7.1, and W-shaped arrangement of cylinders.

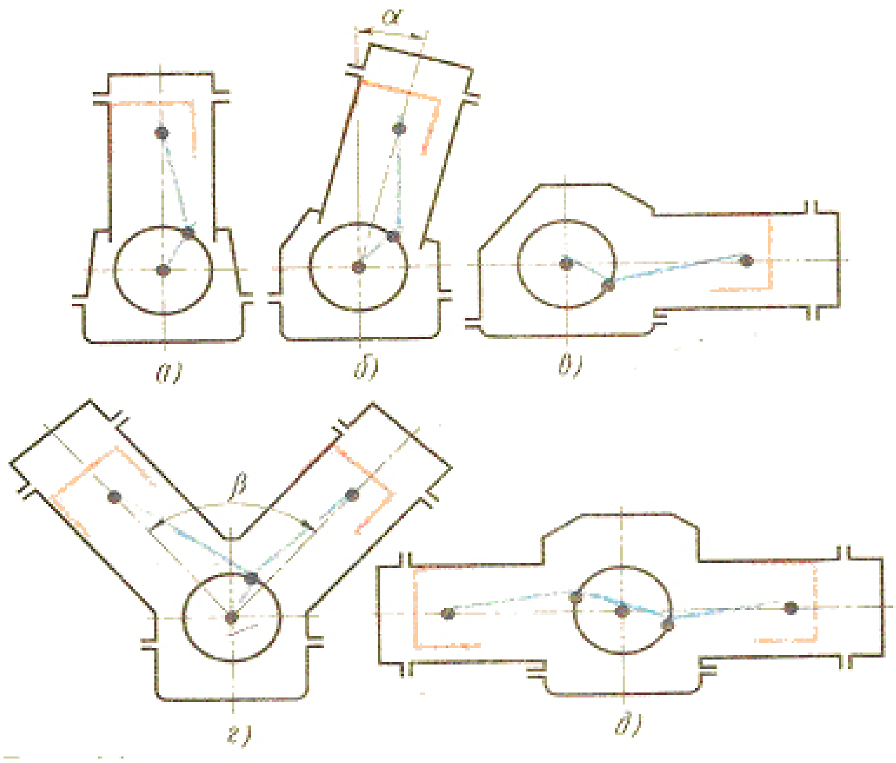

Fig. 7.1. **Trunk CSM**

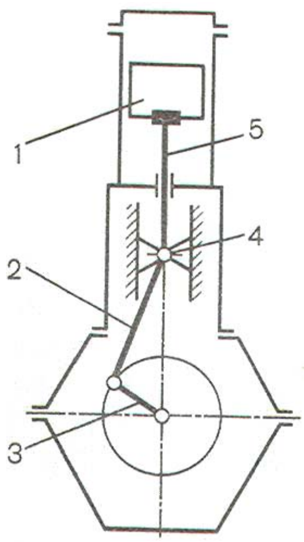

Fig. 7.2. **Crosshead CSM: 1 - piston; 2 - connecting rod; 3 - crank of the crankshaft; 4 - crosshead; 5 – stock**

In-line internal combustion engines can have a vertical (VAZ, GAZ), horizontal (Ikarus) and inclined (AZLK, Lancha) arrangement of cylinders. For V-shaped internal combustion engines, the camber angle of the cylinders can be 60 ° (YaMZ - 240), 90 ° (YaMZ - 236) and 180 ° (K-750) degrees.

7.4. *Forces and moments in CSM*

The analysis of the forces acting in the CSM is necessary for calculating the strength of the engine parts and for determining the loads on the bearings, they are shown in Fig.7.3.

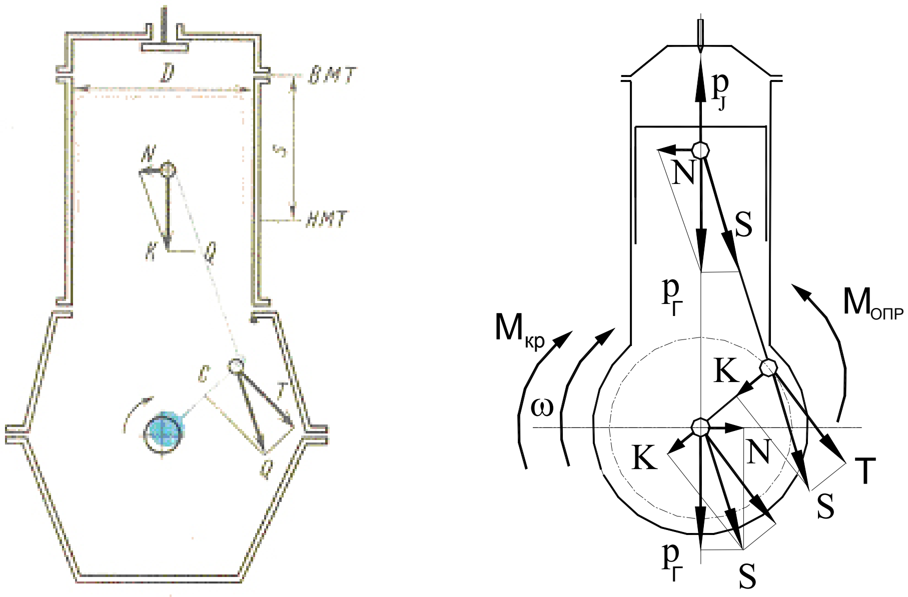

Fig. 7.3. CSM scheme: P_i is the inertia force; P_r is the strength of gases; S is the force acting along the connecting rod; N is the lateral force; T is the tangential force; K is normal force acting on the crank

Torque is

$$M_{кр} = T \cdot r$$

where *r* is the radius of the crank.

Overturning moment is

$$M_{опр} = N \cdot h + P_r \cdot a$$

where *a* is the displacement of the axis of the pin;

h is the projection onto the y-axis.

All forces and moments in the engine are variable in time. They cause the internal combustion engine to vibrate on the supports and can cause damage. Therefore, the engine is usually balanced (for example, install counterweights, etc.).

7.5. *Engine framework*

The housing (framework) of the engine is a part in which mechanisms, systems and auxiliary devices are located and fastened.

The housing can consist of the following parts:

- block;
- crankcase (block crankcase);
- cylinder;
- heads;
- pallet;
- seals;
- fasteners.

The structure of the framework depends on the overall layout and placement of the engine. Depending on the perception of the force of pressure gases by the elements of the engine housing, 3-4 power schemes can be distinguished:

1) Carrying block crankcase (VAZ), the advantages are: great rigidity, simplicity of design; the disadvantages are: deformation by pins when tightening the head.

2) Carrying block of casings (ZIL, GAZ, KamAZ), the advantage is: lightweight wet-type sleeves (especially during repair); the disadvantages are: increased weight and manufacturing cost.

3) Load bearing power pins (D-21; MeMZ, DT-4).

The working conditions of the housing are:

- it experiences significant power and temperature stresses;
- its works in conditions of insufficient lubrication;
- it perceives external loads from the engine frame;

Requirements for the ICE housing are:

- the engine housing must be rigid and durable, wear-resistant;
- the core of the housing must be made of a viscous material;
- it must be highly adaptable when replacing attachments;
- it must have small dimensions and weight.

The thickness of the walls of cast-iron cases is 5-7 mm, aluminum – 2mm thicker. Aluminum housings are 50-60% lighter than cast iron housings.

The crankcase is the main element of the framework (housing) of the internal combustion engine. Cylinders are attached to it, parts of the CSM, valve train are placed in it as well as lubrication systems, flywheel housing, internal combustion engine mounting paws.

The length of the crankcase depends on the size and number of cylinders, and the transverse dimensions depend on the radius of the crank and the size of the connecting rod.

Since it perceives all power loads, it is given longitudinal and lateral rigidity. For this, transverse partitions are performed. The common casting with cylinders is made with ribbing.

Carters can be:

- detachable;
- one-piece.

The main journals of the crankshaft are placed in the upper half in the sockets (crankcase beds). The covers are made massive with ribs. They are bored from one device. With this embodiment of the crankcase, the lower half of the crankcase is a sump. It is made of stamped steel; cast from aluminum or cast iron. It houses the oil supply and the oil intake. The pallet is sealed with a gasket.

The crankcase contains oil lines (channels), camshaft sockets, guide pushers, cylinder studs, etc.

The level of the joint between the pallet and the crankcase can be above or below the level of the main bearing connector.

In modern engines, crankcases with a connector level along the crankshaft axis are used and removable cast frames, which are made together with the main bearing caps.

7.6. *Cylinders*

The walls of the cylinder are the main working cavity guiding the movement of the piston.

The working conditions are as follows:

- a sharp change in pressure;
- contact with high temperature gas;
- contact with aggressive media;
- friction of parts in conditions of limited lubrication.

There are strict requirements to the quality of the material (pearlitic cast iron with the addition of alloying elements).

The inner surface of the cylinders is called the cylinder mirror (due to the surface finish).

7.6.1. Air-cooled ICE cylinders

Cylinders are molded individually and approved. The distance between the ribs is made from the conditions of least resistance for the passage of air cooling and the intensity of heat transfer. The shape of the cylinders can be:

- cylindrical;
- conical.

By design:

- all-metal;
- combined.

They are fastened with power pins or as a bearing cylinder. The joint is sealed with gaskets.

7.6.2. Liquid-cooled ICE cylinders

The cylinders are double-walled. The inner ones form the cylinder liner, the outer ones form the engine cooling jacket.

Combined cylinders are made with short inserts (50-60 mm long) either for the entire length of the block, or in the form of easily removable sleeves. The inserts are made of special cast iron (non-resist inserts). They increase the service life of the liner in 2.5-3 times. Sleeves can be dry and wet (Fig.7.4):

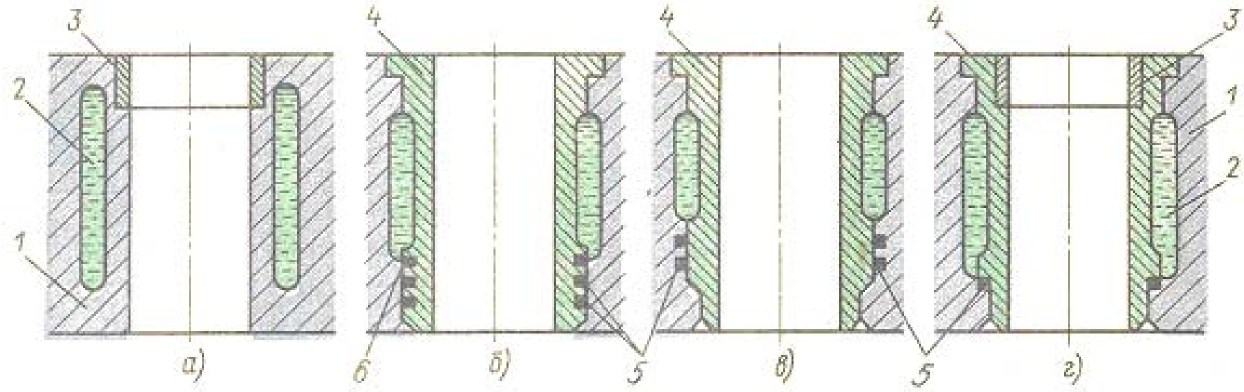

Fig. 7.4. **Configuration of engine cylinders**:
a - without sleeves but with a short insert (ZIL-157KD, GAZ-50-04);
b and *c* - with a wet sleeve (diesel engines YaMZ-236, KamAZ-740); *g* - with a wet sleeve into which a short insert is pressed (ZIL-130); *1* is a cylinder block; 2 is a water jacket; 3 is an insert; 4 is a cylinder liner, 5 is sealing rings; 6 is anti-cavitation ring

Dry cylinder liners are pressed in and protected during repairs; wet liners (usually easily removable) have three mounting belts: top, middle, bottom. Gaskets can be copper and rubber**.**

7.7. *Cylinder heads*

ICE head is a cover that covers the cylinder. It contains: the cavity of the combustion chamber; valve train parts; inlet and outlet channels; channels of the cooling and lubrication system.

The walls of the heads are 1.5–2 times thicker than the sleeves. The heads are cast on a number of cylinders or are made separately.

They are cast from cast iron or aluminum, or combined. They are usually fitted with insert seats and heat-resistant inserts. The heads are subject to great mechanical and thermal loads during operation.

7.8. *Gaskets and seals*

The gas joint is sealed with metal or metal-asbestos gaskets.

At the heart of metal-asbestos gaskets is asbestos. For additional strength they are reinforced with thin steel sheets or mesh, the thickness of the gasket sheet is 1.5 mm. The gasket is edged for strength and non-burnout and covered with graphite for non-sticking during disassembly. Earlier, they used to be covered with brass foil.

Depending on the material of the sleeve and head, metal gaskets can be:

- made of steel up to 5 mm thick (GAZ-542);
- made of a set of soft steel sheets (YMZ);
- made of copper for sealing cast iron heads.

The reliability of the gas joint depends on the correct tightening pattern. The tightening torque for gasoline internal combustion engines is 70–120 Nm, and for diesel engines – up to 200 Nm.

References

1. Кисликов В.Ф., В.В. Лущик. Будова й експлуатація автомобілів. Київ: Либідь, 2018. – 400 с.
2. Скляров В.М., Волков В.П., Скляров М.В. Автомобільні двигуни. Особливості конструкції: навч. посібник – Харків: ХНАДУ, 2012. – 405с.
3. Омеличев А.А. Підручник з будови автомобіля. – Дніпро: Моноліт, 2019. – 288 с.
4. Білоус Б.Д., Ткачук П.П., Андрусик Ю.Ф., Білоус Н.Б., Онищенко В.В. Армійська техніка. Основи руху, будова, характеристика: навч . посібник. – Л.: Вид-во Національного університету «Львівська політехніка», 2007. – 536 с.

Test questions

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1. What systems does the engine consist of?
2. What mechanisms does the internal combustion engine consist of?
3. What conditions and requirements for the internal combustion engine body do you know?
4. What are the types of crankcases?
5. What is the engine head?
6. What confugurations of engine cylinders do you know?

8 CONCEPTUAL MODULE

Piston group. Connecting rod group. Crankshaft group

8.1. The composition and purpose of the piston group.
8.2. Piston. Design features.
8.3. Piston rings.
8.4. Piston pins.
8.5. Purpose and composition of the connecting rod group.
8.6. Operating conditions and requirements for the connecting rod group.
8.7. Design features of the connecting rod elements.
8.8. Connecting rod bolts and bearings.
8.9. Design features of single and articulated connecting rods.
8.10. Purpose, composition and operating conditions of the crankshaft group (CSG).
8.11. Crankshaft.
8.12. Main bearings bearers.
8.13. Shaft seal.
8.14. Shaft layout diagram.
8.15. Flywheel and torsional vibration dampers.

8.1. *The composition and purpose of the piston group (PG)*

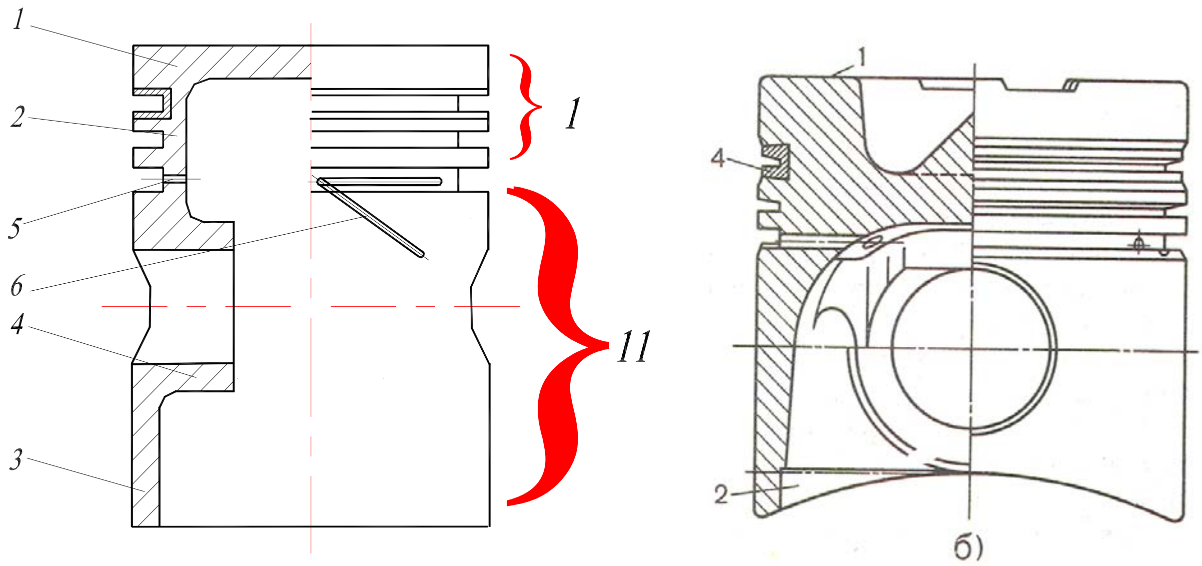
The piston group includes: piston, pin, rings, mountings.

Purpose: it perceives the pressure of gases and transfers the force through the connecting rod to the crankshaft, seals the combustion chamber, and also controls gas exchange.

Working conditions: high temperature and mechanical variable voltage in conditions of insufficient lubrication.

8.2. *Piston design features*

Piston materials are: aluminum alloys, cast iron, steel alloys, magnesium alloys. The piston design is shown in Fig. 8.1. The bottom of the piston can be: flat, concave, convex, shaped. Structural forms are selected based on engine operating conditions.



a

Fig. 8.1. **Piston diagram**:
a) I - piston head with annular grooves; II - guiding part;
1 - crown; 2 - head; 3 - skirt (guide part); 4 - bosses;
5 - holes for oil drainage, 6 - technological section
b) 1 - bottom; 2 - skirt; 4 - heat-resistant insert.

The piston head has grooves on the side surface for the installation of piston rings. Usually, a cast iron annular insert 3 is embedded in the upper groove, as is shown in Fig. 8.2 b, to reduce wear and increase durability.

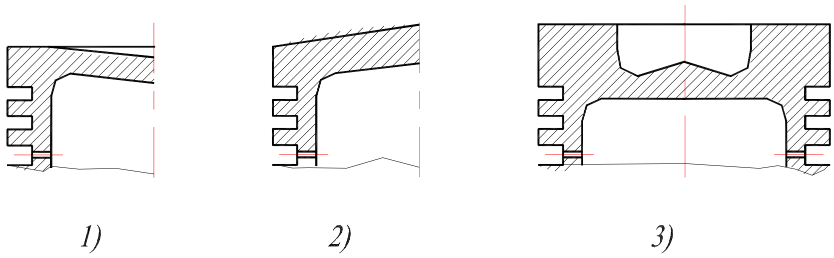


Fig. 8.2. **Types of piston crowns**:
1 - concave; 2 - convex; 3 – shaped

The piston skirt has thinner walls than the head. In the middle part there are bosses - lugs for installing a finger.

There are the following measures to maintain optimal clearances (anti-seizure) between the piston and the cylinder liner:

a) Aluminum expands when heated much more than cast iron. In a cold engine, the clearance should not be excessively large so as not to cause piston knocking and gas leakage; the section of the skirt is not round, but oval. Axis difference is 0.15-0.5 mm.

b) For the same purpose, a technological cut is made on the skirt that does not reach the end of the piston skirt (Fig.8.3).

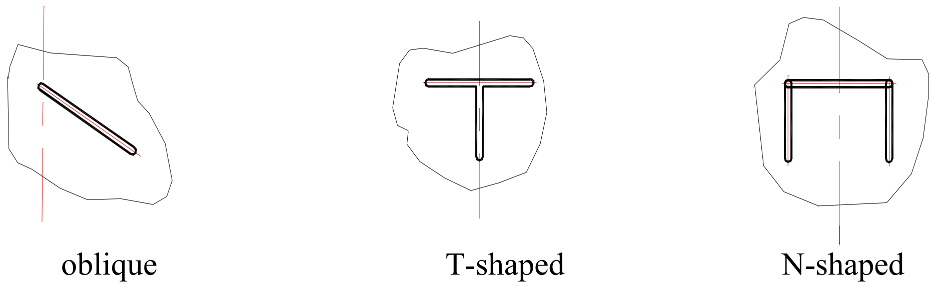


Fig. 8.3. **Types of technological sections of the piston skirt**

c) Pistons are made stepped or tapered along the length. The clearance along the length of the "skirt" of the piston in the upper piece of the part must be greater than in the lower part and is 0.12–0.08 mm.

d) So that the pistons expand less when heated, as well as to increase the strength during casting, plates of "low-expanding" steel are embedded in them.

e) Only all-metal steel rings are used (for diesel engines).

f) A skirt profile must be oval-barrel.

g) On forced diesel engines, oil nozzles are used to intensively remove heat from the piston crown.

h) They are covered with tin (graphite) for running-in (layer thickness is 0.004 - 0.006 mm.)

Pistons are selected by weight (the difference should not be 2–8 g). The pistons have alignment marks. Composite (combined) pistons are used for highly loaded engines.

8.3. *Piston rings*

The purpose of the piston rings is to seal the combustion chamber and transfer heat from the piston to the cylinder, prevent oil from entering the combustion chamber.

They are split spring elements (Fig. 8.4).

Rings are divided into: compression (Fig.8.6) and oil scraper (Fig.8.6–8.7).

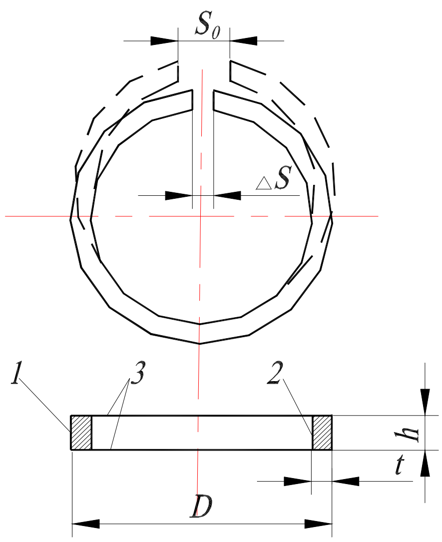


Fig. 8.4. **Compression ring diagram:**
1 - outer side; 2 - internal; 3 - end or side;
h is the height of the ring; *t* is the radial thickness; S_0 is the clearance in locks

The slits or locks of the rings are made:
- straight;
- oblique; (are not used).
- stepwise.

Clearance *S* (in cold condition equals (0.15–0.5 mm)).
Material: pearlitic cast iron, steel.

The upper compression rings are subject to porous chrome-plating, the rest are coated with molybdenum, tin.

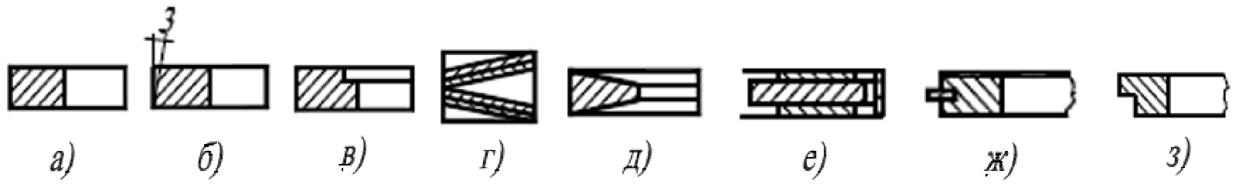


Fig. 8.5. **Compression rings**

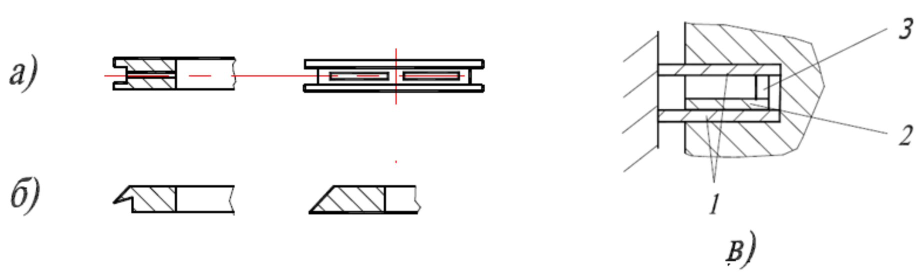


Fig. 8.6. **Oil scraper rings**

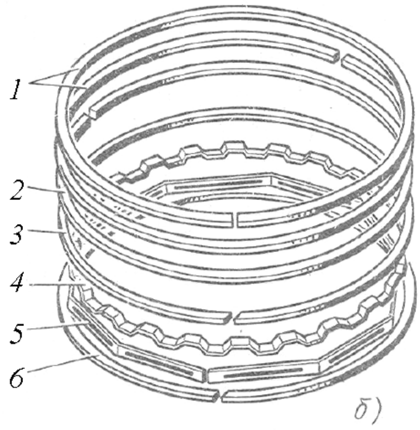


Fig. 8.7. **A set of oil scraper or oil drainage rings**:
b - piston rings; 7 - upper compression rings; 8 - lower compression ring; 9.12 - oil scraper rings; 10 - axial expander; 11 - radial expander.

8.4. *Piston pins*

Piston pin serves as an axis in the articulated connection of the piston with the connecting rod and perceives alternating loads.

Material: carbon and alloy steels.

Pins can be: floating and fixed (Fig. 8.8).

Pins are considered fixed if they are fixed in the connecting rod head or piston bosses.

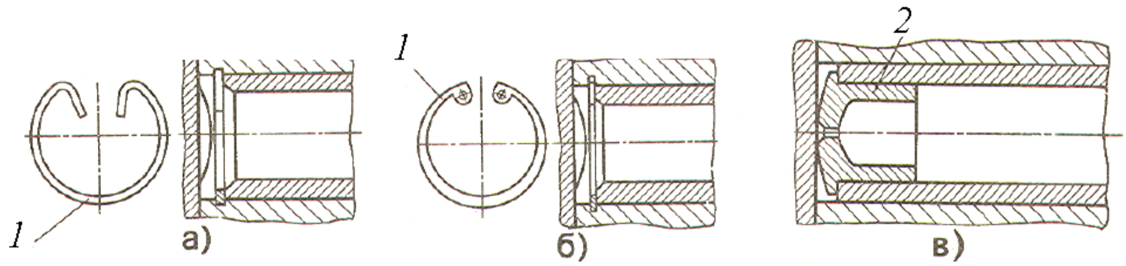


Fig. 8.8**. Floating piston pins**:
1 - spring retaining rings; 2 - special limiter

To reduce the unevenness of wear, the pins are made floating, they are fixed only against axial displacement by retaining rings or knobs.

The axis of the pin in the bosses is slightly displaced relative to the axis of the cylinder (1.2–2mm) towards the action of a greater lateral force (Fig. 8.9) to reduce knocking in the cold state of the internal combustion engine, when shifting the piston and to reduce the lateral force N.

Piston pin requirements:

- they must have a low weight, limited dimensions and high wear resistance.

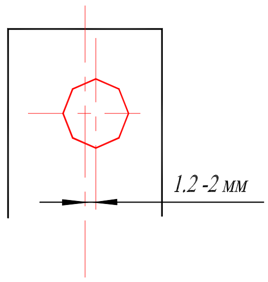


Fig. 8.9. **Diagram of the displacement of the pin relative to the axis of the piston**

8.5. *Purpose and composition of the connecting rod group (CRG)*

The connecting rod group is designed to transfer force from the piston to the crankshaft and vice versa, i.e., it takes part in the reciprocating movement of the piston and the rotational movement of the crankshaft.

The CRG consists of a connecting rod (piston head, rod, curved head), bushings, liners, fastening parts (Fig.8.10).

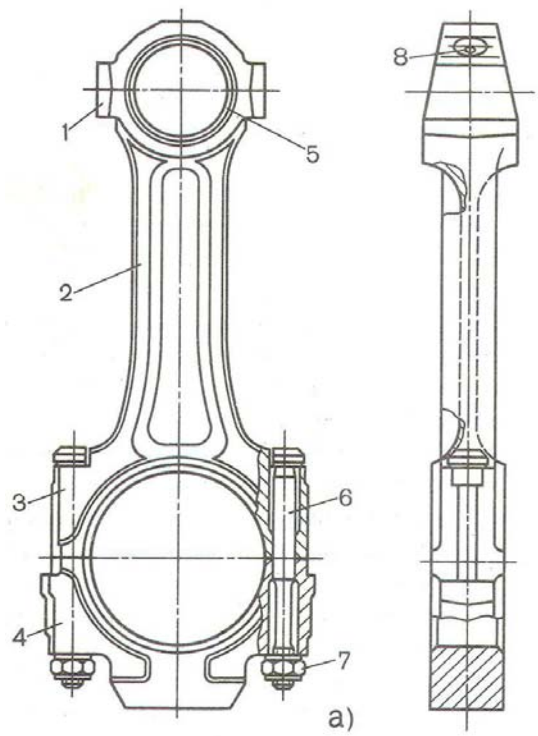


Fig. 8.10. **General view of the connecting rod**: 1 - upper head; 2 - rod; 3 - lower head; 4 - lower head cover; 5 - bushing of the upper head; 6 - connecting rod bolt; 7 - nut; 8 - opening for lubrication

8.6. *Operating conditions and requirements*

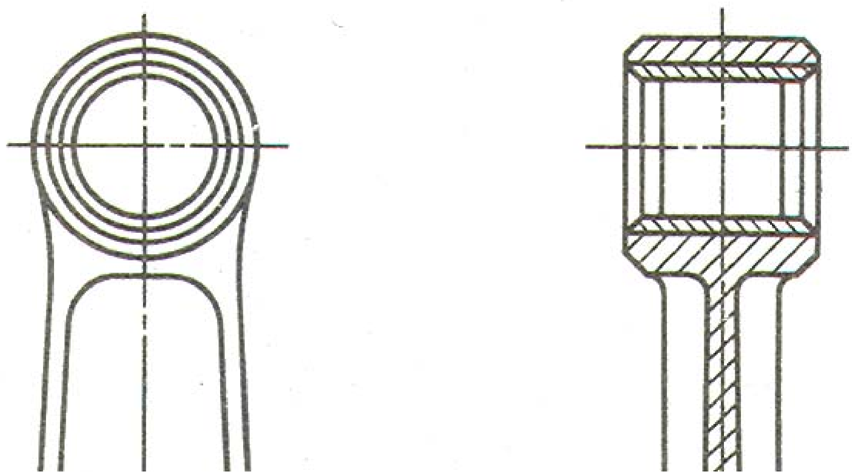
The connecting rod group works under conditions of influence of variables by magnitude of gas and inertial forces, close to impact, as well as in an environment of insufficient lubrication.

Requirements for the connecting rod are: it must have high rigidity and hardness, minimum weight and manufacturability.

The part is made by hot stamping from medium-carbon steels, and in special cases – from alloy steels.

8.7. *Design features*

The upper head of a connecting rod has a cylindrical shape, and its structure depends on the method of attaching the piston pin (Fig.8.11)



A б

Fig. 8.11. **Design features of the upper heads of a connecting rod**
a - installed with an interference fit; b - floating - solid
with pressed-in bronze bushing (thickness of 0.8–2.5 mm)

For better lubrication, a hole is made in the head, as well as a screw-shaped channel on the sleeve. The top head bushing is spray lubricated with oil mist or under pressure. To cool the piston with oil, special nozzles are placed on the upper head for supplying and atomizing oil.

The body of the connecting rod, subject to longitudinal bending, most often has an I-profile, but sometimes cross-shaped, tubular, round, and other profiles are used (Fig.8.12).

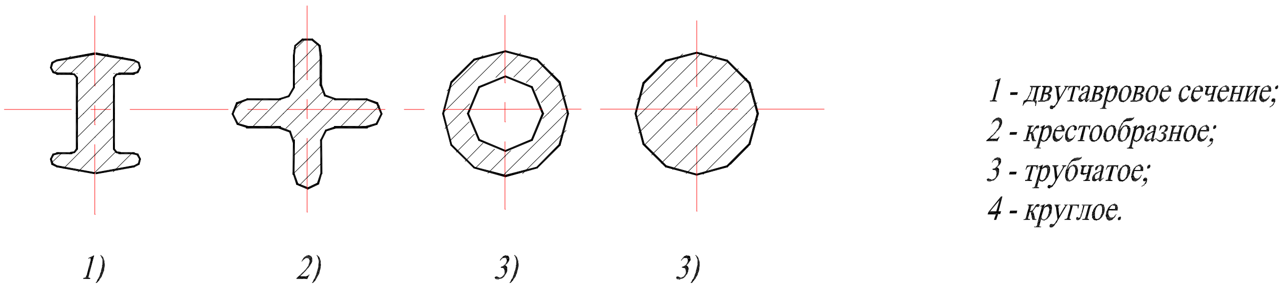


Fig. 8.12. **Types of connecting rod profile**

Smooth transitions from the rod to the heads are applied, which increases the rigidity of the connecting rod structure.

The lower heads of the connecting rods are usually split, with reinforcing lugs and stiffening ribs. Sometimes the cover is secured with 4 or 6 screws. It is processed in assembled form, and is marked in 2 places. Usually, the straight connector shown in (Fig. 8.13, a) is used. In the case when the lower head does not pass through the cylinder, an oblique connector (b) is used, which somewhat relieves the connecting rod bolts (improves assembly conditions).

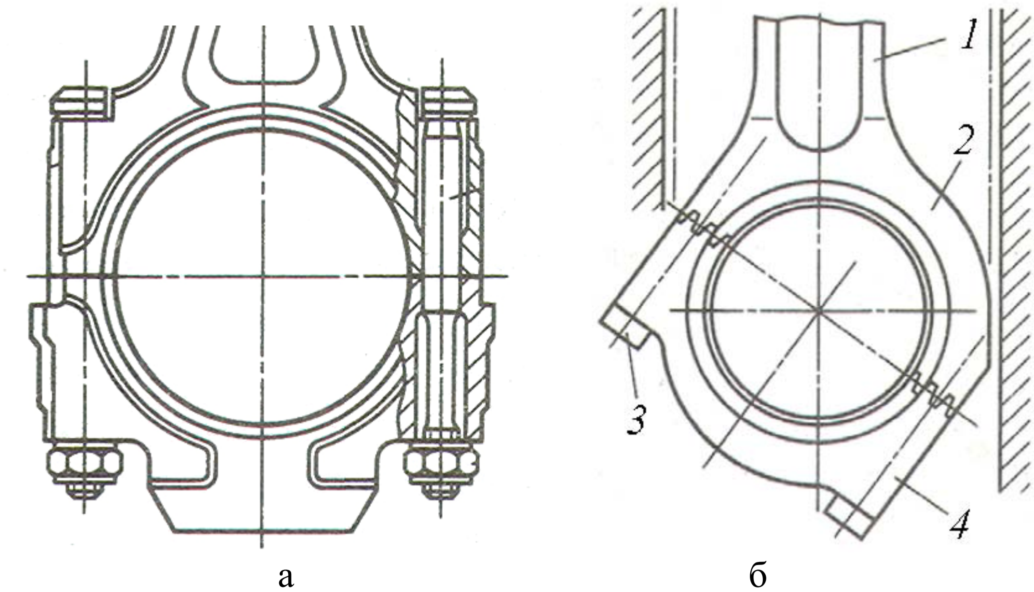


Fig. 8.13. **Connector types of the lower head of the connecting rod**:
2 - rod; 3 - lower head; 4 - lower head cover; 6 - connecting rod bolt

The plane of the oblique connector is usually placed at an angle of 45 ° (possible from 3 ° to 60 °).

8.8. *Connecting rod bolts and bearings*

Connecting rod bolts are one of the critical parts of the internal combustion engine. In most cases, it is at the same time the installation elements of the CRG.

The bolt heads have fixing flats against turning. The transitions on the "body" are made as smooth as possible.

The tightening of the bolts is selected from the conditions of not opening the joint of the split head. Usually, the bolts are secured with splint pins. For gasoline internal combustion engines, the bolt tightening torque is 70–80 Nm, for diesel engines - 180–240 Nm.

The material for the bolts is: chrome-nickel steel with heat treatment. The lower connecting rod ends are usually fitted with sleeve bearings. In rare cases, rolling bearings are used (trailed head, collapsible crankshaft).

Anti-friction bearing alloys are:

- bosses on a tin base B - 83;
- lead-based bosses SOS 6 - 6;
- high-tin aluminum alloys;
- lead bronze Br. C - 30.

In older ICE models, the alloy was poured over the "body" of the connecting rod head. In modern engines, liners are used, made of 2 half rings.

The connecting rods are supplied with thin-walled bushings made of steel tape (1.5–2.0 mm) coated with an antifriction alloy with a thickness of (0.2–0.4 mm), shown in Fig. 8.14.

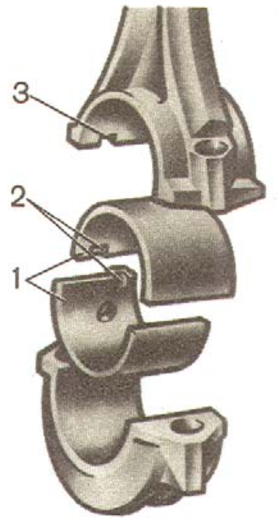


Fig. 8.14. **Connecting rod bearing**:
1 - steel liners; 2 - holding antennae; 3 – grooves

Such two-layer coatings are called bimetallic. Trimetallic ones are used (a copper-nickel sublayer is applied to the steel strip), which allows high specific pressures. Liners are interchangeable. Thin-walled bushings are fixed with whiskers, thick-walled ones – with pins. The inserts are lubricated with oil, which flows through the openings made in the crank. There are so-called "coolers" on the walls to increase their bearing capacity.

Connecting rods, like pistons, are selected by weight (6–8 g) and size.

In order to obtain a reliable fit on the connecting rod necks, they are made in the way that when tightening the connecting rod bolts, a slight interference is provided.

The diametral clearance between the bushings and the connecting rod journal is 0.025–0.08 mm.

8.9. *Design features of single and articulated connecting rods*

Single connecting rods are installed on single row and V-shaped engines. When installed on a two-row engine, two connecting rods are mounted on one connecting rod journal. As a result, one cylinder bank is displaced relative to the other. It increases the length of the crankshaft, and therefore the entire engine. They are unified with any single connecting rods.

Articulated connecting rods units represent a single structure, consisting of two paired connecting rods (Fig. 8.15).

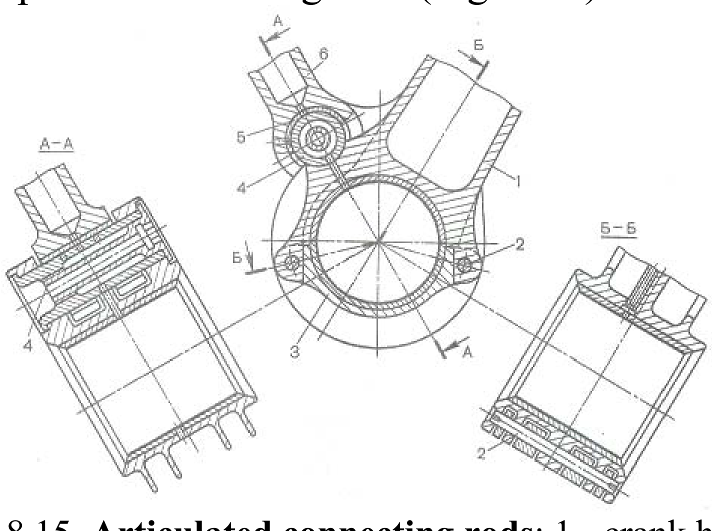


Fig. 8.15. **Articulated connecting rods**: 1 - crank head of the main connecting rod; 2 – split pins-pins; 3 - bottom cover; 4 - pin; 5 - bushing; 6 - connecting rod

By design, they are distinguished into:

a) forked or central;

b) with a trailed connecting rod.

Such connecting rods are structurally more complicated than single ones, but they make it possible to evenly distribute the load along the plane of the crankshaft crank heads. Articulated connecting rods are used on ship and diesel internal combustion engines.

8.10. *Purpose, composition and operating conditions of a crankshaft group (CSG)*

The purpose of a CSG is as follows: it takes part in the transformation of the progressive movement of the piston into the rotational movement of the crankshaft and conveying the torque to the transmission.

The CSG includes: crankshaft, flywheel, camshaft drive gears, seal parts, bearers of main bearings, etc.

The operating conditions are: it perceives the action of forces that are sharply variable in magnitude and direction; when a variable angular velocity occurs, causing torsional vibrations; it operates under conditions of increased friction and limited lubrication.

The requirements are as follows: it must have high strength, rigidity, wear resistance, low weight.

8.11. *Crankshaft*

The crankshaft diagram is shown in Fig. 8.16.

Main journals 7 serve as supports for the shaft, on which it rests and rotates.

The connecting rod journals are used to pivot the shaft with the lower connecting rod heads.

The cheeks combine the connecting rod and main journals into one unit and form cranks.

Shank is the back of the shaft, usually ends with a flange (for attaching the flywheel).

In the end face of the shank there is a hole for the bearings of the gearbox primary shaft. On a cylindrical surface, an oil-reflecting bead is made, an oil scraper thread or a smooth neck for a sealing gland.

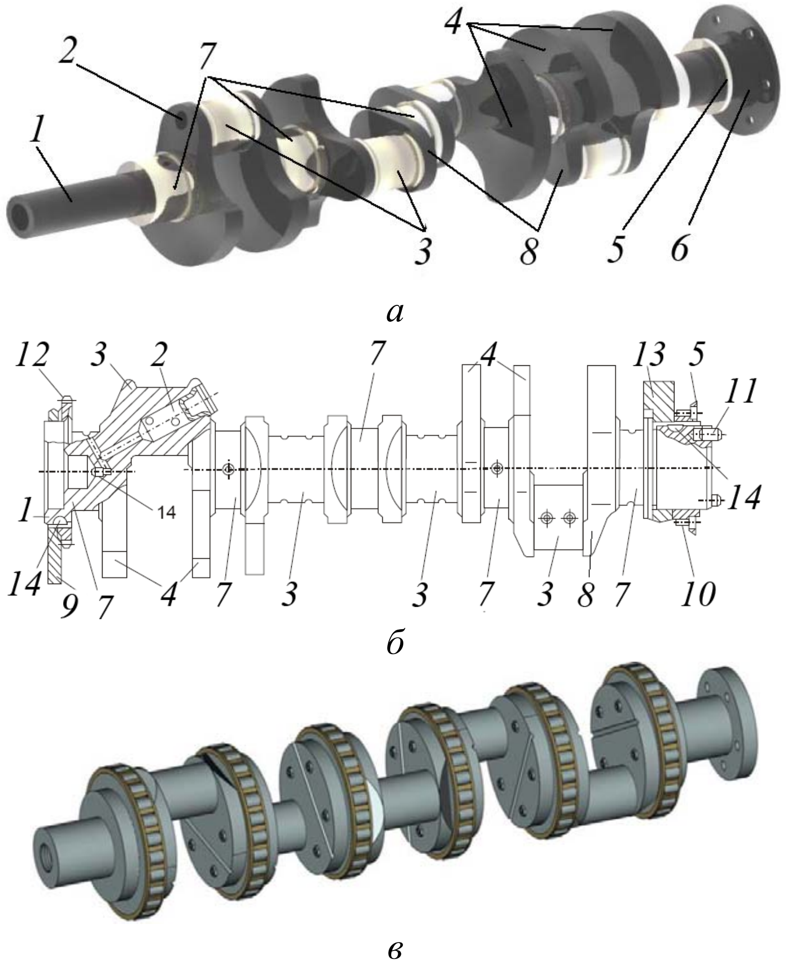


Fig. 8.16. **Varieties of crankshafts**: a – crankshaft of ZIL - 130 car engine; b - the crankshaft of KamAZ-740 diesel engine; c - collapsible crankshaft of TATRA-815 vehicle;
1 - the front end of the crankshaft; 2 - dirt trap cavity;
3 - connecting rod neck; 4 - counterweights; 5 - oil deflector; 6 - flange for fastening the flywheel; 7 - root neck; 8 - cheek; 9 and 13 - removable counterweights; 10 - a distribution gear wheel; 11 - locating pin; 12 - gear wheel of the oil pump drive; 14 – key

The toe is the front part of the crankshaft, on which the timing gear, oil deflector and fan pulley are installed. From the end there is a ratchet gear. On the side surface there is a groove for a key that fixes the gear.

Counterweights are installed on the cheeks on the side opposite to the crank; they serve for full or partial unloading of the main bearings from local centrifugal forces.

To supply oil to the connecting rod bearings, the shaft has drilling and technological channels. The connecting rod journals are usually equipped with dirt traps, which significantly improve oil cleaning. Crankshafts are distinguished into full-support and partial-support (MeMZ). The larger the number of supports, the higher the stiffness of the shaft. The shaft with the most possible number of supports is called full support.

The materials used are: carbon steel, made by hot stamping or forging (M-412, ZIL-130, YaMZ-236, 238), high-strength magnesium cast iron (GAZ-24, VAZ, GAZ-53A). Crankshafts are statically and dynamically balanced. The stiffness of the shaft increases due to the "overlap" of the journals.

To increase the overall strength of the shaft, the mating of the necks is performed with smooth transitions – with dumbbells.

8.12. *Main bearing bearers*

Bimetallic or trimetallic bushings are used as main bearings. The design and manufacturing technology are the same as for connecting rod bushings. It features a thicker steel strip.

Crankshafts are strictly fixed against axial displacement (no more than 0.2 mm is allowed). Axial fixation is carried out by fixing washers, as a rule, only at one of the main supports, either extreme (with a helical gear or a timing chain drive), or in the middle of the internal combustion engine. Washers are made of sheet steel with an anti-friction coating.

8.13. *Shaft seal*

The crankshaft is sealed in the crankcase using various oil seals, and also has oil and dust repelling devices (Fig.8.17).

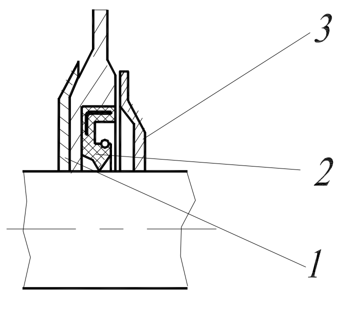


Fig. 8.17. **Crankshaft seal**:
1 - dust deflector; 2 - stuffing box; 3 - oil deflector

For some cars, the seals of the rear end of the crankshaft are used from a graphited asbestos cord (GAZ-24, GAZ-66). Additionally, the crankshaft has an oil deflector flange and oil-wiping thread.

8.14. *Shaft layout diagram*

The schemes are chosen so as to ensure a uniform alternation of working strokes, regardless of the cycle time.

The alternation of working strokes in the cylinders is called the *engine work sequence*.

There is a principle that consistently working the engine cylinders should be as far apart as possible.

Example: for a four-stroke engine

1 - 2 - 4 - 3

or 1 - 3 - 4 - 2

Working stroke alternates 720 °: 4 = 180 °

This conditionally satisfies the crankshaft, where the cranks are located in the same plane.

In six-cylinder there is 720° : 6 = 120°

8.15. *Flywheel and torsional vibration dampers*

The flywheel serves to balance the angular speed of the crankshaft, remove the CSM parts from dead spots and carry out auxiliary operation strokes. The flywheel is cast from cast iron in the form of a disk with a massive rim and is subject to dynamic balancing as an assembly with the crankshaft.

To scroll the shaft when starting the engine with an electric starter, a gear ring is pressed onto the flywheel rim.

The flywheel with the crankshaft is fixed with a dowel pin or asymmetrically located bolt holes on the flange. Marks are applied to the cylindrical surface TDC.

A clutch is attached to the flywheel. When meshed with one side of the crankshaft, it will perform elastic vibrations.

When oscillations from forces coincide with its own, the phenomenon of *resonance* occurs. The number of revolutions corresponding to the resonance is called *critical*. In this case, the destruction of the shaft is possible. The stiffer the shaft, the higher the number of critical revolutions. If the stiffness is changed, but the critical speed is not successful, a vibration damper is installed.

A damper is usually installed on the toe (Figure 8.18), where torsional vibrations have the greatest value.

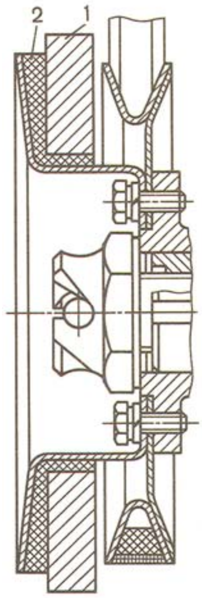


Fig. 8.18. **Torsional vibration damper**:
1 - flywheel; 2 - vulcanized rubber gasket

In automobile engines, *frictional* (dry friction), *internal friction* (rubber) and *liquid friction* dampers are used.

Internal friction dampers are the most common.

References

1. Кисликов В.Ф., В.В. Лущик. Будова й експлуатація автомобілів. Київ: Либідь, 2018. – 400 с.

2. Скляров В.М., Волков В.П., Скляров М.В. Автомобільні двигуни. Особливості конструкції: навч. посібник – Харків: ХНАДУ, 2012. – 405с.

3. Омеличев А.А. Підручник з будови автомобіля. – Дніпро: Моноліт, 2019. – 288 с.

4. Білоус Б.Д., Ткачук П.П., Андрусик Ю.Ф., Білоус Н.Б., Онищенко В.В. Армійська техніка. Основи руху, будова, характеристика: навч . посібник. – Л.: Вид-во Національного університету «Львівська політехніка», 2007. – 536 с.

Test questions

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1. What are the main functions of the crank mechanism of the engine?
2. What are the main functions of the engine crankshaft?
3. What does a flywheel do?
4. What are the functions of piston?
5. What part of the crank mechanism is the main base part of the engine?
6. What part of the crank mechanism is the effective engine power removed from??
7. Which part of the mechanism has a camshaft drive gear?
8. What part of the crank mechanism ensures uniform rotation of the crankshaft?

9 CONCEPTUAL MODULE

Gas distribution mechanism (GDM)

9.1. Purpose of GDM
9.2. Valve GDM
9.3. Parts of valve GDM
9.4. Spool and combined GDM
9.5. Valve timing
9.6 Variable valve timing

9.1. *Purpose of GDM*

The gas distribution mechanism serves to timely intake into the engine cylinder the air-fuel mixture (for engines with external mixing) or air (for engines with internal mixing) and the timely exhaust of waste gases in accordance with the flow of the work cycle in each engine cylinder, as well as to seal the intake and exhaust ports.

The main task of GDM is to ensure the intake of the maximum possible amount of the air-fuel mixture (or air) into the engine cylinder and the best cleaning of the combustion chamber from waste gases.

The gas distribution mechanism consists of a gas distribution mechanism itself and a gas distribution mechanism drive.

Depending on the sealing method, the gas distribution mechanisms are divided into *valve*, *spool* and *combined* GDM. Gas distribution mechanisms can also be with a lower and upper engine camshaft arrangement. With a lower camshaft arrangement, the GDM design has the largest number of moving parts, which increases the cost of the engine. On modern engines, gas distribution mechanisms with an upper camshaft arrangement are used; such designs allow increasing engine power through the use of additional valve timing control devices.

On widespread four-stroke piston internal combustion engines, the following types of gas distribution mechanism drives are used: gear, chain, belt, combined and electromagnetic.

9.2. *Valve gas distribution mechanism*

The valves that cover the intake and exhaust ports respectively are called *intake* and *exhaust* valves.

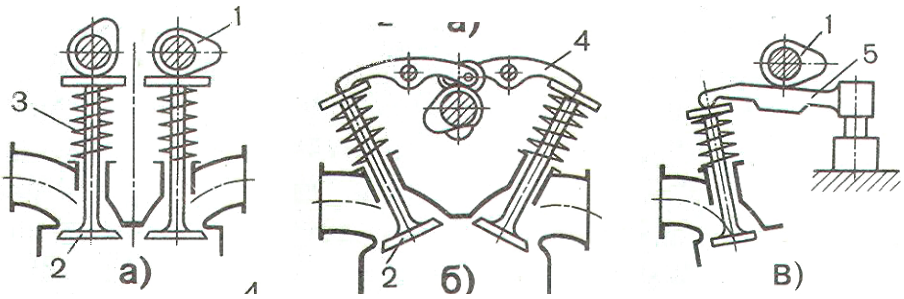
Each cylinder has at least 2 valves: an intake valve and an exhaust valve.

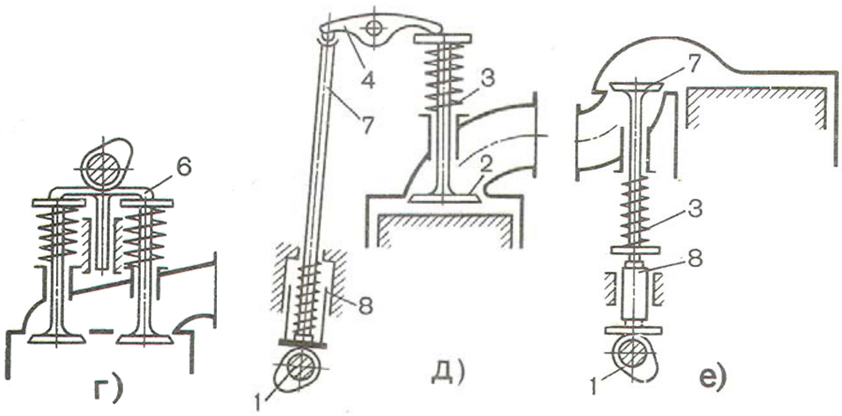
The valves are controlled by camshaft cams, which are driven by the crankshaft. During the operating cycle, i.e. during two revolutions of the crankshaft, each of the valves is opened once. Consequently, the camshaft must be turned once per two revolutions of the crankshaft.

Depending on the position of the valve in the cylinder, there are upper-valve, lower-valve and mixed GD mechanisms (Fig. 9.1).

On modern four-stroke internal combustion engines, the camshaft can be located both in the cylinder head and in the cylinder block. There are four camshaft arrangements: lower camshaft arrangement with overhead valve arrangement (OverHead Valve "OHV"); upper camshaft arrangement with overhead valve arrangement (OverHead Camshaft "OHC"); upper camshaft arrangement with overhead arrangement of the double number of valves (Single OverHead Camshaft "SOHC"); upper double camshaft arrangement with overhead arrangement of the double number of valves (Double OverHead Camshaft "DOHC").

Due to the use of four valves per cylinder, preference is given to the "DOHC" layout (one camshaft drives the intake valves, the other – the exhaust ones).





а) – a)	б) – b)	в) – c)
г) – d)	д) – e)	е) – f)

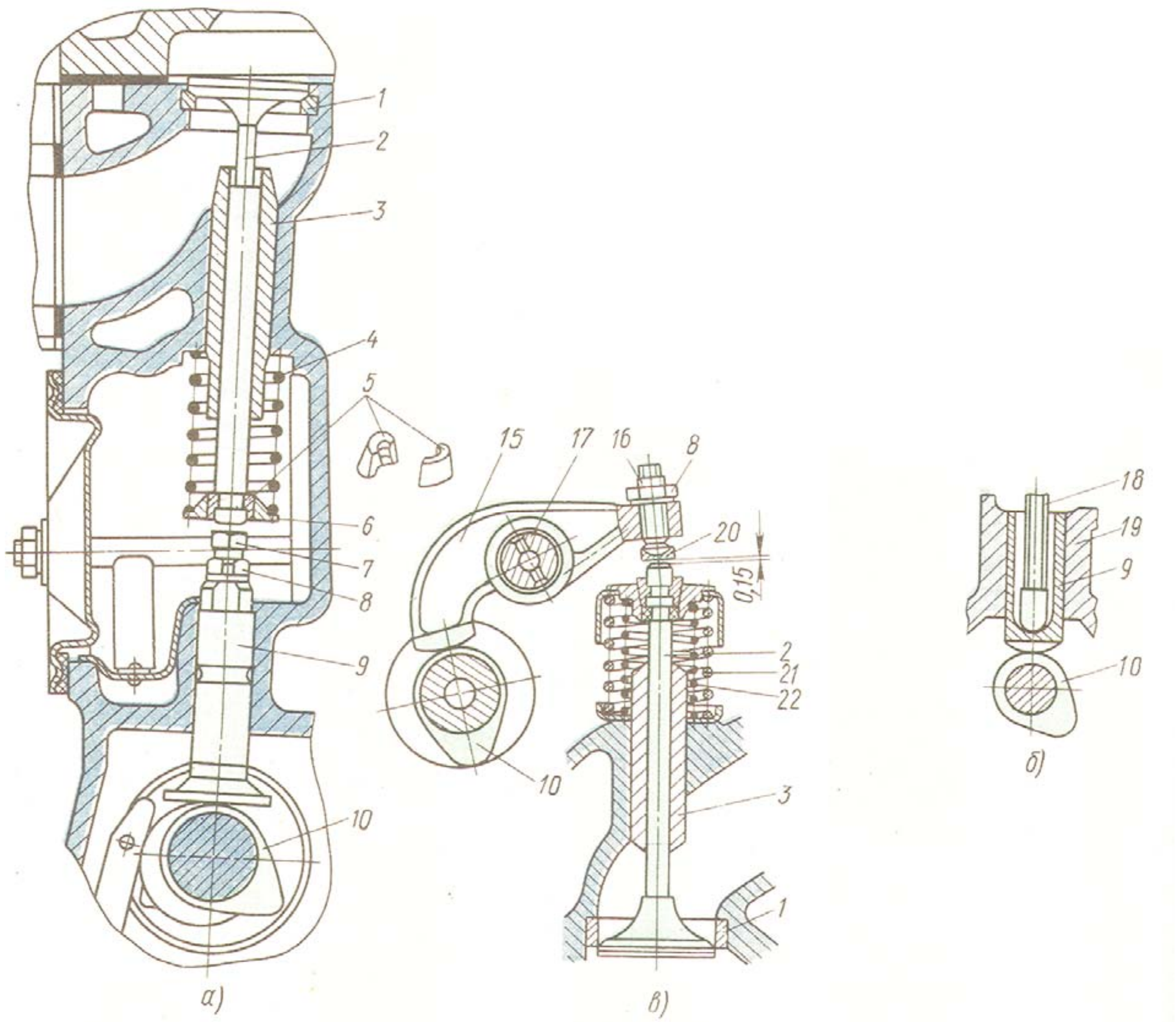
Fig. 9.1. **Arrangement diagram and valve drive:**
a, b, c and d – overhead arrangement of the valves with a drive from the camshaft mounted on the cylinder head; e – overhead arrangement of the valves with lower arrangement of the camshaft; f – lower arrangement of the valves; 1 – camshaft with cams; 2 – valve; 3 – spring; 4 – rocker arm; 5 – lever; 6 – traverse; 7 – push rod; 8 – pusher

Table 9.1 **- Comparison of the mechanisms shown in Fig. 9.2**

Advantages (a)	Advantages (b)
1. Simple, low-cost in manufacturing	1. The WP is significantly improved due to the radial CC
2. Reliable in operation	2. Convenient adjustment
3. Keeps adjustment well during operation	
Disadvantages (a)	Disadvantages (b)
1. Irrational shape of CC	1. Requires frequent adjustments
2. Worse filling	2. Rapid wear
3. Inconvenient adjustment	3. Noise in operation

Mixed arrangement – some of the valves are located in the head, some in the block. It combines the advantages and disadvantages of both layouts. There are also desmodromic gas distribution mechanisms. The desmodromic gas distribution mechanism is radically different from other gas distribution mechanisms, since its valve groups do not have return springs.

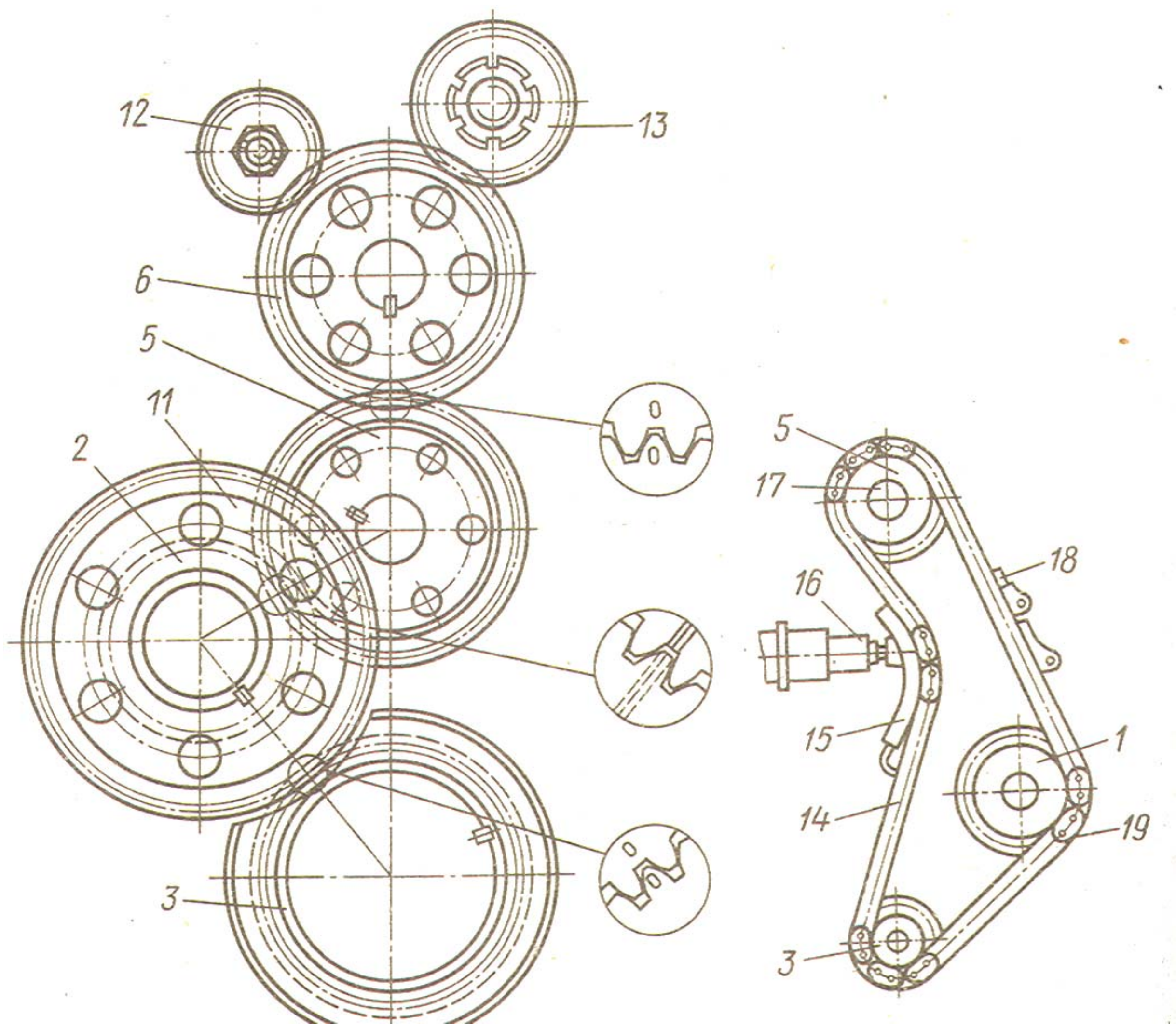
The role of the valve return springs is performed by additional rocker arms, which forcibly close the valves with the same intensity as they open them.



а) – a)	б) – b)	в) – c)

Fig. 9.2. **Lower shaft arrangement:**
a – with lower arrangement of valves and camshaft;
b – with overhead valve arrangement and lower camshaft arrangement;
c – with overhead valve arrangement and upper camshaft arrangement

The drives of the engine gas distribution mechanism are of the following types: gear, chain, belt, combined and electromagnetic. An example of a gear and chain type is shown in Fig. 9.3.



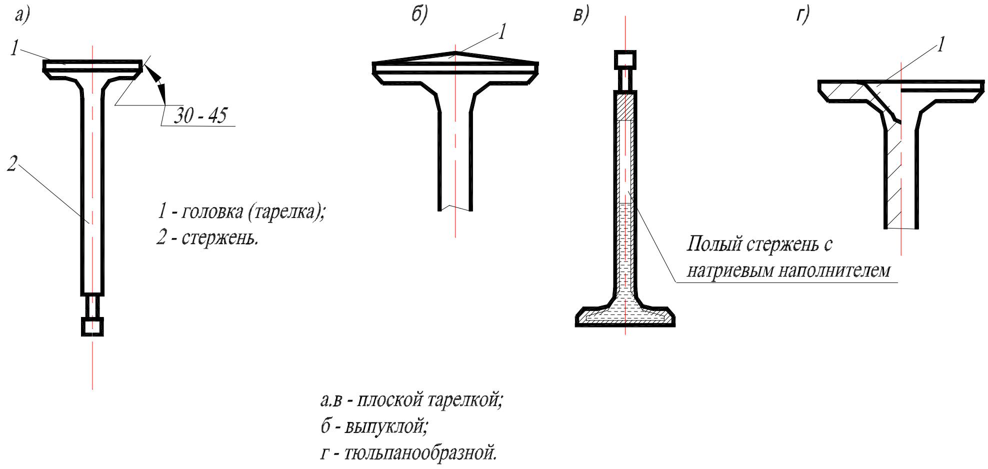
a b

Fig. 9.3. **The drives of the engine gas distribution mechanism:**
a – KAMAZ-740; b – VAZ-2107 car; 1 – gear wheel; 2 and 11 – intermediate gear wheels; 3 – crankshaft distribution gear wheel; 4, 7 and 10 – marks; 5 – camshaft gear wheel; 6 and 9 – gear wheel of the fuel pump; 8 – gear wheel of the fan drive; 12 – gear wheel of the drive of the hydraulic booster pump; 13 – gear wheel of the compressor drive; 14 – slack side of the chain; 15 – shoe of the tensioning mechanism; 16 – tensioning mechanism; 17 – camshaft; 18 – accelerator; 19 – driving side

9.3. *Parts of valve gas distribution mechanisms*

The *valves* consist of a head (cap) and a stem (see Fig. 9.4).

They come with different heads: flat, arched and tulip-type. Some are sodium cooled (ZIL-130) (Fig.9.5). The valves are made of heat-resistant chromium-nickel steels.



а) – a)	б) – b)	в) – c)	г) – d)
1 – головка (тарелка);		1 – head (cap);	
2 – стержень.		2 – stem.	
а, в – плоской тарелкой;		a, b – flat head;	
б – выпуклой;		c – arched head;	
г – тюльпанообразной.		d – tulip-type.	
полый стержень с натриевым наполнителем		sodium filled hollow stem	

Fig. 9.4. **Intake and exhaust valves**

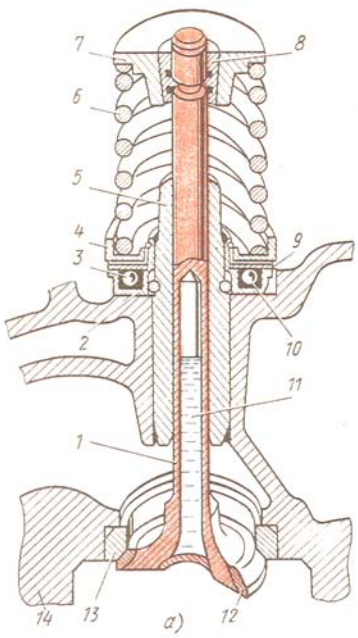


Fig. 9.5. **Intake valve of the gas distribution mechanism**
1 – stem; 2 – body; 3 – balls; 4 – stop plate;
5 – stem guide; 6 – spring; 7 – plate; 8 – split taper cotter;
9 – disc spring; 10 – spring; 11 – inner cavity of the valve; 12 – head;
13 – seat; 14 – head of the block

Seats – valve rings – are inserted directly into the cylinder block or head.

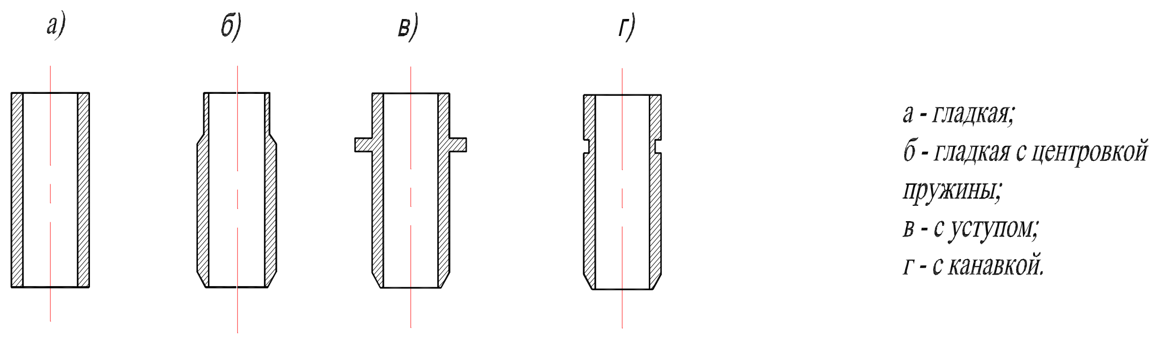
Material: special cast iron, alloy steel, cermet.

V*alve springs* ensure a tight fit between the valves and the seats.

Coiled cylindrical springs are used. To eliminate resonance, two springs are placed or a spring with a variable number of coils. To increase the operating time of the exhaust valves, mechanisms for forced rotation of the valves relative to the valve seat are used (see Fig. 9.5).

In order to avoid "sticking", the valve guides are made of a smaller diameter near the head.

Valve guides (see Fig. 9.6) are made of bronze, pearlitic cast iron, cermet.



а) – a)	б) – b)	в) – c)	г) – d)
а – гладкая;		a – smooth;	
б – гладкая с центровкой пружины;		b – smooth with spring centering;	
в – с уступом;		c – with a ridge;	
г – с канавкой.		d – with a groove.	

Fig. 9.6. **Valve guides of various shapes**

They are supplied with oil deflector caps for protection against oil.

The *camshaft* is designed for timely opening of the valves shown in Fig. 9.7.

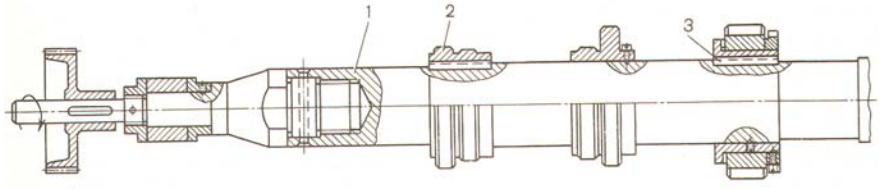
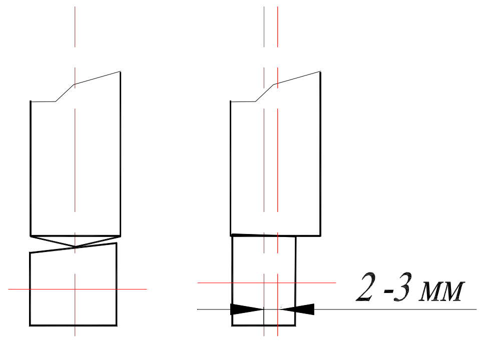


Fig. 9.7. **Camshaft:**
1 – shaft; 2 – removable cam; 3 – key

Material: alloy steel and carbon steel as well as high-strength cast iron.

Bearings: bimetallic bushings or rings.

The *push rod* can be positioned either on the tapered cam or with off-center of the cam (Fig. 9.8). The rods are made “monolithic” or tubular. They are made of steel or duralumin (with a pressed-in tip).



мм	mm

Fig. 9.8. **Variants of pusher arrangement**

Rocker arms are manufactured with different arms required to open the valve. The short arm is provided with a hole for an adjusting bolt. The guide is most often made of tin bronze. Oil is fed through the rocker shaft.

The valve clearance is compensated for by thermal expansion (0.15–0.3 mm).

9.4. *Spool and combined gas distribution mechanisms*

They have a reciprocating or rotary motion. Rotating with a cylindrical flat and tapered spool.

Two-stroke internal combustion engines with slots are also spool valves. Combined gas distribution mechanisms consist partly of valve gas distribution mechanisms and partly of those with a valve-slotted scavenging.

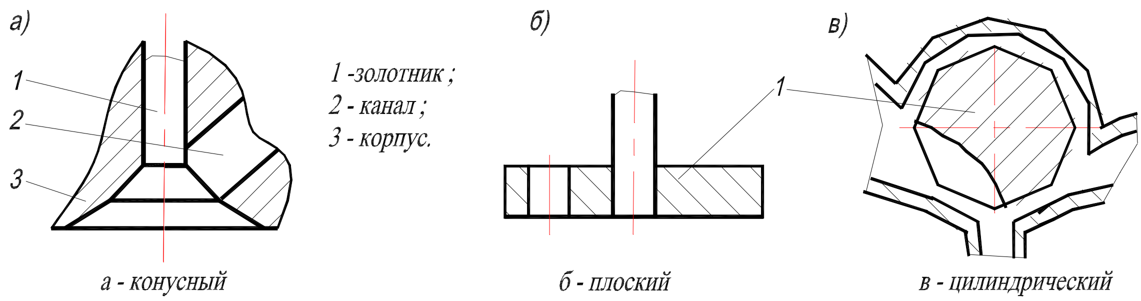
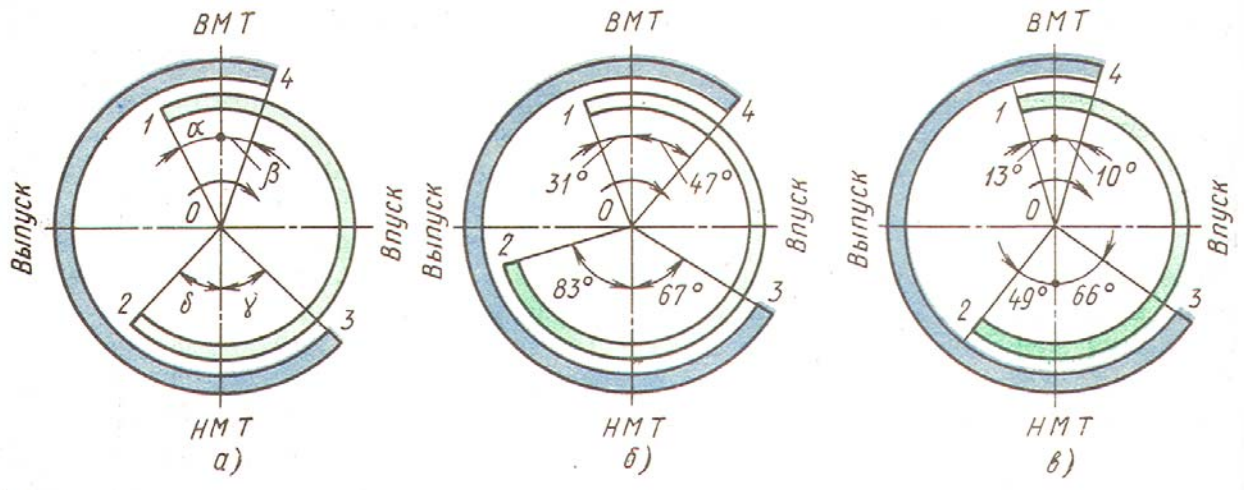


Fig. 9.9. **Spool and combined GDM**

<table>
<tr><td colspan="2">а) – a)</td><td colspan="2">б) – b)</td><td colspan="2">в) – c)</td></tr>
<tr><td colspan="3">а – конусный</td><td colspan="3">a – conical</td></tr>
<tr><td colspan="3">б – плоский</td><td colspan="3">b – flat</td></tr>
<tr><td colspan="3">в– цилиндрический</td><td colspan="3">c – cylindrical</td></tr>
<tr><td colspan="3">1 – золотник;</td><td colspan="3">1 – spool;</td></tr>
<tr><td colspan="3">2 – канал;</td><td colspan="3">2 – passage;</td></tr>
<tr><td colspan="3">3 – корпус.</td><td colspan="3">3 – body.</td></tr>
</table>

9.5. *Valve timing*

The opening moments and expressed in degrees of rotation of the crankshaft in relation to the corresponding points of TDC and BDC are called valve timing. They are represented in the form of a diagram (Fig. 9.10).



<table>
<tr><td colspan="2">а) – a)</td><td colspan="2">б) – b)</td><td colspan="2">в) – c)</td></tr>
<tr><td colspan="3">выпуск</td><td colspan="3">exhaust</td></tr>
<tr><td colspan="3">впуск</td><td colspan="3">intake</td></tr>
<tr><td colspan="3">ВМТ</td><td colspan="3">TDC</td></tr>
<tr><td colspan="3">НМТ</td><td colspan="3">BDC</td></tr>
</table>

Fig. 9.10. **Valve timing diagrams:**
a – general for four-stroke engine; b – engine of ZIL-130 car;
c – diesel engine of KAMAZ-740; 1 – 2 – intake phase; 3 – 4 – exhaust phase;
0 – the center of rotation of the shaft

Intake valve	Exhaust valve
$\alpha = 12–31°$	$\gamma = 42–67°$
$\delta = 40–83°$	$\beta = 10–47°$

9.6 *Variable valve timing*

The efficiency of the internal combustion engine is mainly determined by the organization of the gas exchange process, that is, high-quality and timely filling and cleaning of the engine cylinders. This task is assigned to the valve timing mechanism and depends on the valve timing – the moments and duration of the open state of the intake and exhaust valves. If the valves are open for a short time, the phases are called "narrow". The longer the valves are open, the "wider" the phases.

At low crankshaft speeds, the volumes and speed of movement of the air-fuel mixture (air in diesel engines) and exhaust gases are small, therefore, the phases should be narrow, and the overlap (the time of simultaneous opening of the intake and exhaust valves) should be minimal. In this case, the fresh mixture is not forced into the exhaust manifold through the open exhaust valve and, accordingly, the exhaust gases do not enter the intake manifold. If the phases are "widened" at low speeds, the exhaust gases will mix with the fuel-air mixture (clean air in diesel engines), thereby reducing its quality, which will inevitably lead to a drop in engine power and its unstable operation.

With an increase in revolutions, the volumes and speed of movement of the air-fuel mixture (air for diesel engines) and exhaust gases per unit of time increase proportionally, therefore, "wide" phases and longer overlap times are required for better cylinder scavenging. Scavenging is the displacement of exhaust gases from the cylinder by a fuel-air mixture moving at a high speed.

The phase width is determined by the shape of the camshaft cams. The higher the cam height, the higher the valve lift. The blunter its end, the longer the maximum valve lift time. Thus, by choosing the shape of the cams, designers can tune the engine to work only in a certain range of revolutions.

In the design of a conventional car, an average camshaft is designed to balance power and economy.

With a deviation from this range, both in the direction of decreasing and in the direction of increasing, the efficiency of the internal combustion engine will decrease. For example, a "narrow-phase" engine will not allow high power to be developed, and a "wide-phase" engine will operate unstably at low speeds, as a result of which it is necessary to increase the frequency of idling revolutions.

Therefore, the ideal solution would be to vary the phase width depending on the engine speed. This is how the valve timing control systems appeared.

For the technical implementation of the idea of phase control, many designs have been created that significantly increase the efficiency of the GDM, and, consequently, improve the characteristics of the engine.

Depending on the adjustable parameters of the gas distribution mechanism, the following methods of the variable valve timing are distinguished:

– camshaft rotation (*VANOS (Double VANOS); Variable Valve Timing with intelligence “**VVT-I**” (**Dual VVT-i**); Variable Valve Timing “**VVT**”; Variable Timing Control “**VTC**”; Continuous Variable Valve Timing “**CVVT**”* и *Variable Cam Phases “**VCP**”*);

– stepwise variable valve lift (*Variable Valve Timing and Lift Electronic Control “**VTEC**”*; *Variable Valve Timing and Lift with intelligence “**VVLT-i**”; Mitsubishi Innovation Valve Timing Electronic Control “**MIVEC**”; Audi Valvelift System “A**VS**”*);

– continuously variable valve lift (***Valvetronic, Valvematic****; Variable Valve Event and Lift System “**VVEL**”; Variable Valve and Timing Injection “**VTI**”* и ***MultiAir***).

References

1. Кисликов В.Ф., В.В. Лущик. Будова й експлуатація автомобілів. Київ: Либідь, 2018. – 400 с.

2. Скляров В.М., Волков В.П., Скляров М.В. Автомобільні двигуни. Особливості конструкції: навч. посібник – Харків: ХНАДУ, 2012. – 405с.

3. Омеличев А.А. Підручник з будови автомобіля. – Дніпро: Моноліт, 2019. – 288 с.

4. Білоус Б.Д., Ткачук П.П., Андрусик Ю.Ф., Білоус Н.Б., Онищенко В.В. Армійська техніка. Основи руху, будова, характеристика: навч . посібник. – Л.: Вид-во Національного університету «Львівська політехніка», 2007. – 536 с.

Test questions

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1. How does the gas distribution mechanism work?
2. What is the main and secondary purpose of the camshaft?
3. At what angle are the camshaft cams of the same name located?
4. What is the main purpose of a camshaft?
5. What is the main purpose of the push rod of the gas distribution mechanism?
6. What is the main purpose of the GDM timing gear?
7. What is the main purpose of the pusher in the gas distribution mechanism?
8. Under which valves are inserts (made of high-temperature cast iron) installed?
9. What effect does the wear of the drive gears of the gas distribution mechanism have on the valve timing?
10. What is the effect of increasing the clearance between the valve stem and the toe of the rocker arm on the valve timing?
11. What is the effect of decreasing the clearance between the valve stem and the toe of the rocker arm on the valve timing?
12. What is the effect of incorrect installation of the crankshaft and camshaft gears on the valve timing (the designations on the gears do not coincide)?
13. Which part of the gas distribution mechanism is provided with a locking device for the perception of axial forces?
14. Which part of the gas distribution mechanism is marked with alignment marks?
15. Which part of the gas distribution mechanism is provided by the helical gear of the drive of the oil pump and the distributor cam?
16. Which part of the gas distribution mechanism is provided with a special eccentric of the fuel pump drive?

10 CONCEPTUAL MODULE

Fuel system of gasoline internal combustion engines

10.1. Purpose and main parts of the fuel system.
10.2. Mixture formation and composition of the combustible mixture.
10.3. Elements of the fuel system.
10.4. Basic carburetor.
10.5. Auxiliary devices of the carburetor.
10.6. Fuel injection system.

10.1. *Purpose and main parts of the fuel system*

The fuel system is used to store the fuel supply, purify fuel and air, prepare a combustible mixture and supply it to the cylinders, as well as for the removal of exhaust gases (Fig. 10.1).

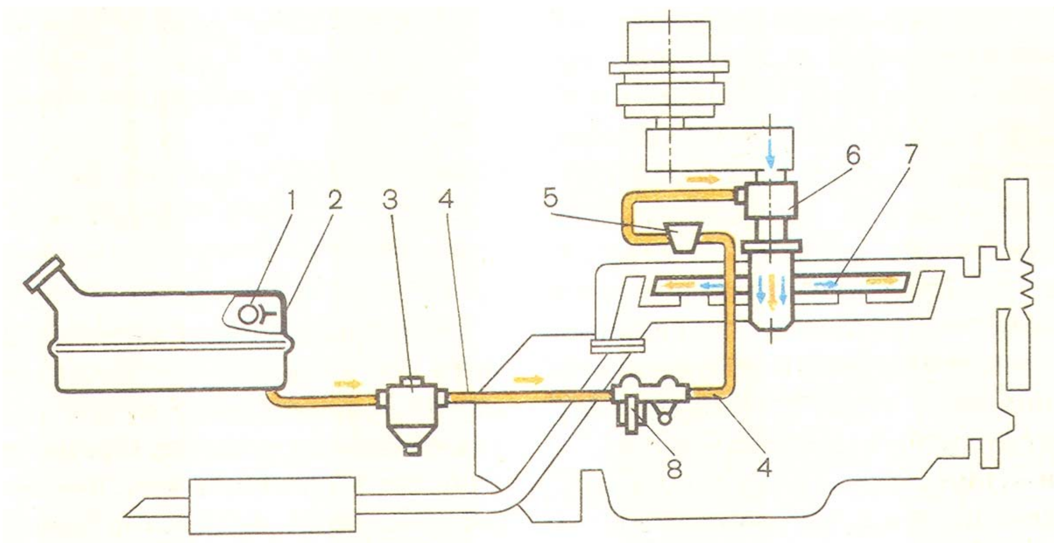


Fig. 10.1. **Diagram of the power supply system of carburetor internal combustion engine (ICE):**
1 – fuel level indicator; 2 – fuel tank; 3 – fuel filter;
4 – fuel line; 5 – fine fuel filter; 6 – carburetor;
7 – intake manifold; 8 – fuel pump

10.2. *Mixture formation and composition of the combustible mixture*

The mixing process consists in mixing fuel with air in a certain proportion. For complete combustion of 1 kg of gasoline, theoretically 15 kg of air is needed.

However, the actual amount of air can be more or less than the theoretical one. Therefore, the composition of the combustible mixture is usually characterized by the *excess air coefficient* α.

α is the ratio of the actual amount l of air in a mixture containing 1 kg of fuel to the theoretical amount l_o required for its complete combustion:

$$\alpha = l/l_0 = G_A/G_F \cdot l_0$$

where $l = G_A/G_F$ (air consumption kg/h divided by fuel consumption, kg/h);

There are the following compositions of the fuel-air mixture:

Rich	α = 0.55–0.85.
Enriched	α = 0.85–0.95.
Proper	α = 1.
Diluted	α = 1.05–1.15.
Lean	α = 1.15–1.35.

The main operating modes of the gasoline ICE:

- starting the engine (α = 0.2–0.6);
- idling and low loads (α = 0.7–0.8);
- medium loads (α = 1.05–1.15);
- full loads (α = 0.85–0.9);
- rapid change from low loads to large ones (α = 0.85–0.9) $0.5 < \alpha < 1.35$, – the limits of combustion of the combustible mixture.

10.3. *Elements of the fuel system*

10.3.1. Fuel tank.

Fuel tank is similar to diesel one (see section 11.3.1).

10.3.2. Fuel filters

They are similar to diesel ones (see section 11.3.2).

10.3.3. Fuel pump

Typically, a combustion engine uses a diaphragm-type fuel pump (see section 11.2.3).

The schematic diagram of the fuel pump is shown in Fig. 10.2.

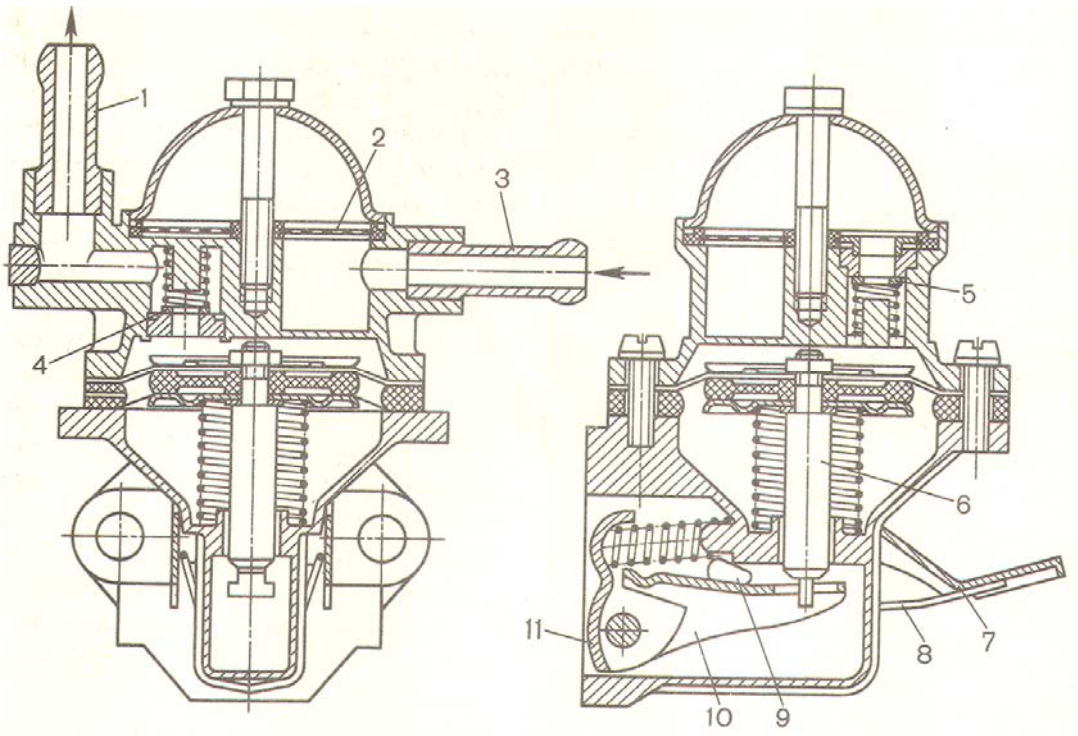


Fig. 10.2. **Fuel pump:**
1 – discharge pipe; 2 – strainer; 3 – suction pipe; 4 – discharge valve;
5 – suction valve; 6 – lifter; 7 – manual pumping lever; 8 – return spring;
9 – cam; 10 – balancer; 11 – mechanical pumping lever

The pump is driven from an eccentric of the oil pump drive shaft using a lifter and a mechanical fuel pumping lever, or a camshaft eccentric.

10.4. ***Basic carburetor***

The carburetor is designed to mix fuel and air in certain proportions, depending on the operating mode.

If passage *5* is connected to the intake manifold, the float chamber is called *balanced* as opposed to unbalanced (Fig. 10.3).

Regulation is carried out by throttle valve 4.

The main air passage consists of 3 parts:

– upper – confuser;

– middle – neck;

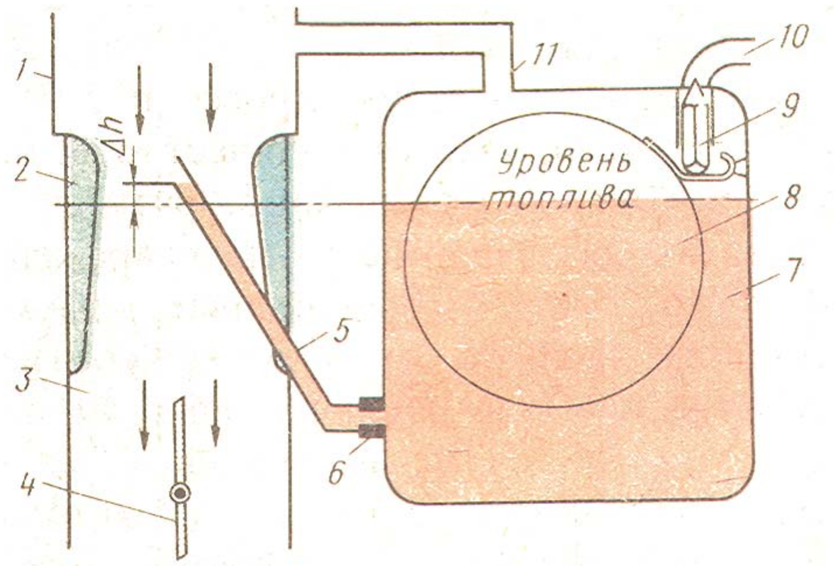
– bottom – venturi, and is designed so to increase the high-speed air flow. For the same purpose, not one, but two venturis are installed.

Depending on the location of the axis of the main air passage, the carburetors are divided into:

– horizontal

– inclined

– vertical



уровень топлива	fuel level

Fig. 10.3. **Scheme of the basic carburetor:**
1 – pipe; 2 – venturi; 3 – mixing chamber; 4 – throttle valve;
5 – spray nozzle; 6 – jet; 7 – float chamber; 8 – float;
9 – taper needle; 10 – manifold; 11 – passage

If the carburetor has several mixing chambers, it is called *multi-chamber* one.

Mixing chambers can be main and additional, chambers can be connected in series or in parallel.

10.5. ***Auxiliary devices of the carburetor***

The basic carburetor cannot automatically adjust the fuel dose in different modes. In order to obtain the desired pattern of changes in the mixture composition, it is necessary to compensate the mixture.

Compensation of the combustible mixture is usually called the change in its composition depending on the operating mode of the engine. And the devices that allow to do this are called *metering*.

In addition to the main task of compensation of the mixture at steady-state partial loads, carburetors should ensure easy starting, idling, and fast switching to other modes. Such devices are called *optional*.

10.5.1. Medium loads.

Automatic correction of the mixture composition at medium loads is carried out by the main metering system.

The most common are:

1 – lowering the vacuum in the venturi (Fig.10.4)

2 – with compensation of the mixture with two fuel jets (Fig.10.5)

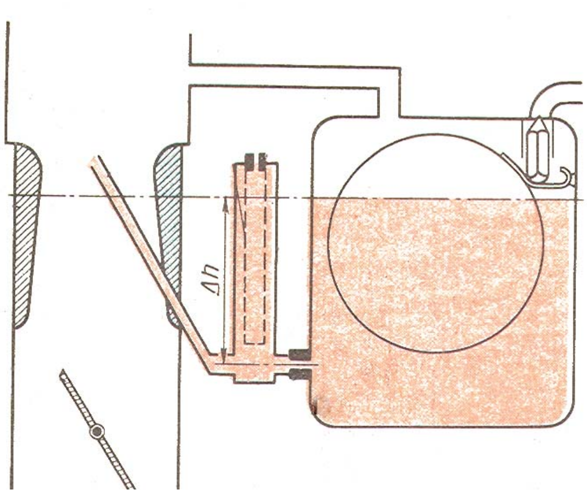
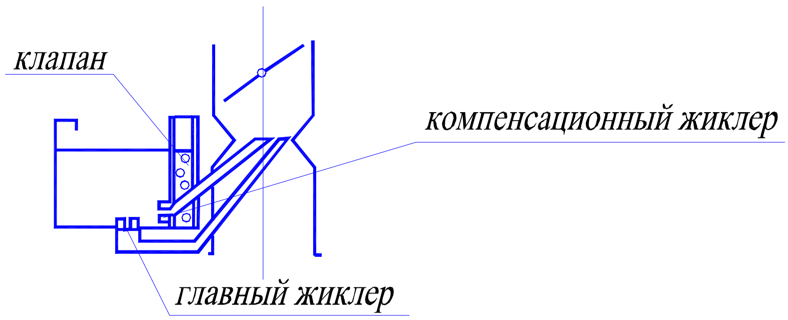


Fig. 10.4. **Correction of the mixture composition by lowering the vacuum in the venturi**

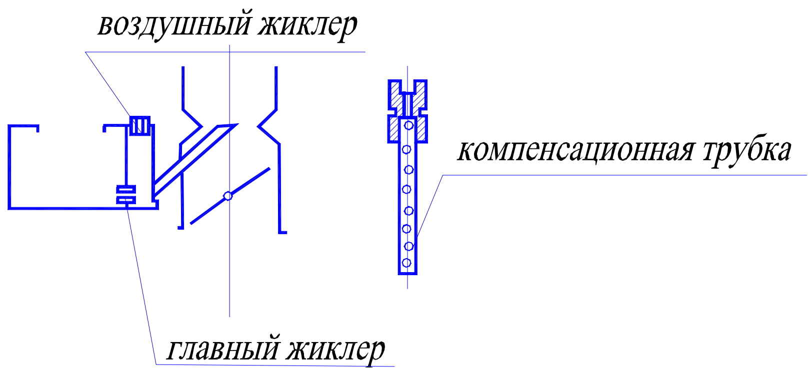


клапан	valve
компенсационный жиклер	compensating jet
главный жиклер	main jet

Fig. 10.5. **Compensation of the mixture with two fuel jets**

Due to the vacuum, the fuel level in the well decreases sharply. Air gets there, as a result of which an emulsion is formed and the mixture is leaned.

3 – with reduced vacuum at the fuel jet (pneumatic fuel braking) (Fig. 10.6).

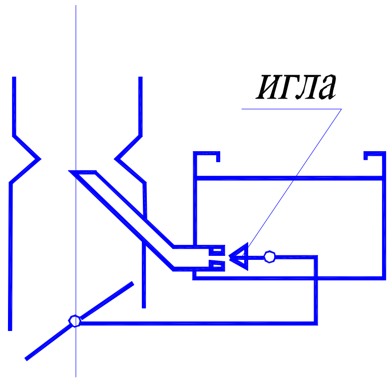


воздушный жиклер	air jet
компенсационная трубка	compensation tube
главный жиклер	main jet

Fig. 10.6. **Correction of the mixture composition by lowering the vacuum at the fuel jet (pneumatic braking of the fuel)**

With increasing the vacuum, holes in the emulsion tube open, the emulsion enters the spray nozzle, and the mixture becomes leaner.

4 – with metering pin (Fig. 10.7)



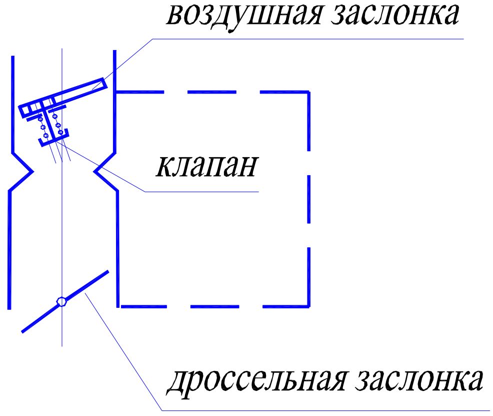
игла	pin

Fig. 10.7. **Correction of the mixture composition with a metering pin**

The orifice of the fuel jet is adjusted by the profiled metering needle.

10.5.2. Starter

The device is kinematically connected to the throttle, the latter opens slightly. After start, the valve opens (Fig. 10.8).



воздушная заслонка	choke
клапан	valve
дроссельная заслонка	throttle

Fig. 10.8. **Starter**

The heat controller is automatically regulated (thermostat, bimetallic plate).

10.5.3. Idle system

The fuel does not enter the spray nozzle in the main metering system, goes further through the passage, mixes with air and forms a fuel emulsion. It is regulated by the pilot screw (Fig. 10.9).

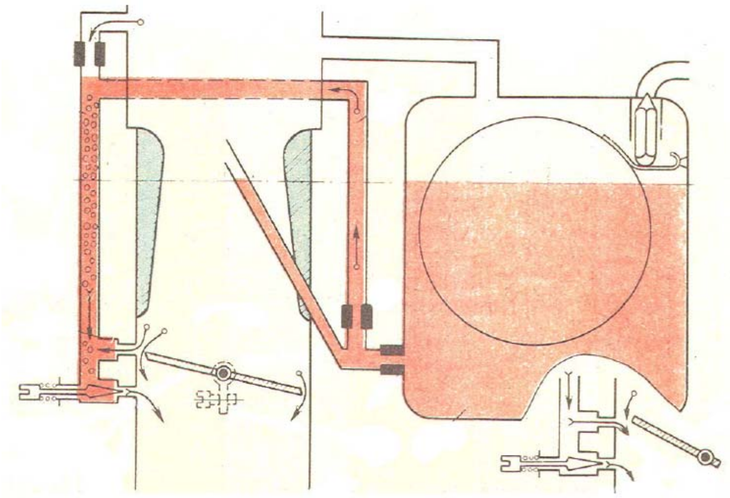


Fig. 10.9. **Scheme of economizer**

10.5.4. Transient power system

Designed for the smooth operation of ICE when the secondary chamber of the carburetor is opened. The device resembles an idle system, but its only hole is located above the edge of the throttle of the secondary chamber.

10.5.5. Accelerator pump (variable load mode)

If the valve opens slowly, then the piston also moves slowly, and the fuel smoothly flows around the bypass ball valve 1 and falls back into the float chamber (Fig.10.10).

When pressed hard, the valve closes and fuel enters the main air passage.

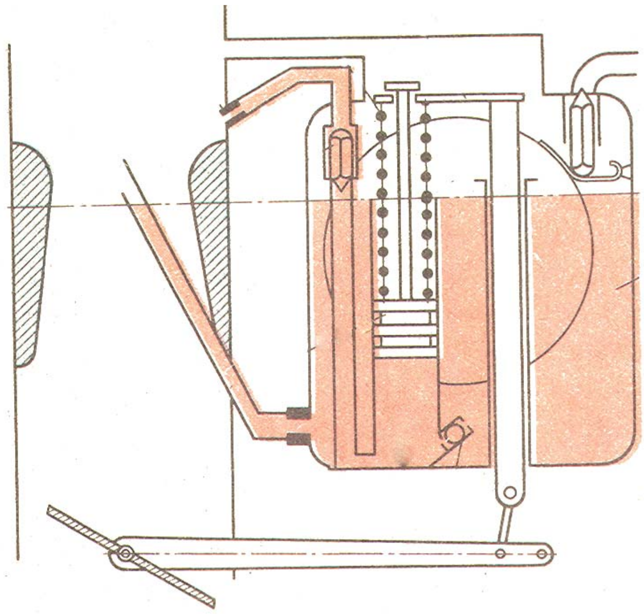


Fig. 10.10. **Scheme of accelerator pump**

10.5.6. Economizer (full load mode)

When pressing the pedal more than 80%, valve 1 opens, and the mixture is additionally enriched (Fig. 10.11).

There are a mechanical drive and a pneumatic drive.

Econostat is an enrichment device, a kind of economizer. It has no moving parts. Its autonomous system is similar to the main metering system, but may resemble a basic carburetor.

Econostats supply fuel either to the neck of the smaller venturi or to the area of the suction pipe of the main air passage (VAZ).

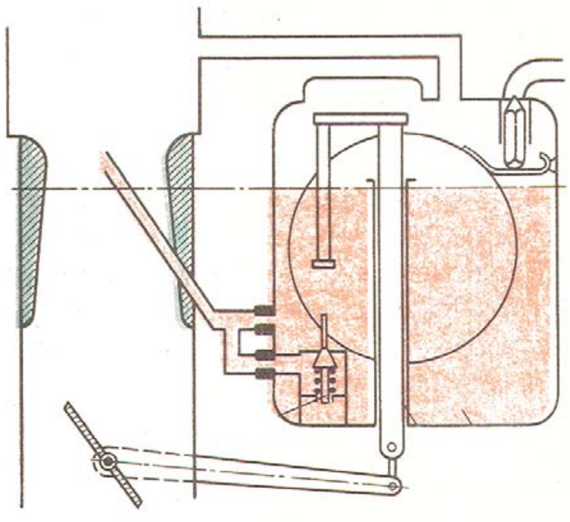


Fig. 10.11. **Economizer**

References

1. Кисликов В.Ф., В.В. Лущик. Будова й експлуатація автомобілів. Київ: Либідь, 2018. – 400 с.
2. Скляров В.М., Волков В.П., Скляров М.В. Автомобільні двигуни. Особливості конструкції: навч. посібник – Харків: ХНАДУ, 2012. – 405с.
3. Омеличев А.А. Підручник з будови автомобіля. – Дніпро: Моноліт, 2019. – 288 с.
4. Білоус Б.Д., Ткачук П.П., Андрусик Ю.Ф., Білоус Н.Б., Онищенко В.В. Армійська техніка. Основи руху, будова, характеристика: навч . посібник. – Л.: Вид-во Національного університету «Львівська політехніка», 2007. – 536 с.

Test questions

?

1. Which carburetor device maintains a constant fuel level in the spray nozzle of the jet?
2. Which carburetor device regulates the amount of the combustible mixture that is supplied to the cylinder?
3. Which carburetor device meters the amount of fuel that enters the carburetor mixer chamber?
4. Which carburetor device regulates the quality of the combustible mixture?
5. What auxiliary devices and systems in modern carburetors provide diluted mixture maintenance within the limits of medium engine loads?
6. What functions does the accelerator pump perform?

11 CONCEPTUAL MODULE

The fuel system of diesel engines

11.1. Purpose and types of fuel systems.
11.2. Schematic diagram of the direct injection fuel system and its operation.
11.3. Fuel system elements.
11.4. Injection pump.
11.5. Pump-injector unit.
11.6. Common rail injection systems.

11.1. *Purpose and types of fuel systems*

The *fuel system* is designed for storage, preparation, metering of fuel at a certain period of the working cycle and its distribution in the combustion chamber (CC).

Fuel supply systems in diesel engines are divided into direct injection systems and common rail injection ones.

In the former, fuel injection is provided directly by an injection pump.

In the latter, the fuel is pumped into the accumulator, in which the required amount of fuel is supplied to the CC.

The advantages of diesel internal combustion engines (ICEs) over gasoline ones:

– they are more cost-efficient than gasoline ICEs;

– the fuel is more stable during storage and less fire hazardous;

– there are fewer toxic components in the exhaust gases;

– less corrosive effect on the ICE parts;

– diesel engines are more reliable in operation (due to the absence of the ignition system).

However, they have the following *disadvantages*:

– worse vehicle responsiveness;

– more difficult start, especially in winter;

– have larger dimensions and weight (by 25%) in comparison with gasoline ICEs.

11.2. *Schematic diagram of the direct injection fuel system and its operation*

The diagram of the diesel power system is shown in Fig. 11.1.

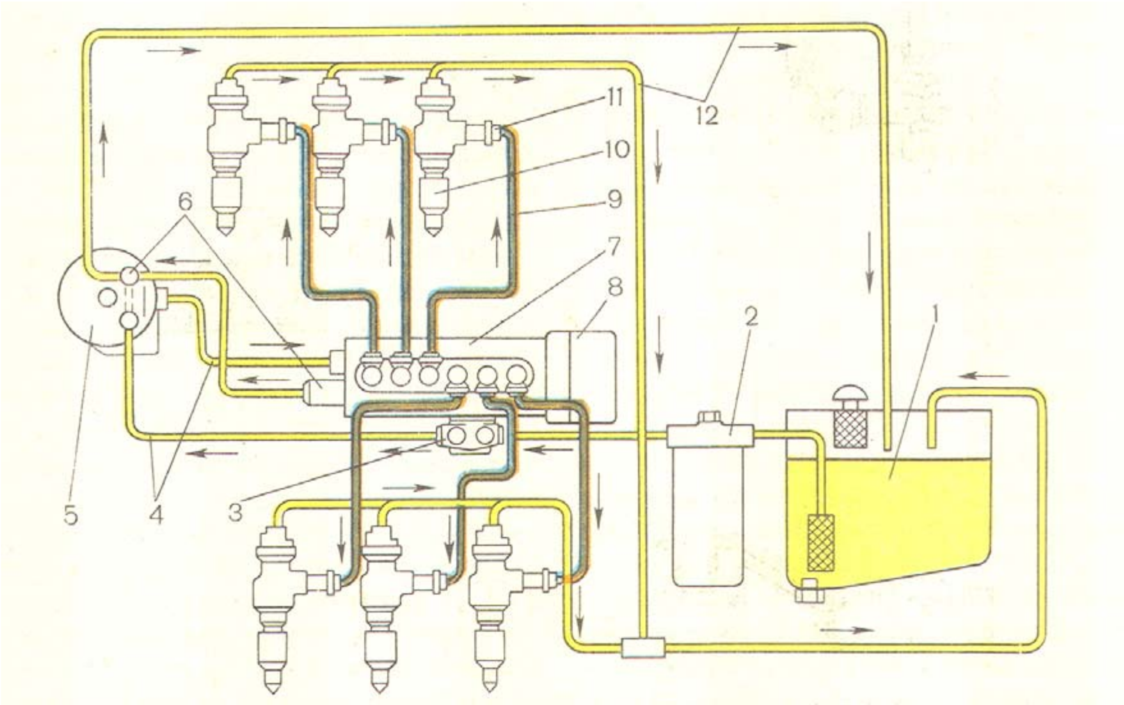


Fig. 11.1. **Diesel engine power system diagram**
1 – fuel tank; 2 – fuel strainer; 3 – fuel transfer pump; 4 – fuel supply pipes; 5 – fine filter; 6 – bypass valves; 7 – injection pump; 8 – automatic air to fuel ratio control; 9 – discharge pipe; 10 – injector; 11 – fitting with a safety filter; 12 – drain line

In the injection pump 7, fuel is supplied from the tank 1 through strainer 2 and filter 5 by the fuel transfer pump 3. Under high pressure, the fuel is supplied through the pipes to the injectors.

11.3. *Fuel system elements*

11.3.1. Fuel tank

It is fastened to the frame with brackets. It is welded from sheet steel and has two baffles inside. The filler pipe, which has a retractable neck with a strainer, is hermetically sealed with a double-valve plug. A fuel intake tube with a mesh filter is fixed inside, sometimes with a strainer.

The fuel level in the tank is monitored using a sensor with a float and an electrical indicator located in the cab. Some vehicles have multiple tanks.

11.3.2. Filters

11.3.2.1. Strainers

Raw fuel enters the strainer (Fig. 11.2) through the adapter 7, enters the housing 1, is pressed between the pairs of the filter element 2 and passes to the fine filter.

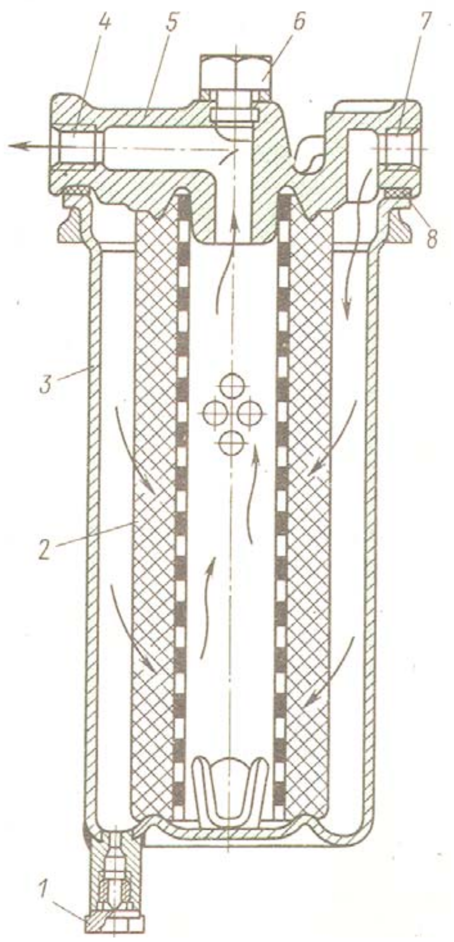


Fig. 11.2. **Strainer for automotive diesel engine:**
1 – drain plug; 2 – filter element; 3 – housing; 4, 7 and 13 – openings; 5 – cap; 6 – plug; 8 – gasket

The fine filter shown in Fig. 11.3 is similar in construction to the one described above.

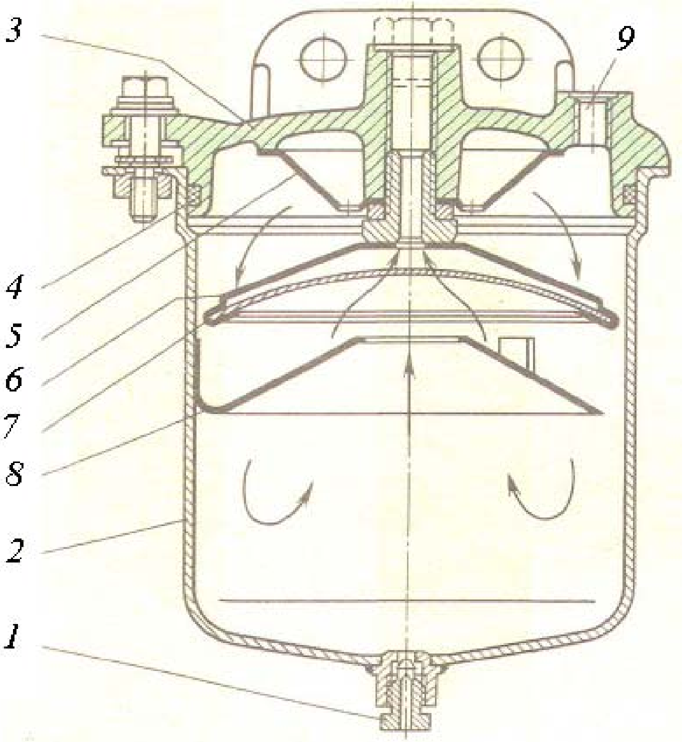
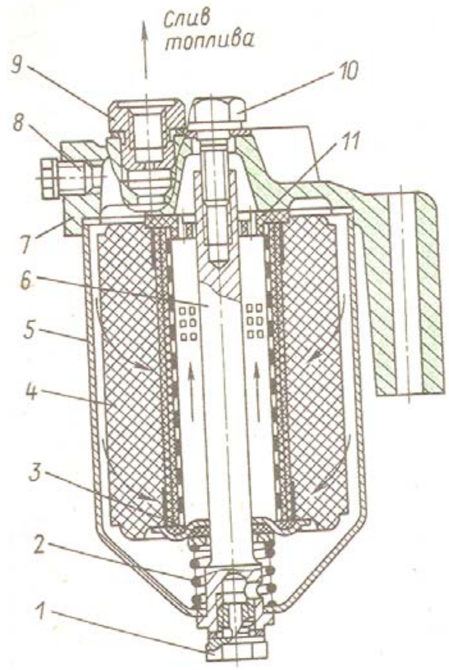


Fig. 11.3. **Fine filter:** 1 – drain plug; 3 – housing; 5 – cap; 8 – gasket; 9 – nozzle; 10 – reflector; 11 – filtering mesh; 12 – damper; 13 – opening

11.3.2.2. Fine filters



слив топлива	fuel drain

Fig. 11.4. **Diesel fuel fine filter: YaMZ-236**

1 – drain plug; 2 – spring of the filtering element; 3.11 – gasket; 4 – filtering element; 5 – housing; 6 – stem; 7 – cap; 8 – plug; 9 – fitting with a calibrated orifice; 10 – bolt

11.3.3. Fuel feed pump

Fuel feed pumps of various types are shown in Fig. 11.5. and 11.6.

11.3.3.1. Piston type fuel feed pump

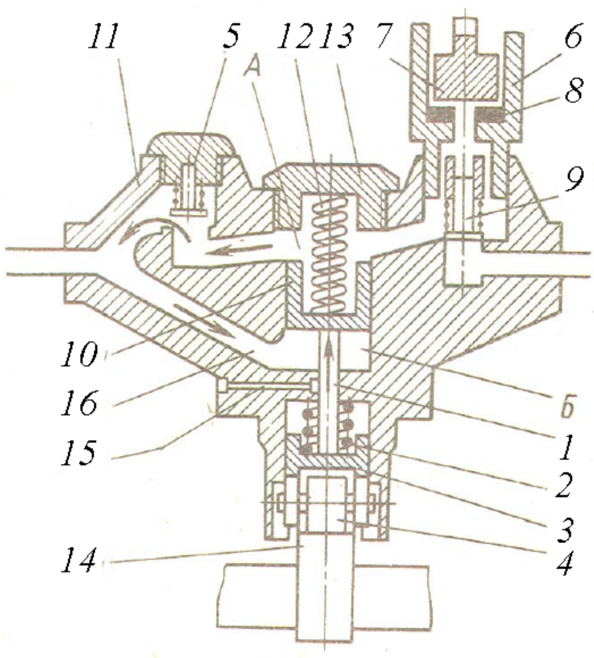


Fig. 11.5. **Piston type fuel feed pump.**
1 – pusher rod; 2 – spring; 3 – pusher; 4 – roller; 5 – exhaust valve; 6 – cylinder; 7 – piston; 8 – gasket; 9 – inlet valve; 10 – piston; 11 – pump casing; 12 – spring; 13 – plug; 14 – eccentric; 15 – valve 16 – discharge cavity

It serves to supply fuel from the tank through pipelines and filters to the injection pump sections (P = 0.12 – 0.4 MPa).

For smooth operation and cooling, the pump performance is 2 – 7 times higher than the injection pump supply. The difference in the height of the fuel level between the tank and the pump is 1 – 1.8 m.

11.3.3.2. Rotary-vane type fuel feed pump.

They are used in combination with an injection pump and work independently or from an electric drive.

The pressure in the pump can be 0.15 – 0.17 MPa, regardless of the rotation of the rotor.

Diaphragm and gear pumps are similar in operation to gasoline ones.

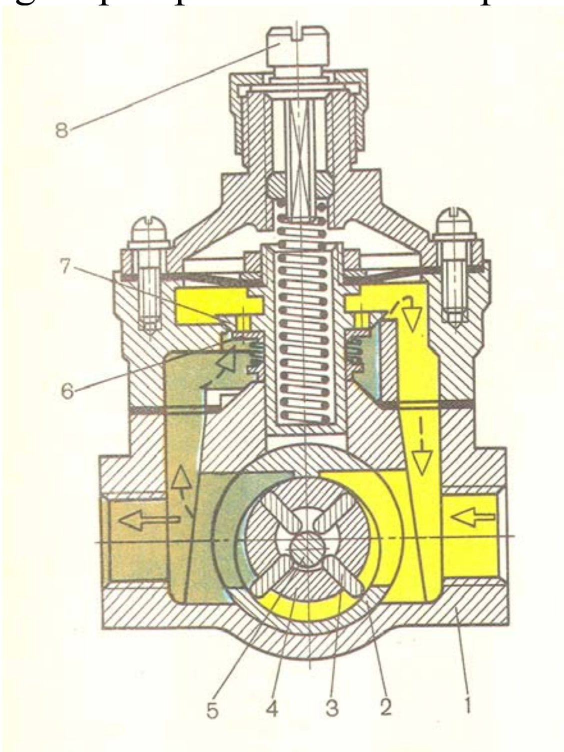


Fig. 11.6. **Rotary-vane type fuel feed pump.**
1 – pump casing; 2 – bucket; 3 – blade; 4 – rotor; 5 – floating pin;
6 – filling valve; 7 – bypass valve; 8 – adjusting screw

11.3.4. Injectors

The *injectors* are a spraying device installed in the cylinder head that allows fuel to flow into the combustion chamber in accordance with the selected mixture formation.

There are open and closed fuel injectors.

A schematic diagram of a closed injector is shown in Fig. 11.7.

Closed injectors, depending on the design of the nozzle, can be valve-nozzle, multi-hole and pintle.

The main element of the injector is the nozzle, which forms the spray of fuel with the specified parameters.

The lifting pressure of the nozzle needle (pin) is 160 – 200 kg/cm^2. The number of nozzle openings, diameter, direction of flow depend on the used combustion chamber.

Fuel injection through an open injector starts at the moment when the pressure in the atomizer cavity is higher than in the cylinder. The differential pressure must be sufficient to allow fuel to flow through the nozzle orifices.

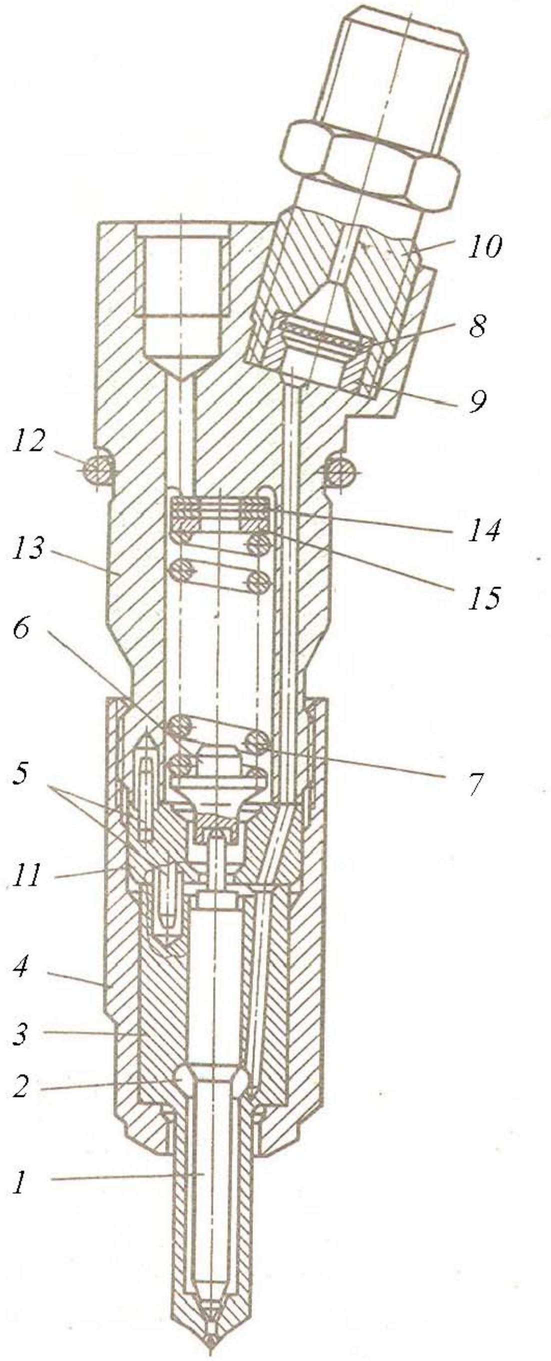


Fig. 11.7. **Closed injector:** 1 – nozzle needle; 2 – annulus; 3 – nozzle; 4 – cap nut; 5 – pin; 6 – spring; 7 – sleeve; 8 – mesh filter; 9 – filter housing; 10 – fitting, 11 – spacer; 12 – sealing ring; 13 – nozzle body; 14 – adjusting washers; 15 – support washer

11.4. *Injection pump*

Injection pump is designed to supply fuel to the injectors in the required quantity, under high pressure, in accordance with the order of operation of the engine cylinders.

A schematic diagram with a plunger spool is shown in Fig. 11.8.

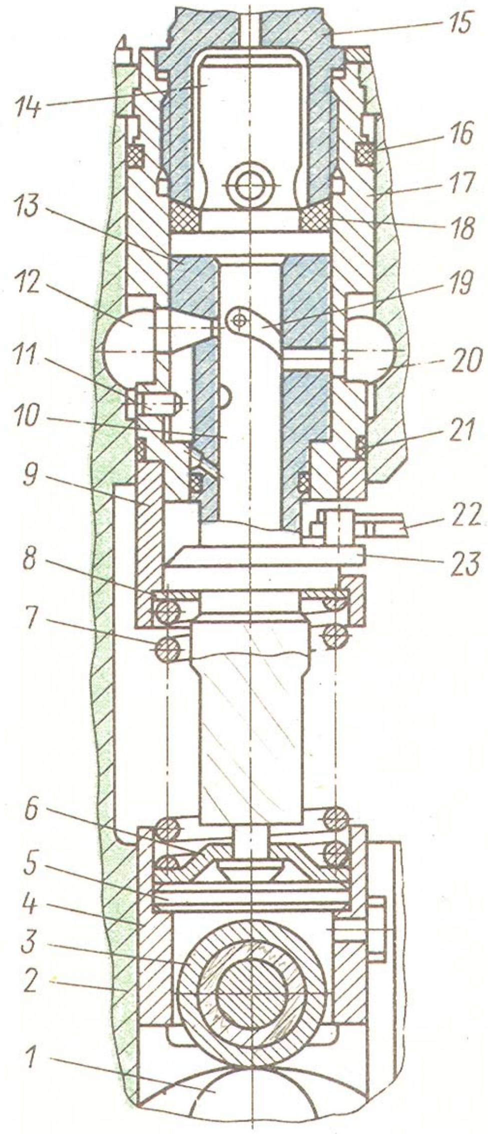
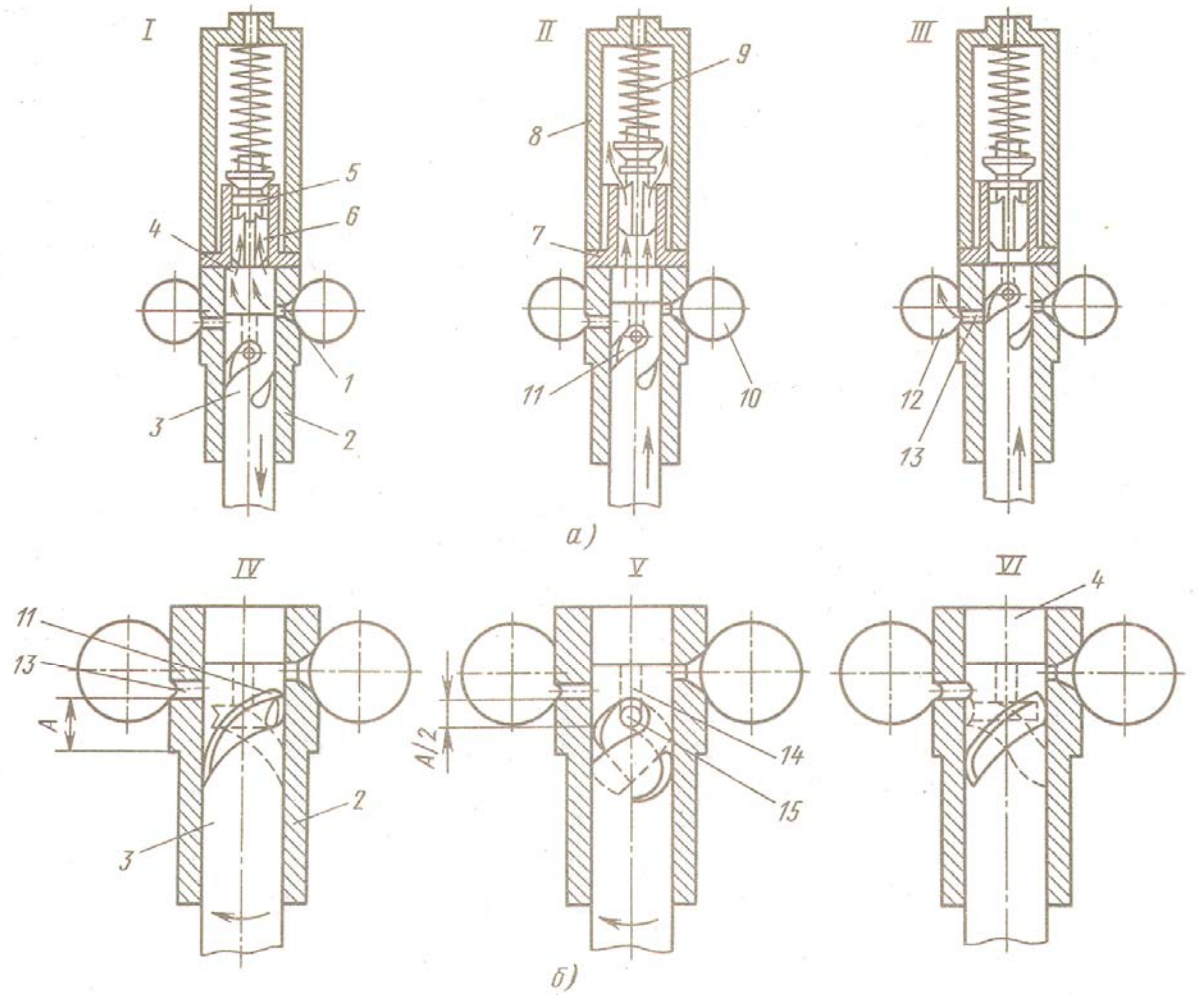


Fig. 11.8. **Scheme of fuel supply to the cylinder of a diesel fuel injection pump with a plunger spool:** 1 – camshaft cam; 2 – pump casing; 3 – pusher roller; 4 – pusher; 5 – pusher bearing; 6 – spring seat; 7 – spring; 8 – support washer; 9 – support sleeve; 10 – plunger; 11 – pin; 12 – inlet opening; 13 – plunger sleeve; 14 – discharge valve; 15 – fitting; 16 and 21 – section sealing rings; 17 – pump housing sections; 18 – washer; 19 – spiral plunger groove; 20 – bypass opening; 22 – rack; 23 – plunger control sleeve

The principle of operation of the pump is the same as that of the piston type pump.

11.4.1. Plunger assembly

Various versions of plunger assemblies are shown in Fig. 11.9.



а)	a)
б)	b)

Fig. 11.9. **Plunger assemblies:** a – diagrams of pump sections operation; b – diagrams of changing the amount of inlet fuel; I – fuel inlet; II – start of feed; III – end of feed; IV – maximum feed; V – half feed; VI – no feed; 1 – inlet opening; 2 – plunger sleeve; 3 – plunger; 4 – over-plunger space; 5 – unloading belt; 6 – discharge valve; 7 – discharge valve seat; 8 – fitting; 9 – discharge valve spring; 10 – fuel supply passage; 11 – spiral groove on the plunger; 12 – fuel outlet passage; 13 – bypass bore; 14 – axial hole in the plunger; 15 – cross hole in the plunger

11.4.2. Automatic timing device

It is designed to automatically change the moment when the pump starts supplying fuel, depending on the change in the engine speed.

The schematic diagram of the device is shown in Fig. 11.10.

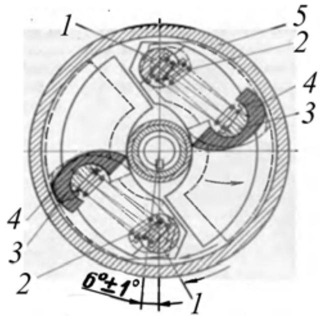


Fig. 11.10. **Automatic timing device for diesel engine fuel:** 1 – driven plate; 2 – drive plate; 3 – pins; 4 – weights; 5 – springs

At the maximum number of revolutions of the camshaft (2 times less than the crankshaft), the clutch weights move apart to the stop, and the angle increases to 6–8 relative to the initial one.

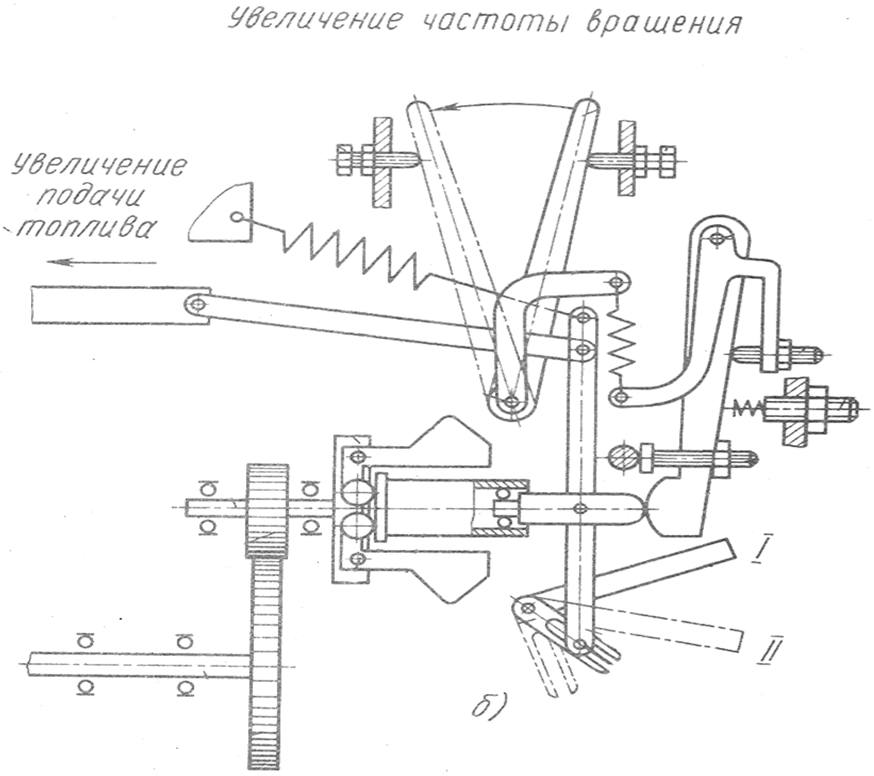
11.4.4. Speed regulator

It automatically maintains the operating number of the engine crankshaft speed set by the driver using the fuel pedal, sets the required min number of revolutions, as well as the max number.

Depending on the maintenance of speed modes, the regulators are divided into *dual-mode* and *all-mode*.

Dual-mode regulators limit the max number of revolutions and maintain the min number (Fig.11.11).

For a more complete correspondence of the diesel engine mode with the operating conditions and to achieve a more stable operation of it in the entire range of operating modes, an all-mode regulator is used. A feature of such a regulator is that the fuel supply is controlled through an elastic link – a spring that is installed between the pedal and the rack. By changing the tension of this spring with the pedal, the driver changes the maximum number of revolutions at which the diesel engine can operate.



увеличение частоты вращения	increase in rotational speed
увеличение подачи топлива	increase in fuel supply

Fig. 11.11. **All-mode centrifugal regulator:**
I – slide bracket in the "Operation" position;
II – slide bracket in the "Stop" position

11.4.5. Distribution injection pumps

Along with many positive qualities, multi-section pumps are more expensive in manufacturing and do not provide uniform flow through the cylinders. Therefore, distribution type pumps are used.

In such pumps, one plunger assembly serves several cylinders. They are simpler, have less weight and dimensions. However, the plunger assembly wears out faster.

11.5. *Pump-injector unit*

Pump-injector unit combines a pumping section and an injector in one unit. Due to the absence of an intermediate volume (high-pressure pipe), the fuel in the section is compressed to an injection pressure of 200 MPa. The drive is carried out from a crankshaft or camshaft.

11.6. *Common rail injection systems.*

In common rail injection systems, the fuel supply is controlled by a special element that is not connected with the movement of the plunger.

Common rail injection systems with electro-hydraulically controlled injectors allow using a microprocessor to optimize the fuel supply in accordance with the mode and operating conditions of the diesel engine.

References

1. Кисликов В.Ф., В.В. Лущик. Будова й експлуатація автомобілів. Київ: Либідь, 2018. – 400 с.
2. Скляров В.М., Волков В.П., Скляров М.В. Автомобільні двигуни. Особливості конструкції: навч. посібник – Харків: ХНАДУ, 2012. – 405с.
3. Омеличев А.А. Підручник з будови автомобіля. – Дніпро: Моноліт, 2019. – 288 с.
4. Білоус Б.Д., Ткачук П.П., Андрусик Ю.Ф., Білоус Н.Б., Онищенко В.В. Армійська техніка. Основи руху, будова, характеристика: навч . посібник. – Л.: Вид-во Національного університету «Львівська політехніка», 2007. – 536 с.

Test Questions

?

1. How is the amount of fuel supplied to the injector by each section of the fuel pump for one full revolution of the injection pump camshaft regulated?
2. How are the fuel supply lines of the injection pump filled before starting the diesel engine?
3. With which node is the fuel control pedal installed in the driver's cab connected with the rod and levers?
4. What is the purpose of the turbocharger used in the diesel power system?

12 CONCEPTUAL MODULE

Fuel system of gas ICE and injection of light fuel into ICE

12.1. Fuel for gas engines.
12.2 Gas cylinder installations.
12.3 Instruments and fittings.
12.4 Fuel injection system.

12.1. *Fuel for gas engines*

Combustible gases can be natural or artificial.

Natural gases are produced in gas or oil fields. Artificial ones are obtained at chemical or metallurgical plants, gas generating units.

Advantages of gas fuels over liquid ones:

- higher octane number,
- less amount of toxic substances in exhaust gases;
- longer service life due to the absence of condensation of water vapor in the fuel and oil washout from the cylinder walls;
- increased service life of the oil (not diluted);
- increased service life of plugs.

Disadvantages:

- the carrying capacity is reduced due to the presence of cylinders;
- gases with a higher density than air can accumulate in depressions and buried places and create an explosive and fire capacity;
- reduce of the ICE power due to the low heating value;
- more labor intensive in maintenance.

Compressed (compressible) gases are called gases that, at normal ambient temperature and high pressure up to 20 MPa, retain their gaseous state and do not lose their properties when the pressure decreases (natural – methane, industrial – coal, coke oven, synthesis gas).

Liquefied (liquefiable) gases are called gases that turn into a liquid state at normal temperature and low pressure up to 1.6 MPa (propane-butane mixtures, other hydrocarbons).

12.2. *Gas cylinder installations*

12.2.1. Compressed gas installation.

The installation scheme is shown in Fig. 12.1.

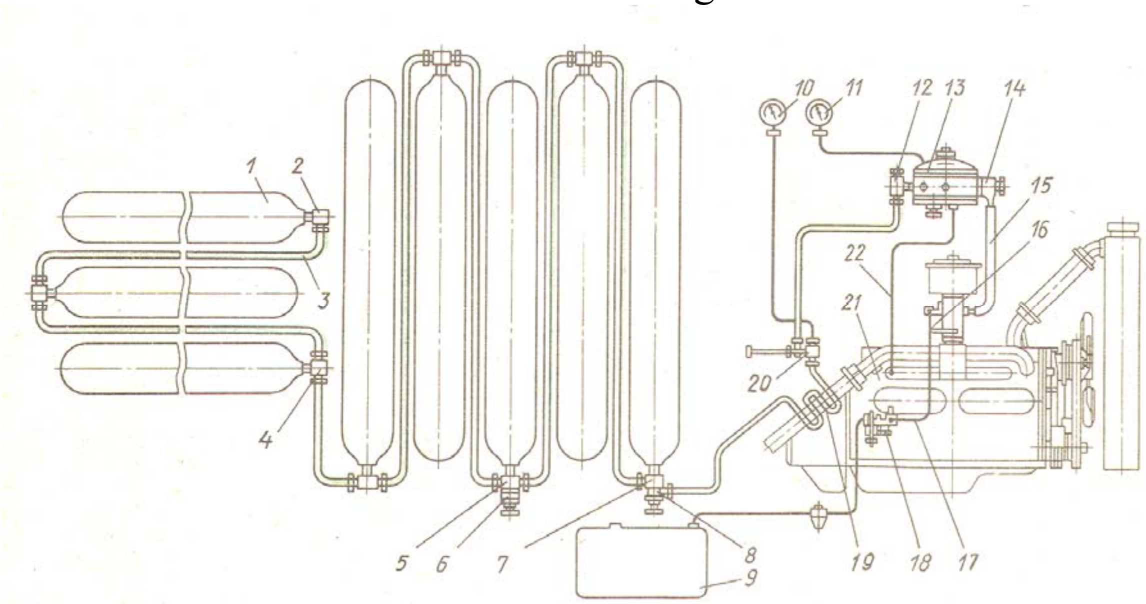


Fig. 12.1. **Scheme of the vehicle gas cylinder installation for compressed gas:** 1 – cylinder; 2 – angle joint of cylinder; 3 – high pressure gas pipeline; 4 – T-joint of cylinder; 5 – crosspiece of the filling valve; 6 – filling valve; 7 – angle joint of valve; 8 – flow valve; 9 – fuel tank; 10 and 11 – high and low pressure gauges, respectively; 12 – gas filter; 13 – two-stage gas reducer; 14 – dosing device of the gas reducer; 15 – low pressure gas pipeline; 16 – carburetor mixer; 17 – fuel line; 18 – fuel pump; 19 – compressed gas heater; 20 – main valve; 21 – engine; 22 – tube

Principle of operation:

The compressed gas from the cylinders 1 through the flow valve 3 enters the heat exchanger 7, is heated in it and then through the main valve 5 and the filter 9 enters the two-stage reducer 10, where the pressure drops to atmospheric. Two high and low pressure gauges monitor the system. The cylinder is filled through the accumulator valve 4.

12.2.2. Liquefied gas installation.

It is shown in Fig. 12.2.

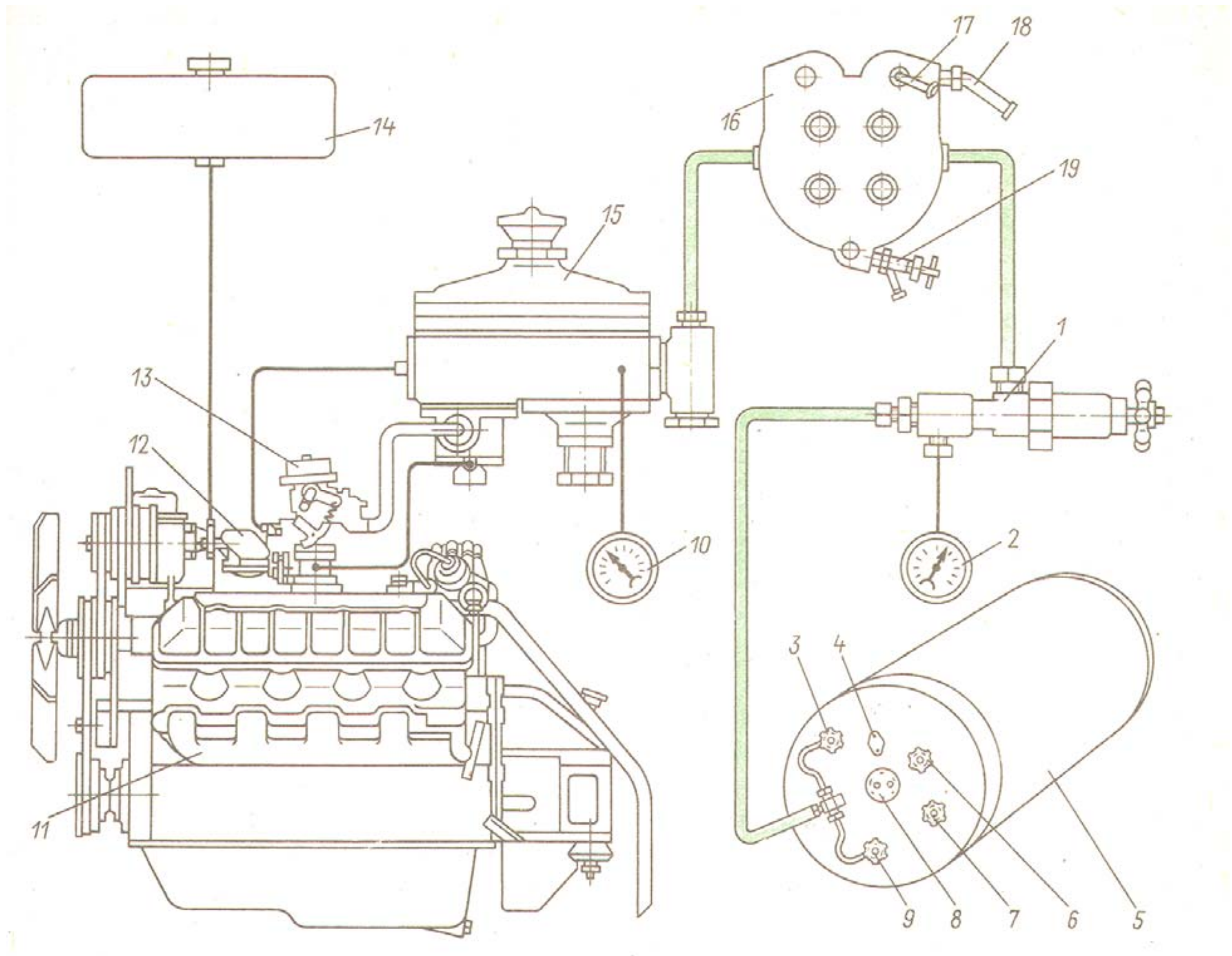


Fig. 12.2. **Scheme of the gas cylinder installation for liquefied gas:**
1 – main valve; 2 – cylinder pressure gauge; 3 – steam valve; 4 – safety valve; 5 – cylinder for liquefied gas; 6 – control valve; 7 – filling valve; 8 – indicator of the level of liquefied gas; 9 – liquid valve; 10 – reducer pressure gauge; 11 – engine; 12 – carburetor; 13 – gas mixer; 14 – gasoline tank; 15 – gas reducer; 16 – evaporator; 17 – fitting for hot water supply; 18 – fitting for discharge; 19 – tap for draining water

Principle of operation:

Liquid gas through the main valve 8 enters the evaporator 10 and through the filter 11 is directed to the gas reducer 13, where the gas pressure is reduced to 0.1 MPa (to atmospheric). The cylinder is usually filled with gas to 90% to prevent an explosion.

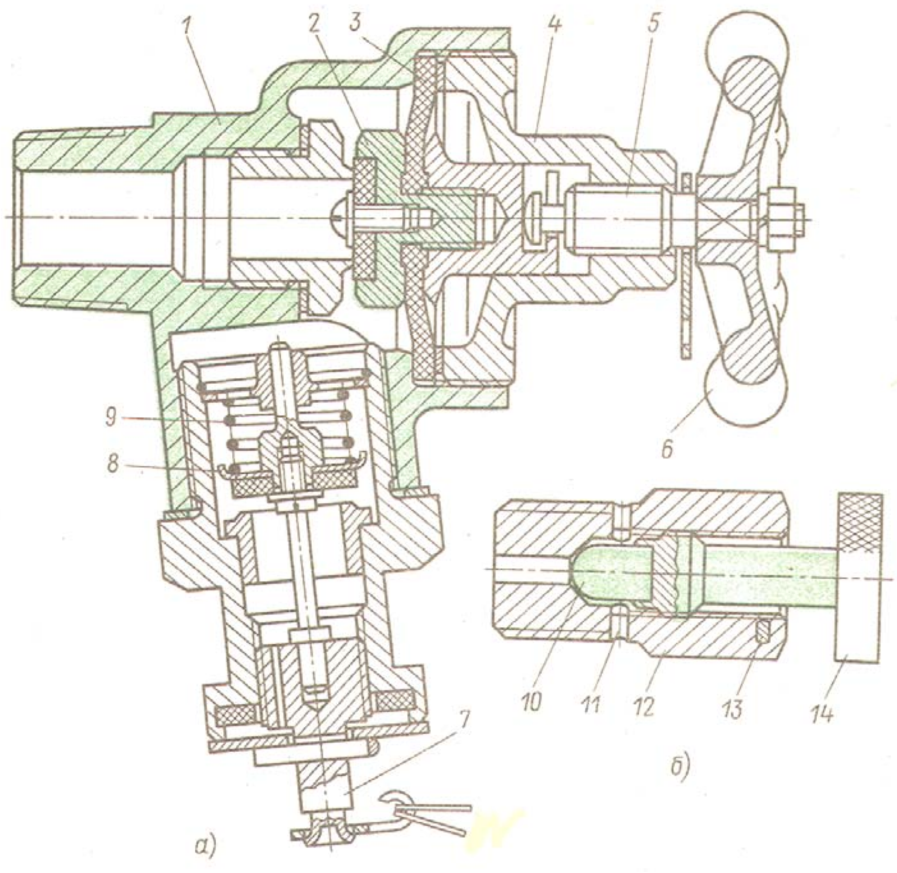
12.3. *Instruments and fittings*

12.3.1. Cylinders

Seamless alloy steel is used for the manufacture of compressed gas cylinders. The cylinders must be stamped with the date of the last test. There are copper and steel pipes, oil-resistant rubber hoses.

12.3.2. Filling and control valves

They are shown in Fig. 12.3.



а)	a)
б)	b)

Fig. 12.3. **Valves**: a – filling; b – control; 1 and 12 – of body; 2 – small valve; 3 – membrane; 4 – bonnet; 5 – stem; 6 and 14 – flywheel; 7 – plug; 8 – check valve; 9 – spring; 10 – sealant; 11 – control hole; 13 – pin

Operation:

When refueling, loose the plug and insert the refueling hose, unscrew the valve 2 and 6. When full refueling, liquid appears through the control hole 7. Tighten in reverse order.

12.3.3. Safety valve and flow valve

The *safety valve* is triggered when the pressure rises above 1.6 MPa. The SV is made by analogy with the steam valve of the radiator.

The design of the *flow valve* is the same as that of the filling valve.

12.3.4. Level sensor

The same as in the gas tank.

12.3.5. Main valve

The design is the same as that of the flow one. Installed inside the cab, must be fully open.

12.3.6. Gas reducer

Reducers of modern gas cylinder installations are a two-stage diaphragm-lever pressure regulator. Simultaneously with a decrease in the pressure of the gas entering the carburetor mixer, the necessary dosage of it and the shutdown of the gas line when the engine is turned off are carried out in them.

Principle of operation:

The valve of the 1st stage is open, and gas entering the 1st stage increases the pressure in it to 100 – 200 kPa. However, it does not enter the second stage, since it is reliably closed by a valve. When the engine is started, due to the resolution, the cavities of the 1st and 2nd stages are communicated. With additional vacuum, the economizer is switched on. When the pressure rises to 450 kPa, the check valve is triggered.

12.3.7. Gas mixer

It is a gas supply pipe with several fixed openings and a check valve.

The gasoline equipment installed on the same vehicle is simple and made in the form of an emergency equipment (distance is not more than 30 mm for GAZ-53-07).

12.4. *Fuel injection system*

Modern fuel injection systems are distinguished by the place and method of fuel supply, the principle of operation and the type of regulation, as well as the design of the executive components of the fuel metering system.

They are classified:

1 – by the place of fuel supply (into cylinders or inlet pipeline);

2 – by the type of fuel metering units:

a) with metering by plunger pumps;

b) with metering control valves or spool valves;

c) with metering by nozzles with electromagnetic and electronic control;

d) with fuel pressure regulated systems;

3 – by the method of regulating the amount of the mixture: (pneumatic, mechanical and electronic control);

4 – by the main parameters of regulating the composition of the mixture: (vacuum in the intake system, hourly air consumption, angle of rotation of the throttle valve).

According to the number of electromagnetic injectors (EMIs) and the scheme of their placement, the systems of central (single-point, single-injection) and distributed (multi-point, group) fuel injection are distinguished. The central fuel injection system provides fuel by one injector into the intake manifold, and the distributed one – the fuel is supplied by separate injectors into the intake manifold or directly into each cylinder of the engine.

By the principle of supply, injection systems are distinguished with continuous, cyclic and phased fuel delivery schemes.

By the fuel supply time, systems with simultaneous, pairwise-parallel (group) and phased injection are distinguished.

Simultaneous injection is accompanied by the supply of fuel by separate injectors together to all cylinders, regardless of the engine stroke performed, i.e. all injectors open at the same time.

With pairwise-parallel (group) injection, *half of the EMIs injects fuel simultaneously*.

Phased injection delivers fuel from each injector at a specific point in time to each cylinder of the engine.

The value of fuel pressure in distributed injection systems is 0.3 MPa, and with direct injection – 5.0 MPa. In some cases, the central fuel injection system is additionally equipped with a starting injector that works when the engine is cold and turns off automatically as it warms up. In modern designs, a starting injector is not used.

The distributed injection scheme provides fuel supply to the intake manifold, to the intake valve or to the bridge between the intake valves. Regulation of the amount of supplied fuel is carried out by changing the duration of opening of the metering valve of the electromagnetic injector.

Phased injection is carried out into the inlet pipe, directly into the cylinder or into an additional chamber (swirl chamber, prechamber).

By the type of *regulation*, injection systems are distinguished with open engine control circuits and closed ones with closed loop (λ–probe).

The *block diagram of the central injection system* (Fig. 12.4) contains an intake manifold 3, an air nozzle 7 with a located in it injector 6 with an electrical connector 5 and a fuel supply pipeline. When the throttle valve 4 is opened, the fuel from the injector 6 enters in the form of a torch through the intake pipe 3 into the intake pipes 2, then into the intake channels 1, and then into the cylinders 9 of the engine 8.

Fuel supply in the case of central injection is carried out into the common air nozzle 7 by one injector 6 installed above the throttle valve 4. The injector is equipped with six nozzles providing the required level of mixture formation. The central injector is characterized by a low resistance of the electromagnet winding (4–5 Ohm).

The *distributed fuel injection system* (Fig. 12.5) contains an intake manifold 6 with an intake pipe 2 and a channel 1, a fuel pipe 7 with a union 4, an air pipe 9 with a throttle valve. The fuel pipe 7 is equipped with a fuel supply nozzle 5, a pressure regulator 11 with a fitting 10 and a fuel return line fitting 12.

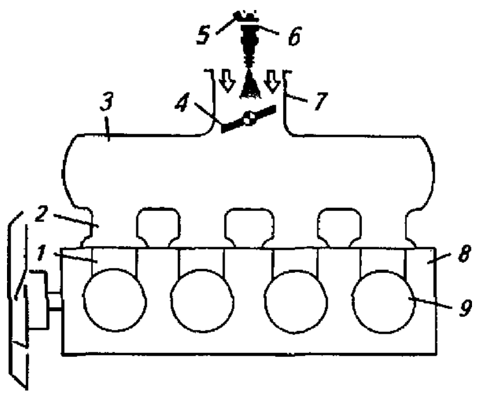


Fig. 12.4. **Block diagram of the central fuel injection system:** 1 – intake channel; 2 – intake pipe; 3 – intake manifold; 4 – throttle valve; 5 – electrical connector; 6 – fuel injector; 7 – air nozzle; 8 – engine; 9 – cylinder

The air supply system contains an air throttle located in the main air channel 8 with the formation of before-throttle and after-throttle space, an air temperature sensor and an idle air control actuator (IACA). The intake pipeline 6 is connected through a fitting 10 and a rubber hose with an air flow meter. The ECU is connected through an electrical circuit with a potentiometer and an air temperature sensor.

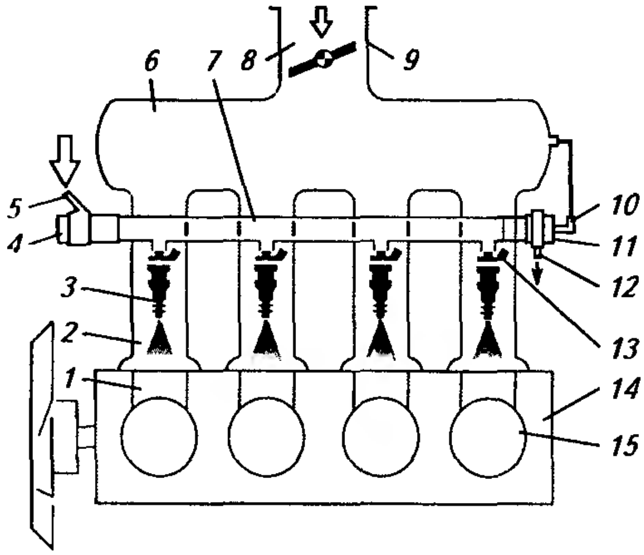


Fig. 12.5. **Block diagram of the distributed fuel injection system:** 1 – intake channel; 2 – intake pipe; 3 – fuel injector; 4 – fuel union; 5 – air supply pipe; 6 – intake manifold; 7 – fuel pipeline; 8 – main air channel; 9 – air pipe; 10 – control line fitting; 11 – fuel pressure regulator; 12 – fuel return line fitting; 13 – electrical connector; 14 – engine; 15 – cylinder

Separate injectors 3 supply fuel to the intake pipes 2 of each cylinder. They are located in the cylinder head housing and have a relatively high winding resistance (12–16 Ohm). The exception is the turbocharged ICE injectors, which have a winding resistance of 4–5 Ohm. On some new generation vehicles, fuel is fed directly into the combustion chamber (direct injection).

In direct injection (DI) systems (Fig. 12.6), electromagnetic fuel injectors located in each cylinder inject fuel directly into the combustion chamber. Mixture formation takes place inside the cylinder. To ensure efficient combustion of the mixture, the process of atomization of the fuel leaving the injector plays an essential role. The intake manifold of a direct injection engine is supplied only with air, in contrast to an engine with externally mixture formation. Thus, the ingress of fuel on the walls of the intake manifold is excluded.

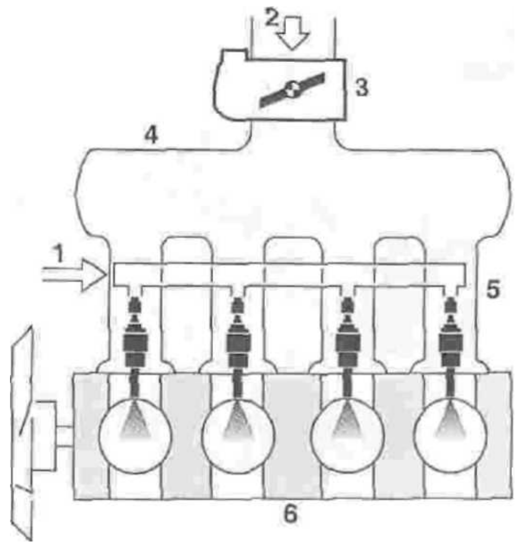


Fig. 12.6. **Block diagram of the direct fuel injection (DI) system:** 1 – fuel supply; 2 – air intake: 3 – throttle valve (electronically controlled gas pedal EGAS); 4 – intake manifold; 5 – injectors; 6 – engine

While a homogeneous air-fuel mixture is usually present in external mixing during combustion, then during internal mixing, the engine can operate with both a homogeneous and an inhomogeneous mixture.

In the operation of an engine with a direct injection system, three different modes can be distinguished:

1) the mode of operation on ultra-lean mixtures;

2) the mode of operation on a stoichiometric mixture;

3) the mode of sharp accelerations from slow speeds.

The **first mode** is used when the vehicle moves without sharp accelerations at a speed of about 100–120 km/h. In this mode, an ultra-lean fuel mixture with an excess air ratio of more than 2.7 is used. Under normal conditions, such a mixture cannot be ignited by a spark, so the injector injects fuel with a compact torch at the end of the compression stroke (like in a diesel engine). A spherical recess in the piston directs a jet of fuel to the spark plug electrodes, where the high concentration of gasoline vapors allows the mixture to ignite.

The **second mode** is used when the vehicle is moving at high speed and during sharp accelerations, when it is necessary to obtain high power. This mode of movement requires a stoichiometric composition of the mixture. A mixture of this composition is highly flammable, but the GDI engine has a higher compression ratio, and in order to prevent detonation, the injector injects fuel with a powerful torch. Finely atomized fuel fills the cylinder and evaporates to cool the cylinder surfaces, reducing the likelihood of knocking.

The **third mode** is necessary to obtain a large torque when the accelerator pedal is pressed sharply when the engine is running at slow speeds. This operating mode of the engine differs in that the injector is triggered twice during one cycle. During the intake stroke, an ultra-lean mixture ($\alpha = 4.1$) is injected into the cylinder to cool it with a powerful torch. At the end of the compression stroke, the injector once again injects fuel, but with a compact torch. In this case, the mixture in the cylinder is enriched and knocking does not occur.

Compared to a conventional engine with multipoint injection, a GDI engine is approximately 10% more economical and emits 20% less carbon dioxide. The increase in engine power reaches 10%. However, as shown by the operation of vehicles with engines of this type, they are very sensitive to the sulfur content of gasoline.

Orbital developed the original direct petrol injection process. In this process, gasoline is injected into the engine cylinders, which is pre-mixed with air using a special injector. The Orbital nozzle consists of two injectors, fuel and air (Fig. 12.7).

Fig. 12.7. **The piston of a direct petrol injection engine has a special shape (combustion process above the piston)**

Advantages of injection systems over carburetors:

– the filling factor η_v increases, since there is no carburetor;

– the uniformity of fuel distribution among the cylinders is increased;

– the inhomogeneity of the fuel mixture is reduced;

– in 2-stroke ICEs, mixture losses during blowing are reduced.

Disadvantages of injection systems compared to carburetors:

– more difficult to manufacture and repair;

– less durable (poor lubricity with gasoline);

– higher cost of manufacturing and repair.

12.4.1 Central petrol injection unit

Central injection unit. The injector is located above the throttle valve. The jet of fuel is applied directly into the crescent-shaped hole between the body and the throttle valve, where, due to the large pressure difference, optimal mixture formation is ensured, excluding the possibility of fuel deposition on the walls of the intake tract (Figure 12.8–12.9).

The injector operates at 1 bar overpressure. Atomization of the fuel ensures a homogeneous distribution of the mixture even under full load conditions. Fuel injection through the injector is synchronized with the ignition pulses.

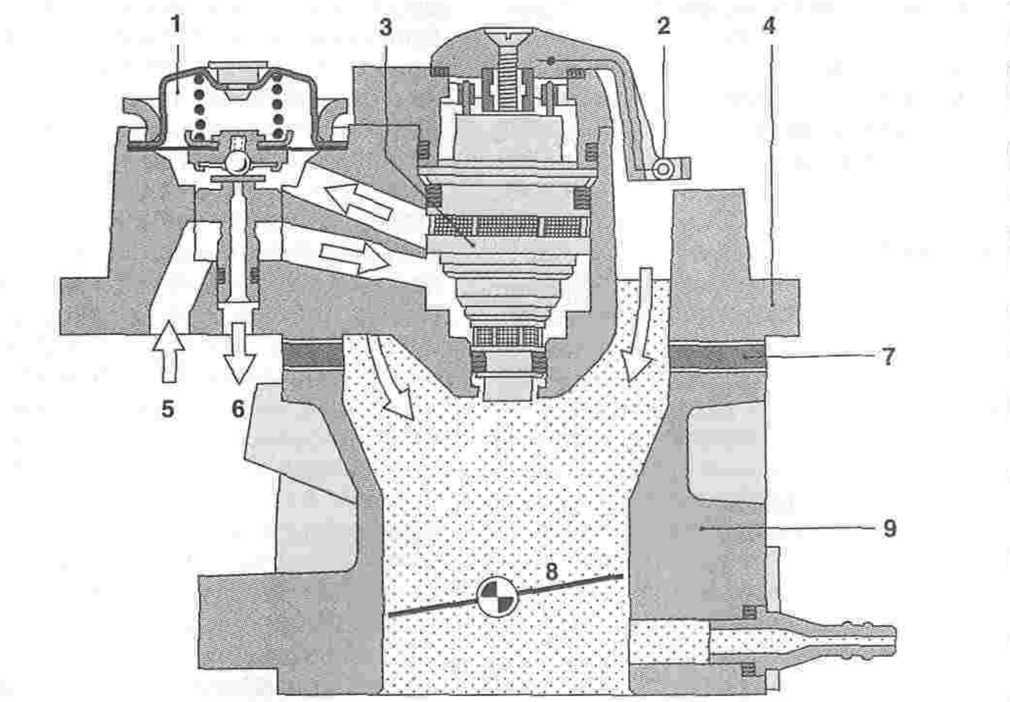


Fig. 12.8. Central injection unit of Mono-Jetronic system:
1 – pressure regulator; 2 – temperature sensor; 3 – injector;
4 – upper part (hydraulic); 5 – fuel supply; 6 – fuel return; 7 – heat-insulating plate; 8 – throttle valve; 9 – lower part

12.4.2 Air flow sensor

Air flow sensor. The air at the inlet acts on the sensor flap against the spring force. The potentiometer converts the flap angle value into voltage, which sets the pulse duration by a time relay in the ECU. The temperature sensor included in the air flow meter reflects changes in air density, which depends on temperature (Fig. 12.10).

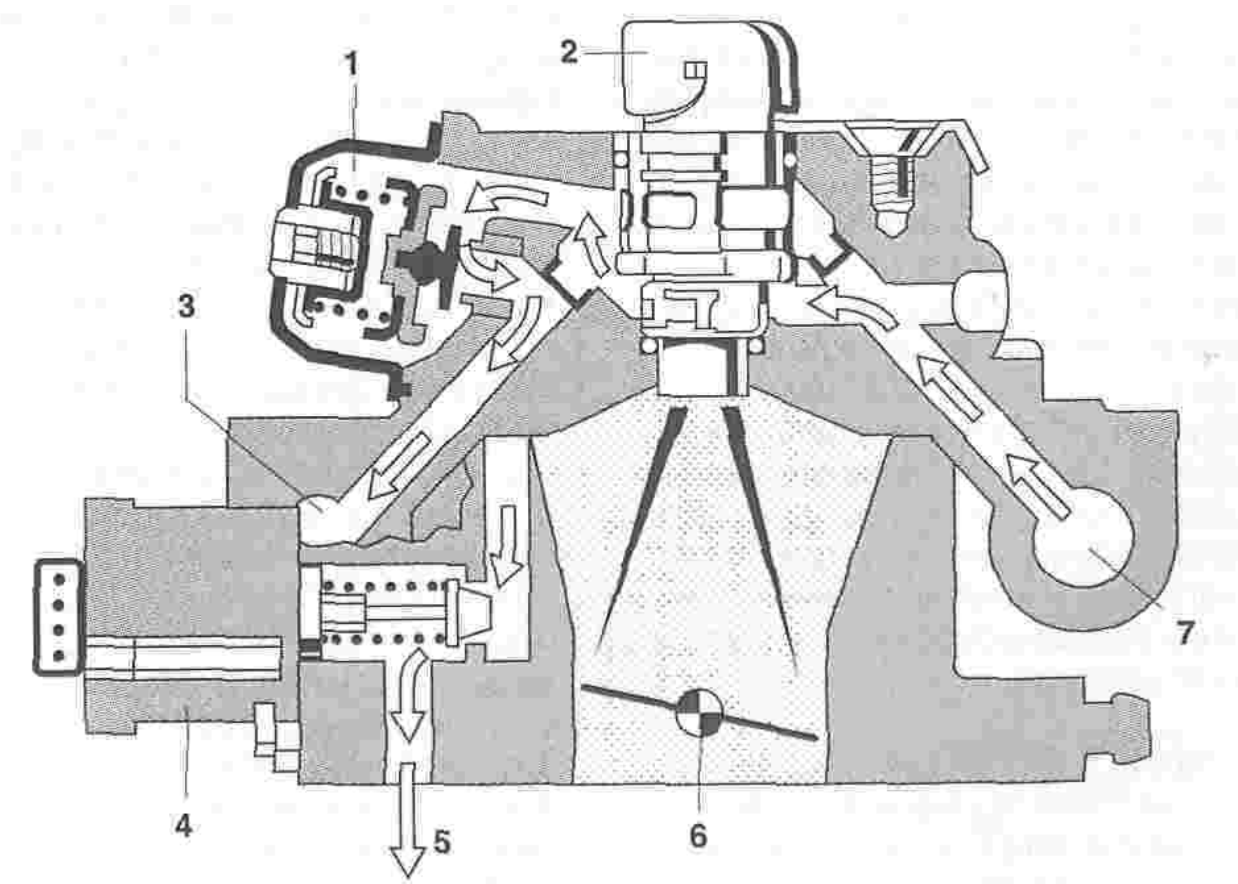


Fig. 12.9. **Central injection unit (Opel):** 1 – pressure regulator; 2 – injector; 3 – fuel return; 4 – stepper motor to control the engine idling; 5 – to the engine intake manifold; 6 – throttle valve; 7 – fuel intake

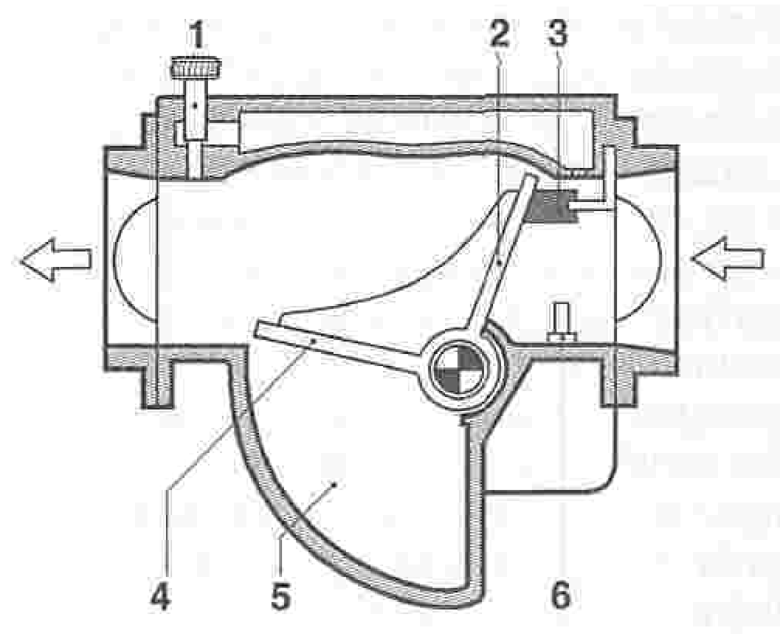
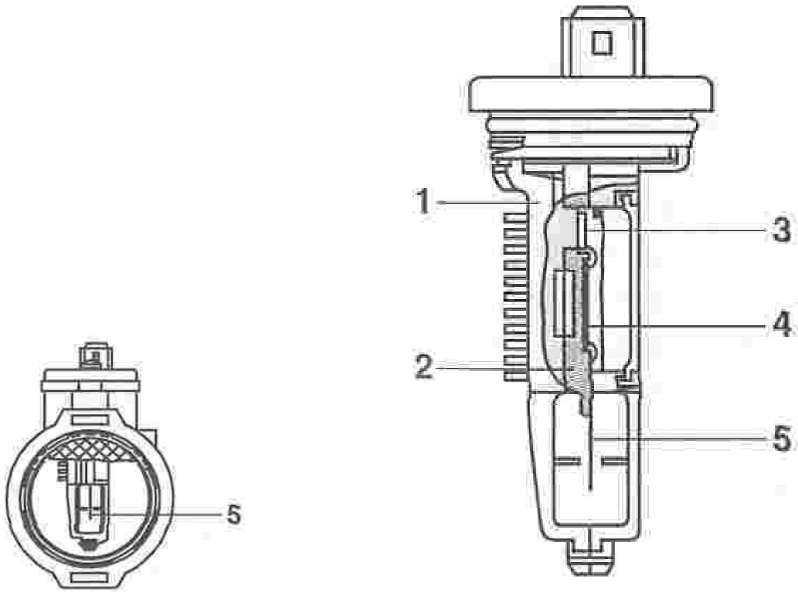


Fig. 12.10. **Air flow sensor:** 1 – screw for adjusting the mixture at idle; 2 – air flow sensor damper; 3 – stopper; 4 – compensation damper; 5 – damping chamber; 6 – air temperature sensor

12.4.3 Film mass air flow meter

Film mass air flow meter (Fig. 12.11). The principle of operation of the film meter is similar to the principle of operation of the thermal meter. However, in order to simplify the design, most of the electrical bridge circuit of the meter is placed on a ceramic substrate, in the form of thin-film resistors. In addition, there is no need to incinerate contaminating films.

This problem is solved by placing the meter behind the air stream, which reduces the deposition of contaminants on the meter film.



a b

Fig. 12.11. **Film mass air flow meter:**
a – block; b – film meter (installed in the center of the block);
1 – heat-sinking element; 2 – spacer element; 3 – master stage;
4 – hybrid circuit; 5 – measuring element (metal film)

12.4.4 Karman vortex mass air flow meter

Karman vortex mass air flow meter. Another option for measuring the flow of the air intake into the cylinders is a *volumetric* flow meter operating on the principle of vortices of the Karman type (Fig. 12.12). This meter detects the vortices of air flow passing through the turbulence generators. The frequency of these vortices is a measure of the volumetric air flow rate. It is measured by the emitted waves of ultrasonic vibrations directed perpendicular to the intake air flow. The change in the speed of these waves is detected by an ultrasonic receiver and the received signals are analyzed in the ECU.

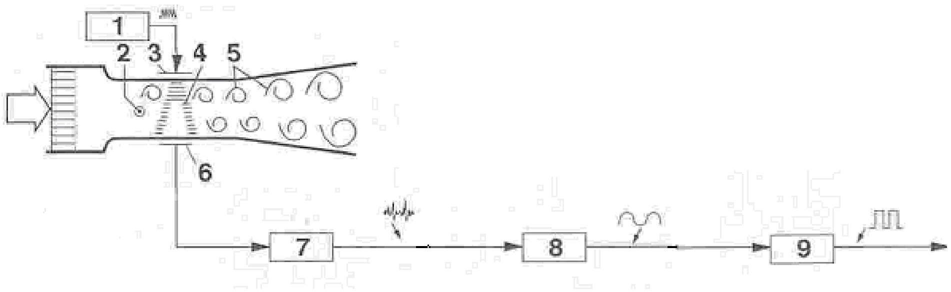


Fig. 12.12. **Karman vortex mass air flow meter:** 1 – oscillator; 2 – turbulence generator; 3 – transmitter; 4 – ultrasonic waves; 5 – vortex flows; 6 – receiver; 7 – amplifier; 8 – filter; 9 – pulse shaper

12.4.5 Mass air flow sensor

Mass air flow sensor. IVKSh 4087282000 (Russia, Fig. 12.13) or HLM2-4.7 0280212014 Bosch (Germany, Fig. 12.14) serves to determine the amount of air for filling the cylinders when the engine is running. The sensor is installed in the intake tract after the air filter and is connected to the electrical harness of the control system with a six-terminal block of wires. The sensor contains a sensing element 5 (see Fig. 12.13) and a temperature compensation resistor 4, included in the bridge circuit of the electronic module 15. The sensing element is a platinum thread with a diameter of 0.07–0.1 mm, placed inside ring 6, which in its turn is installed in the housing 9. The electronic circuit of the module 15 maintains the temperature of the platinum filament at about 150 °C. When the engine is running, the air entering the engine cylinders passes through the ring 6, cooling the platinum thread.

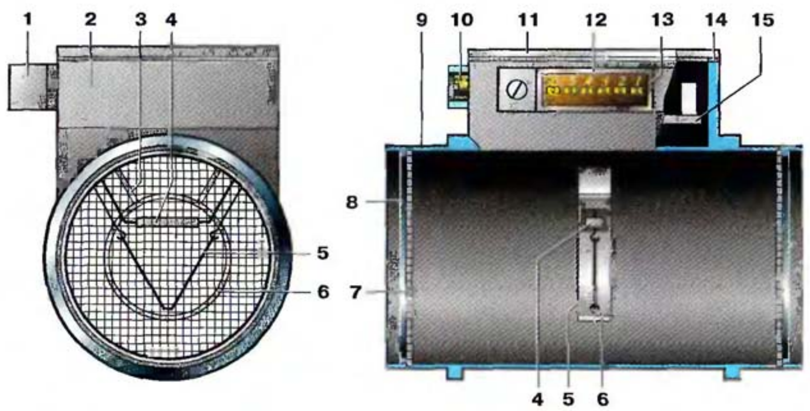


Fig. 12.13. **Mass air flow sensor** IVKSh 4087282000:
1 – air tube; 2 – electronic module housing; 3 – ring mounting bracket; 4 – temperature compensation resistor; 5 – platinum thread; 6 – ring; 7 – guard mesh; 8 – retaining ring; 9 – sensor body; 10 – CO adjustment screw; 11 – cover; 12 – electric block

The electronic module restores the thread temperature to the previous level. The more air passes through the sensor, the more the thread is cooled and the more power is spent by the electronic module to restore the thread temperature. The sensor output signal is proportional to the power expended by the electronic module, and therefore to the amount of air passing through the sensor.

Fig. 12.14. **Mass air flow sensor HLM2-4.7 0280212014**

The sensor signals are sent to the control unit, processed and used to determine the optimal duration of electrical pulses under the given conditions for opening the fuel injectors (i.e., the required amount of fuel for a given amount of air is determined). To prevent contamination of the platinum thread in the electronic module, a short-term supply of increased voltage to it is provided to warm it up to 1000 °C. At this temperature of the thread, all the dirt deposited on it burns out. The sensor has a screw 10, with which the content of CO and CH in the exhaust gases is regulated.

The mass air flow sensor for VAZ vehicles (Fig. 12.15) is located between the air filter and the intake pipe hose. Domestic and General Motors sensors are rectangular, while Bosch sensors are round. Receivers from Bosch are round, from General Motors are oval.

The sensor consists of a body 2, a flow channel 8 with a stabilizer grid 1 placed at the inlet and a diffuser 7. In the bypass channel 10, there are measuring 3, 11, 16 and thermal compensation 6, 15 elements, as well as a connecting block 5. The sensor is installed in the intake path between the air filter and the throttle body.

The entire volume of air entering the cylinders passes through a grid of thin platinum threads (measuring elements) heated by an electric current to 170 °C. The higher the flow, the higher the current must be to maintain the temperature of the threads.

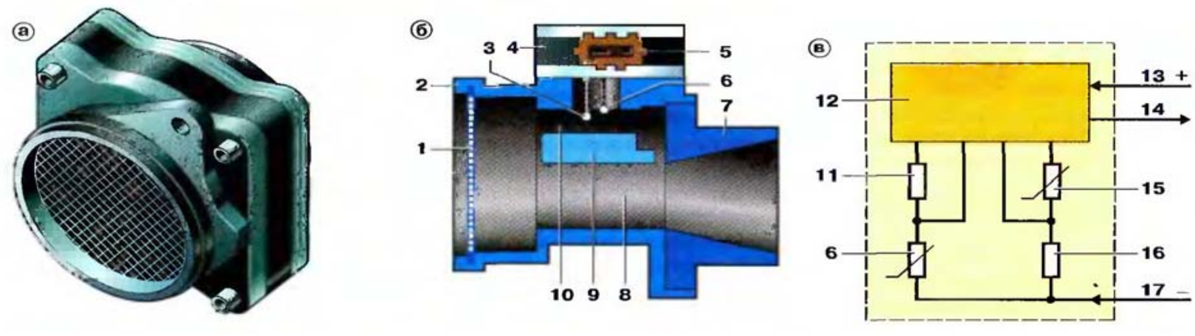


Fig. 12.15. **Mass air flow sensor for VAZ vehicles:**

а – a	б – b	в – c

a – appearance; b – device; c – electrical circuit; 1 – stabilizer grid; 2 – body; 3, 11, 16 – measuring elements; 4 – block; 5 – connector; 6, 15 – thermal compensation elements; 7 – diffuser; 8 – flow channel; 9 – support; 10 – bypass channel; 12 – signal amplification unit; 13, 17 – electric power supply circuits; 14 – output signal

The absence of adjusting screws indicates that the control system is adaptive. The internal electronic circuit is designed in such a way that the temperature of the measuring thread remains constant, even if it is 120 °C higher than the intake air temperature.

General wiring diagram of the sensor connections (see Fig.12.15 c)) contains measuring elements 11 and 16, thermal compensation resistors 6 and 15, signal amplification unit 12 connected to the controller. The sensor output signal is of frequency type.

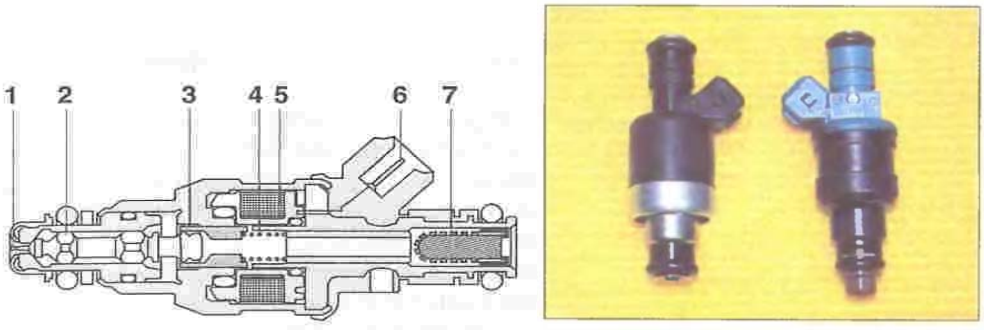
Contamination of the thread can lead to incorrect determination of the parameters of the combustible mixture. The thread ignition function is activated when the system is turned off. In this case, the thread is heated to 1000 °C, which makes it possible to remove the deposits accumulated on it.

The controller uses information from the mass air flow sensor 0280218004 to determine the duration of the injector opening pulse.

12.4.6 Injectors

The injectors meter and spray the fuel. When voltage is applied to the winding of the electromagnet, the needle of the atomizer rises 0.05 mm from the seat.

Design and principle of operation of the electromagnetic injector. The electromagnetic injector contains a valve body with a coil and an electrical connection, a valve seat with a disc equipped with one or more spray holes, and a movable valve needle with a solenoid armature (Fig. 12.16).



a **b** **c**

Fig. 12.16. **Electromagnetic injectors of a gasoline engine:**
a – section of the injector; b – GM injector; c – Bosch injector; 1 – pin; 2 – needle; 3 – anchor; 4 – spring; 5 – electromagnet winding; 6 – electrical contact; 7 – fuel filter

A filter in the fuel delivery device protects the injector from contamination. Two sealing rings are located between the injector fuel supply pipe and the intake manifold. When the winding is de-energized, the valve needle moves under the force of the spring and fuel pressure in the direction of the valve seat, which allows the power system to be isolated from the intake manifold (see Fig. 12.17).

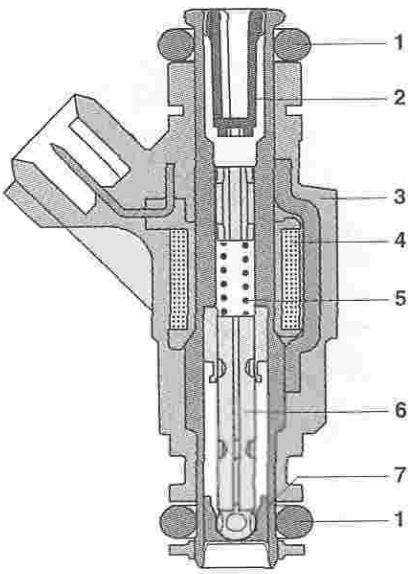


Fig. 12.17. **Electromagnetic injector EV6:** 1 – sealing ring; 2 – mesh filter; 3 – valve body with electrical connector; 4 – winding; 5 – spring; 6 – needle valve with solenoid armature; 7 – valve seat with a disc with a spray nozzle

When an electric current is applied to the injector, the coil creates a magnetic field that acts on the solenoid armature, which causes the valve needle to move away from the seat, allowing fuel to be injected. The amount of fuel injected per unit of time is mainly determined by the pressure in the system and the cross-sectional area of the spray nozzle in the injector disc. When the electrical current is cut off, the valve needle returns to its place, blocking the spray nozzle.

12.4.7 Engine temperature sensor

The temperature sensor is made in the form of a temperature-sensitive resistor (thermistor). It corrects (enriches) the composition of the mixture when the engine is warming up.

12.4.8 Throttle or choke position sensor

These sensors are of the potentiometric type. The output signal is a voltage proportional to the travel of the current collecting contact, which in turn depends on the position of the throttle valve.

The **throttle position** sensor 0KS-1 0280122001 (**Germany**) or NRK1-8 (**Russia**) of GAZ vehicles (Fig. 12.18) is installed on the throttle body, mechanically linked to the throttle axis and is connected to the electrical harness of the control system through a three-pin connector.

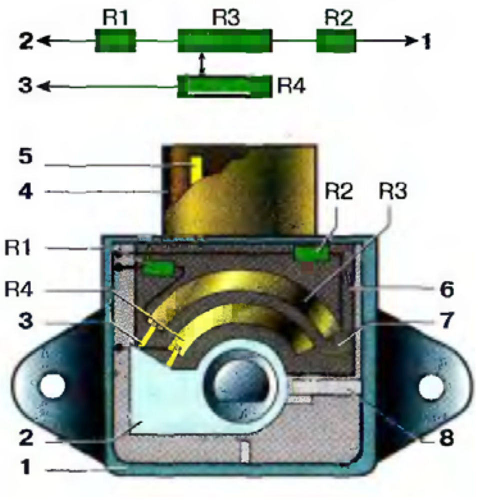


Fig. 12.18. **Throttle position sensor:**
1 – housing; 2 – control sleeve; 3 – movable contact; 4 – plug block; 5 – plug;
6 – printed circuit board; 7 – stop; 8 – throttle spindle; R1, R2, R3, R4 – resistors

The sensor is a variable resistor on a ceramic substrate and consists of a housing 1, a printed circuit board with resistors R1, R2, R3 and R4 and movable contacts 3 mounted on a control sleeve 2 fixed on the throttle spindle 8. When the throttle position is changed the magnitude of the voltage drop across the variable resistance changes. This voltage is supplied to the control unit, which takes it into account when calculating the duration of the injector control pulses and the ignition timing.

If the sensor fails, the control unit switches to the standby mode of operation, using the data of its memory and data of the mass fuel flow.

The **throttle position** sensor 2112-1148200 of VAZ vehicles (Fig. 12.19 and 12.20) is installed on the side of the throttle tube and is connected to the throttle spindle.

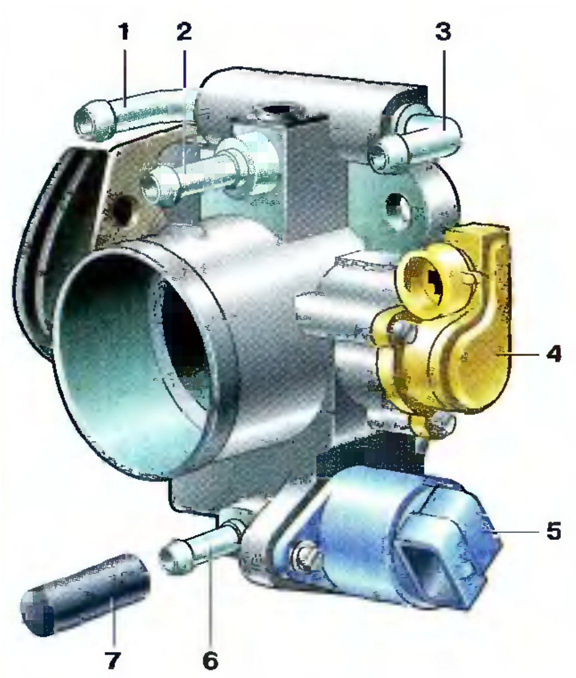


Fig. 12.19. **Throttle tube**: 1 – cooling water inlet; 2 – branch pipe of the crankcase ventilation system at idle; 3 – cooling water outlet; 4 – choke (throttle) position sensor; 5 – idle speed regulator; 6 – nozzle for blowing out the adsorber; 7 – plug

The sensor is a potentiometer, one terminal of which is supplied with a reference voltage of the controller equal to 5 V, and the other terminal is connected to the "mass" of the vehicle. From the third terminal of the potentiometer (from the slider), the sensor output signal is fed to the controller. When the throttle is closed, the sensor output signal should be in the range of 0.3–0.7 V. When the throttle opens (by pressing the gas pedal), the voltage at the sensor output begins to rise and at fully open throttle is 4.05–4,75 V. By monitoring the value of the output voltage of the throttle position sensor, the controller calculates the value of the ignition timing and the duration of the injection pulse.

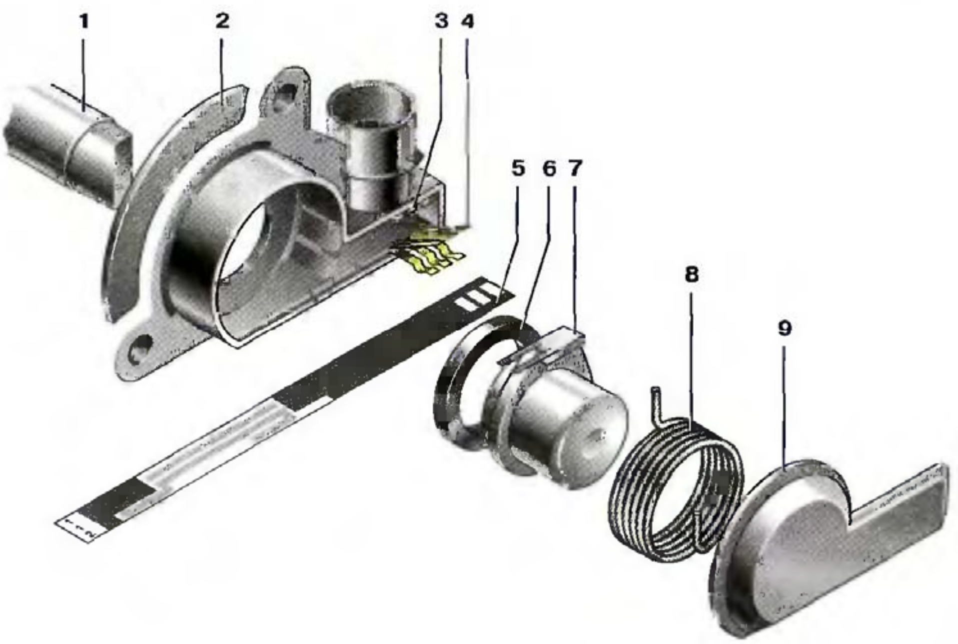


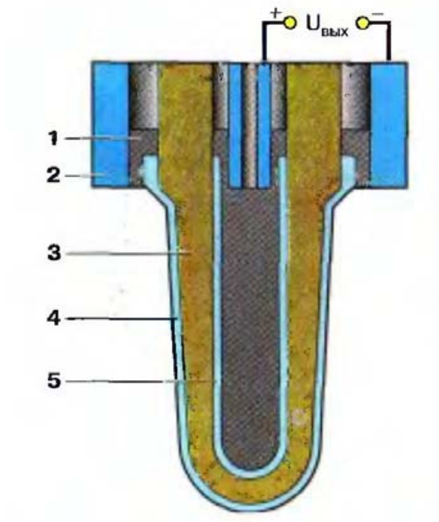
Fig. 12.20. **Throttle position sensor:**
1 – throttle spindle; 2 – housing; 3 – connector contacts; 4 – hold-down spring; 5 – resistive plate; 6 – stuffing box; 7 – slider contacts; 8 – return spring; 9 – cover

12.4.9 Oxygen sensors

For normal combustion of 1 kg of gasoline, 14.7 kg of air is required. Such a mixture has an excess air coefficient λ = 1. In order for the composition of exhaust gases to meet modern requirements for toxicity, the mixture of gasoline and air entering the cylinders must be somewhat lean (λ > 1). At the same time, the exhaust gases contain a certain amount of oxygen. If the mixture is rich (λ < 1), then the oxygen concentration in the exhaust gases decreases. In closed-loop injection systems, this amount of oxygen in the exhaust gases is monitored by an oxygen sensor (lambda probe), according to the signals of which the control unit adjusts the fuel supply to the cylinders, maintaining a rational composition of the working mixture.

This sensor has the following principle of operation.

The sensor (Fig. 12.21) is a galvanic current source, the output voltage of which depends on the oxygen concentration in the environment. The sensor has external 4 and internal 5 platinum electrodes, which are separated by a solid electrolyte based on zirconium dioxide $ZrO2$. The external electrode is flushed with the flow of exhaust gases with a variable oxygen partial pressure, and the environment surrounding the internal electrode has a constant oxygen partial pressure. When heated to a high temperature (more than 300 °C), zirconium dioxide acquires the properties of an electrolyte and a voltage arises between the electrodes 4 and 5 of the sensor, which is proportional to the difference in the partial pressures of oxygen in the ambient air (inside the sensor) and in the exhaust gases.



$U_{вых}$	U_{out}

Fig. 12.21. **Diagram of a zirconium oxygen sensor (λ-probe):**
1 – electrically conductive seal; 2 – housing; 3 – solid electrolyte;
4, 5 – external and internal electrodes

The oxygen concentration sensor O258092121 (Germany) (Fig. 12.22) of the closed-loop injection system is installed on the front pipe of the exhaust system.

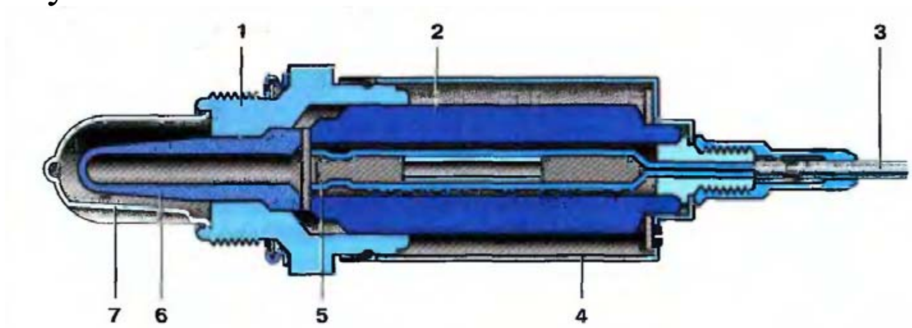


Fig. 12.22. **Zirconium oxygen sensor:** 1 – housing; 2 – seal; 3 – connecting cable; 4 – casing; 5 – contact rod; 6 – solid electrolyte of zirconium dioxide;
7 – protective cap with slots

The oxygen in the exhaust gases reacts with the oxygen sensor creating a potential difference at the sensor output. It varies from about

0.1 V (high oxygen content – lean mixture) to 0.9 V (little oxygen – rich mixture).

For normal operation, the sensor must have a temperature of at least 360 °C. Therefore, for quick warm-up after starting the engine, there is a built-in heating element in the sensor. By monitoring the output voltage of the sensor, the controller determines which command on adjusting the composition of working mixture to generate for the injectors. If the mixture is lean (low potential difference at the sensor output), then a command is given to enrich the mixture. If the mixture is rich (high potential difference), a command is given to lean the mixture.

12.4.10. Electric fuel pump

An **electric fuel pump** (usually a roller one) can be installed both inside the fuel tank (Fig. 12.23) and outside.

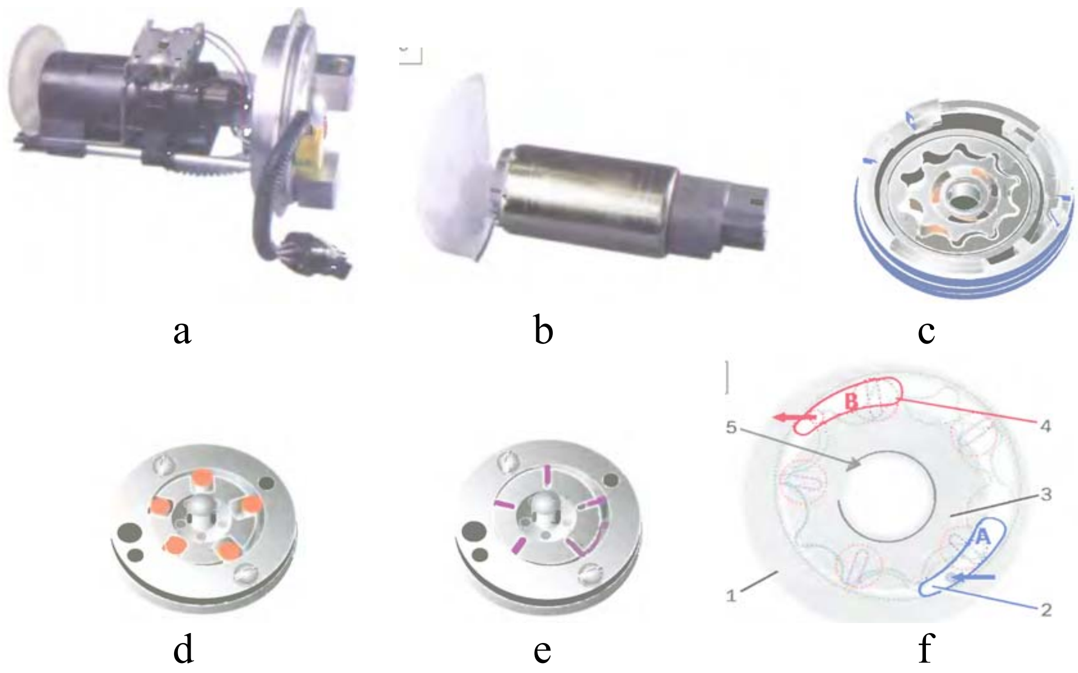


Fig. 12.23. **Submersible electric fuel pump:**
a – fuel intake with a pump; b – external view of the pump and the pumping section of a rotary type fuel pump with an electric drive; c – gear; d – roller; e – lamellar; f – scheme of the pump section of the rotary type: 1 – body; 2 – suction zone; 3 – rotor; 4 – discharge zone; 5 – direction of rotation

The fuel pump is switched on by an electromagnetic relay. Gasoline is sucked in by the pump from the tank and at the same time washes and cools the pump's electric motor.

There is a check valve at the pump outlet that prevents fuel from flowing out of the pressure line when the fuel pump is off. A safety valve serves to limit the pressure.

The fuel coming from the fuel pump, at a pressure of at least 280 kPa, passes through a fine fuel filter and enters the fuel rail. The filter has a metal body filled with a paper filter element.

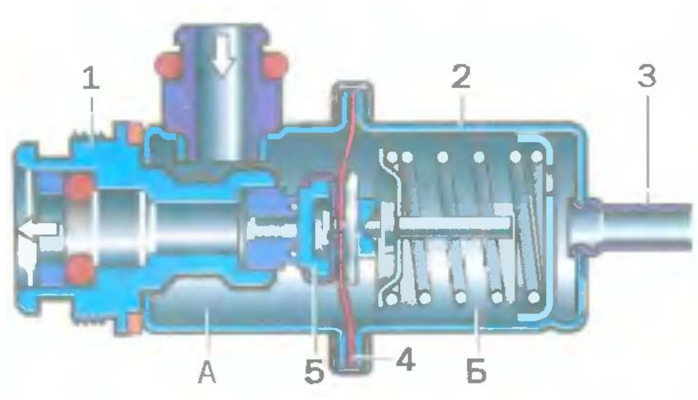
12.4.11 Rail

The **rail** (Fig. 12.24) is a hollow structure to which the injectors and pressure regulator are attached. The rail is bolted to the engine intake manifold. A connector is also installed on the rail, which serves to control the fuel pressure. The connector is closed with a screw plug to protect it from contamination.

12.4.12 Pressure regulator

The fuel pressure regulator (Fig. 12.25) serves to change the pressure in the rail, depending on the vacuum in the intake manifold. The steel body of the regulator houses a spring-loaded needle valve connected to the diaphragm. The diaphragm, on the one hand, is affected by the fuel pressure in the rail, and on the other, the vacuum in the intake manifold. With an increase in vacuum, while closing the throttle, the valve opens, excess fuel is drained through the drain pipe back into the tank, and the pressure in the rail decreases.

Fig. 12.24. **Fuel rail of a five-cylinder engine with mounted injectors, pressure regulator and pressure control connector**



А – А	Б – В

Fig. 12.25. **Fuel pressure control valve:**
1 – case; 2 – cover; 3 – branch pipe for a vacuum hose; 4 – membrane; 5 – valve; A – fuel cavity; B – vacuum cavity

Recently, injection systems have appeared in which there is no fuel pressure regulator. For example, there is no pressure regulator on the V8 engine rail of a New Range Rover vehicle, and the fuel mixture is provided only by the operation of the injectors, which receive signals from the electronic unit.

12.4.13 Catalytic converter

A **catalytic converter** (Fig. 12.26) is installed in the exhaust system to reduce the content of harmful substances in the exhaust gases.

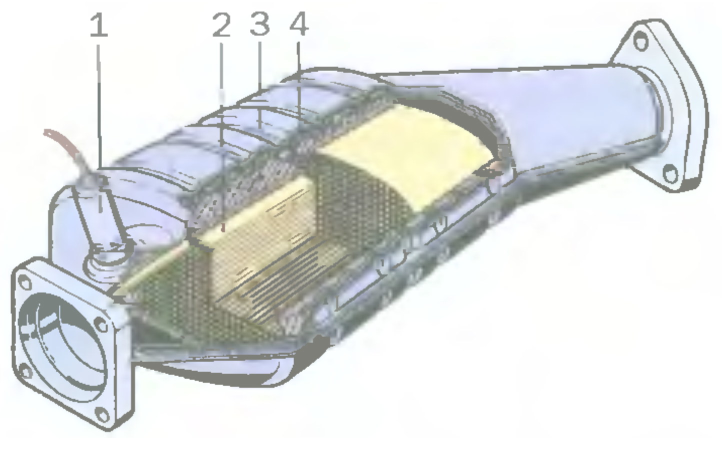


Fig. 12.26. **Two-layer three-component catalytic converter of exhaust gases:**
1 – oxygen concentration sensor for a closed control loop;
2 – monolithic block-carrier; 3 – mounting element in the form of a wire mesh;
4 – double-shell thermal insulation of the converter

The converter contains one reduction (rhodium) and two oxidation (platinum and palladium) catalysts. Oxidation catalysts promote the oxidation of unburned hydrocarbons (CH) to water vapor.

References

1. Кисликов В.Ф., В.В. Лущик. Будова й експлуатація автомобілів. Київ: Либідь, 2018. – 400 с.
2. Скляров В.М., Волков В.П., Скляров М.В. Автомобільні двигуни. Особливості конструкції: навч. посібник – Харків: ХНАДУ, 2012. – 405с.
3. Омеличев А.А. Підручник з будови автомобіля. – Дніпро: Моноліт, 2019. – 288 с.
4. Білоус Б.Д., Ткачук П.П., Андрусик Ю.Ф., Білоус Н.Б., Онищенко В.В. Армійська техніка. Основи руху, будова, характеристика: навч . посібник. – Л.: Вид-во Національного університету «Львівська політехніка», 2007. – 536 с.

Test questions

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1. What are the advantages of using liquefied gas in the power supply system of engines with external mixture formation?
2. Where are the cylinders with liquefied gas located in the vehicle?
3. What are electromagnetic injectors intended for and what is their design?
4. What is the design of the λ-probe and how does it work?
5. What is a catalytic converter for?
6. What is a rail and what is it for?

13 CONCEPTUAL MODULE

ICE cooling system (CS)

13.1. Purpose and functions of the cooling system (CS).
13.2. Classification of cooling systems, their advantages and disadvantages.
13.3. Liquid cooling system.
13.4. Air cooling system.

13.1. *Purpose and functions of the cooling system*

Purpose of CS: the system is designed to maintain optimal thermal conditions of the internal combustion engine (ICE).

The temperature of gases in the ICE cylinder reaches up to 2500 ºC during combustion and 900 ºC at discharge.

The parts of the ICE overheat, which can lead to seizure, thermal destruction, insufficient filling from the cylinders, deterioration of the lubrication system performance, and as a result, high wear of parts and ICE.

With overcooling, there is also an increase in mechanical losses, a decrease in efficiency due to a deterioration in the working process of the internal combustion engine.

System functions: 1 – automatic maintenance of optimal thermal conditions; 2 – fast warming up of the ICE to operating temperature; 3 – long-term preservation of heat after stopping; 4 – small energy costs associated with the drive of the cooling system units.

13.2. *Classification of cooling systems, their advantages and disadvantages*

The cooling system (CS) of vehicles is of the liquid and air type. The advantages and disadvantages of each of the systems are presented in Table 13.1.

Table 13.1 – **Advantages and disadvantages of liquid and air cooling systems**

Liquid CS	**Air CS**
Advantages:	*Advantages:*
– lower average temperature of parts; – less noise; – reduction of the ICE due to the block structure; – easier start-up and heating of the cab	– stability of heat removal from the walls; – reduction of warm-up time; – less probability of cylinder overcooling; – higher reliability of the system
Disadvantages:	*Disadvantages:*
– liquid leaking; – liquid freezing	– increase in the dimensions of the ICE; – increased noise; – added complexity of producing and manufacturing; – higher requirements for oils and fuels

Cooling system diagrams are shown in Fig. 13.1.

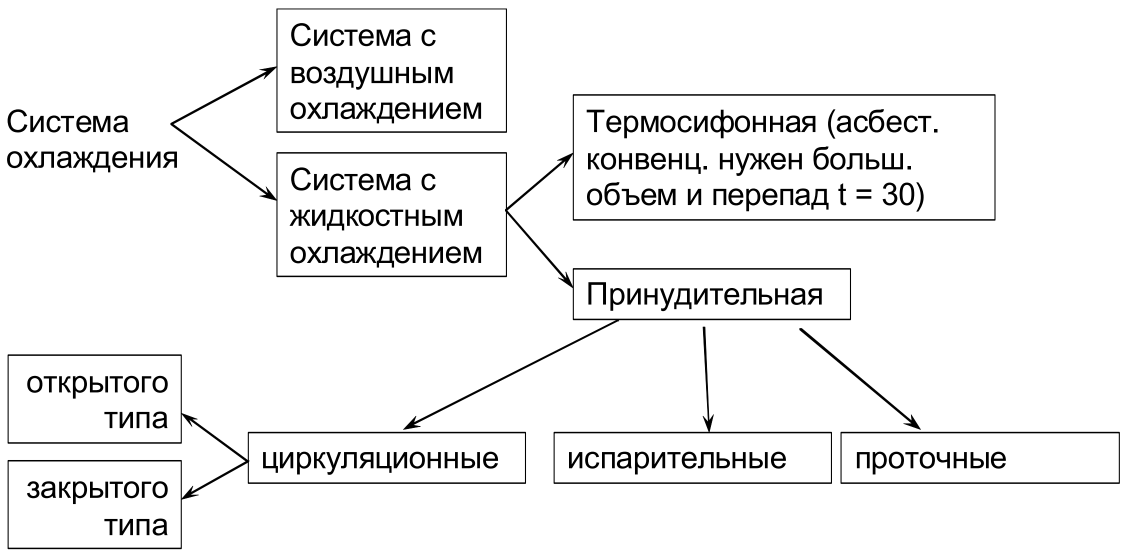

Figure 13.1 – **Diagram of the cooling system**

13.3. *Liquid cooling system*

The liquid cooling system includes the following units, which are shown in Fig. 13.2.

The radiator serves as a heat exchanger for the system. It includes the following: the upper tank (pipes, inlet with branches, necks), the lower tank (with outlet branches, drain cock).

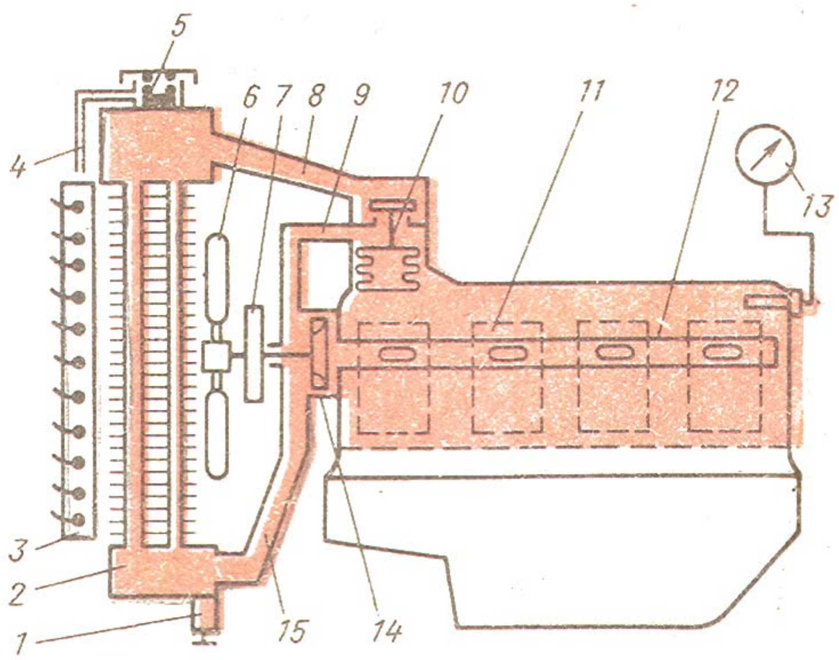

Fig. 13.2. **ICE water cooling system diagram:**
1 – drain edge; 2 – radiator; 3 – shutters; 4 – tube; 5 – plug; 6 – fan; 7 – pulley; 8 – branch pipe; 9 – tube; 10 – thermostat; 11 – cylinders; 12 – pipeline; 13 – thermometer; 14 – pump; 15 – branch pipe

Radiator *2* cap *5* of filler neck is made with two safety valves: steam and air.

Steam valve actuates at 1.3–1.5 kg/cm^2

Air valve actuates at 0.1 kg/cm^2

The liquid pump *14* imposes the required speed of movement to the liquid and provides a predetermined supply of liquid to the ICE CS. It consists of cast iron or aluminum housing, roller with hub for the fan, two ball bearings, impeller, sealing device (cast iron, aluminum, plastic). The pump generates a pressure of 0.4–1 kg/cm^2.

Fan *6* provides the necessary air supply to the radiator grilles at the design speed of the air mass. Usually one-stage fans with 2, 4, 6 – 8 blades are used. To reduce noise, an uneven arrangement of the blades around the circumference is taken. Usually a V-belt drive is used, rarely a gear drive (YaMZ-236). The fan is usually placed in a guiding casing (diffuser) to improve its efficiency.

Automatic clutches, fans with removable blades, electric fans are used.

Thermostat *10* is used to automatically adjust the temperature of the water in the cooling system, it is an automatic valve, the action of which is based on the use of low-boiling liquids and low-melting solids. There are one and two valve thermostats, liquid (bellows) and solid filled. Bellows-type two-valve thermostats (liquid type) are usually used.

Shutters *3* are made in the form of a set of vertical or horizontal thin plates. They are controlled from the cab.

13.4. *Air cooling system*

In air cooling systems, axial and centrifugal fans are used (Fig. 13.3).

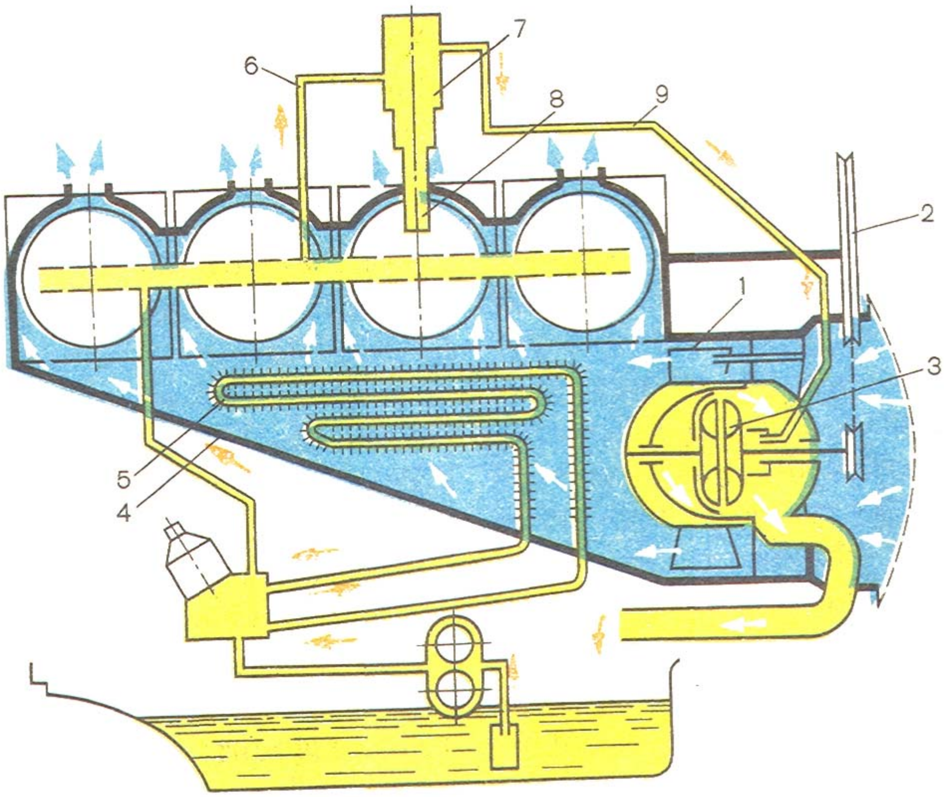

Fig. 13.3. **ICE air cooling system diagram:**
1 – fan; 2 – belt drive; 3 – hydraulic clutch; 4 – hood; 5 – oil cooler; 6 and 9 – oil lines; 7 – thermal valve; 8 – sensor

Depending on the location of the fan, systems with suction (ZAZ-968) or air injection (GAZ-542) are used.

Suction systems are relatively rarely used. They are characterized by greater uniformity and better utilization of the heated air.

Lack of fan power N_{vent} increases in proportion to T_{cool} (MeMZ-966). Typically, injection systems are installed. Regulation is carried out by oil pressure through a hydraulic clutch and a thermal sensor (GAZ-542).

References

1. Кисликов В.Ф., В.В. Лущик. Будова й експлуатація автомобілів. Київ: Либідь, 2018. – 400 с.
2. Скляров В.М., Волков В.П., Скляров М.В. Автомобільні двигуни. Особливості конструкції: навч. посібник – Харків: ХНАДУ, 2012. – 405с.
3. Омеличев А.А. Підручник з будови автомобіля. – Дніпро: Моноліт, 2019. – 288 с.
4. Білоус Б.Д., Ткачук П.П., Андрусик Ю.Ф., Білоус Н.Б., Онищенко В.В. Армійська техніка. Основи руху, будова, характеристика: навч . посібник. – Л.: Вид-во Національного університету «Львівська політехніка», 2007. – 536 с.

Test questions

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1. What are the main elements of a liquid cooling system?
2. What are the main elements of an air cooling system?
3. What are the thermostat and fan in the liquid cooling system intended for?
4. What are the main disadvantages of an air cooling system?
5. What are the main disadvantages of a liquid cooling system?
6. What kind of cooling systems are there in the vehicle?
7. What are the advantages of a liquid cooling system?

14 CONCEPTUAL MODULE

Lubrication system

14.1. *The purpose of the lubrication system (LS), classification.*

Purpose of the lubrication system:
– reduces friction in friction pairs;
– enables partial cooling of parts;
– produces removal of wear products;
– carries out a seal of gas joints;
–has anti-corrosion properties.
Lubrication systems supply lubricant to the parts:
– under pressure;
– by splashing;
– in a combined way.
They are divided into systems:
– with a wet crankcase;
– with continuous oil supply;
– with a dry crankcase;
– with pulsating oil flow.
The system includes:
– oil tank;
– oil receiver;
– oil pump;
– filters;
– oil radiator;
– reduction valves;
– control devices.

The dry sump lubrication system is used on cross-country vehicles, tractors working on slopes, sports cars, airplanes, etc.

Lubrication of two-stroke engines is carried out with a combustible mixture, into which oil is mixed in a ratio (1:25–1:50). When such a mixture enters the cylinder, the gasoline evaporates, and the oil remains on the cylinder walls. Special metering pumps change the oil flow ratio (1:25–1:200) to improve the workflow.

In automobile engines, the combined lubrication system is the most common.

14.2. *Principle of operation.*

A schematic diagram of the lubrication system is shown in Figure 14.1.

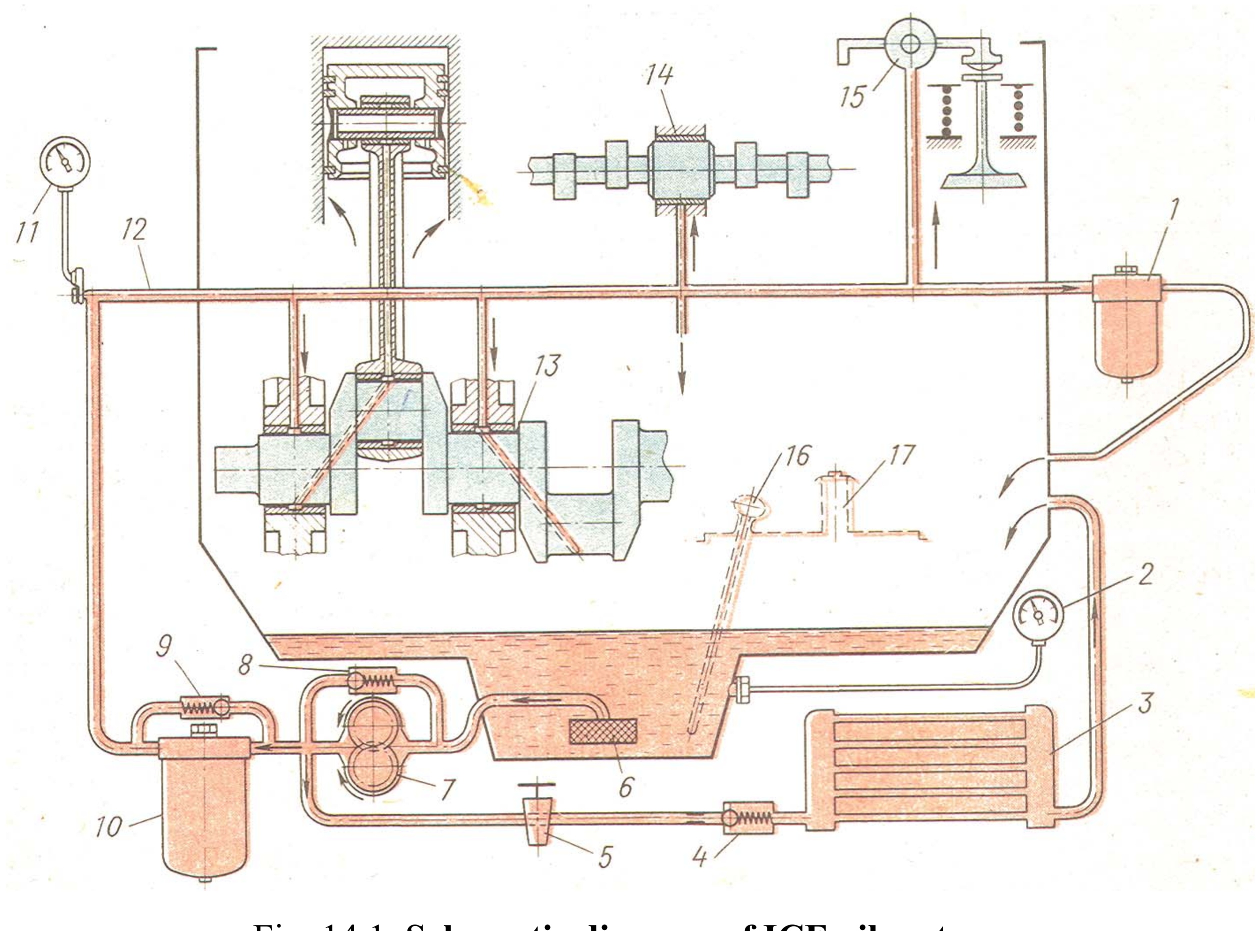


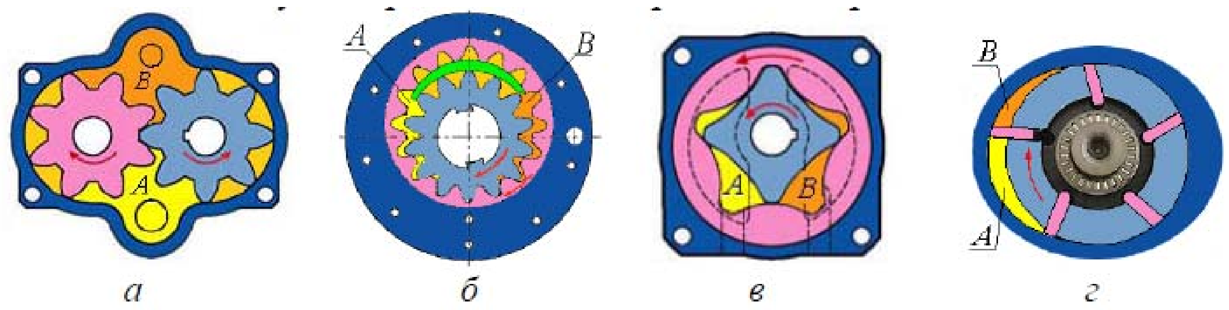
Fig. 14.1. **Schematic diagram of ICE oil system:**
1 – filter; 2 – electric thermometer; 3 – crane; 4 – safety valve; 5 – valve; 6 – oil receiver; 7 – pump; 8 – lamp; 9 – bypass valve; 10 – filter; 11 – electric pressure gauge; 12 – oil line; 13 – fluid coupling; 14 – bearing; 15 – hollow axis

Under the action of vacuum, oil is captured by the teeth of the oil pump 7, passes through the coarse filter 10 and enters the oil line 12 and the oil cooler 3. In the cooler 3, the oil is cooled and enters the sump. In line 10, part of the oil goes to the bearings of the crankshaft 13, and other part goes to the fine filter 1, and then to the sump. The rest of the oil goes to the GDM, lubricates the camshaft bearings 14.

14.3. *Elements of the lubrication system.*

14.3.1. Oil pumps

The oil pump is designed to supply oil under pressure to the most loaded rubbing surfaces, as well as to oil cleaning and cooling devices. In vehicle engines, gear-type oil pumps (with external or internal gearing of gear wheels), rotary and rotary-blade type are used (Fig. 14.2).



а – a	б – b	в – c	г – d

Fig. 14.2. **Operating principles of oil pumps:**
a – gear pump with external gear teeth; b – gear pump with internal gear teeth; c – rotary pump; d – rotary-blade pump; A and B – zones of low and high oil pressure, respectively.

A gear pump with internal gearing and a rotary pump are structurally similar, the main difference between them is that rotary pumps use rotors of a special shape and geometry instead of gears.

14.3.2. Oil receiver

The oil receiver can be *fixed* or *floating*. It serves for taking oil from the sump of the engine crankcase. The oil receiver, as a rule, is mounted on the pump and is the primary oil filter. It is a body in which a mesh is fixed with a spring. The body of the oil receiver has ribs where the edge of the mesh rests, creating slits between it and the body. If the filter mesh is clogged, then untreated oil enters the pump through the slits between the mesh and the oil receiver body.

14.3.3. Relief valve

The relief valve is intended to limit pressure in the lubrication system. The pressure in the system increases at excessively high speeds or thick oil (Fig. 14.3).

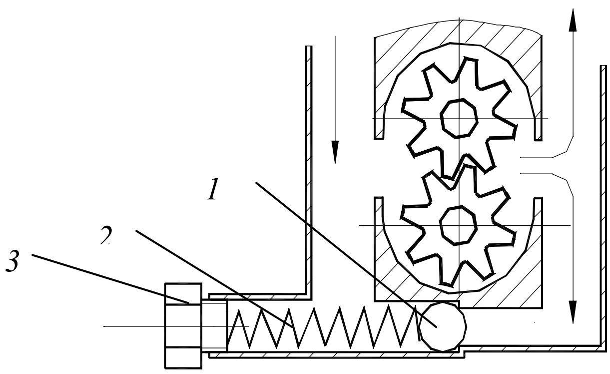


Fig. 14.3. **Schematic diagram of relief valve:**
1 – adjusting plug; 2 – ball; 3 – spring

14.3.4. Oil filters

They serve for cleaning oil from mechanical impurities.

Type	Depth of cleaning, μm	Way of including
Slotted: – surface – depth	Coarse cleaning (up to 40)	Full-flow
Centrifugal: – mechanically driven – jet driven	Fine cleaning (up to 1 – 2)	Part-flow

Coarse oil filters are of the following types:
- slotted tape;
- slotted plate;
- cardboard filter of ASFO or DASFO type;

– depth filter:
– full-flow paper filter.

Oil centrifuges are used on trucks and tractors. Also a centrifuge was used on a MeMZ-968 passenger car.

14.3.5. Oil radiators

An oil radiator can be:
– oil-air;
– water-oil.

Structurally, it is similar to a water radiator.

14.3.6. Control devices

Control devices for:

1. oil level;
2. oil pressure (the alarm lamp turns on when the pressure is below 0.9 – 0.8 kg/cm^2)

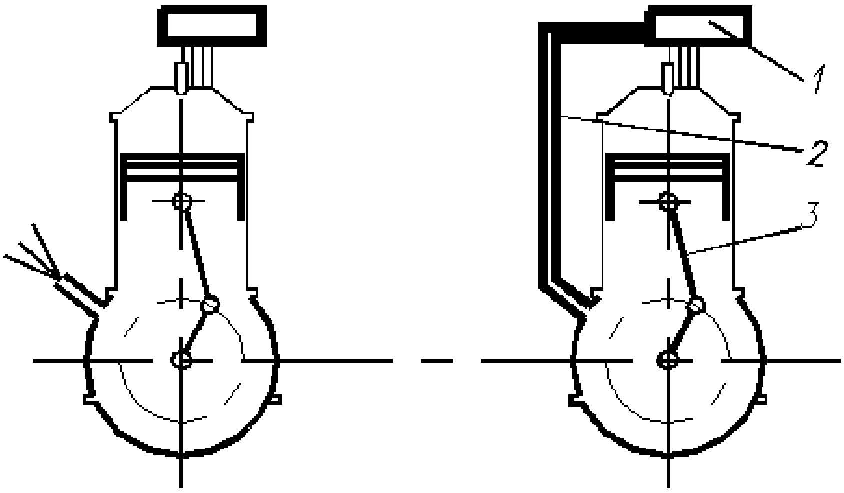
gasoline engine	diesel engine
3 – 5 kg/cm^2	5 – 7 kg/cm^2

14.3.7. Ventilation system for crankcase gases.

Gases leak into the crankcase. They contain CO, sulfur, nitrogen, fuel vapor, water vapor, etc., therefore it is necessary to blow through the crankcase space.

The crankcase ventilation systems are divided into:
– exhaust;
– supply and exhaust**.**

The crankcase ventilation systems can be the following (Fig. 14.4):
– open;
– closed.



a b

Fig. 14.4. **Open normal (a) and closed positive (b) ventilation system:**
1 – air filter; 2 – manifold; 3 – ICE

References

1. Кисликов В.Ф., В.В. Лущик. Будова й експлуатація автомобілів. Київ: Либідь, 2018. – 400 с.

2. Скляров В.М., Волков В.П., Скляров М.В. Автомобільні двигуни. Особливості конструкції: навч. посібник – Харків: ХНАДУ, 2012. – 405с.

3. Омеличев А.А. Підручник з будови автомобіля. – Дніпро: Моноліт, 2019. – 288 с.

4. Білоус Б.Д., Ткачук П.П., Андрусик Ю.Ф., Білоус Н.Б., Онищенко В.В. Армійська техніка. Основи руху, будова, характеристика: навч . посібник. – Л.: Вид-во Національного університету «Львівська політехніка», 2007. – 536 с.

Test questions

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1. What kind of oil pumps are used in vehicles?
2. What types of crankcase ventilation systems are used on vehicles?
3. What is the oil pump for?

15 CONCEPTUAL MODULE

ICE intake and exhaust systems. Starting system

15.1. Intake and exhaust system.
15.2. Air filtration.
15.3. Silencers.
15.4. Starting system.

15.1. *Intake and exhaust system.*

The *intake and exhaust systems are used* to supply fresh charge (mixture) to the engine cylinders and remove exhaust gases from them.

The general requirement is their low resistance and favorable course of gas-dynamic processes.

The intake system consists of:
– air intake;
– compressor for air compression;
– air cooler;
– intake units.

The intake manifold is made cast-in, usually from light alloys. To improve the evaporation of the mixture, it is heated with a cooling liquid. In high-power engines, the intake manifold is a cylindrical receiver with branch pipes welded to it.

In two-stroke engines, the air from the compressor is supplied directly to the receiver located in the cavities of the block or frame.

The exhaust system includes:
– exhaust units;
– branch pipes, exhaust manifold;
– afterburner, catalyst;
– gas turbine, compressor;

– ejection device for removing dust from the air purifier and sweeping of cooled air;

– silencer.

The exhaust manifolds on small-sized ICEs are made in the form of a common manifold made from cast iron.

When pressurized, the volume of the manifold increases and such a device is called a pulse converter.

To prevent burns, the exhaust manifolds are insulated with a screen or cooled with water.

When heating and cooling, the length of the manifold changes. Therefore, expansion joints (piston rings) are installed in front of the turbine.

15.2. *Air filtration.*

Filters are used to clean the air from dust.

Filters must have:

- low hydraulic resistance;
- required dust holding capacity;
- operational reliability;
- convenience in service;
- compact and technologically advanced design;
- efficiency of air purification.

Filters are divided according to the cleaning method:

1 – inertial (dry and wet);

2 – filtering (dry and wet);

3 – combined (dry, wet and mixed).

15.2.1. Inertial filter elements

In these elements (see Fig. 15.1), a sharp change in the direction of the air flow is performed. Since the density of dust particles is greater than the density of air, some of the dust is collected in a special container (dry inertial filter), or in an oil bath – (wet inertial filter).

In wet filter elements (see Fig. 15.2), dust particles settle either in an oil bath, or on the wetted surface of a metal element, or on the fibers of a dry element.

In inertial centrifugal filters, a cyclone (multicyclone) device is often used, in which a vortex motion is imparted to the polluted air.

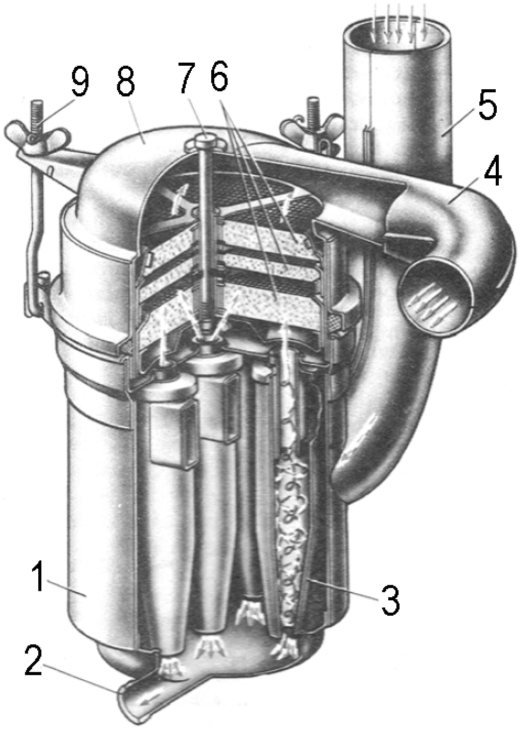


Fig. 15.1. **Combined dry air filter for engines of the SMD type:**
1 – housing; 2 – branch pipe for dust extraction; 3 – cyclone; 4 – branch pipe for air outlet; 5 – branch pipe for air supply; 6 – cartridges of the filtering element; 7 and 9 – tie bolts; 8 – filter cover

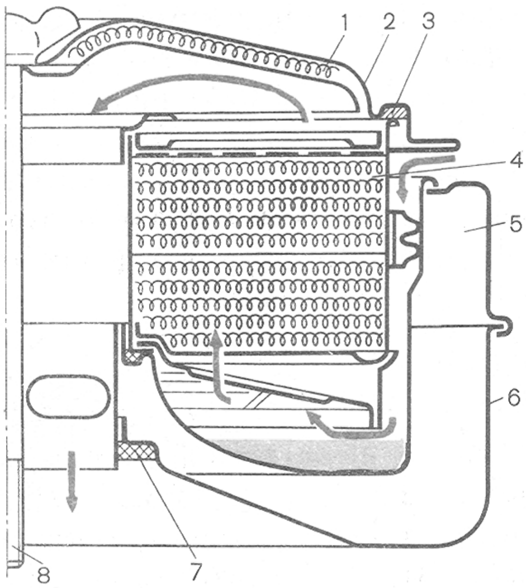
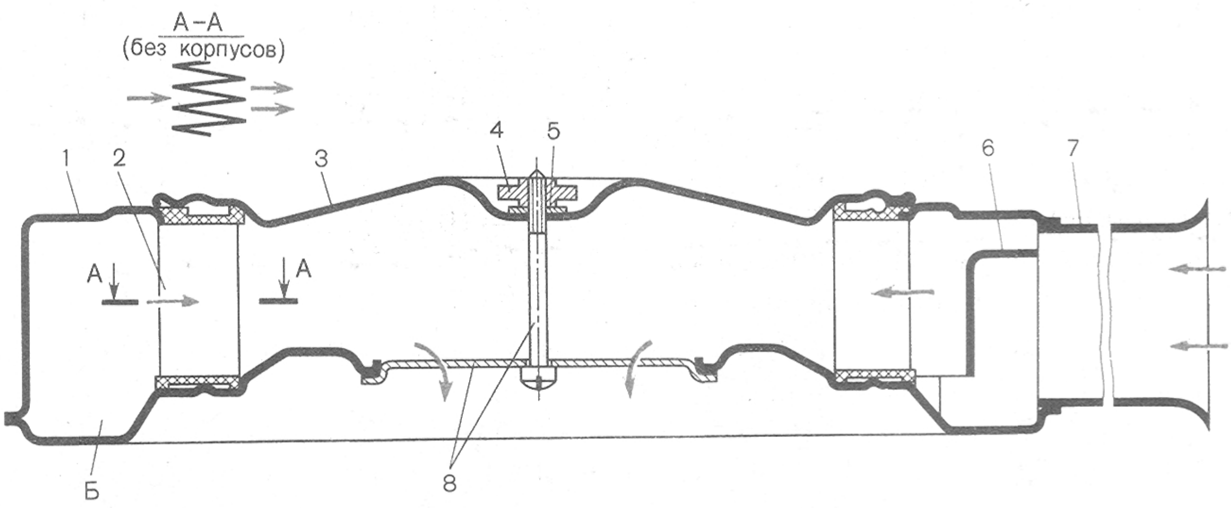


Fig. 15.2. **Combined wet air filter of YaMZ-236 and YaMZ-238 engines:**
1 – noise absorber; 2 – cover; 3 and 7 – gaskets; 4 – filter element; 5 – intake noise suppression chamber; 6 – body; 8 – the rod for attaching the air filter

15.2.2. Filtering air filters

Wet filtering elements are made of wire metal mesh, nylon or wire mesh, fiberglass, metal shavings.

Dry filtering elements (Fig. 15.3) are made of special filter carton, urethane foam, non-woven materials.



А – А	Б – В	без корпусов – without bodies

Fig. 15.3. **Filtering air filter of type VSG-4:**
B – annular cavity for noise suppression; 1 – body;
2 – filter element; 3 – cover; 4 – nut;
5 – gasket; 6 – reflector; 7 – air branch pipe;
8 – parts (screw and plate) protecting filter during transportation

15.2.3. Combined air filters

Combined air filters combine the above cleaning methods. Typically, a wet inertial filter (first stage) and a wet filtering element (second stage) or a multicyclone and cardboard filter element are used.

The resistance of air systems is 0.6 – 5.5 kPa.

15.3. *Silencers*

The noise level in the ICE reaches 120 dB, and is created due to the noise of mechanical and gas-dynamic origin:

– performance of crankshaft-and-connecting-rod assembly;

– intake and exhaust of working medium;
– combustion process;
– operation of fuel pump and oil pumps;
– valve mechanism operation.

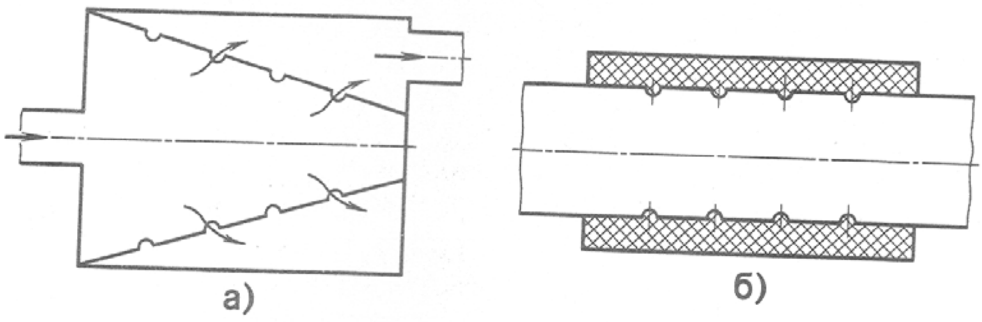
The noise level is reduced by nosing-over, using sound-absorbing partitions, constructive measures to reduce noise:

– an increase in the length of the piston skirt;
– the use of an offset mechanism;
– smooth cam profile;
– an increase in the thickness of liner of the cylinder and CC;
– the use of noise-absorbing gaskets.

Silencers are divided into:

– active;
– reactive.

Active silencers. Energy is converted into heat when a wave passes through resistances (meshes, perforated sheets, sound-absorbing material). A schematic diagram of active silencers is shown in Fig. 15.4.



а) – a)	б) – b)

Fig. 15.4. **Schematic diagrams of active silencers:**
a – with a perforated body;
b – with sound-absorbing material

Reactive silencers are either an expansion chamber or a series of resonance chambers. These silencers are shown in Fig. 15.5.

Reactive silencers more effectively “muffle” low-frequency noise, and active silencers – high-frequency noise.

Usually a combination of both types is used. The combined silencer is shown in Fig. 15.6.

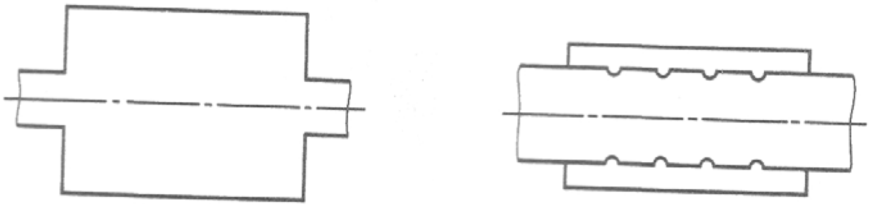


Fig. 15.5. **Schematic diagrams of jet silences:**
a – with an expansion chamber; b – with resonance chambers

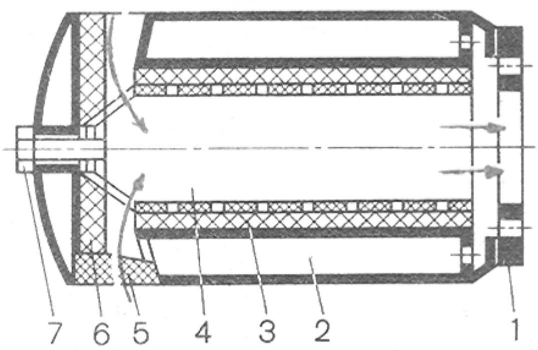


Fig. 15.6. **Active-reactive intake silencer:**
1 – flange for attachment to the intake branch pipe; 2 – jet silencer;
3 – sound absorber; 4 – perforated tube; 5 – protective mesh;
6 – sound absorber on the cover; 7 – screw for adjusting the intake clearance

15.4. *Starting systems.*

All types of ICEs require preliminary untwisting of the crankshaft (by an external source) to a given rotational speed, at which a stable start and operation of the power unit is carried out.

The minimum stable speed of the ICE shaft for the following engines is:

- gasoline – 50–70 min^{-1};
- diesel – 100–250 min^{-1};
- rotary piston – 200–500 min^{-1};
- gas turbines – 20000 min^{-1}.

Starting systems are classified:

By the method of rotating the crankshaft:

- mechanical intake systems;
- pneumatic intake systems.

Mechanical starting systems (kinematically connected to the ICE shaft):

- human muscular strength (inertial starters, hand lever);

– electric starter;
– pneumatic and hydraulic accumulators;
– auxiliary starting engines.

Pneumatic starting systems:

– compressed air (air supply to the cylinder or GTE blades);
– powder cartridges.

Devices that facilitate starting:

– those reducing the viscosity of the oil (use of easily evaporating fractions of gasoline or heating);

– those intensifying fuel evaporation (air heating, heater plugs, easily evaporating gasoline);

– combined.

A combined (cascade) starting is used (starter – starting ICE – diesel).

The starting qualities of engines are assessed by the minimum starting temperature at which the working medium is ignited, the duration of the starting and the time until the load is received.

References

1. Кисликов В.Ф., В.В. Лущик. Будова й експлуатація автомобілів. Київ: Либідь, 2018. – 400 с.
2. Скляров В.М., Волков В.П., Скляров М.В. Автомобільні двигуни. Особливості конструкції: навч. посібник – Харків: ХНАДУ, 2012. – 405с.
3. Омеличев А.А. Підручник з будови автомобіля. – Дніпро: Моноліт, 2019. – 288 с.
4. Білоус Б.Д., Ткачук П.П., Андрусик Ю.Ф., Білоус Н.Б., Онищенко В.В. Армійська техніка. Основи руху, будова, характеристика: навч . посібник. – Л.: Вид-во Національного університету «Львівська політехніка», 2007. – 536 с.

Test questions

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1. What is a partial flow filter?
2. What is a full flow filter?
3. What are the kinds of silencers?
4. What intake silencers do you know?

16 CONCEPTUAL MODULE

Ignition systems

16.1. Purpose. General information. Working conditions.
16.2. Battery ignition. Device. Elements of the ignition system: ignition coil, breaker, distributor, capacitor, additional resistance. Principle of operation.
16.3. Electronic ignition systems: contact-transistor systems, thyristor, surface discharge, digital.
16.4. Spark plugs: Applicable materials.

16.1. *Purpose. General information. Working conditions*

The ignition system is used to create a high voltage current, to distribute it over the engine cylinders and to ignite the combustible mixture in the combustion chamber at specified times.

An ignition system is a set of devices and appliances that ignite the working mixture in the cylinders in accordance with the order and mode of operation of the internal combustion engine.

The magnitude of the spark breakdown voltage depends on the gap in the spark plugs, the pressure in the cylinder and is 8–12 kW. To increase the reliability of ignition, the voltage reaches 16–25 kW.

Since the working mixture does not burn instantly, it should be ignited with some advance, that is, before the piston reaches TDC.

The ignition advance of the mixture is called ignition advance and is usually measured in degrees of the engine crankshaft angle.

The ignition timing should change with changes in engine speed and load.

Depending on the operating conditions of the internal combustion engine, the ignition system can be conventional (single-wire) or shielded.

16.2. *Battery ignition*

The system consists of the following ignition elements: ignition coil, breaker-distributor, capacitor, additional resistance.

A single-wire ignition system is used on modern engines. The second conductor is mass. The negative terminals of the system are connected to the ground, and the positive ones are isolated from it.

The battery ignition contact system includes: an ignition coil 1 with an additional resistor, a low voltage breaker with a capacitor 2, a high voltage pulse distributor 3, spark plugs 4, low and high voltage wires (Fig. 16.1).

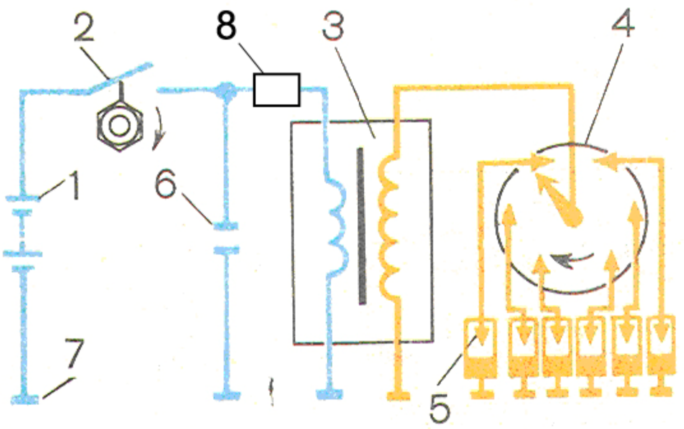

Fig. 16.1. **Schematic diagram of the ignition system:**
1 - current source; 2 - breaker; 3 - ignition coil;
4 - distributor; 5 - spark plug; 6 - capacitor; 7 - ground

16.2.1. Ignition coil (IC)

IC serves to convert low voltage current (6 or 12 V) into high voltage current (12000-20000 V).

The main parts of the coil are the plunger, primary and secondary windings.

The primary winding is made of thick wire and has a small number of turns (300). One end is connected, through a breaker and ground, the other one is connected to the storage battery. The secondary winding consists of a large number of turns (20,000) and is wound from very thin wire to obtain small dimensions. One end of the IC is connected to the side electrode (through the ground), the other one is connected to the central one.

When the contacts are closed, current flows through the primary winding. When the contacts are opened, an EMF is induced in each turn of the secondary winding of the coil, and a high voltage arises at its ends. As a result, a spark jumps between the electrodes of the plug.

When the contacts are opened, an EMF appears in the primary winding, the voltage increases, and a strong sparking appears between the contacts.

A capacitor is installed to absorb the self-induction current during opening and reducing the sparking between the contacts.

Two types of coils are used:

- FC filled with solid insulating compound mass (B - 1, B - 7A)
- FC filled with transformer oil (such coils use a higher voltage) (B - 13, B - 115, B - 117).

Some coils for automatic regulation of the primary current have an additional resistance (variator), which is switched off at cranking.

Explanation of abbreviations on IC:

D - from the ignition distributor.

SC - from a switch or a starter relay.

SC - B - from the ignition switch.

Shielded coils are used on engines for special purpose vehicles (ZIL - 131) B 102 B.

16.2.2 Breaker – distributor.

The breaker is used to open and close the primary circuit of the ignition coil, the distributor is used to direct (distribute) the high voltage current to the spark plugs in accordance with the operating procedure.

The breaker and distributor are made in a common tank.

In the lower part there is a platform where the breaker contacts are located. The short-circuit current is supplied to the moving contact (from the cam shaft). The fixed contact is connected to ground. A capacitor is switched on in parallel with the contacts (its capacity is 0.17 - 0.35 mKf).

To adjust the ignition timing in terms of rotations, there is a centrifugal regulator connected to a moving contact.

For load regulation, there is a movable vacuum regulator connected to the contacts.

The distributor (rotor) is made of a carbolite rotor with a brass conductive plate and a carbolite cover with contact sockets for high voltage wires.

16.3. *Electronic ignition systems*

To improve fuel efficiency in modern internal combustion engines, the compression ratio is increased and the mixture is leaned out. Sustained ignition of the mixture requires an increase in the spark gap. Due to the increase in the current in the primary coil, the contacts of the breaker burn out. These disadvantages are eliminated in electronic ignition systems.

16.3.1. Contact transistor ignition system

The ignition system diagram is shown in Fig. 16.2.

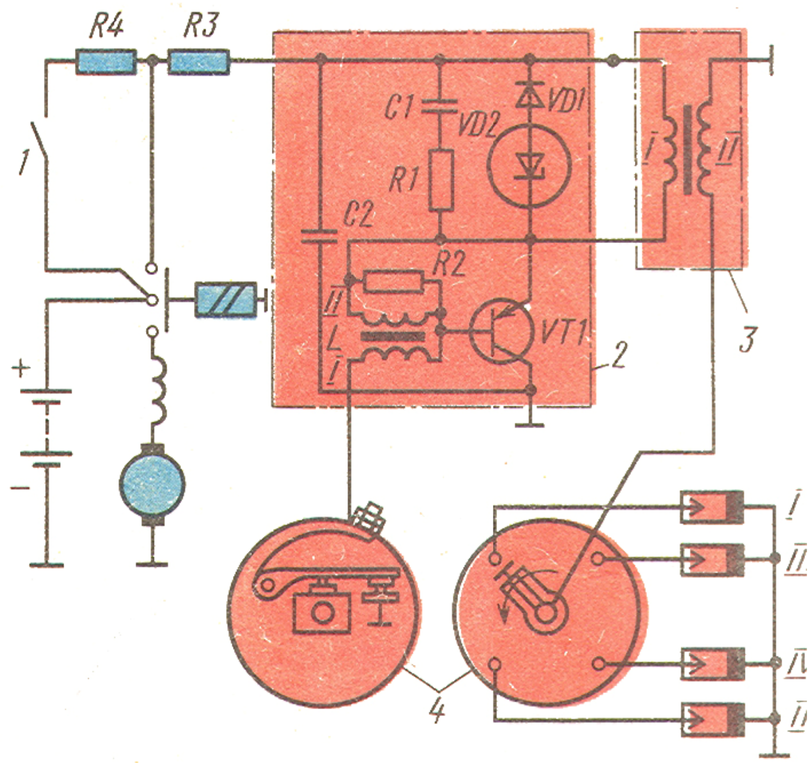

Рис. 16.2. **Diagram of the contact transistor ignition system:**
1 - ignition switch; 2 - transistor switch;
3 - ignition coil; 4 - distributor; I-IV - number of cylinders

In addition to the distributor and, the system also has a transistor switch, which is included in the circuit between the primary winding of IC and the breaker. There is no condenser in the breaker. Two resistors are included in the primary winding circuit, one of which closes at start-up.

16.3.2. Non-contact transistor ignition system.

Such a system allows for a high voltage in the secondary circuit, which allows you to get a more powerful and continuous charge and a more stable ignition of the mixture. Due to the absence of rubbing wear elements, the ignition moment does not change, regardless of the service life.

16.3.3. Electronic (digital) ignition system

The signals from the temperature sensors D, and the vacuum Dp in the intake manifold through the ADC (analog-to-digital converter) are fed to the MP (microprocessor) connected to the PROM (programmable read-only memory) RAM (processing memory). After the processing results, the MP outputs a signal to the IC (ignition coil) and (distributor) P to the spark plugs (diagram 16.1).

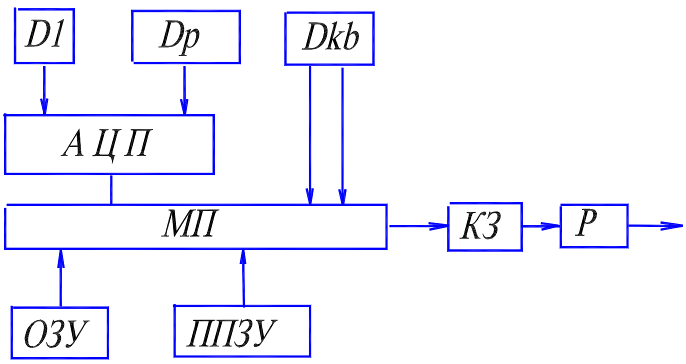

Схема 16.1 **Electronic (digital) ignition system**

16.3.4. Thyristor ignition system

Ignition system with energy storage in a tank. A thyristor is usually used as a switching device with capacitance accumulation.

The coil windings have low inductance and low resistance. This system reduces plug deposits. The high frequency of sparking (600 sparks/s) allows them to be used in Wankel and other engines.

16.4. ***Spark plugs***

Design diagrams of spark plugs are shown in Figure 16.3.

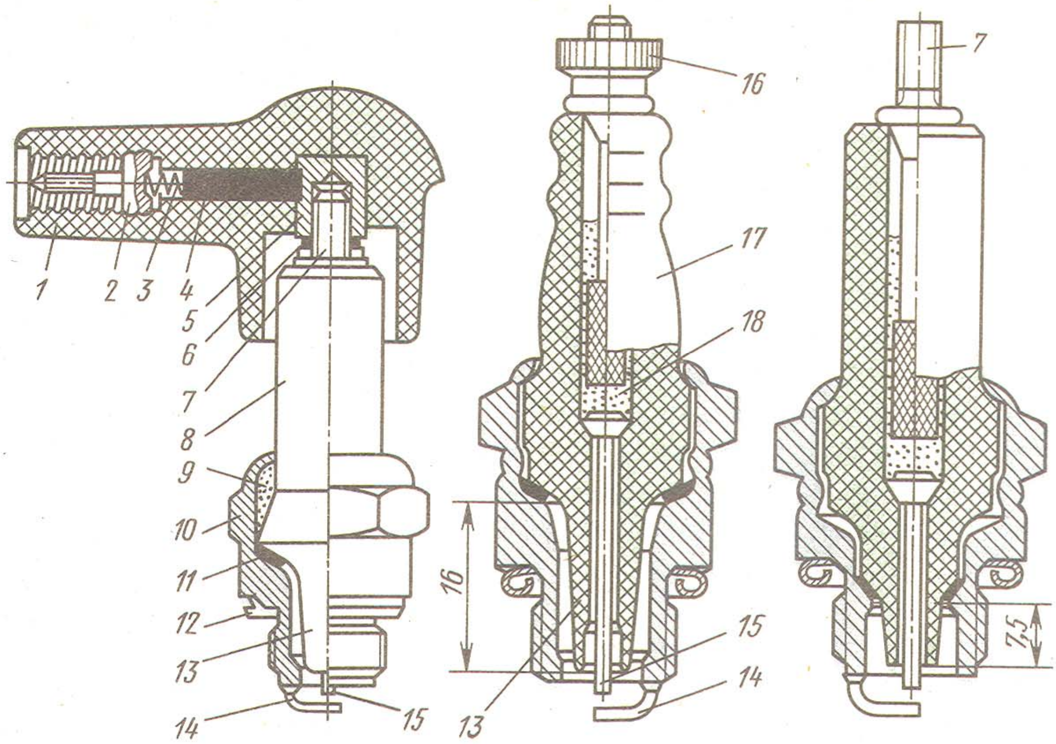

Fig. 16.3. **Spark plugs**: a - device; b - hot plug;
в - cold plug; 1 - shell; 2 - output; 3 - contact
spring; 4 - suppression resistor; 5 - contact;
6 - retaining spring; 7 - rod of the central electrode;
8 - insulator; 9 - sealing powder; 10 - plug shell;
11 - copper washer; 12 - copper asbestos washer; 13 - thermal cone;
14 - side electrode; 15 - central electrode; 16 - contact nut;
17 - contact head; 18 - conductive glass sealant

The shorter the plug, the better the heat dissipation and the "colder" the plug. The higher the heat rating, the "colder the plug", ie, it can operate in a higher thermal mode.

Designations and marking of spark plugs: A 20 DV

A – diameter and pitch of the thread (A – 14 × 1,25; M – 18 × 1,5).

20 – heat rating (8; 11; 14; 17; 20; 23; 26).

D – thread length (H – 11mm; D – 19mm; if 12mm it is not indicated)

B – the lower part of the insulator protrudes;

T – sealing with a thermosealant is applied.

References

1. Кисликов В.Ф., В.В. Лущик. Будова й експлуатація автомобілів. Київ: Либідь, 2018. – 400 с.

2. Скляров В.М., Волков В.П., Скляров М.В. Автомобільні двигуни. Особливості конструкції: навч. посібник – Харків: ХНАДУ, 2012. – 405с.

3. Омеличев А.А. Підручник з будови автомобіля. – Дніпро: Моноліт, 2019. – 288 с.

4. Білоус Б.Д., Ткачук П.П., Андрусик Ю.Ф., Білоус Н.Б., Онищенко В.В. Армійська техніка. Основи руху, будова, характеристика: навч . посібник. – Л.: Вид-во Національного університету «Львівська політехніка», 2007. – 536 с.

Test questions

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1. Which of the electric accessories of the car is the source of current when the engine is not running?
2. Which of the electric accessories of the car is the most powerful consumer of current?
3. Which of the electric accessories of the car is the source of power for the starter when the engine is started?
4. Which of the electric accessories of the car is the main source of electrical energy when the engine is running at high crankshaft speeds?
5. In what units is the current strength measured?
6. In what units is the power of electric current measured?
7. In what units is voltage measured?
8. In what units is the battery capacity measured?
9. What material is an electrical insulator?
10. What material is the electrolyte?
11. What material is a semiconductor?

17 CONCEPTUAL MODULE

Electrical equipment of installations with internal combustion engines

17.1. *Purpose and schematic diagram of electrical equipment*

The whole complex of electrical devices and equipment, including sources of current, together form *a car electrical system* (Fig. 17.1).

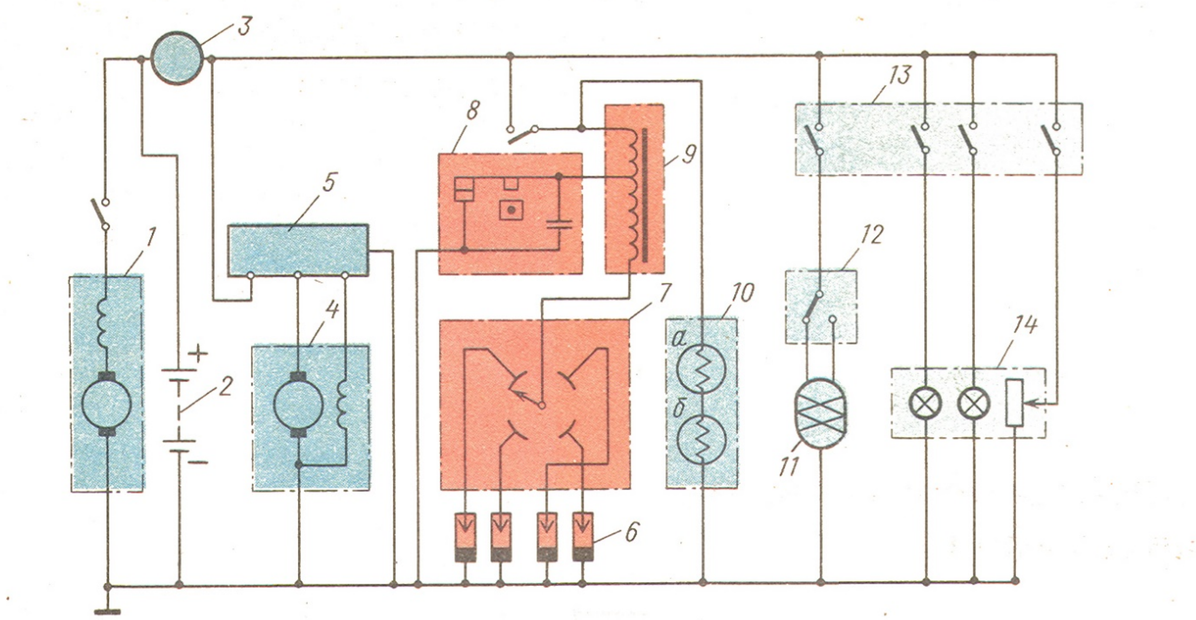


Fig. 17.1. **Schematic diagram of the electrical equipment of the car:**
1 - starter; 2 - storage battery; 3 - ammeter;
4 - generator; 5 - regulator; 6 - spark plugs; 7 - distributor;
8 - breaker; 9 - ignition coil; 10 - testing equipment; 11 - headlights; 12 - foot switch of headlight beam; 13 - main light switch;
14 - illumination and indicating lights devices

The electrical system is designed to perform a number of functions necessary for the normal operation of vehicles using electric current:

– ignition of the working mixture;
– starting the internal combustion engine;
– lighting (roads, interior, body);
– signaling (about changing the direction of movement, braking);
– sound alarm;
– testing equipment and additional equipment);
The electrical equipment diagram is shown (see Fig. 17.1).
Electrical equipment is divided into:
– sources of current;
– consumers of current;

17.2. *Sources of current*

Two power sources are used in cars.
– *a storage battery* that supplies consumers when the engine is not running;
– *a generator* supplying power to consumers when the engine is running.

17.2.1. Storage battery (battery SB)

Lead-acid batteries, consisting of several batteries connected in series, have been used. Such batteries have little internal resistance and are capable of delivering a current of several hundred amperes in a few seconds.
The battery is a vessel filled with electrolyte, into which lead electrodes (plates) are lowered.
The electrolyte is a solution of sulfuric acid in distilled water.
The electrodes are the lead plates: one plate consists of a spongy lead Pb, the other one consists of a lead dioxide (PbSO4).
Separator – the insulating pads between the electrodes.
Battery marking:
6ST - 60 EM - N
6 - the number of series-connected elements (cans);
ST - starter;
60 - capacity in ampere hours (Ah);
E - ebonite; T - thermoplastic (monoblock material);
n - asphalt-pitchy plastic;

M - miplast, C - fiberglass, R - mipor (separator material);
H – non-dry-charged, З - dry-charged.

17.2.2. Generator

A generator is an electrical machine that converts mechanical energy into electrical energy.

Generators of direct and alternating current are used.

The advantages of alternators:

1 - the rotor of the alternator can rotate at a higher frequency than the direct current armature, i.e. the winding is securely fixed under the sprockets;

2 - reaches nom frequency at lower revolutions, which destroys the battery;

3 - the brush assembly of the generator is more durable since the brushes slide along a solid ring, and not along a collector consisting of separate lamellas (sections).

17.2.3. Relay-regulator (RR)

It is necessary to provide all the elements of electrical equipment with a constant electric current from the generator at a variable number of revolutions of the engine crankshaft, as well as when the engine is not running. Regulation is carried out by special automatic devices.

These devices are divided according to their purpose:

1 - voltage regulator;
2 - current limiter;
3 - reverse current relay;
4 - switching relay;

1 - ensures the maintenance of the required voltage of the generator at a variable number of revolutions of the crankshaft and generator rotor.

2 - serves to prevent overloading the generator of high amperage, which can cause overheating of the generator and the burnout of its windings.

3 - ensures that the generator is connected to the consumer circuit when its voltage becomes greater than the voltage of the parallel connected battery, as well as to turn off the generator when its voltage drops below the battery voltage, in order to avoid its discharge through the generator windings.

4 - provides connection of the generator excitation winding to the battery when the ignition is on and the internal combustion engine is started.

For DC generators, 1,2,3,4 connected nodes are used, which are called *a relay-regulator*.

For alternators, 1 and 4 are applicable.

1 - electromagnetic, contact-vibration;

2 - contactless transistor;

3 - contact transistor (mixed).

The principle of operation of the devices is based on the use of the properties of an electromagnet, which attracts an armature with a contact system to its core or releases it, depending on the current strength.

17.3. *Consumers of the current*

17.3.1. Starters

Starters - are used for cranking the crankshaft of the internal combustion engine at start-up (Fig. 17.2).

DC motors are used. The starter is powered by the battery.

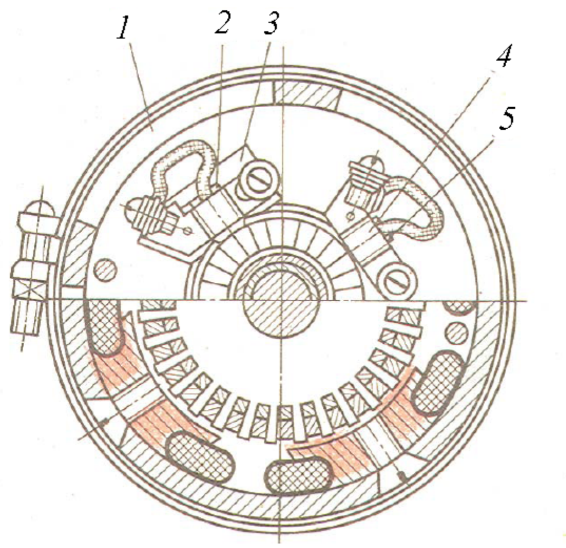


Fig. 17.2. **Starter ST-130A2:** 27 - windows; 28 - brush; 29 - brush holder; 30 - brush; 31 - brush holder

The starter does not differ much from DC generators; it is based on the phenomenon of reversibility of electric machines.

Starters are basically the same design and differ in the type of drive mechanism and the method of activation.

Usually, switching is used with the help of 2 gears (starter and flywheel of the internal combustion engine).

Actuating units:

- foot drive;
- electromagnetic.

Freewheel operation

17.3.2. Lighting and light signaling system

The lighting and light signaling system is used to ensure the operation of the car at night and in dark places.

It includes:

- headlights;
- sidelights;
- rear lights;
- illumination lamps of instrument panel;
- interior roof lightings;
- commutators and switches;
- preventers.

All devices are powered by a battery or generator.

17.3.3. Sound signal

Signals with an electromagnetic vibration system (noise and tonal ones) are used.

17.3.4. Testing equipment and signaling

Testing equipment includes:

1 - ammeter;
2 - liquid temperature indicator;
3 - oil pressure indicator;
4 - indicator of the level of gasoline in the gas tank.

Devices are divided into:

- thermal;
- electrical impulse (bimetal plates);
- electromagnetic (rheostat sensors);
- additional drives (fan motor, power windows).
- signaling

17.4. *Electronic systems*

The car can be equipped with:
- electronic fuel injection system;
- electronic system for adjusting the valve timing;
- electronic differential lock system;
- electronic turbocharging control system;
- electronic ignition system;
- ABS (anti-lock braking system);
- electronic system of roadholding, etc.

EDC - electronic digital computer;
A - actuator.
Sw - wheel electromagnetic sensor;

References

1. Кисликов В.Ф., В.В. Лущик. Будова й експлуатація автомобілів. Київ: Либідь, 2018. – 400 с.
2. Скляров В.М., Волков В.П., Скляров М.В. Автомобільні двигуни. Особливості конструкції: навч. посібник – Харків: ХНАДУ, 2012. – 405с.
3. Омеличев А.А. Підручник з будови автомобіля. – Дніпро: Моноліт, 2019. – 288 с.
4. Білоус Б.Д., Ткачук П.П., Андрусик Ю.Ф., Білоус Н.Б., Онищенко В.В. Армійська техніка. Основи руху, будова, характеристика: навч . посібник. – Л.: Вид-во Національного університету «Львівська політехніка», 2007. – 536 с.

Test questions

1. How are the storage battery and the electric current generator connected to the electrical network? And how are they connected to each other on the car?
2. What is the name of the phenomenon when an EMF is generated in a conductor that moves in a magnetic field of force?
3. What is the name of the phenomenon when an EMF appears in a conductor when the electric current disappears in it?

18 CONCEPTUAL MODULE

Transmission. Clutch

18.1. *Purpose and structure. Classification of transmissions*

Transmission is designed to transfer torque from the engine to the driving wheels of the car.

The change in torque in the transmission is estimated by its gear ratio, which is equal to the ratio of the speeds of the engine crankshaft and the driving wheels

$$P_{тяги} = M_{кр}/r_k,$$

where $P_{тяги}$ $P_{traction}$ is the traction force;

$M_{кр}$ T is the torque supplied to the wheel;

r_k r_w is the radius of the wheel.

The traction force consists of:

- rolling resistance force of wheels;
- air resistance force;
- grade resistance force;
- force of resistance to acceleration.

The amount of forces can vary widely, depending on traffic conditions.

Traction is limited by the tractive resistance of the driving wheels to the road. The maximum traction force is equal to the multiplication of the coefficient of adhesion of the wheel to the road and the adhesion weight of the vehicle.

The greatest traction force is realized when there is a drive to all wheels.

By the nature of the connection between the internal combustion engine and the driving wheels, **the transmission** is divided into:

- mechanical;
- hydromechanical;
- electric;
- combined (hydromechanical, electromechanical).

To assess the transmission and to characterize the car, the wheel formula (4 × 2) is used. The first digit indicates the total number of wheels; the second one indicates the number of driving wheels.

18.2. *Mechanical transmissions*

A diagram with a front-mounted internal combustion engine, rear driving wheels and a central location of the main transmission units with regard to the longitudinal axis is shown in Fig. 18.1.

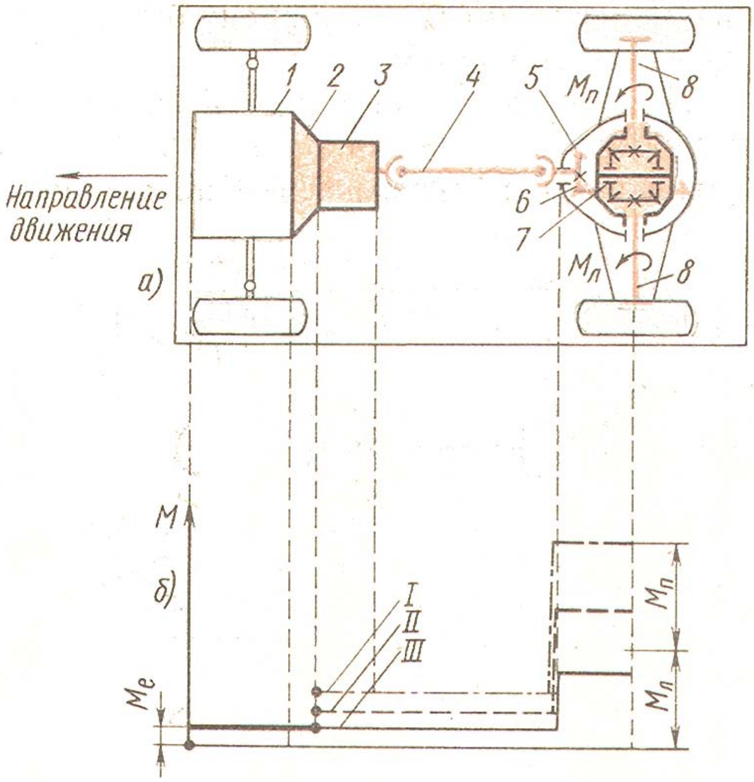


Fig. 18.1. **4 × 2 car transmission:**
a - transmission diagram; b - bending moment diagram; I-III - transmissions;
1 - engine; 2 - clutch; 3 - gear box; 4 - cardan drive;
5 - driving axle; 6 - cardan joints; 7 - drive transfer box;
8 – interaxle differential

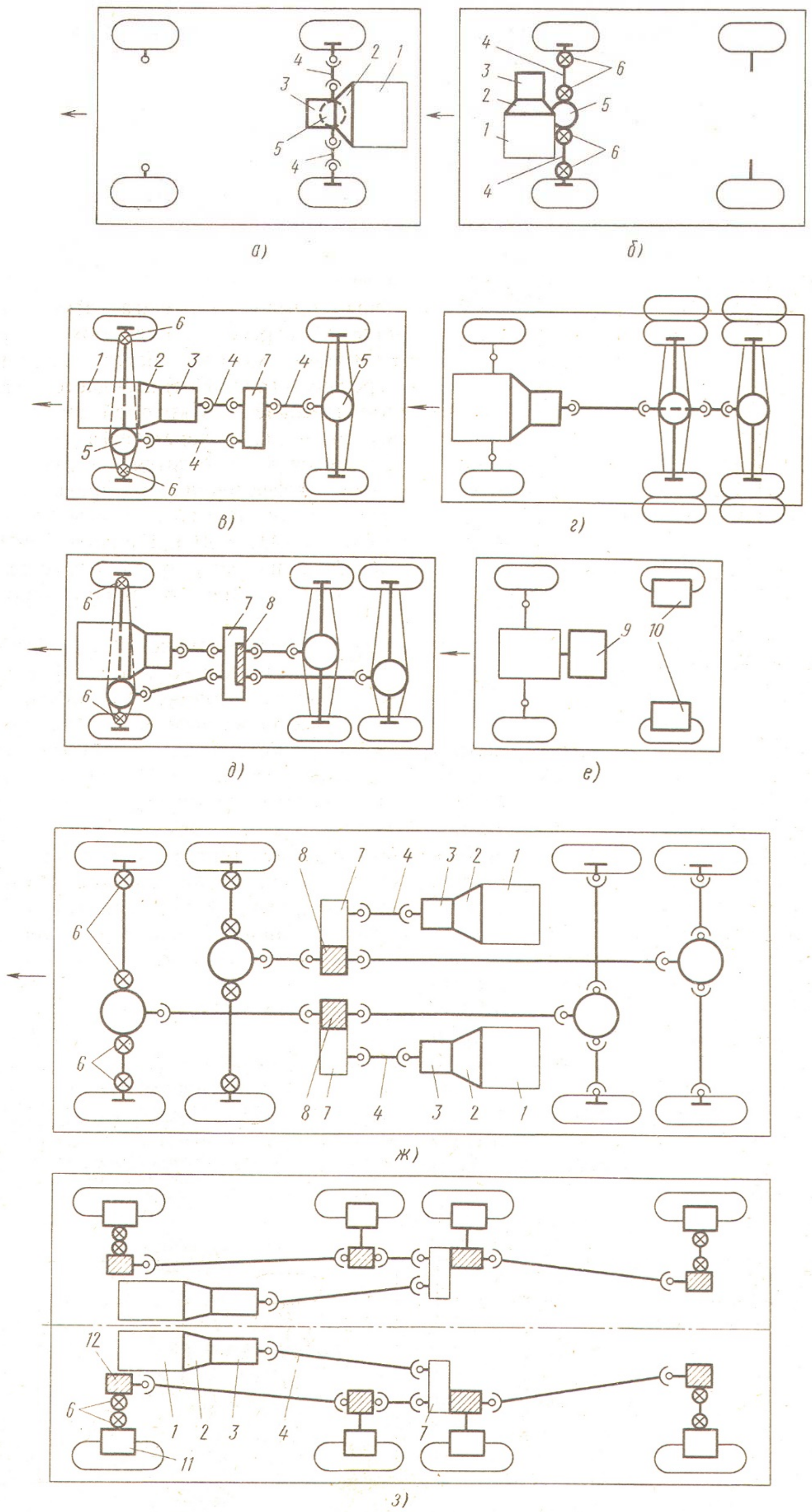


Fig. 18.2. **Transmission diagrams**: a, b - mechanical transmission of a 4 × 2 car; c - mechanical transmission of a 4 × 4 car;
d - mechanical transmission of a 6 × 4 car; e - mechanical transmission of a 6 × 6 car; f - hydrostatic and electric transmission of a 4 × 2 vehicle; g and h - mechanical transmission of a 8 × 8 car

Transmissions, internal combustion engines, clutches and gearboxes are combined into a common unit which is called a power unit.

The torque is increased in the main gear.

The differential divides (differentiates the moment) the moment between the right and left wheels.

Fig. 18.2 shows various diagrams of transmission of national and foreign cars with different wheel formulas.

Hydromechanical transmissions are more widely used on heavy-duty trucks and wheeled tractors. The torque converter is installed instead of the clutch. The torque from the torque converter is transmitted to the gearbox, where the gears are engaged using friction mechanisms.

18.3. *Hydrostatic and electric transmissions*

The hydrostatic head of the liquid created by the pump is realized in the form of $M_{кр}$ M_{kr} on wheels.

In electric transmissions, the internal combustion engine drives a direct current generator, from which voltage is supplied to electric motors that are mounted in the wheels of a car (BelAZ).

When using high-speed hydraulic and electric motors in the drive wheels, step-down gears (wheel reduction gears) are used.

18.4. *Road train transmissions*

The road train consists of a tractor and a trailer or (semi-trailer).

Only the tractor unit has a transmission.

Trailers designed for off-road use have drive axles. $M_{кр}$ M_{kr} is transmitted to them mechanically, hydraulically and electrically.

The power take-off, connected to the gearbox, drives additional equipment (winches, locklifts, etc.)

18.5. *Purpose and main types of clutch*

The clutch is designed for short-term separation of the crankshaft of the internal combustion engine from the transmission and their subsequent smooth connection, which is necessary for starting the car from a place, and then, for changing gears while driving.

Rotating clutch parts are referred to either the driving part connected to the crankshaft, or to the driven part connected to the gearbox and disconnected from the driving part when the clutch is disengaged.

By the nature of the connection between the driving and driven parts, clutches are distinguished:

- frictional;
- hydraulic;
- electrical (powdery).

18.5.1. Frictional

18.5.1.1. Single-disk

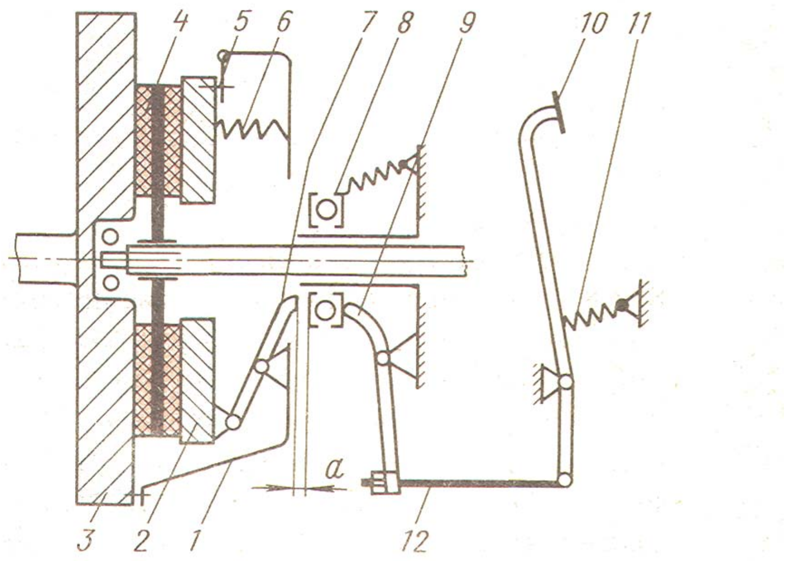


Fig. 18.3. **Diagram of a frictional clutch:**
1 - casing; 2 - pressure plate; 3 - flywheel; 4 - driven disk;
5 - plates; 6 - springs; 7 - lever; 8 – bearing part;
9 - plug; 10 - pedal; 11 - spring; 12 - traction

Clutch work. When the clutch is engaged, the torque from the crankshaft through the flywheel and the pressure plate is transmitted through the driven disc sandwiched between them, the hub of which has a splined connection with the main shaft of the gearbox.

To disengage the clutch, the driver presses (through the drive) on the plug and ring joint, as well as the lever and fingers, as a result of which the throw-out disk moves. In this case, the pressure springs are compressed and release the driven disc, on both sides of which gaps are formed.

When the clutch pedal is loosened, everything returns to its initial condition.

18.5.1.2. Double-disk clutch

In the double-disk clutch shown in fig. 18.4, there are additional second pressure and intermediate discs. Such clutches are used on medium-sized trucks (MAZ, KamAZ, etc.).

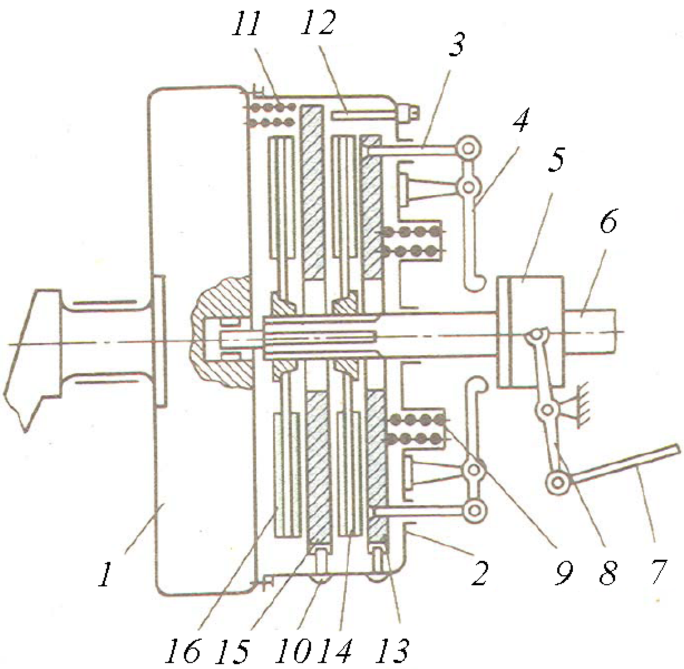


Fig. 18.4. **Double-disk clutch:** 2 - flywheel; 7 - pulling pin; 9 - pull-back lever; 10 - clutch collar; 11 - drive shaft; 13 - traction; 14 - switch plug; 16 - pressure spring; 17 - guide pin; 19 - release spring of the intermediate disc; 20 - adjusting screw of the intermediate disc; 21 - thrust driving disk; 22 - rear driven disc; 23 – intermediate driving disk; 24 - front driven disc

18.5.1.3. Torsional vibration damper

To protect the transmission shafts from torsional vibrations, a **torsional vibration damper (damper)** is installed.

The selection of washers is used to regulate the compression force of the driven disk. In the absence of torque, the slots of the hub flange and the disc match. The transmission of torque from the disc to the hub of the clutch driven disc is carried out using the damper springs.

Springs dampen clutch shock loads.

18.5.2. Hydraulic clutch (fluid coupling and torque converter)

The diagram of the hydraulic clutch (fluid coupling and torque converter) is shown in Fig. 18.5 and fig. 18.6.

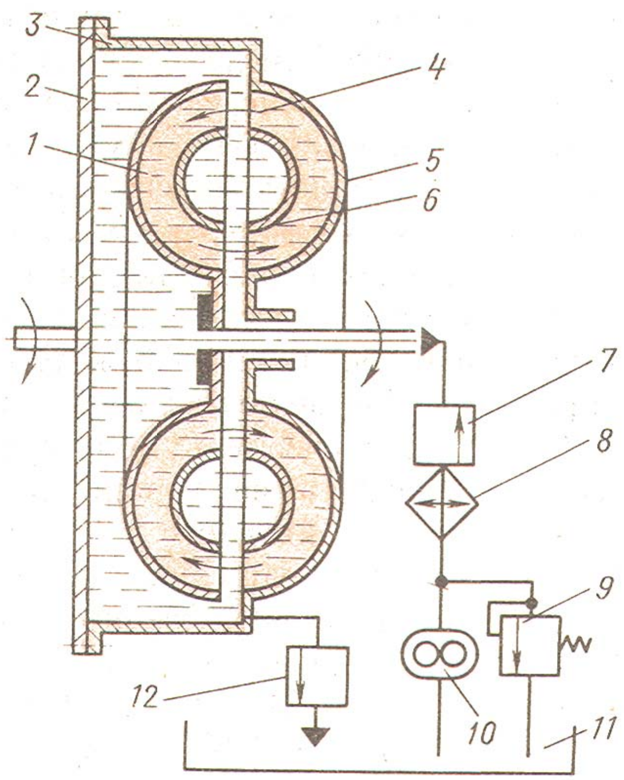


Fig. 18.5. **The diagram of the hydraulic clutch:**
1 - turbine wheel; 2 - cover; 3 - pump wheel;
4 - blades; 5 - outer torus; 6 - inner torus;
7 - valve; 8 - radiator; 9 - safety valve;
10 - pump; 11 - tank; 12 - emptying valve

Low viscosity oil is used as a working fluid. The impeller rotates with the flywheel. Filling the space between the turbine and impeller wheels, having received energy from the impeller, it transfers it to the turbine wheel. The moment is regulated by the completeness of the tank filling.

A torque converter differs from a fluid coupling in that there is a reactor in the circuit. The reactor is a unit in which there are rotary blades that allow you to change their angular position. When oil gets on the blades, by turning the latter, you can adjust the oil flow supplied to the turbine wheel of the torque converter, and thereby change the torque in the vehicle transmission.

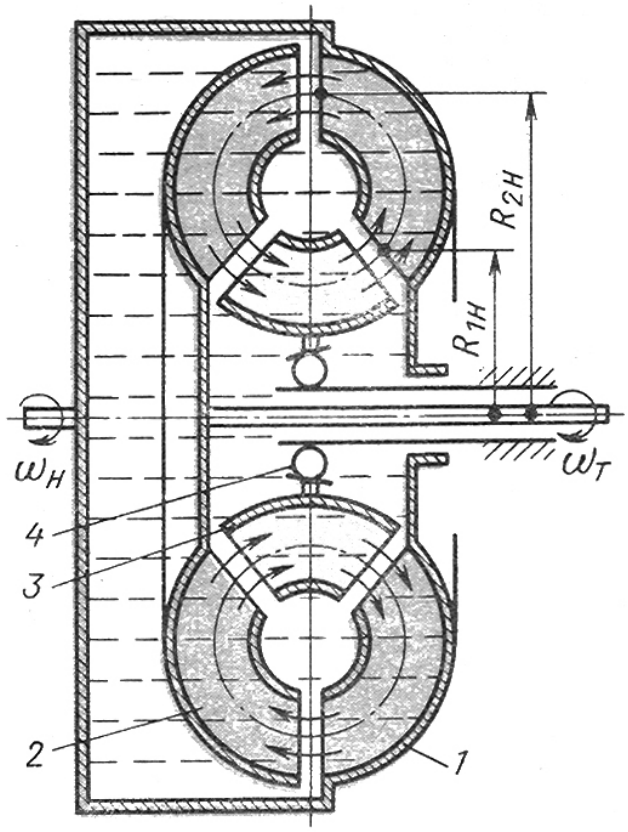


Fig. 18.6. **The torque converter:**
1 - driving pump wheel; 2 - driven turbine wheel;
3 - wheel - reactor; 4 – free-wheel mechanism

18.5.3. Electromagnetic powder clutch

A diagram of the electromagnetic clutch is shown in Fig. 18.7.

The working fluid is a special iron powder. When a magnetic field passes through the powder, its particles are concentrated along the magnetic lines of force, forming "hard threads" connecting the driven and driving parts. When the magnet is turned off, the powder becomes free flowing again.

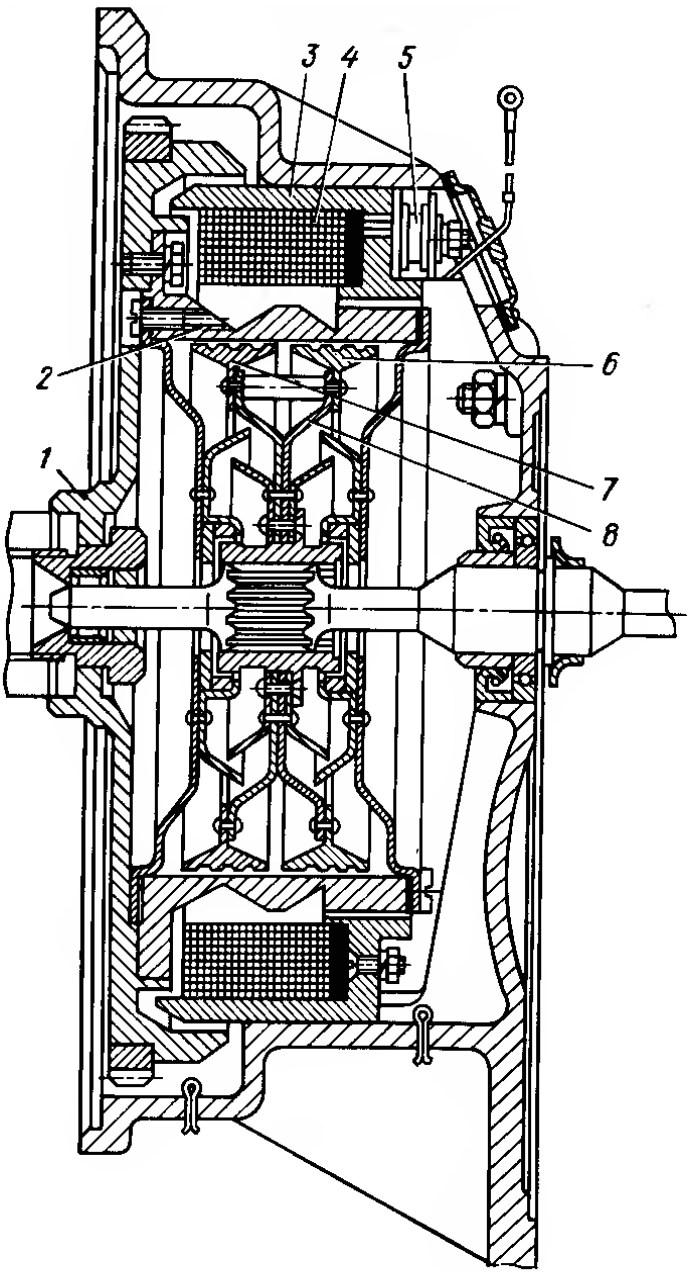


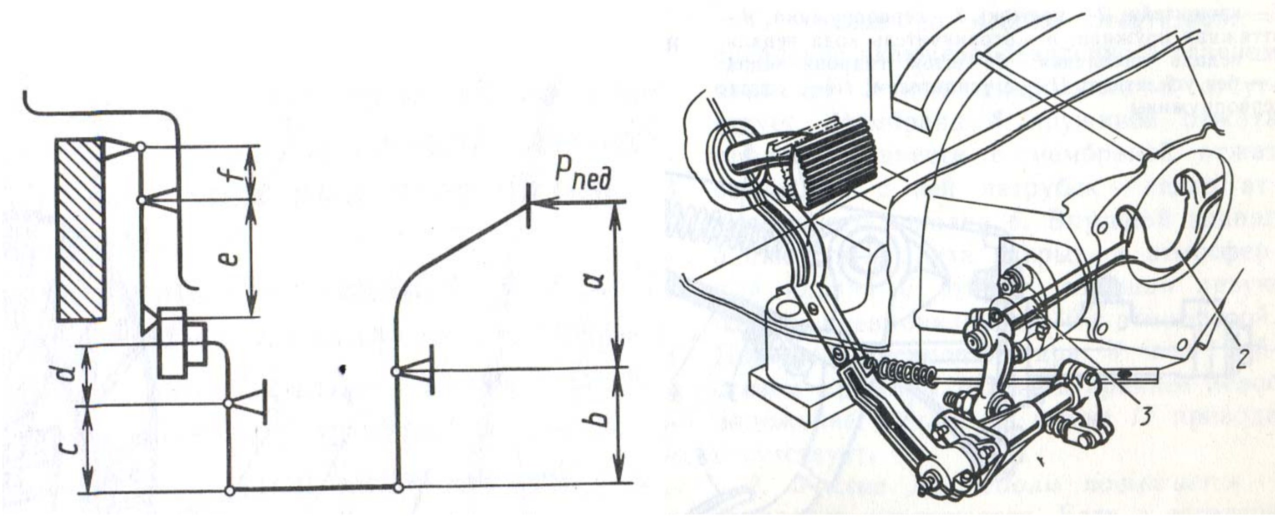
Fig. 18.7. **Electromagnetic powder clutch diagram:**
1 - flywheel; 2, 3, 6 and 7 - magnetic cores; 4 - excitation winding;
5 - electrical outlet; 8 - disc made of non-magnetic material

18.6. *Clutch drive*

18.6.1. Mechanical drive

Mechanical drive - used in the immediate vicinity of the clutch pedal.

It consists of systems of levers and tractions (fig. 18.8).



a b

Fig. 18.8. **Mechanical clutch drive:**
a - a diagram of a mechanical drive; b - general view of the mechanical drive

The total gear ratio of the clutch drive includes the gear ratio of the release levers and the gear ratio of the pedal drive.

The total gear ratio of the mechanical clutch drive, as well as the hydraulic one, is determined from the condition that the effort on the pedals in the absence of an amplifier should not exceed 150 H N for cars, and 250 H N for trucks. The full pedal travel should be within 120 ... 190 mm, including pedal free play. For existing designs, the total gear ratio of the clutch drive is in the range of 25 ... 50 units.

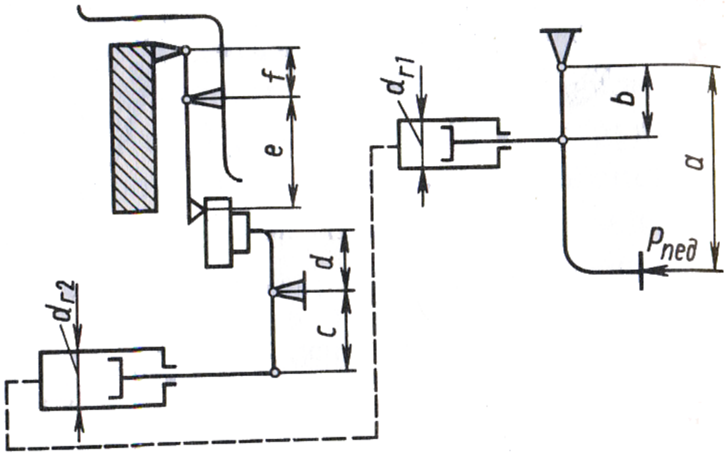
18.6.2. Hydraulic drive

Hydraulic drive - provides power transmission using fluid (fig. 18.9).

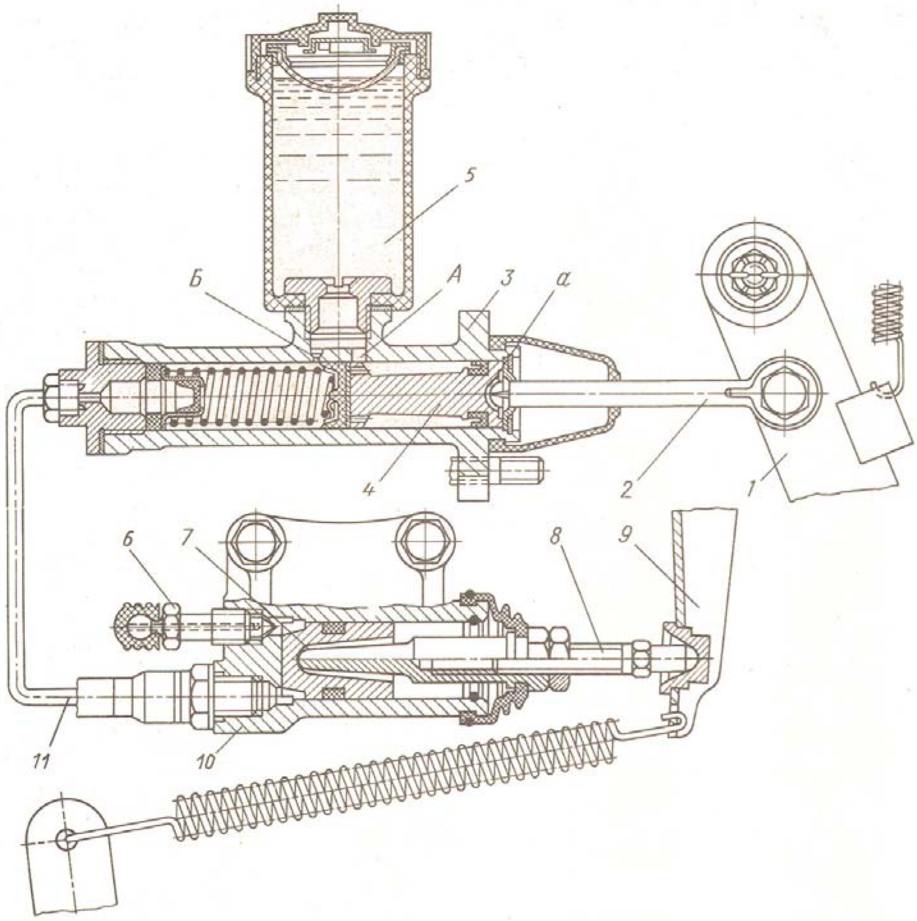
Unlike a mechanical drive, a hydraulic one has a more complex structure, but it also has more advantages. For example, such a drive has a higher efficiency, which reduces the free travel of the clutch pedal. The hydraulic clutch drive also reduces clutch pedal effort and has a small layout dimensions for different engine and driver positions in the vehicle.

When the clutch pedal is depressed, fluid pressure is transmitted to the piston of the clutch master cylinder and then to the slave cylinder, and then to the clutch release fork.

If the pedal is suddenly released, a vacuum may develop in the master cylinder. Then part of the liquid through the bypass hole by squeezing the rubber seal A enters the cylinder cavity. If excess liquid collects in the cylinder, then under the influence of pressure through the compensation port, it flows back into the tank.



a



b

Fig. 18.9. **Hydraulic clutch drive:**
a - hydraulic drive diagram; b - general view of the hydraulic drive;
1 - pedal; 2 - traction; 3 - the master cylinder; 4 - piston;
5 - tank; 6 - valve; 7 - piston; 8 - stock; 9 - plug;
10 - slave cylinder; 11 - pipeline

The total gear ratio of the clutch drive includes the gear ratio of the release levers, the gear ratio of the pedal drive and the gear ratio of the hydraulic section.

18.7. *Drive amplifier*

18.7.1. Pneumatic amplifier

Pneumatic amplifier installed in the hydraulic clutch drive consists of (Fig. 18.10):

- energy source (compressor, receivers);
- an executive mechanism (executive cylinder);
- switchgear (which controls the cylinder).

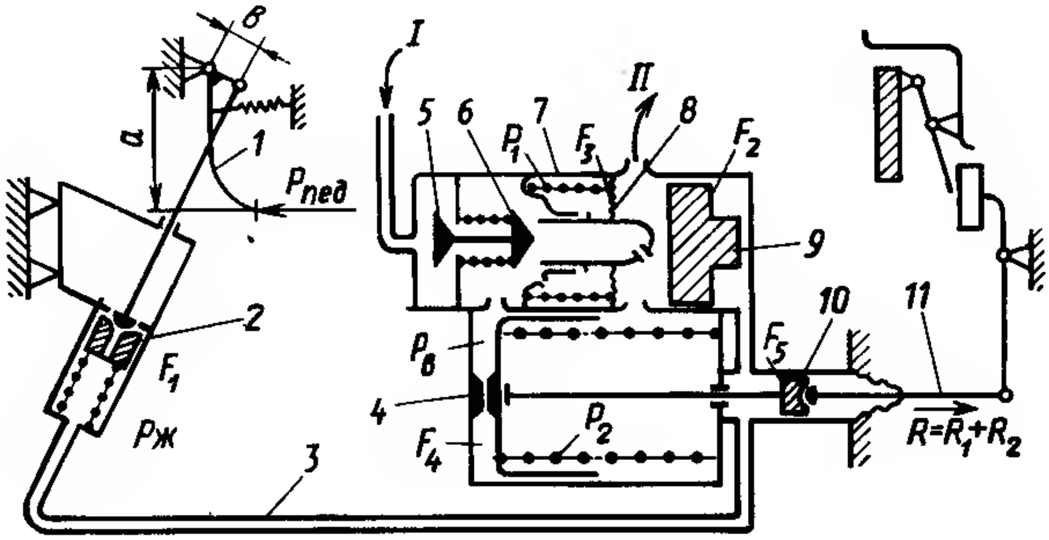


Fig. 18.10. **Diagram of the pneumatic amplifier of the hydraulic clutch drive:** 1 - drive pedal; 2 - the master cylinder; 3 - hydraulic line; 4 - pneumatic cylinder; 5 - inlet valve; 6 - atmospheric valve seat; 7 - tracking device; 8 - membrane; 9 - the piston of the tracking device; 10 - hydraulic cylinder; 11 - stock

18.7.2. Electro-vacuum clutch control

The electro-vacuum clutch control is built into the hydraulic drive (fig. 18.11). In addition to the drive, it also consists of a servo camera and an electromagnet with an automation unit.

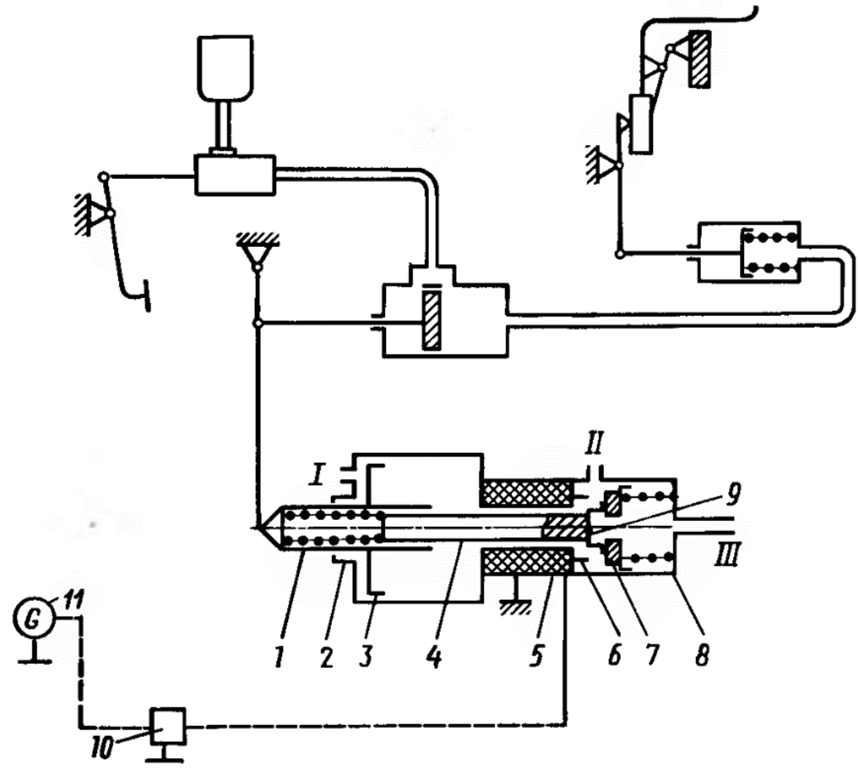


Fig. 18.11. **Diagram of the electric vacuum amplifier by clutch:**
1 - operating spring; 2 - vacuum cylinder; 3 - piston; 4 - electromagnet armature; 5 - electromagnet; 6 - valve seat; 7 - vacuum valve; 8 - valve device; 9 - seat; 10 - control unit; 11 - generator; I and II - atmospheric outputs; III - inlet pipeline

References

1. Кисликов В.Ф., В.В. Лущик. Будова й експлуатація автомобілів. Київ: Либідь, 2018. – 400 с.

2. Скляров В.М., Волков В.П., Скляров М.В. Автомобільні двигуни. Особливості конструкції: навч. посібник – Харків: ХНАДУ, 2012. – 405с.

Test questions

?

1. Which of the transmission mechanisms provides reverse gear?
2. Which of the mechanisms ensures the rotation of the driving wheels at different speeds when the car turns?

19 CONCEPTUAL MODULE

Gearbox

19.1. *Purpose and main types of gearboxes*

The gearbox is designed to change the traction force, speed and direction of the vehicle.

During starting and lifting movement, it is necessary to decrease $\boldsymbol{n}_{дв}$ and increase $\boldsymbol{M}_{кр}$. For this, the gearbox serves.

Depending on the nature of the change in the gear ratio, the gearbox is divided into:

- step-by-step;
- Multitronic;
- Easytronic.

By the nature of the connection, there can be:

- mechanical;
- hydraulic;
- electrical;
- combined.

By the way of control they are classified into:

- mechanical;
- automated (robotic, non-automatic, semi-automatic);
- automatic.

19.1.1. Step-by-step mechanical

The diagram of a step-by-step mechanical gearbox is shown in Fig. 19.1.

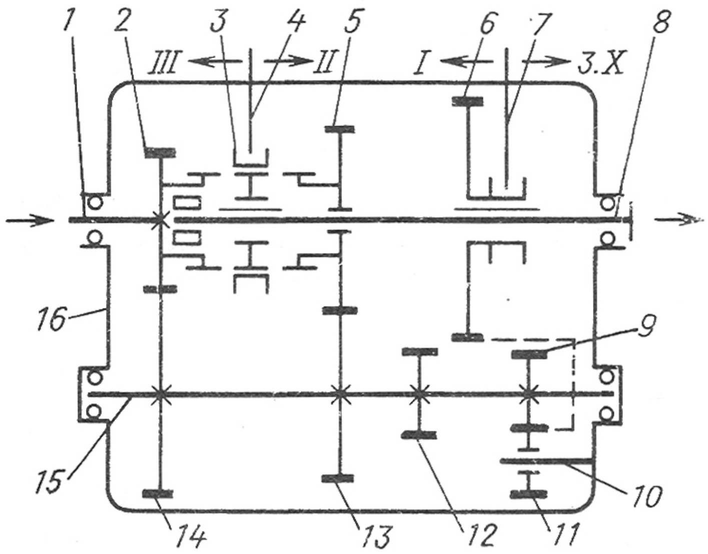


Fig. 19.1. **Three-stepped gearbox diagram:**
1 - drive shaft; 2 - gear; 3 - toothed clutch; 4 - plug;
5 - wheel; 6 - bogie wheel; 7 - plug; 8 - driven shaft;
9 - gear; 10 - axis; 11 - gear; 12 - gear;
13 - gear; 14 - wheel; 15 - intermediate shaft; 16 - crankcase

The work of a gearbox:

The gears with straight teeth move, with the oblique ones they are in constant engagement. The toothed clutch alternately meshes with any pair of gears, and some of those transmission units is engaged while this.

19.1.2. Planetary

Planetary (with movable axes of some toothed gears) gear trains (Fig. 19.2).

If one shaft (one of the three) is the driving one, the second one is driven, and the third one is positive, then the planetary gear train turns into a planetary gearbox.

Additional gearbox (step-up gear and step-down gear).

The step-up gear (divider or as it is also called the speed increaser) has a ratio of less than 1 and allows you to accelerate the rotation of the gearbox output shaft in each gear.

The step-down gear (the dual high transmission) has a ratio more than 1 and allows you to increase the torque coming to it from the gearbox.

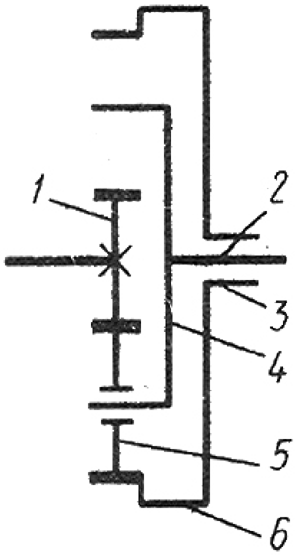


Fig. 19.2. **Diagram of the planetary gear train.**
1 - shaft with a gear wheel; 2 - shaft; 3 - shaft; 4 - carrier;
5 - gear wheel; 6 - gear wheel

Hydromechanical gearbox - consists of a torque converter, mechanical gearbox, shift mechanisms and a control system.

Hydrostatic gearbox - consists of pumps and hydraulic motors connected by pipelines.

Multitronic mechanical gearboxes.

V-belt transmission.

The diagram of such a transmission is shown in Fig. 19.3

Changing of $M_{кр}$ of the Multitronic mechanical gearbox is carried out by axial movement of the 6 bevel wheel.

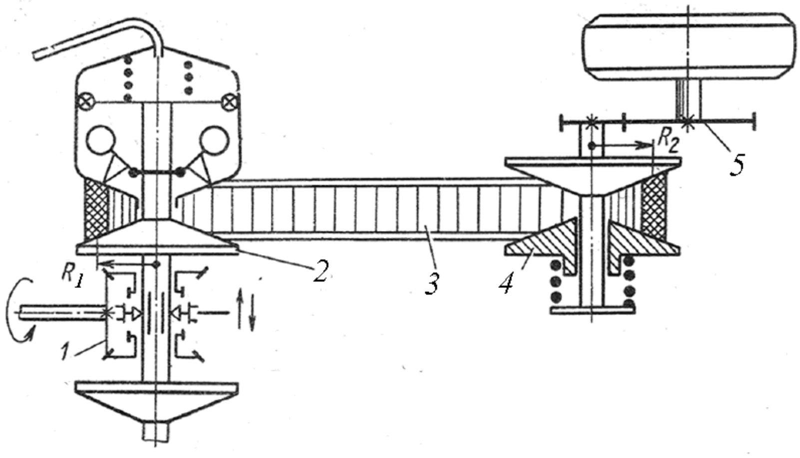


Fig. 19.3. **V-belt transmission diagram:**
1 - reverse gear; 2 - driving pulley; 3 - belt drive; 4 - driven pulley; 5 - wheel propeller gearbox; R1, R2 - radii of pulleys;

Frontal transformer.

The frontal transformer diagram is shown in Fig. 19.4

The change of $M_{кр}$ in the frontal transformer is carried out by moving the 17 wheel.

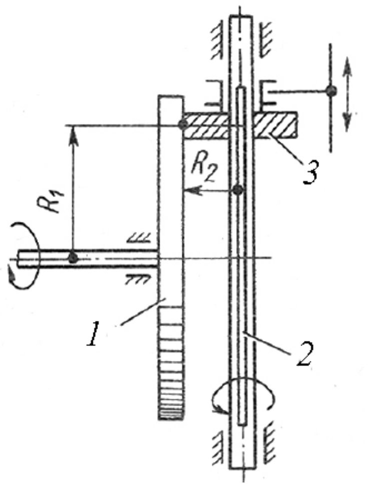


Fig. 19.4. **Frontal transformer diagram:**
1 - friction wheel pressed against the end; 2 - driven shaft;
3 - friction wheel; R1, R2 - wheel contact radii

Toroidal transformer.

The diagram of the toroidal transformer is shown in Fig. 19.5.

In a toroidal transformer, the $M_{кр}$ is changed by changing the angular position of the 20 roller in relation to the 21axis.

Disadvantages: wear of rubbing surfaces.

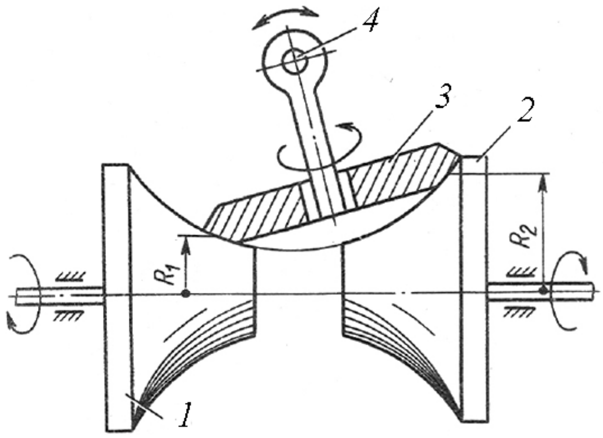


Fig. 19.5. **Toroidal transformer diagram:**
1 - driving toroidal wheel; 2 - driven toroidal wheel;
3 - roller; 4 - axis; R1, R2 - wheel contact radii

Multi-disc friction gears.
A diagram of such a transmission is shown in Fig. 19.6

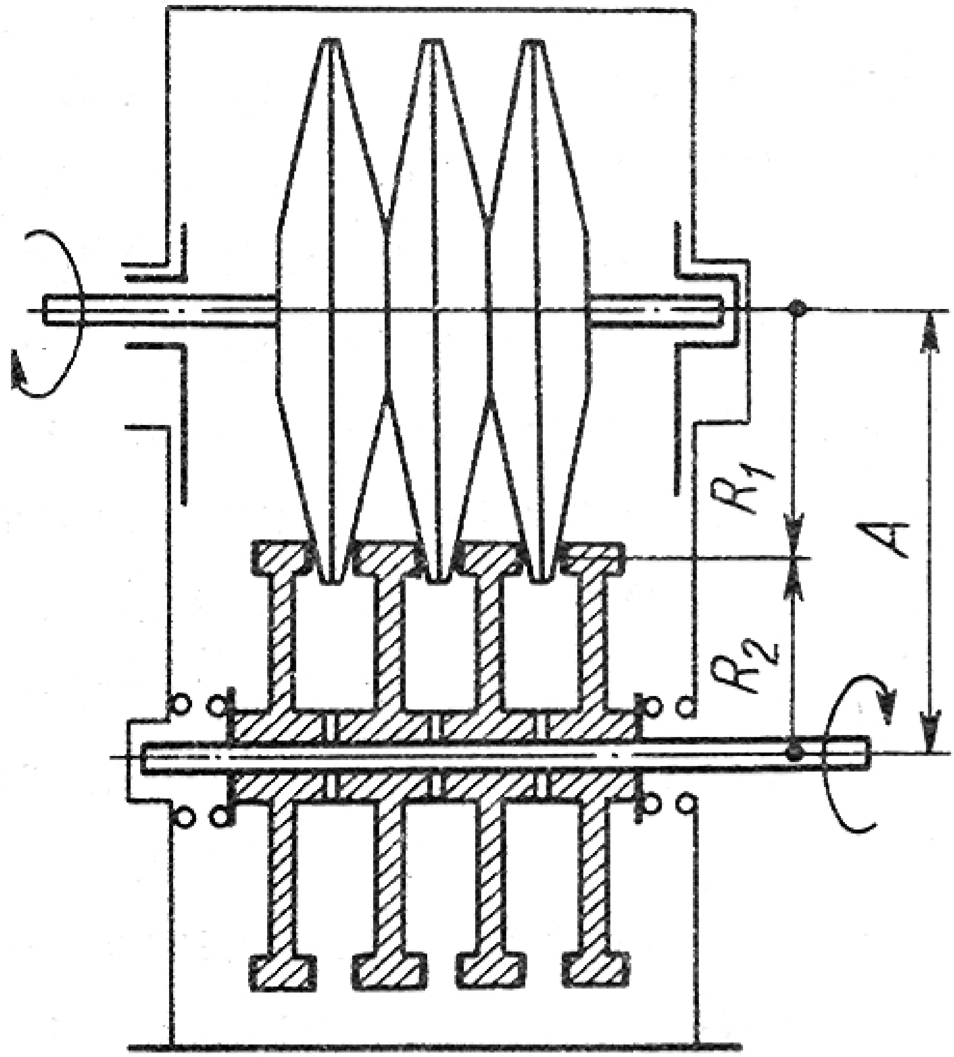


Fig. 19.6. **Multi-disc friction mechanical transmission diagram**

In a multi-disc friction transmission, the torque is transmitted by the frictional forces (between the discs and clamps).

19.1.4.5. Impulse transmissions

Impulse transmissions are based on the transformation of rotational motion into oscillatory motion (Fig. 19.7).

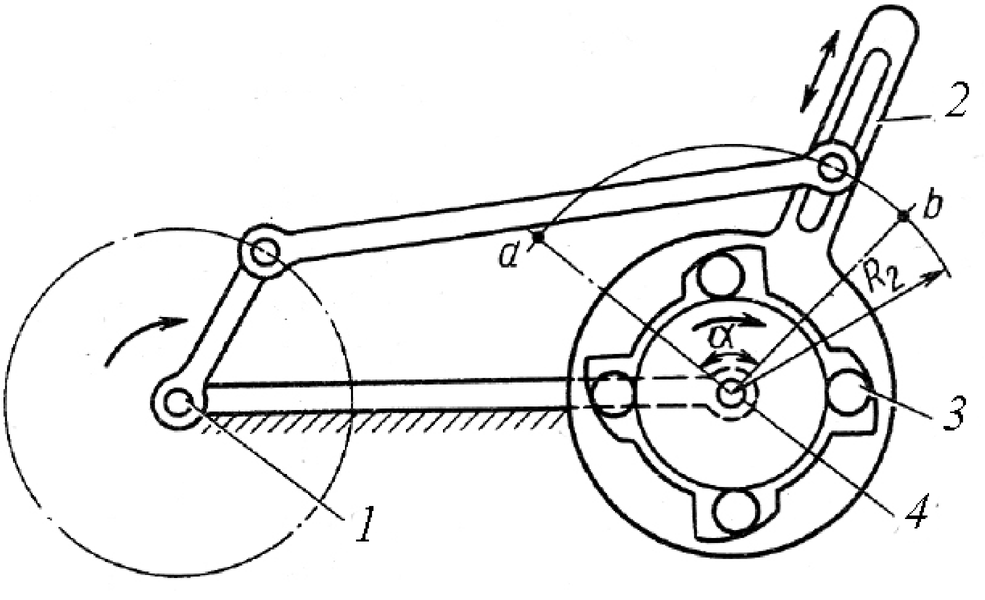
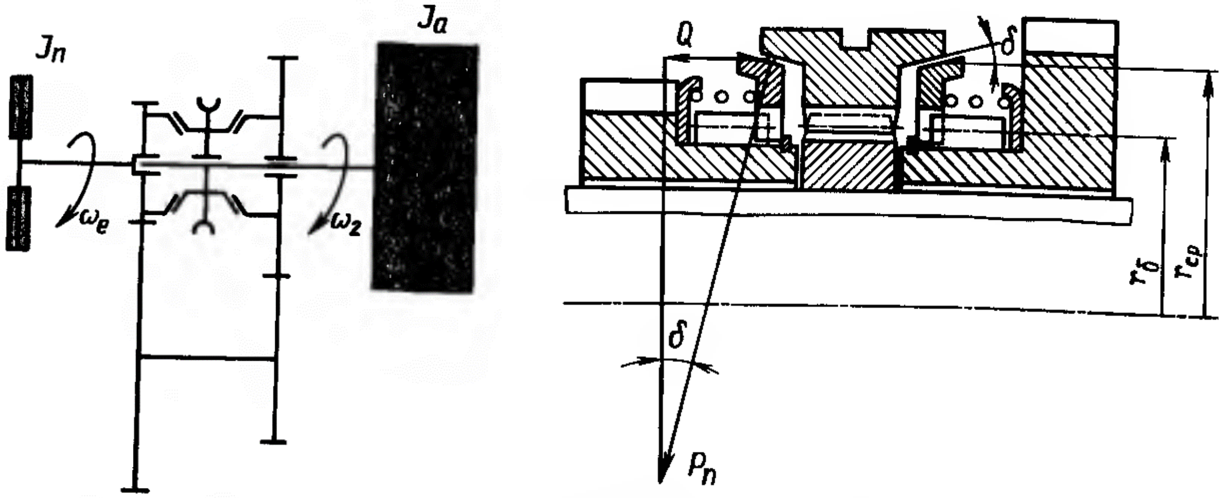


Fig. 19.7. **Multitronic impulse transmission diagram:**
1 - crankshaft; 2 - intermediate part;
3 - freewheel mechanism; 4 - driven shaft

19.2. *Synchronizers*

Gear shifting is accompanied by impacts of gear wheels, leading to their wear and breakage. **Synchronizers** are used to reduce gear wear and noise (Fig. 19.8).

It consists of a fixed hub, the dowels, a movable hub, and the locking rings.



a b

Fig. 19.8. **Synchronizer**:
a - a diagram of the synchronizer operation; b - synchronizer device

19.3. *Gearbox control mechanism*

A diagram of the control gear is shown in Fig. 19.9.

The speedometer drive can be:

- mechanical;
- electric;

19.4. *Speedometer and its drive*

The speedometer and its drive consists of:

- speed meter;
- accumulated odometer;

The operation of high-speed units is based on the magnetic induction method.

The counting unit of the speedometer is made as mechanical one. The signal is transmitted through the cable to the speedometer.

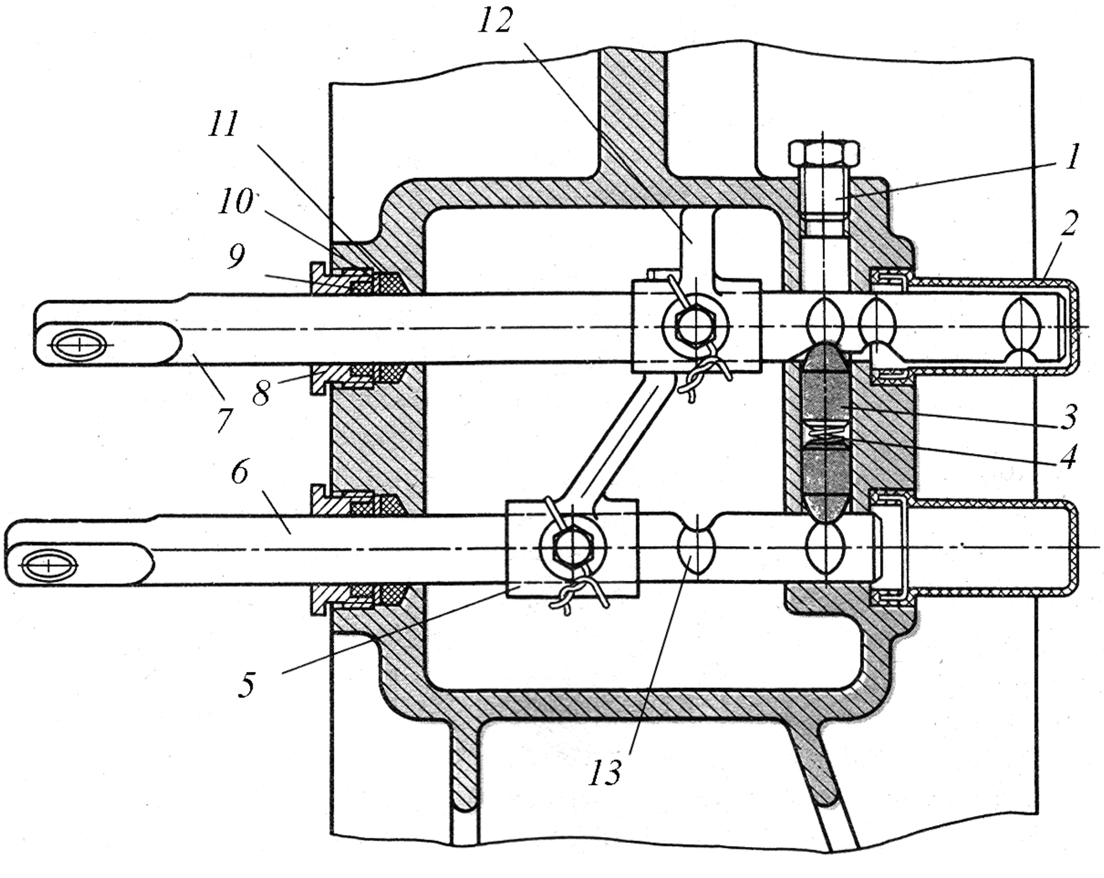


Fig. 19.9. **Gearbox control mechanism:** 1 - plug; 2 - cap fitting; 3 - dowel; 4 - spring; 5 and 12 - plugs; 6 and 7 - sliders; 8 - inside screw; 9 - ring; 10 - plate; 11 - cumulative; 13 - notches on the slider

References

1. Кисликов В.Ф., В.В. Лущик. Будова й експлуатація автомобілів. Київ: Либідь, 2018. – 400 с.

2. Скляров В.М., Волков В.П., Скляров М.В. Автомобільні двигуни. Особливості конструкції: навч. посібник – Харків: ХНАДУ, 2012. – 405с.

3. Омеличев А.А. Підручник з будови автомобіля. – Дніпро: Моноліт, 2019. – 288 с.

4. Білоус Б.Д., Ткачук П.П., Андрусик Ю.Ф., Білоус Н.Б., Онищенко В.В. Армійська техніка. Основи руху, будова, характеристика: навч . посібник. – Л.: Вид-во Національного університету «Львівська політехніка», 2007. – 536 с.

Test questions

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1. Which of the transmission mechanisms allows you to change the vehicle speed?
2. What kind of gearboxes can be installed on the car?
3. How is the three-shaft transmission structured and operated?
4. How is the twin-shaft transmission structured and operated?
5. What is the operation concept of the Multitronic?

20 CONCEPTUAL MODULE

Cardan drive

20.1. Purpose and principle of operation.
20.2. The design of cardan drives.

20.1. *Purpose and principle of operation*

Cardan drive is designed to transfer torque from one mechanism to another, if the axes of their shafts change their relative position or do not lie on one straight line (Fig. 20.1).

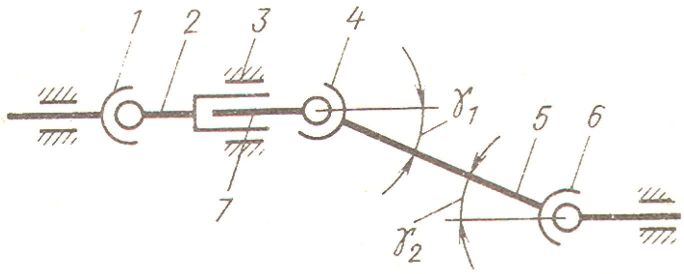


Fig. 20.1. **General scheme of the cardan drive:**
1, 4 and 6 - cardan joints; 2 and 5 - cardan shafts;
3 - intermediate bearings; 7 - compensating connections

Cardan joints can be:
- of equal angular velocities (ball, cam and double);
- of unequal angular velocities (flexible and rigid);

Cardan drives can be (Fig.20.2):
- of open type;
- of closed type.

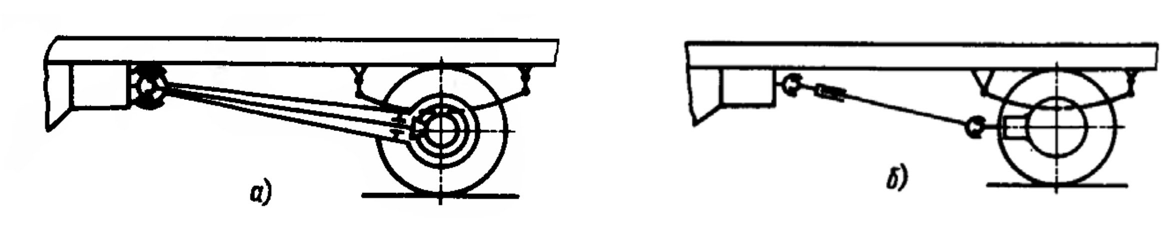


Fig. 20.2. **Types of cardan drives:**
a - closed type; b - open type

Flexible universal joints transfer the torque between the shafts with axes intersecting at an angle of 2-3 or more, as a result of elastic deformation of the connecting elements (the latter serve as an additional damper for torsional vibrations).

Rigid universal joints of unequal angular velocities transmit torque from one shaft to another through the movable joints of rigid parts.

The compensating connection ensures that the length of the cardan shaft is changed. As a result of uneven rotation of the shaft located behind the universal joint of unequal angular velocities, additional pulsating loads arise in the transmission.

When γ = 5 - 10, the additional loads are small.

At γ = 15 - 20 these loads can exceed the loads from $M_{кр}$. They try to do so that the angles in the universal joints are equal ($\gamma1 = \gamma2$).

Constant-velocity joint.

The design diagram of such a joint is shown in Fig. 20.3.

1 and 2 shafts are connected by 3 and 4 levers. The levers are controlled at point B, the linear speed of which is $\omega = \omega_1 b = \omega_2 a$. Equality of angular velocities $\omega1 = \omega2$ is possible when b = a. This condition is satisfied when $\gamma = \omega_1$, i.e., point B lies on the bisector of 180 - γ angle. Structurally, this is provided in various ways.

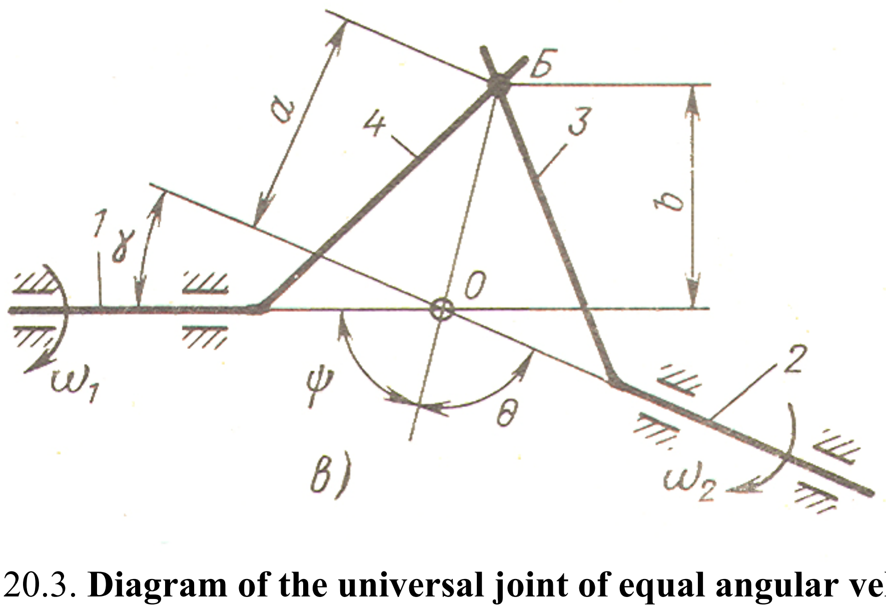


Fig. 20.3. **Diagram of the universal joint of equal angular velocities:**
1 and 2 - shafts; 3 and 4 - levers

20.2. *Cardan joints of unequal angular velocities*

They consist of 2 plugs and a yoke (rigid ones). One of the plugs is welded to the flange, the other one is welded to the shaft, which is made of a thin-walled tube. The yoke pins fit into the lugs of both plugs with the needle bearings (Fig. 20.4 a-c).

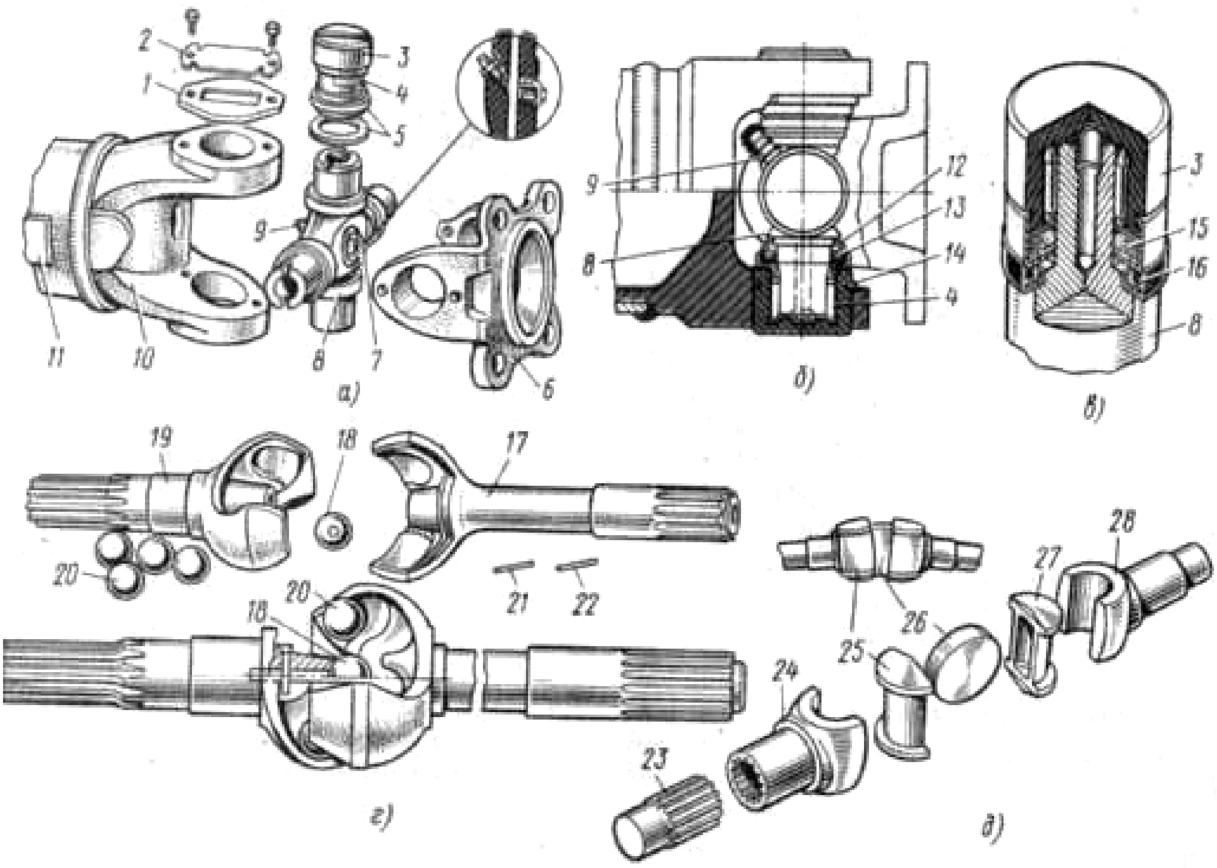


Fig. 20.4. **Cardan joints:** a - c – of unequal angular velocities; d and e – of equal angular velocities; 1 - cover; 2 - locking plate; 3 - bearing body; 4 - needles; 5 - felt cumulatives; 6, 10, 24 and 28 - plugs; 7 - safety valve; 8 - yoke; 9 - greaser; 11 - cardan shaft; 12 - reflector; 13 - self-tightening cumulative; 14 - retaining ring; 15 and 16 - cumulatives of radial and end seals; 17 - inner lug; 18 - central ball; 19 - outer lug; 20 - leading balls; 21 - finger; 22 - stud pin; 23 - semiaxis; 25 and 27 - semi-cylindrical lugs; 26 - center plate.

The bearings are held in the plug eyelet by a cover that is attached to the plug with two bolts. For lubrication of the unit, a combined seal (single-lip gland and end seal) is used, the maximum angle of deflection of the shafts is 15–20°. Slider bearers are sometimes used instead of needle bearers. To reduce lateral loads, the shafts are dynamically balanced assembled with cardan joints.

20.3. *Cardan joints of equal angular velocities*

20.3.1. Ball joint with the dividing grooves

It consists of 2 lugs, made as one piece with the shafts. In each lug there are 4 grooves, into which 4 balls are laid, and the 5th ball is located between the ends of the lugs and ensures their centering. It is fixed with fingers.

$M_{кр}$ is transmitted only through two balls. Each ball lies simultaneously in the grooves of both lugs. In this case, the center of the ball is located at the intersection of the axes of the grooves in the bisector plane (such cardan joints are used on UAZ-169, GAZ-66, ZIL-131 vehicles).

The angle of rotation of the universal joint is 30 - 32.

The disadvantages:

- precise fixation of the shafts in the axial direction;
- high pressures on contact surfaces;

20.3.2. Ball joint with a dividing lever.

The connection between the driving and the spherical cup (integral with the shaft) is carried out by six balls enclosed in a separator. When the shafts are rotated relative to each other, the dividing lever is transmitted through all 6 balls through the $M_{кр}$ guide cup in the bisector plane. The rotational angle in the joint can reach 38°.

In the grooves of the plugs of the shafts and axle shafts, the lugs, which are connected to each other by a disk, turn (Fig. 20.5).

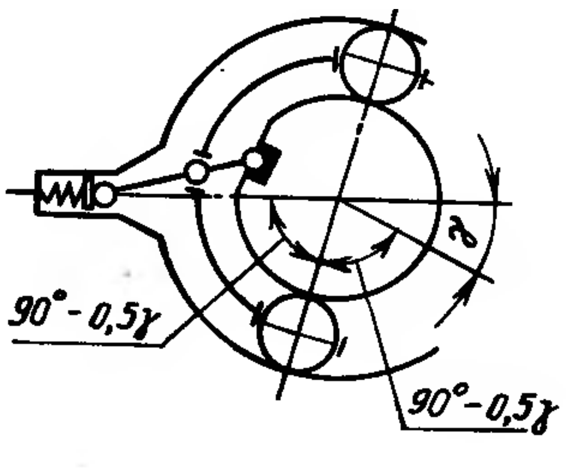


Fig. 20.5. **Diagram of a ball joint with a dividing lever**

The axes of the grooves of the plugs lie in one plane, which passes through the median plane of the disc. These axes are located at equal distances from the point of intersection of the axes of the shafts and are always perpendicular to them; therefore the point of their intersection at any position of the plugs is located in the bisector plane.

20.3.3. Cam cardan joint (Fig. 20.4 e).

The turning angle reaches 50º. The disadvantage: lower efficiency, and as a result, the higher heating during operation (Ural - 375).

20.3.4. Ball joint with the dividing grooves ("Weiss" type) (Fig. 20.4 d).

They are typically used on the front steer wheels.

This cardan joint is a joint with the dividing grooves. The turning angle is 35°.

The inner ball works at deflection angles of no more than 18º, but plays the role of a compensating device. $M_{кр}$. is transferred to all balls evenly.

20.3.5. Flexible semi-cardan joint

The flexible semi-cardan joint allows the transfer of torque from one shaft to another, located at a certain angle, due to the deformation of the elastic linkage connecting both shafts. The elastic linkage can be rubber, rubber-fabric or rubber, reinforced with a steel cable. In the latter case, the semi-cardan joint can transmit a significant torque and at a slightly greater angle than in the first two cases. Due to its elasticity, such a joint allows a small axial movement of the cardan shaft (Fig. 20.6).

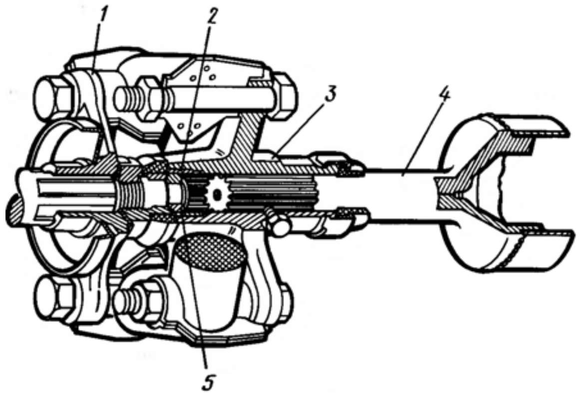


Fig. 20.6. **Flexible semi-cardan joint:**
1 and 3 - flanges; 2 - bushing; 4 - cardan shaft;
5 - centering ring

The flexible semi-cardan joint must be centered, otherwise the balance of the cardan shaft may be disturbed.

References

1. Кисликов В.Ф., В.В. Лущик. Будова й експлуатація автомобілів. Київ: Либідь, 2018. – 400 с.

2. Скляров В.М., Волков В.П., Скляров М.В. Автомобільні двигуни. Особливості конструкції: навч. посібник – Харків: ХНАДУ, 2012. – 405с.

3. Омеличев А.А. Підручник з будови автомобіля. – Дніпро: Моноліт, 2019. – 288 с.

4. Білоус Б.Д., Ткачук П.П., Андрусик Ю.Ф., Білоус Н.Б., Онищенко В.В. Армійська техніка. Основи руху, будова, характеристика: навч . посібник. – Л.: Вид-во Національного університету «Львівська політехніка», 2007. – 536 с.

Test questions

?

1. Which of the mechanisms transmits the torque from one shaft to another at right angle and with a constant gear ratio?
2. Which transmission mechanism transfers the tractive effort from one shaft to another at an angle that changes constantly?
3. What types of cardan drives are there?

21 CONCEPTUAL MODULE

Axles of cars

21.1. *Types of axles*

The front and rear axles of cars are used for the perception of vertical, longitudinal and transverse forces between the body and the road, as well as the transmission of $M_{кр}$ to the wheels (Fig. 21.1).

Vertical forces are transmitted by elastic suspension elements, and longitudinal and transverse forces are transmitted both by the suspension and by special rods.

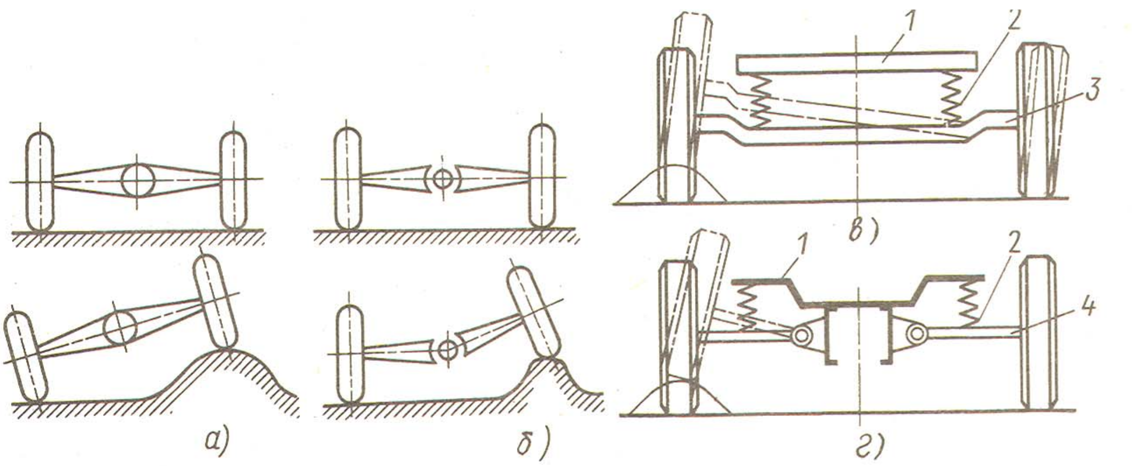


Fig. 21.1. **Axles:** a - continuous leading rear;
b - leading split with independent wheel suspension;
c - front continuous with dependent wheel suspension;
d - front split with independent wheel suspension

When $M_{кр}$ is transmitted, $M_{reactive}$ appears. When braking, there are braking torques.

Rear axle. As a rule, it consists of:

- hollow beam;
- main gear;
- differential;
- half shafts; wheel hubs are attached outside.

21.2. *Driving axle housing*

Detachable, articulated from two bolted parts (it is used on cars).

One-piece, presented in the form of a solid beam with a central annular part, is used on trucks. The design of such a beam is shown in Fig. 21.2.

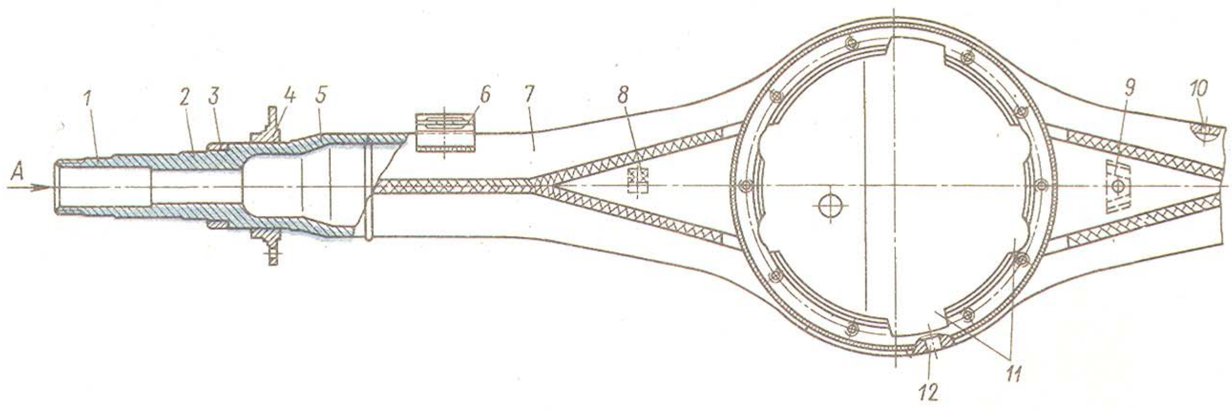


Fig. 21.2. **Rear driving axle beam:**
1 and 2 - journals for hub bearings; 3 - bushing; 4 - flange;
5 - pin; 6 - spring cushion; 7 - crankcase; 8 - bracket;
9 - T- tube bracket; 10 - breather hole;
11 - recesses; 12 - hole for oil drain

A 2 trunnion is welded to the 1 crankcase of the beam, having machined 3 journals for wheel hub bearings. Steel 4 flanges are welded on the trunnion and the brake shields are attached to them. There is a holder for the brake hoses on the beam.

21.3. *Main gear*

It is designed to increase the torque and reduce the rotational speed to the values required by the drive wheel.

Gear ratio:

- for trucks is equal to 6.5 - 9.0;
- for passenger cars is 3.5 - 5.5.

Depending on the gear pairs, it is divided into:

- bevel;
- hypoid;
- worm;
- double.

The main gear diagrams are shown in Fig. 21.3-21.5.

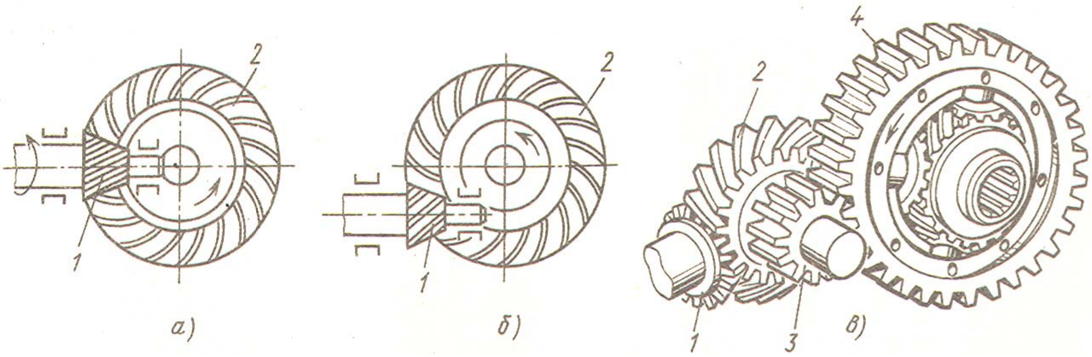


Fig. 21.3. **Main gears:**
a - bevel; b - hypoid; c - double; 1 and 2 - driving and driven bevel gears; 3 and 4 - driving and driven spur gears

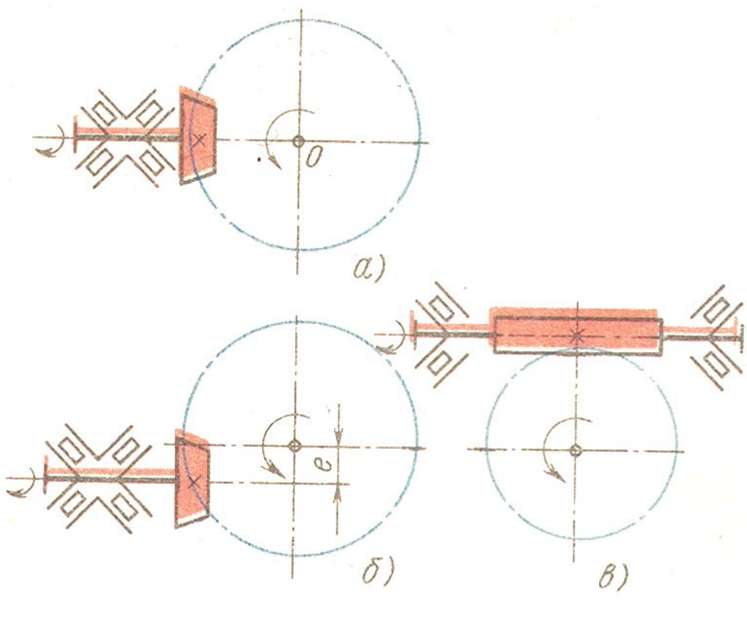
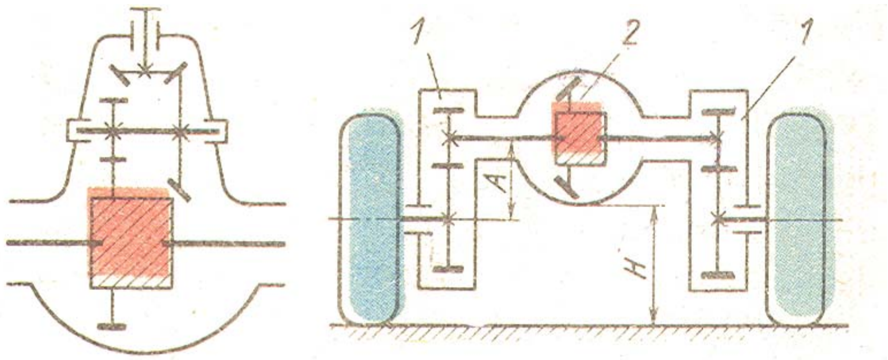


Fig. 21.4. **Single-reduction final drive schemes:**
a - bevel gear; b - hypoid gear; c - worm gear



а б

Fig. 21.5. **Double main gears schemes:**
a - central; b - spaced

21.4. *Differential*

It is designed to distribute $M_{кр}$ between the driving wheels, and it allows them to rotate at unequal frequencies when the car is moving on bends or over bumps (Fig. 21.6).

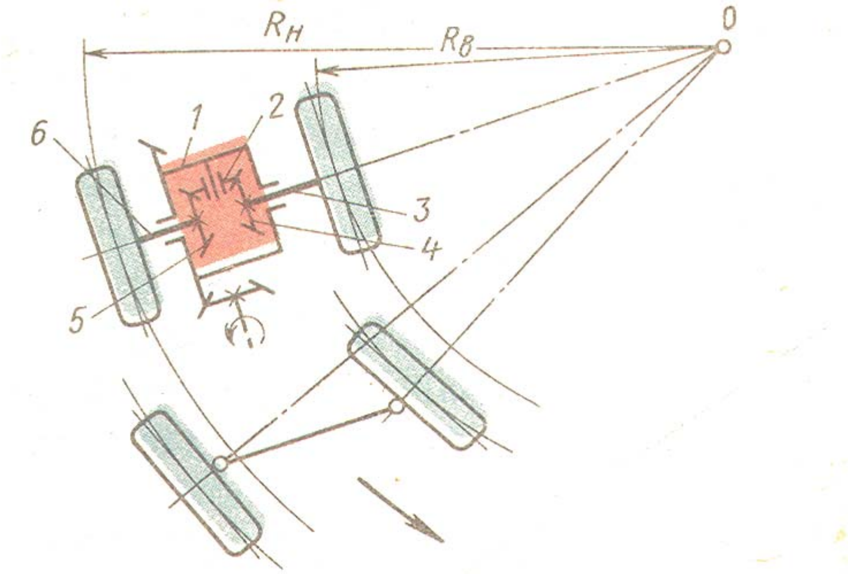


Fig. 21.6. **Turning scheme of the 4 × 2 car:**
1 - case; 2 - satellites; 3 and 6 - half-shafts;
4 and 5 - half-axle gears

The differential diagram is shown in Fig. 21.7.

Redistribution of torque in the bridge is carried out with the help of the satellites.

By the location, the differentials are divided into:

- interwheel (distributing $M_{кр}$ between the driving wheels of one axle);
- interaxle (distributing $M_{кр}$ between the main gears of the driving axles).

According to the ratio of $M_{кр}$:

- symmetrical (the number of teeth of the left and right half-axle gears are equal);
- asymmetrical.

The differential can be (fig.21.7):

- simple (gear one);
- self-locking (limited slip differential or with a freewheel mechanism, cam, worm).

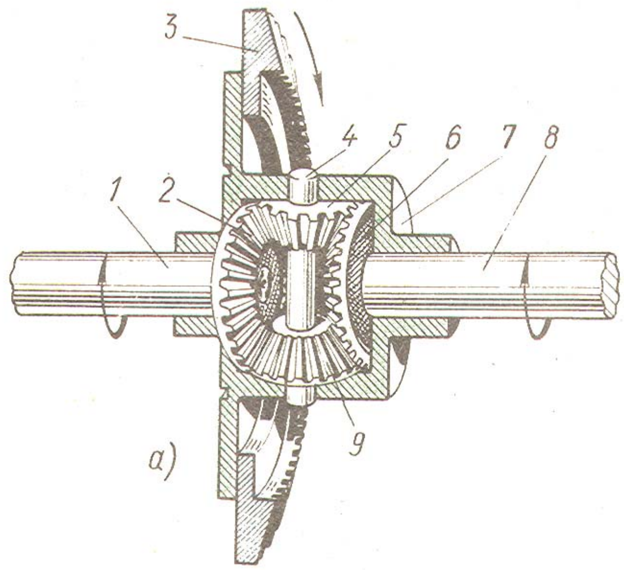


Fig. 21.7. **The scheme of the differential when driving a car in a straight line:** 1 and 8 - half-shafts; 2 and 6 - semi-axial gear wheels; 3 - driven wheel of the main gear; 4 - axis of satellites; 5 and 9 - satellites; 7 - differential box

Configuration and operation.

1. The cross-axle conical symmetric differential is used on a car (GAZ-53);
2. The interaxle symmetric differential is installed on a car (KamAZ-5320, ZIL-133G);
3. The limited slip differential is used on a car (GAZ-66).

21.5. *Half shafts*

$M_{кр}$ is transferred to the driving wheels (Fig. 21.8). Depending on the design of the external support, the half shafts can be:

- semi-unloaded;
- completely unloaded;
- unloaded by three quarters.

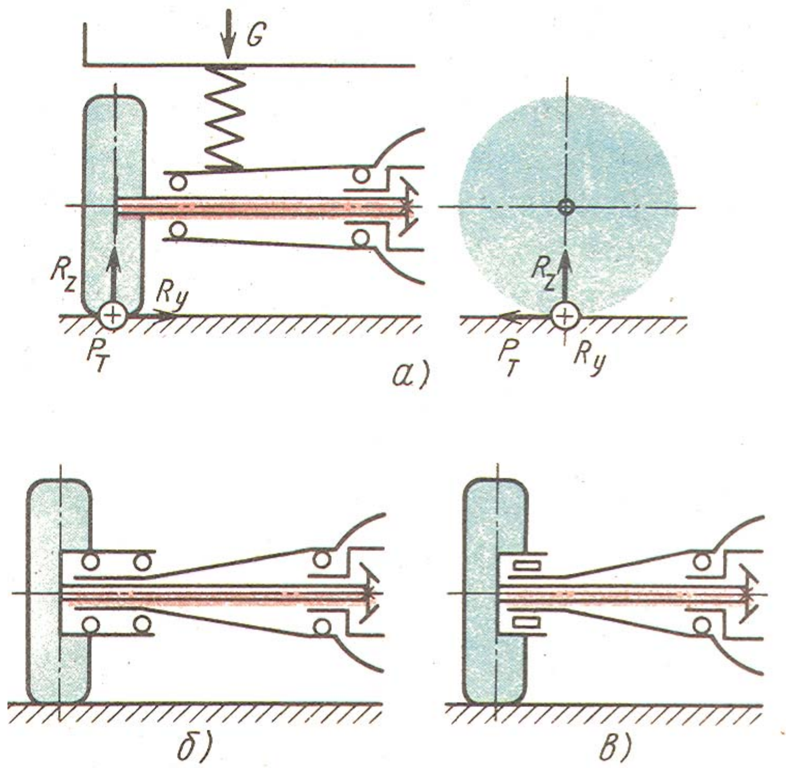


Fig. 21.8. **Schemes of half shafts:** a - semi-unloaded; b - completely unloaded; c - unloaded by three quarters

The half-shafts have the slots and a flange at the ends.

1.1. Design features of the front driving axles.

1.2. Front drive axle (ZIL-131);

1.3. Front drive axle (GAZ-66, VAZ-2108);

1.4. Steerable front axle (GAZ-53).

The beam with the pivots and steering knuckles. Brake discs are attached to the steering knuckle flanges. The wheel hubs are mounted on two bearings (tapered roller bearings). The steering knuckle levers connected with the steering mechanism are fixed in the trunnion.

References

1. Кисликов В.Ф., В.В. Лущик. Будова й експлуатація автомобілів. Київ: Либідь, 2018. – 400 с.

2. Скляров В.М., Волков В.П., Скляров М.В. Автомобільні двигуни. Особливості конструкції: навч. посібник – Харків: ХНАДУ, 2012. – 405с.

3. Омеличев А.А. Підручник з будови автомобіля. – Дніпро: Моноліт, 2019. – 288 с.

4. Білоус Б.Д., Ткачук П.П., Андрусик Ю.Ф., Білоус Н.Б., Онищенко В.В. Армійська техніка. Основи руху, будова, характеристика: навч . посібник. – Л.: Вид-во Національного університету «Львівська політехніка», 2007. – 536 с.

Test questions

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1. What transmission mechanism of a car makes it possible to gain in power due to speed or, on the contrary, to gain in speed due to force, without changing the crankshaft rotation frequency?
2. What mechanism of the car's transmission makes it possible to increase the tractive effort on the driving wheels in excess of what the gearbox and main drive give?
3. What transmission mechanism of the car makes it possible to transfer the torque from one shaft to another, when they are at an angle of 90°?
4. What types of differentials are used on vehicles?
5. Where is the torque from the differential transmitted?
6. What happens to the parts of the differential if the car turns left?
7. Name the transmission mechanisms that increase the tractive effort on the driving wheels by a constant number of times and transmit them different rotational speeds on the curves.
8. Name the transmission mechanisms that allow a change in torque on the driving wheels and a change in wheel rotation (the reverse).
9. Name the transmission mechanisms that allow the transmission of torque at the angles of the shafts, which constantly change.

22 CONCEPTUAL MODULE

Car suspension

22.1. *Purpose and main parts of the suspension*

The suspension carries out an elastic connection of the frame (body) of the car with the axles or directly with the wheels of the vehicle, softening the pushes and shocks that occur when the wheels run into the surface.

The suspension consists of the following devices (fig. 22.1 - 22.2):

1.1. Elastic suspension device - serves to reduce the dynamic loads caused mainly by the action of a part of the car's mass on the wheels. (Prevents the frame from copying the road profile).

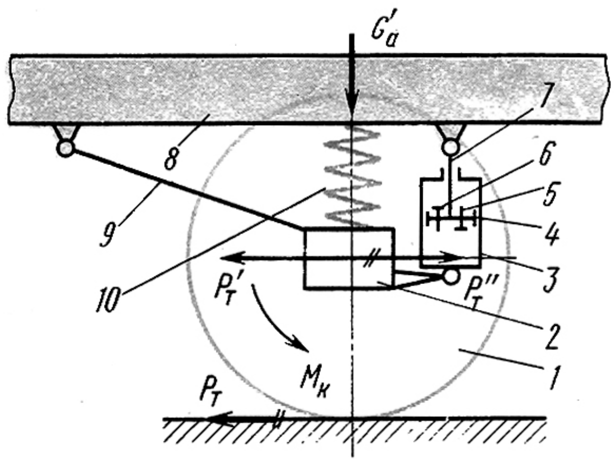

Fig. 22.1. **Car suspension scheme.**
1 - wheel; 2 - bridge beam; 3 - damping device;
4 - piston; 5, 6 - valves; 7 - stock; 8 - frame; 9 - lever;
10 - elastic device

An elastic device consists of one or more elastic elements, which can be metal or non-metallic.

Metal elastic elements (bow springs, torsion springs);

Non-metallic elastic elements (rubber, pneumatic, hydraulic);

1.2. Suspension guiding device – is designed to transmit the P_T tractive force and perceive the reactive moment, as well as the braking and lateral forces.

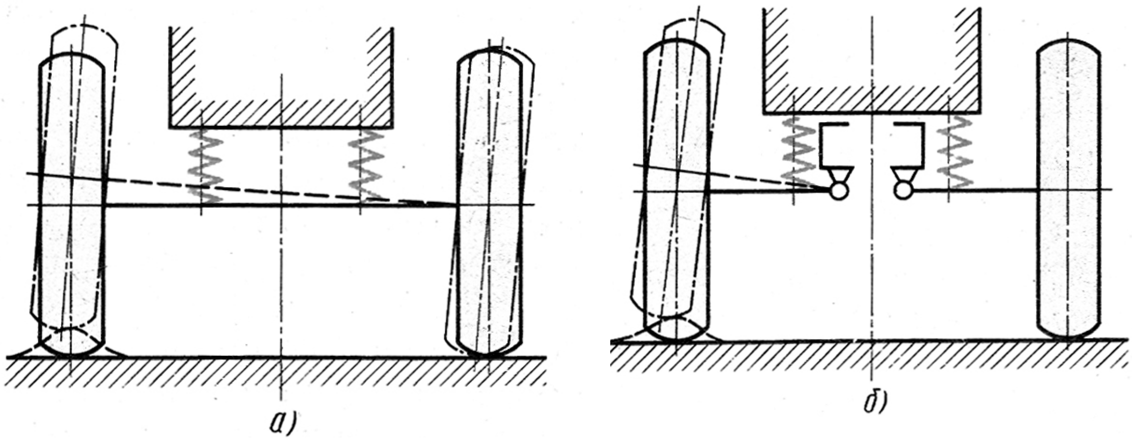

Fig. 22.2. **The main types of suspensions**: a - independent; b - dependent

It also determines the nature of the movement of the wheels relative to the frame (body) of the car.

By the type of guiding devices, the suspensions are divided into:

- dependent;
- independent.

A distinctive feature of the dependent suspension is the presence of a rigid beam connecting the left and right wheels.

1.3. A damping device (the shock absorber) (Fig. 22.3) – is designed to reduce the number of system vibrations.

The resistance of the rebound stroke is 2-5 times higher than the resistance of the compression stroke.

According to the principle of operation, the damping devices are divided into:

- one-sided;
- bilateral.

1.4. The anti-roll bar is a special elastic device. The rod is flat-topped (Fig. 22.4).

It reduces the rolling and the lateral vibrations of the vehicle.

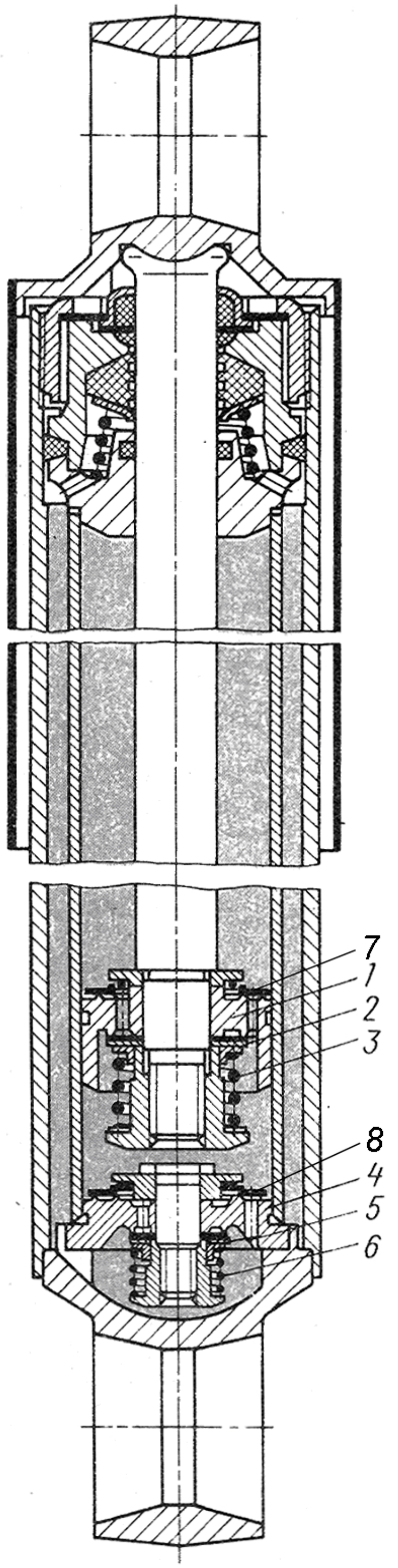

Fig. 22.3. **Shock absorber of the ZIL-130 truck.**
1 - piston; 2 - recoil valve; 3 - spring;
4 - hole in the bottom; 5 - compression valve; 6 - spring

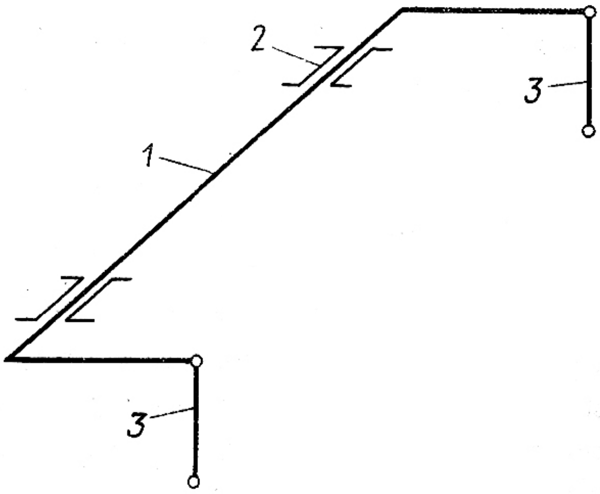

Fig. 22.4. **Anti-roll bar.**

22.2. *The main types of elastic devices*

22.2.1. Leaf spring

It consists of separate curved sheets. The curvature depends on their length (tighter fit and spring relief). The mutual position of the sheets in the assembled spring is ensured by the center bolt and the clamps (fig. 22.5). The 1 leaf, which has the greatest length, is called a root one. When assembling, the springs are lubricated with graphite grease. The front end is usually fixed with a finger; the rear end is movable, and it is fixed in the shackle.

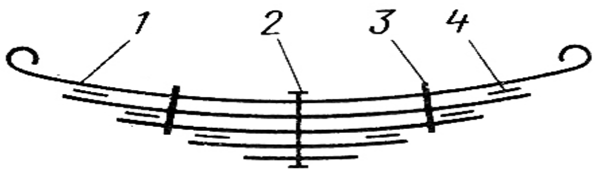

Fig. 22.5. **Leaf spring:**
1 - spring leaf; 2 - center bolt; 3 - clamps; 4 - gaskets

The main advantage of leaf springs is their ability to perform the functions of an elastic and a guiding device simultaneously.

Spiral (coiled) springs are made of a steel bar and have a cylindrical shape. They accept only vertical loads. Therefore, it is necessary to use the damping and guiding devices.

The torsion bar is a steel resilient torsion bar. It can be solid (of circular section) or composite (from round bars or rectangular plates). At the ends there are heads with cut slots. One end of the torsion bar is attached to the body, the other one to the suspension. Like the springs, torsion bars require the guiding and damping devices.

Rubber elastic elements are called restraints or buffers.

They are classified into compression and return buffers. The former restrict the wheel travel upwards, the other ones - downwards.

Air bellows - provide elastic properties of the suspension by compressing air. The most widely used elements are made in the form of double round cylinders.

The casing of the cylinder is rubber-cord (cord is kapron or nylon one). The inner part is covered with an airtight rubber layer, and the outer part is covered with an oil and petrol resistant rubber. To strengthen the beads, a metal wire is embedded in the cord. The carrying capacity of double round cylinders is 2-3 tons, at a pressure of 0.3-0.5 mPa.

The pneumatic element includes: compressor, receiver, filter - oil separator, pressure regulator, pneumatic element.

Pneumatic elements provide high smoothness and stability of the car, increase the wear resistance of tires.

Combined elastic elements combine metal and non-metallic elastic elements.

The combined element includes: tank, pump, accumulator, wheel adjusters, piston pneumatic element.

There is some liquid under the membrane, and some air above the membrane.

Compressed gas is a working medium that provides elastic properties of the suspension; liquid transfers vertical loads. The framing is attached to the body, the piston is attached to the suspension.

By changing the fluid pressure, you can change the gas pressure, and, thereby change the stiffness of the suspension.

22.3. *The design of elastic and damping devices*

The leaf spring is attached to the bridge with two ladders and to the frame via rubber mounts. The rubber mounts are fixed in the brackets riveted to the frame.

The brackets have the covers that allow you to mount and dismantle the springs. The sheets are tightened with a center bolt. Two root leaves, the ends of which are bent at an angle of 90, form an end bearing surface.

Special nuts, increasing the contact area with the rubber mounts, are attached to the deflected ends. To increase the rigidity, *a helper* is used.

Hydraulic shock absorbers.

Hydraulic shock absorbers can be: telescopic and lever ones.

They include:

- a cylinder with the bottom;
- a piston with the rod;
- a guide bush with the seals.

A special feature is the presence of a compensation chamber, which serves to change the volume of fluid in the working cylinder on both sides of the piston.

The liquid compresses the air at a pressure of 80 - 100 kPa. In the time of the rebound stroke, the air forces the liquid to flow back.

22.4. *Forces and torques acting in the suspension*

Fig. 22.6 shows the suspension structures of a truck.

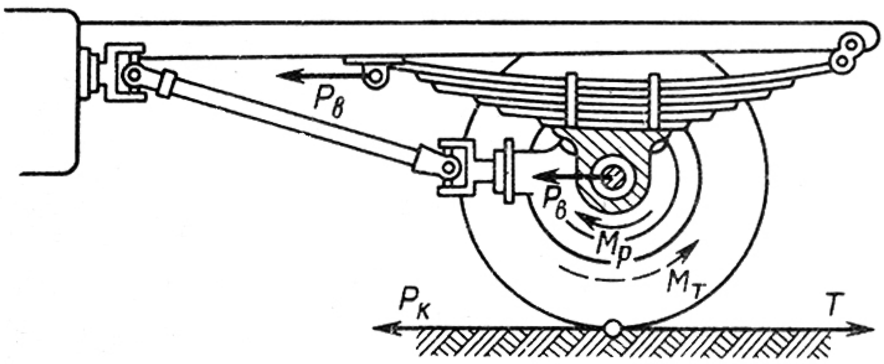

Fig. 22.6. **Forces and torques of suspensions**

Forces and torques in the suspension.

$M_{кр}$ creates the $P_к$ traction force, and $M_{reactive}$ on the bridge.

As a result of the $P_к$ tractive force, the P_b propulsive force is generated through the suspension, and is transmitted to the frame. When braking, the $M_{тр}$ braking torque occurs, and the T braking force occurs on the wheels.

References

1. Кисликов В.Ф., В.В. Лущик. Будова й експлуатація автомобілів. Київ: Либідь, 2018. – 400 с.

2. Скляров В.М., Волков В.П., Скляров М.В. Автомобільні двигуни. Особливості конструкції: навч. посібник – Харків: ХНАДУ, 2012. – 405с.

3. Омеличев А.А. Підручник з будови автомобіля. – Дніпро: Моноліт, 2019. – 288 с.

4. Білоус Б.Д., Ткачук П.П., Андрусик Ю.Ф., Білоус Н.Б., Онищенко В.В. Армійська техніка. Основи руху, будова, характеристика: навч . посібник. – Л.: Вид-во Національного університету «Львівська політехніка», 2007. – 536 с.

Test questions

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1. Purpose and structure of the car suspension.
2. Purpose and structure of the front axle of the car.
3. Purpose and structure of shock absorbers.
4. Why is front wheel alignment necessary?
5. Why camber is necessary?
6. What is the transverse and longitudinal tilt of the pivots for?

23 CONCEPTUAL MODULE

Propellers

23.1. Purpose of propellers.
23.2. Pneumatic tire construction.
23.3. The main types of car tires.
23.4. Dimensions and markings.
23.5. Decoding of tire marking.

23.1. *Purpose of propellers*

The propeller ensures the movement of the vehicle on the road, its suspension, change in the direction of movement, the transfer of vertical loads from the vehicle to the road.

Depending on the performed functions, the propellers are divided into:

- leading;
- driven;
- combined;
- supportive;

Leading propellers convert torque into traction, and rotating motion into forward motion of the vehicle.

Driven propellers perceive the pushing force from the frame, converting the forward motion of the car into its own – rotational one.

Most often, propellers of wheeled, tracked or combined type are used on cars.

During the rolling process of the wheel propeller, its pneumatic tire is being deformed. Some of the energy is lost to internal friction in the rubber. Heating has a detrimental effect on the properties of the tire. The greater the deformation of the tire is, the greater the internal friction loss is.

Tracked propellers load the road surface more evenly, but they have a number of disadvantages, due to which they cannot be used as widely as wheel ones.

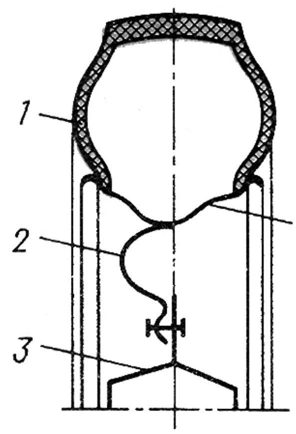

Fig. 23.1. **The propeller (car wheel) consists of:**
1 - pneumatic tire; 2 - connecting element (disk);
3 - hub; 4 - rim

To reduce deformation, the pressure must be increased. However, it is necessary to choose the optimum for each type of vehicle. $P_{ш}$ of the passenger cars is 0.2-0.27 MPa, of the trucks it is 0.5-0.7 MPa, of the regul. - 0.05-0.35 MPa.

The wheel is an integral part of the wheel propeller. It consists of a rim and a disc. Some cars do not have a disc, so wheels that do not have discs are called diskless ones.

The wheels are fitted with the pneumatic tires. Modern pneumatic tires are tubeless. But on some types of cars (trucks and buses) a pneumatic tube is installed inside the tire.

23.2. *Pneumatic tire construction*

Tires are among the most expensive parts of the car (20-30 of the original cost).

The tube tire consists of (Fig.23.2):

The frame serves as the basis of the tire, and gives it the necessary rigidity. It is made of several layers of cord (1 - 1.5 mm). The number of layers is even to 4 - 14.

Cord is a special fabric consisting of longitudinal threads of 0.6 - 0.8 mm in diameter.

- cotton;
- kapron (strength is 2 times higher)
- viscose;
- perlon;

- nylon;
- metal (steel wire of 0.15 mm).

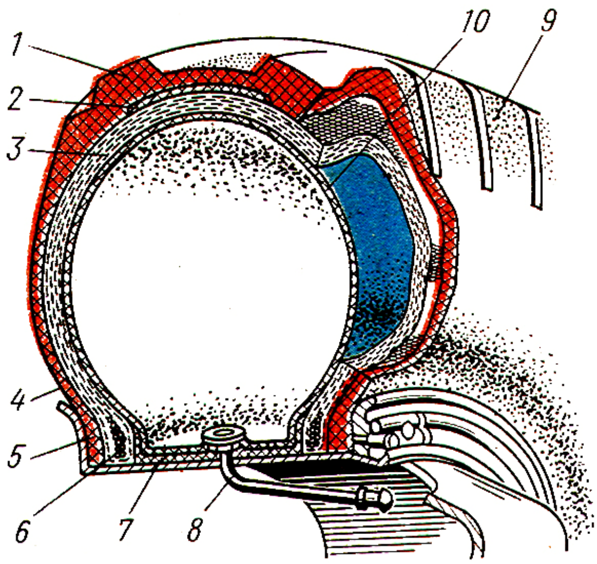

Fig. 23.2. **Tube pneumatic tire.**
1 - protector; 2 - cushion ply (breaker); 3 - frame; 4 - sidewall; 5 - ramp; 6 - core; 7 - rim tape; 8 - rim tape; 9 - tire; 10 - innermost tire

Tread provides tire traction with the road and protects the frame from damage. The pattern and width depend on the purpose of the vehicle.

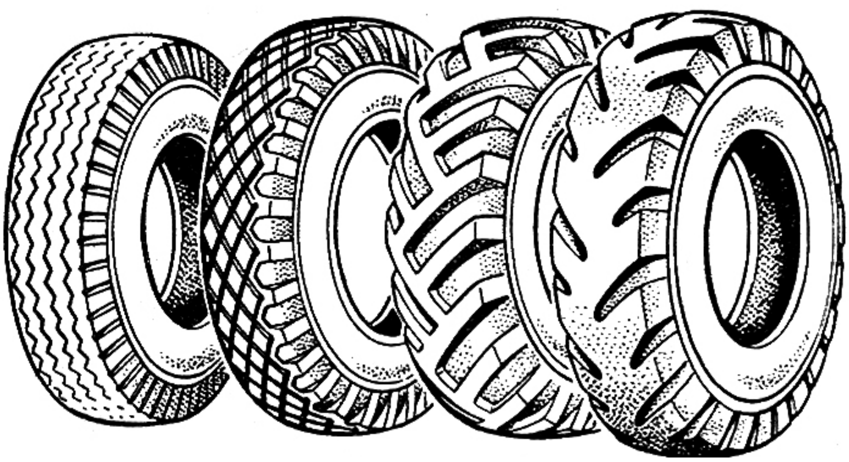

Fig. 23.3. **Tire tread pattern:**
a - road; b - universal;
c – of increased cross-country ability; d – pit-run

The cushion ply (breaker) bonds the tread to the carcass and protects the carcass from jolts and impacts. It consists of several layers of vacuum rubberized cord (with a thickness of 3-7 mm).

Sidewalls - protect the frame from damage and moisture. They are made of tread rubber with a thickness of 1.5–3.5 mm.

Beads - secure the tire securely to the rim. Outside, the beads have 2 layers of rubberized tape, steel wire cores are embedded inside to increase the strength of the beads. Tires with a damaged core are not serviceable.

Tube - keeps the compressed air inside the tire. Elastic rubber shell is in the form of a torus. It is always in a stretched state. It is made of high-strength rubber.

Valve - a special valve for inflation and air release from the tube. The valves are available in different lengths depending on the type and size of the rim.

It consists of:

- framing;
- spool (the rod with a valve);
- cap.

Rim tape - protects the tube from damage and friction against the wheel rim and tire bead. It eliminates the possibility of pinching the tube between the rim and tire. It is made of rubber profiled tape and has the shape of a ring.

Tubeless tire – has no tube or rim tape. A feature of such a tire is the presence on its inner surface of a sealing, airtight rubber layer (with a thickness of 1.5–3.5 mm).

The layer is vulcanized to the inner surface of the tire.

Advantages:

- increases traffic safety;
- easily repaired (in road conditions, they are inserted by the needle of the sealing plug);
- heat up less (outlet through the wheel rim);
- more durable (10–20%);
- simpler in design;
- less weight.

Disadvantages:

- require special rims;
- installation is more difficult.

In case of loss of tightness, they are used as ordinary tires.

Type of pattern:
- zigzag;
- universal;
- winter pattern - consists of separate rubber blocks.

When driving on hard surfaces, they have intense wear and noise.

They can have tires, which consist of a body and a core.

The body is made of steel and lead alloys, and plastic.

The cores are thermoplastic ones.

There are 8–12 studs at the point of contact of the wheel with the road.

23.3. *The main types of car tires*

By purpose:
- passenger car;
- truck;

By the shape of the profile:
- normal profile H/в L/t = 0.9;
- wide-profile H/в L/t = 0.6 - 0.9;
- low-profile H/в L/t = 0.7 - 0.88;
- super low-profile H/в L/t no more than 0.7
- arched H/в L/t = 0.35 - 0.5;
- pneumatic rollers H/в L/t = 0.25 - 0.4.

By dimensions:
- ordinary;
- large-sized B = 350 mm and more outer diameter is 2-3 m.

By design:
- the diagonal arrangement of the cord;
- radial.

Advantages:
- (carrying capacity;
- (radial elasticity;
- (rolling resistance;
- (heating;
- (service life (1.5–2 times).

RS tires differ from P in removable tread.
- frost-resistant;
- tires for tropical climates;

- tires with adjustable pressure.

According to the sealing principle:

- tube;
- tubeless;

23.4. *Dimensions and markings*

Main size:

Width *B* and height of profile *H* rim *d* and outer diameter *D*.

Tire size is designated by two letters (fig. 23.4)

B - *d* in mm (inches)

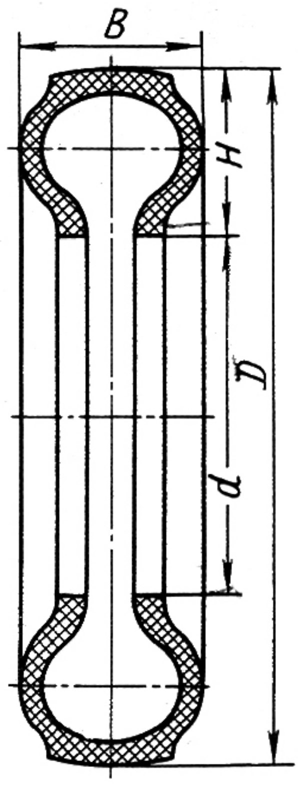

Fig. 23.4. **The main dimensions of the pneumatic tire.**

For example: **195/70 R 14 89H**

195 - tire profile width in mm;

70 - the ratio of height to width (the height of the tire's profile is 70% of the width). If there is no special designation of the profile height (for example 155R 15), then this means that this ratio is normal for radial tires, and it is 82%;

R - radial tire;

14 - rim diameter in inches;

89 - indicates the permissible tire load (load index)

load index	75–3870 N;
	85-5750 N;
	103-8750 N;

H - speed index

Speed index

L - 120 km / h;
M - 130 km / h;
N - 140 km / h;
P - 150 km / h;
Q - 160 km / h;
R - 170 km / h
S - 180 km / h;
T - 190 km / h;
H - 210 km / h
W - 220 km / h

In addition, the following is indicated:

- manufacturer;
- release date (month, year);
- tire model and its serial number;
- GOST number;
- ply rating (for truck).

Additional designations

"Radial" - radial tires;
"Tubeless" – tubeless ones;
"North" - frost-resistant ones;
M + *S* - with a winter pattern;
Ш S - designed for studding.
C - for minibuses
Special types *D* (*B* - *d* - for wide-profile (1200 (500 - 508);
D (*B* - for arched (1140 (700);
D (*B* (*d* - for pneumatic rollers (1000 (1000 (250);

23.5 *Decoding of tire marking*

Tire marking can be inch, millimeter or mixed one.

An example of an inch tire marking **(5.90-13):**

$$b_{шд} - d_{шд}$$

where $b_{шд}$ - is the width of the tire profile (1 inch = 25.4 mm), inches;
$d_{шд}$ - is a wheel rim diameter (inner diameter of the tire), inches.

An example of a millimeter marking of a tire **(1300×530-533):**

$$D_ш \times b_ш - d_ш$$

where $D_ш$ - is the outer diameter of the wheel, mm;
$b_ш$ - tire profile width, mm;
$d_ш$ - diameter of the wheel rim (inner diameter of the tire), mm.

For tires marked in millimeters, the ratio of the tire's profile height to its width is defined as:

$$\xi = \frac{0{,}5 \cdot (D_ш - d_ш)}{b_ш} \cdot 100\%.$$

An example of a duplicate tire marking **(9.00R20 (260R508)):**

$$b_{шд} \boldsymbol{R} d_{шд} \ (b_ш \boldsymbol{R} d_ш)$$

where ***R*** - is a radial tire.
An example of mixed tire marking **(205/70*R*14):**

$$b_ш / \xi \boldsymbol{R} d_{шд}$$

For tires with mixed marking, the ratio of the tire's profile height to its width (ξ) is indicated in the tire marking.

The rolling radius of a wheel r_k is most often taken to be equal to the static radius r_c, since it depends on many parameters: vehicle speed, wheel load, movement resistance, etc. In the absence of the values of r_k

and r_c in the reference literature, you can determine the radius by the following formula

$$r_c = 0{,}5 \cdot d + 0{,}01 \cdot \xi \cdot b \cdot (1 - \lambda)$$

where d - is the diameter of the wheel rim (inner diameter of the tire), m;

b – the tire profile width, (determined by tire marking), m;

λ - coefficient of a real tire deformation:

- for standard and wide-profile tires (lower values for trucks, and large values for cars) …………………………………… $0.1 \div 0.16$
- for arched tires and pneumatic rollers ……………... $0.2 \div 0.3$

ξ - the ratio of the height of the tire's profile to its width in percent, % (for tires the marking of which is carried out in inches or for tires with a duplicate marking the value is $\xi = 100\%$).

References

1. Кисликов В.Ф., В.В. Лущик. Будова й експлуатація автомобілів. Київ: Либідь, 2018. – 400 с.
2. Скляров В.М., Волков В.П., Скляров М.В. Автомобільні двигуни. Особливості конструкції: навч. посібник – Харків: ХНАДУ, 2012. – 405с.
3. Омеличев А.А. Підручник з будови автомобіля. – Дніпро: Моноліт, 2019. – 288 с.
4. Білоус Б.Д., Ткачук П.П., Андрусик Ю.Ф., Білоус Н.Б., Онищенко В.В. Армійська техніка. Основи руху, будова, характеристика: навч . посібник. – Л.: Вид-во Національного університету «Львівська політехніка», 2007. – 536 с.

Test questions

?

1. What kinds of propellers are there?
2. What does a wheel consist of?
3. What is the structure of a pneumatic tire?
4. What can be the marking of tires?

24 CONCEPTUAL MODULE

Steering

24.1. *Car drive*

24.1.1 Turning schemes

Changing the direction of movement of the car is carried out by turning the steered wheels, which, as a rule, are the front ones. Turning schemes of cars are shown in fig. 24.1.

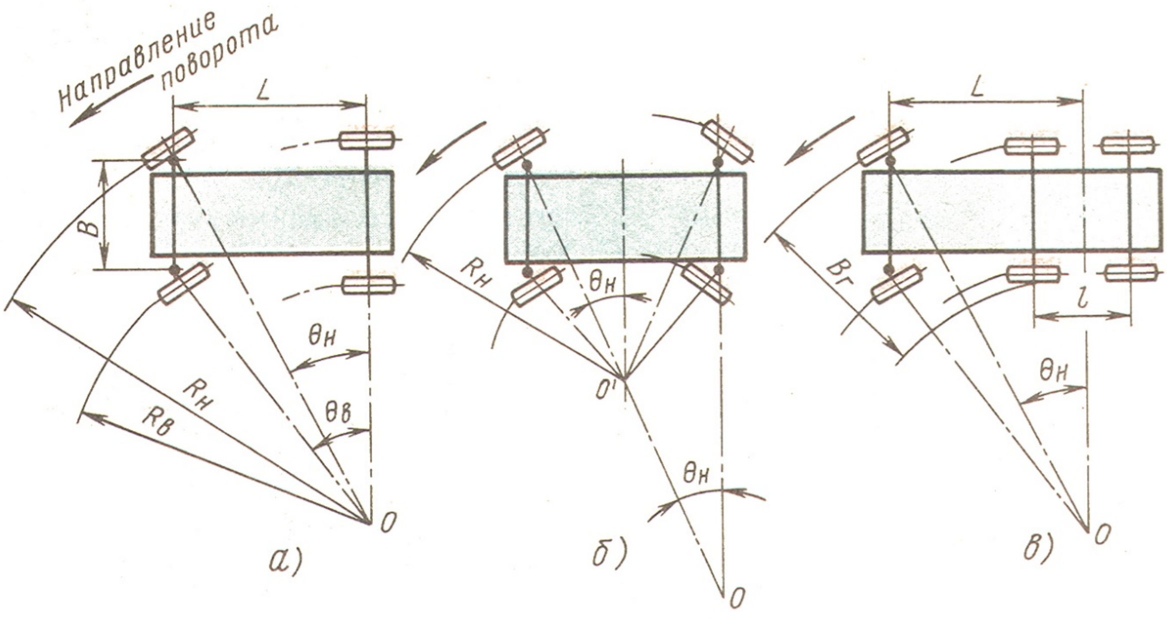

Fig. 24.1. **Turning schemes of cars:**
a - the scheme of the car's movement in a circle with rotated front steer wheels; b - front and rear steered wheels; c - the width of the overall corridor for a three-axle vehicle

The relationship between the angles of rotation is determined from the expression.

$$\mathrm{ctg}\,\theta_{н} = \mathrm{ctg}\,\theta_{в} + B/L$$

where B - is the distance between the wheels

L - wheel base of a car

The ability of a car to turn around in a given area, i.e. its turnability, is characterized by a minimum turning radius

$$R_{нmin} = L/\sin\theta_{нmax}$$

where $\theta_{нmax}$ - is the maximum wheel rotation angle. Usually $\theta_{нmax}$ is approximately equal to 30°, therefore $R_{нmin} = 2L$ for ↓ $R_{нmin}$ ↑ $\theta_{нmax}$ is up to 40–45°. $R_{зил\text{-}130} = 8$ m. $R_{ВАЗ} = 5.6$ m.

The turnability of the car is also characterized by the overall corridor of the lane width, into which the car, making a turn with the minimum radius, fits.

24.1.2. The purpose of the steering

The steering provides the necessary direction of the vehicle by means of separate and coordinated rotation of its steered wheels. Steering is a set of mechanisms that provide a turn.

Steering consists of (Fig.24.2):

- steering gear;
- steering drive;

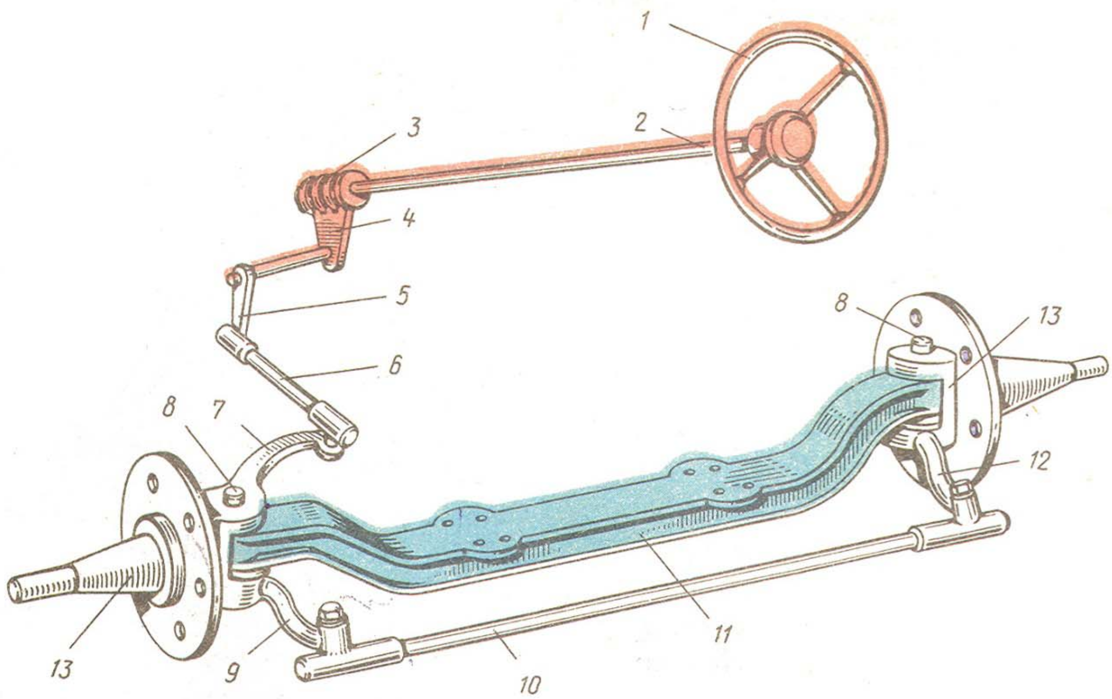

Fig. 24.2. **Steering scheme:** 1 - steering wheel; 2 - shaft; 3 - worm screw; 4 - sector; 5 - bipod; 6 - longitudinal traction; 7 - levers; 8 - kingpin; 9 and 12 - levers; 10 - transverse traction; 11 - beam; 13 – pins

24.1.3. Directional stability

Stabilization is the property of the steered wheels to return to their original position, to maintain straight motion.

Lateral tilt of the king pin causes the center of mass of the vehicle to rise when the steering wheels are turned.

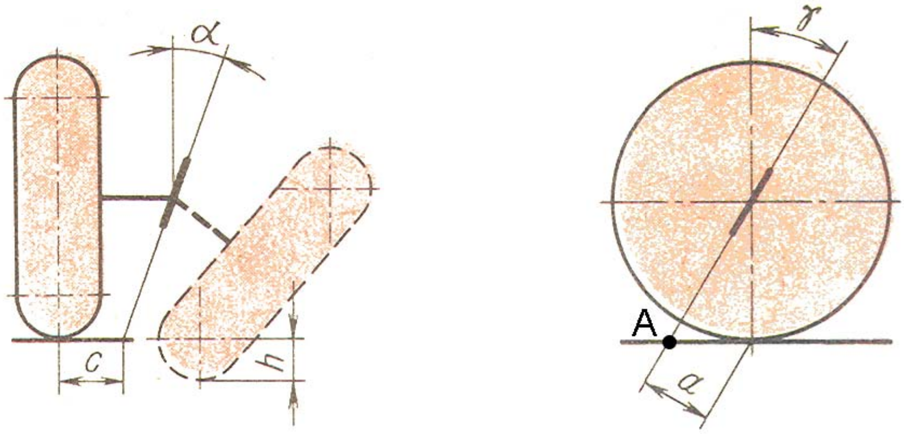

Fig. 24.3 Installation angles of front wheels and steering knuckle pivots:

As you can see from the diagram, when the wheel is turned 180 degrees, the car will lower by the value *h*. In fact, the car is lifted. When the steering wheel is released by the weight of the vehicle, the wheels move back, that is, a stabilizing property will be provided.

The longitudinal tilt of the king pin. Point A is located in front of the contact patch of the wheel with the road.

In the case of a curvilinear movement of the car (Fig. 24.4), the resulting centrifugal force causes the action of lateral reactions from the side of the road to the wheels. The presence of the longitudinal inclination of the pivots leads to the fact that the reactions R_1 – R_2 create the stabilizing moments that tend to return the steered wheels to the straight-ahead position.

If the steered wheels roll in vertical planes parallel to the longitudinal axis of the car, then they experience the least rolling resistance, and therefore, determine the minimum fuel consumption to overcome this resistance. At the same time, the wear of the pneumatic tires of the vehicle is also reduced.

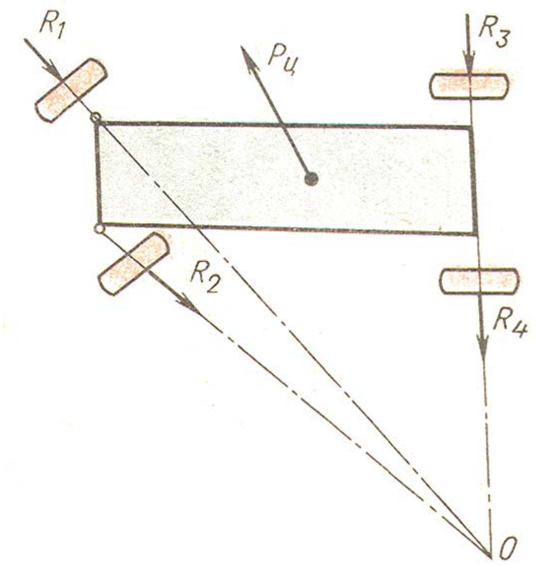

Fig. 24.4 Driving pattern of the vehicle under the action of a centrifugal force

24.2. *Steering gear (PM SG)*

24.2.1. The main types

The steering (PУ S) should provide an easy turn of the steered wheels and reduce the back strokes. PУ S provides the ability to restore the clearance in case of wear and the acceptable free play.

They can be:

- worm screw (worm screw sector and roller)
- crank-driven
- screw-shaped (screw-nut)
- gear (cylindrical, cone, rack and pinion)

To increase the safety of the steering, they introduce into their design:

1. A device that absorbs a striking energy.
- telescopic steering column and shaft;
- rubber couplings connecting parts of the steering shaft;
- plates on the steering column;
2. Airbags

24.2.2. RM SG design

Typical steering gear designs are shown in fig. 24.5 - 24.6. Fig. 24.5 depicts a worm gear, and Fig. 24.6 depicts a screw - nut - sector.

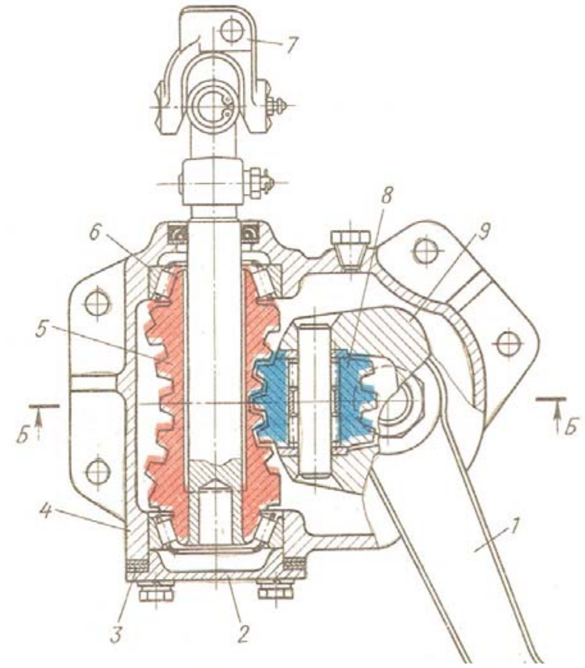

Fig. 24.5. **The steering gear of the KAZ-6086 car:**
1 - steering lever; 2 - cover; 3 - gaskets; 4 - cast iron crankcase;
5 - worm screw; 6 - bearings; 7 - cardan joint;
8 - three-ribbed roller; 9 - shaft

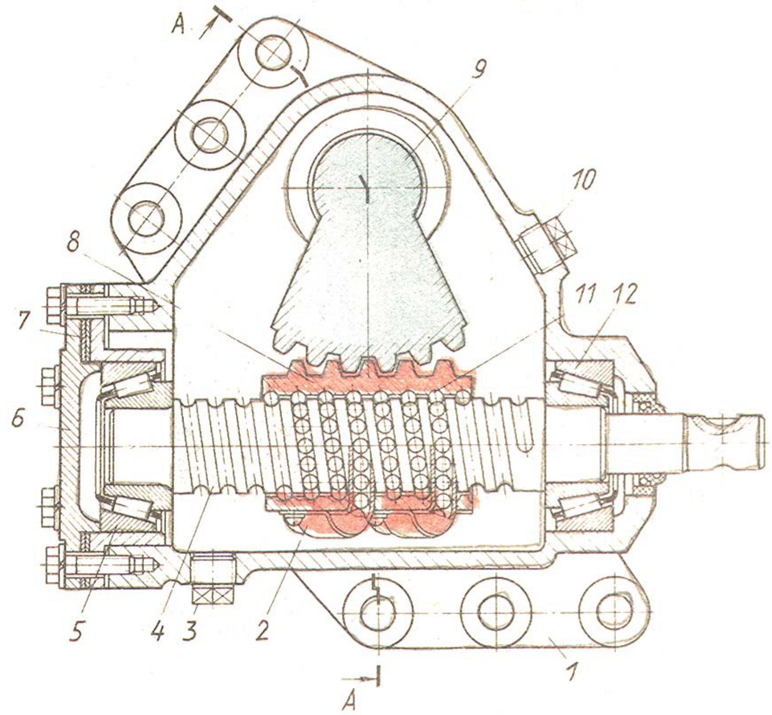

Fig. 24.6. **The steering gear of the BelAZ-540 car:**
1 - crankcase; 2 - guide tube; 3 - drain plug; 4 - screw; 5 and 12 - tapered roller bearings; 6 - nut with rack; 7 - adjusting gaskets; 8 - screw-nut with lath; 9 - sector; 10 - filler plug; 11 - balls

24.3. *Steering drives*

24.3.1. With dependent suspension

With a dependent suspension, a steering drive consisting of a one-piece non-split trapezoid is used (Fig. 24.7).

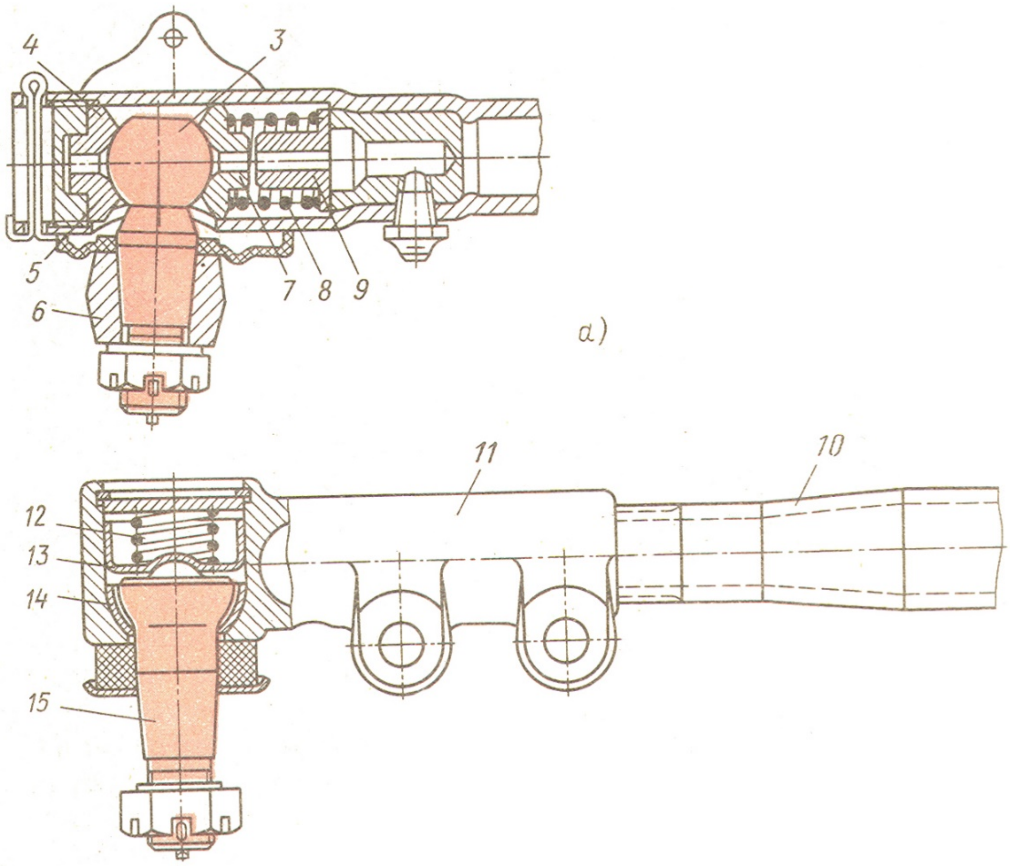

Fig. 24.7. **Steering rods of the GAZ-53A car:**
a - longitudinal; b - transverse; 3 - finger; 4 - dowel;
5 - cap; 6 - tripod; 7 - dowel; 8 - spring;
9 - limiter; 10 - traction; 11 - fixed tips;
12 - compressed spring; 13 - heel; 14 - dowel; 15 – finger

24.3.2. With independent suspension

With an independent suspension, a steering drive consisting of a split trapezoid is used (Fig. 24.8). This trapezoid includes many tractions that can change their position in space and are located at different angles to each other. This is achieved thanks to the ball joints.

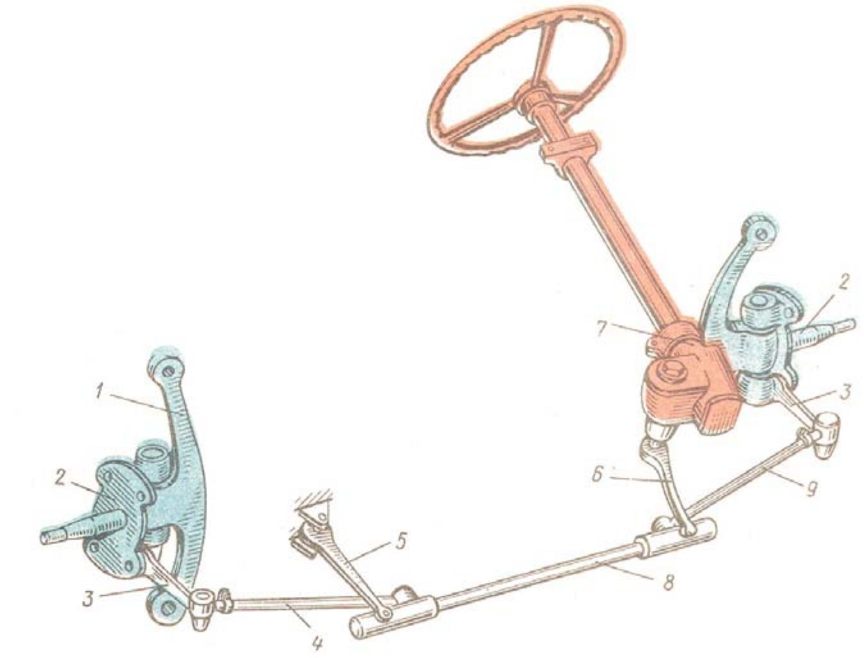

Fig. 24.8. **Steering drive diagram with independent suspension:**
1 - rack; 2 - pivot pins; 3 - the lever of the pivot pin;
4 and 9 - lateral thrusts; 5 - pendulum arm; 6 - tripod;
7 - steering gear; 8 - medium traction

24.3.3. Amplifiers of a steering drive (fig. 24.9)

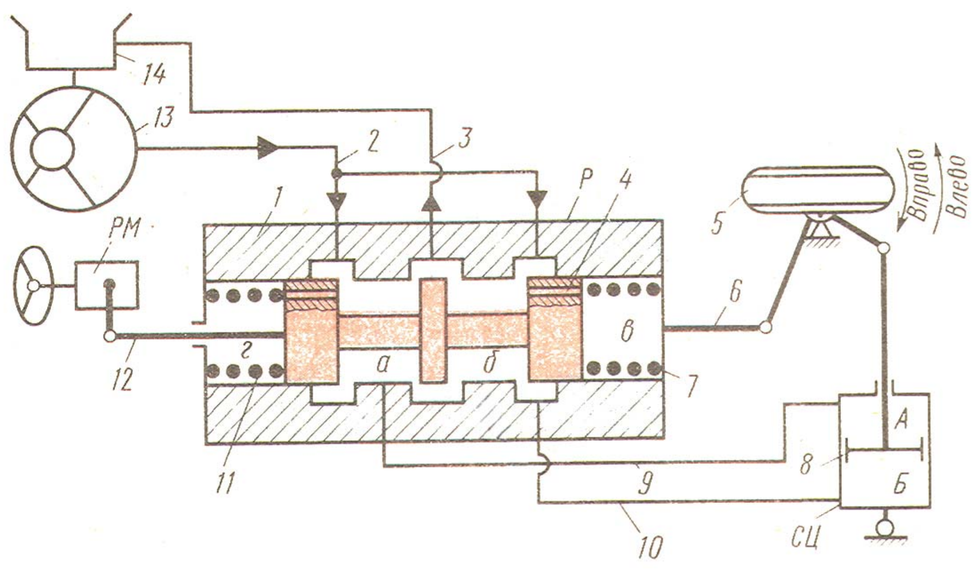

Fig. 24.9. **Steering booster diagram**:
1 - framing; 2 - oil line; 3 - oil line; 4 - spool; 5 - wheel;
6 - beam; 7 - spring; 8 - piston; 9 - oil line;
10 - oil line; 11 - spring; 12 - beam; 13 - pump; 14 - tank

References

1. Кисликов В.Ф., В.В. Лущик. Будова й експлуатація автомобілів. Київ: Либідь, 2018. – 400 с.

2. Скляров В.М., Волков В.П., Скляров М.В. Автомобільні двигуни. Особливості конструкції: навч. посібник – Харків: ХНАДУ, 2012. – 405с.

3. Омеличев А.А. Підручник з будови автомобіля. – Дніпро: Моноліт, 2019. – 288 с.

4. Білоус Б.Д., Ткачук П.П., Андрусик Ю.Ф., Білоус Н.Б., Онищенко В.В. Армійська техніка. Основи руху, будова, характеристика: навч . посібник. – Л.: Вид-во Національного університету «Львівська політехніка», 2007. – 536 с.

Test questions

?

1. How is the simultaneous rotation of the front wheels at different angles achieved, at which the axes of all wheels intersect at the common center of rotation?
2. What is the purpose of the steering mechanism?
3. What is the purpose of the steering drive?

25 CONCEPTUAL MODULE

Brake control

25.1. Purpose of brake control and the main types of brake systems.
25.2. Brake gears.
25.3. Brake drives.
25.4. Structural diagrams of the pneumatic brake drives.
25.5. The design of the elements of the pneumatic drive.
25.6. Combined brake drive.

25.1. *Purpose of brake control and the main types of brake systems*

The brake control is used: to reduce the speed of movement and to stop the car completely, as well as to hold the stationary car in place.

Any brake control consists of several brake systems.

Cars must be equipped with:

- working brake system, used when the car is moving to reduce speed and stop completely.
- parking brake system, serves to hold the stopped car in place.
- extra (emergency) brake system, designed to stop the car when the main working brake system fails.

Depending on the purpose of the vehicle, it can be additionally equipped with the following brake systems:

- secondary brake system (a replacement brake) is used when braking on long descents or in conditions when it is necessary to use the brake for a long time.
- brake control system for trailers or semi-trailers brakes, designed to reduce the speed of a trailer or semitrailer, as well as to automatically brake them in case of a break in the coupling with a tow truck.
- stopping brake system, designed to stop a vehicle carrying passengers when doors are opened while driving. Such a brake system will

not open the doors of the vehicle until it comes to a complete stop and allows the driver to start moving if the doors of the vehicle are not closed.

Work system: usually is driven by the force of the driver's foot applied to the pedal.

The effectiveness of the action is assessed by the braking distance, (the distance on a horizontal dry road with a hard surface when braking a car from a speed of 40 km/h to a complete stop).

Reserve system: is less effective; it can be performed not separately, but in different circuits.

Parking: must withstand a fully laden vehicle on a slope of at least 25%.

Auxiliary: mandatory for vehicles with a total weight of over 12t, as well as for mountainous areas.

The brake system consists of:

- brake mechanisms (brakes);
- brake drive;

Brake systems prevent the wheels from spinning, resulting in a braking force between the wheels and the road. The drive is used to control the brake gears.

25.2. *Brake gears*

Brake systems are mainly frictional ones.

Brake gears can be:

- wheeled;
- transmission (central).

According to the shape of the rotating parts, they are divided into:

- drum-type; (spot-type and ribbon).
- disk-shaped.

25.2.1. Drum-type (spot-type)

Equal driving forces P_1 and P_2 result from the fact that the areas of the cylinder pistons are the same (fig. 25.1). The brake with equal driving forces and one-sided arrangement of supports: 1 – self-clamping shoe; 2 – self-wringing shoe.

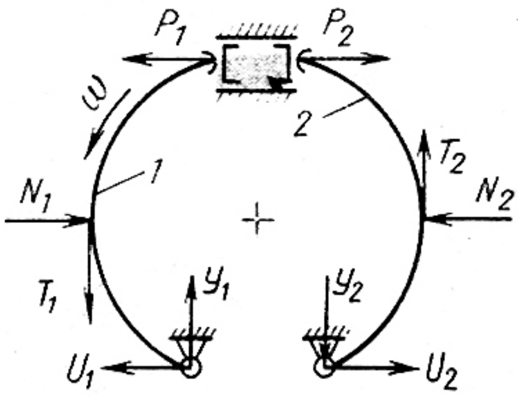

Fig. 25.1. **The brake with equal driving forces and one-sided arrangement of supports:** 1, 2 - shoes

The braking mechanisms are evaluated by:

- efficiency (the more MT, the greater the effect);
- balance (frictional forces do not create loads on the supports of the rotating parts);
- stability (maintaining the effectiveness of the action when changing the coefficient of friction (heating of the shaft)).

Each shoe is driven by its own hydraulic cylinder; it ensures equality of driving forces. Each shoe acts as a primary one.

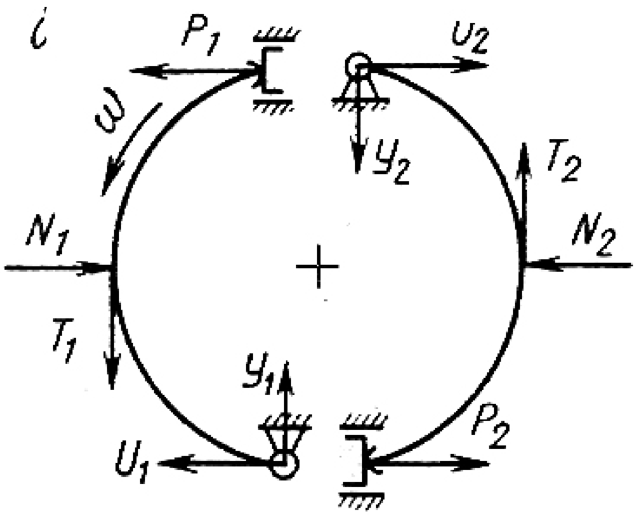

Fig. 25.2. **Each of the shoes is driven by its own hydraulic cylinder.**

The compression springs press the shoe against pin 1. After that, the shoe works as a primary one (fig. 25.3).

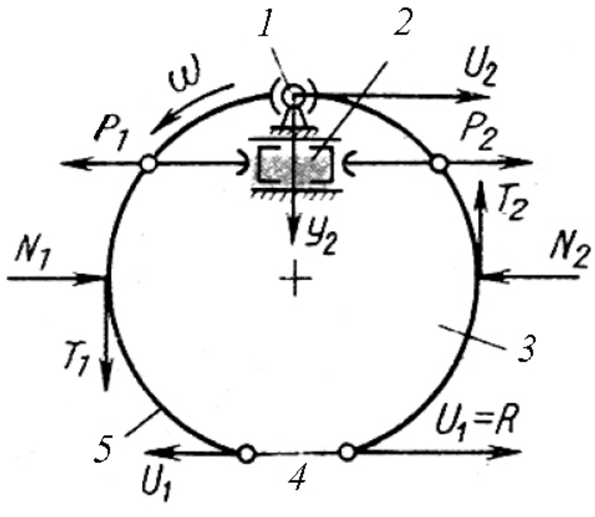

Fig. 25.3. **The brake with additional driving force:**
1 - support pin; 2 - hydraulic cylinder; 3 - rear shoe;
4 - joint; 5 - front shoe

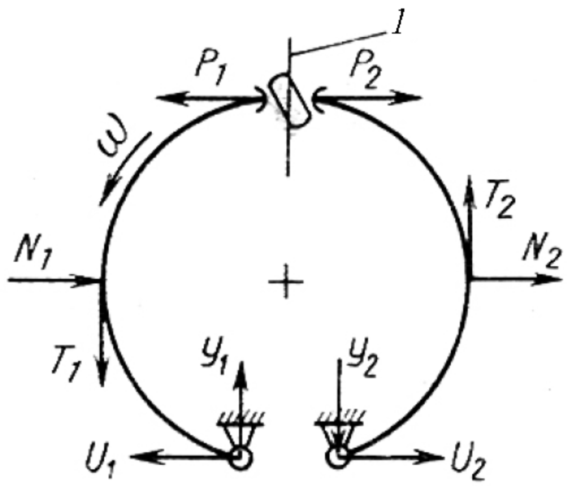

Fig. 25.4. **Expanding cam brake:**
8 - expansion cam

The rolling cam turns the shoes, and $P_2 > P_1$, the same variables create the same reactions N_1 and N_2, as well as T_1 and T_2 (fig. 25.4)

25.2.2. Ribbon drum-type brakes

It consists of a rotating drum and a non-rotating ribbon (fig. 25.5). In this case, large radial loads act on the drum and smooth braking is not ensured. The devices for adjusting the gap in such mechanisms are complex and unreliable in operation. They have found limited use in modern cars.

25.2.3. Disk brakes

It consists of a rotating disc, and two non-rotating shoes installed on both sides of the disc. The efficiency of disc brakes is lower than that of drum brakes, and the stability is higher. The braking torque is unbalanced.

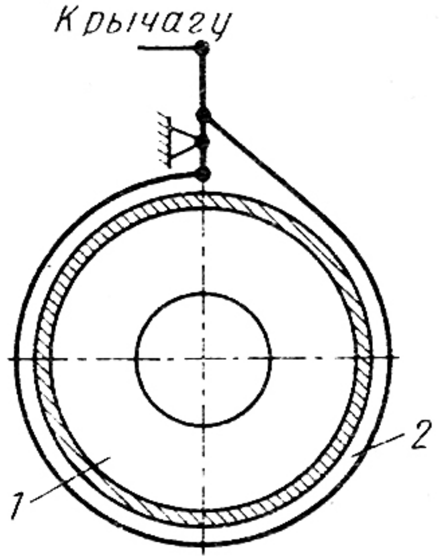

Fig. 25.5. **Diagram of a ribbon drum-type brake:** 1 - rotating drum; 2 - non-rotating ribbon

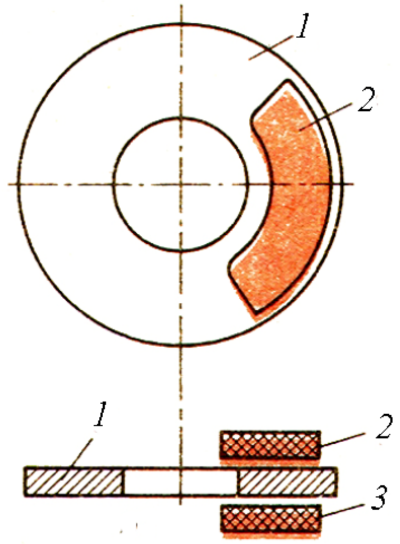

Fig. 25.6. **Diagram of a disc brake:** 1 - rotating disc; 2, 3 - non-rotating shoes

25.3. *Brake drives*

Brake drives are:
- mechanical;
- hydraulic;
- pneumatic;
- electrical;
- combined.

The most commonly used are mechanical, hydraulic, pneumatic and combined drives.

25.3.1. Mechanical drive

A mechanical brake drive is currently not used at all as a drive for a service brake system. The reasons for this are the following disadvantages of a mechanical drive: the complexity and difficulty of its layout on the car; labor intensity of maintenance (the need for periodic regulation and lubrication); low efficiency. The mechanical drive is of two types: lever and lever-cable (fig. 25.7).

The mechanical drive is used to transmit force from the pedal or lever to the brake gears mechanically (cables, tractions).

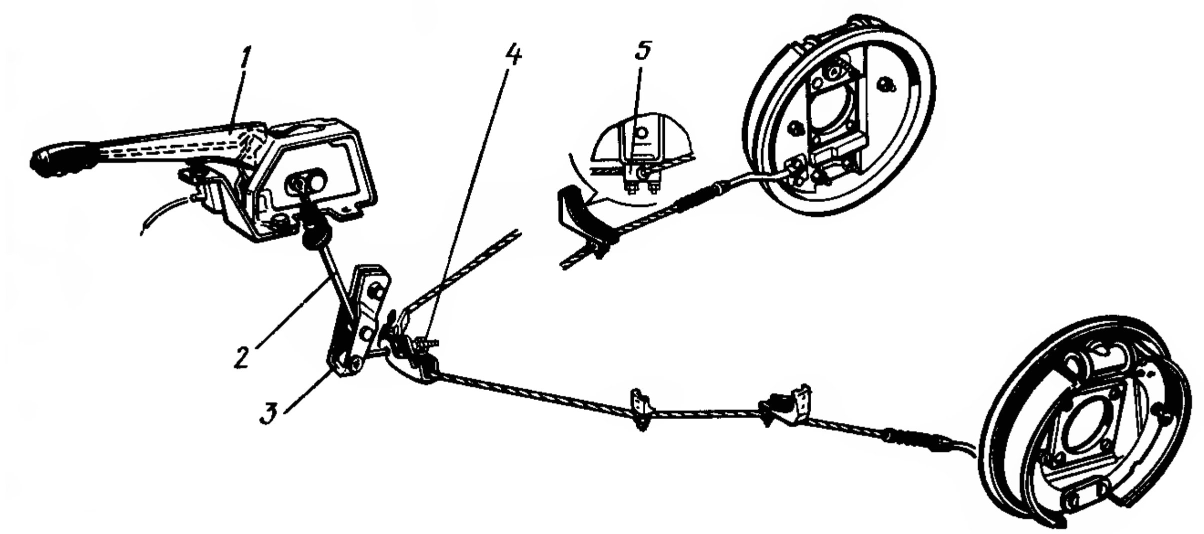

Fig. 25.7. **The mechanical drive of the parking brake system:**
1 - brake drive lever; 2 - traction; 3 - control drive lever;
4 - equalizer; 5 - bracket of a plastic guide

25.3.2. Hydraulic drive

25.3.2.1. Drive diagram (fig.25.8)

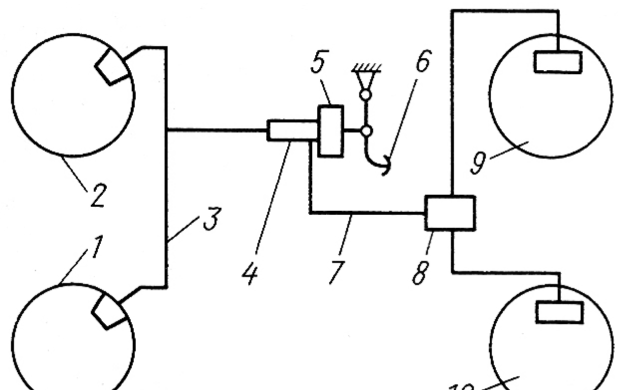

Fig. 25.8. **Diagram of the working brake system of the VAZ-2103 car:**
1, 2 - front disc brakes; 3 - shape of the front brakes;
4 - brake cylinder; 5 - vacuum amplifier;
6 - pedal; 7 - shape of the rear brakes; 8 - brake force regulator; 9, 10 - rear shoe brakes

Advantages:
- good distribution of braking forces;
- short response time;
- high η;
- convenient arrangement of drive units.
Disadvantages:
- impossibility of long-term braking;
- failure of the entire system in case of local damage;
- low η at low temperatures.

25.3.2.2. Main brake cylinder

The main brake cylinder is used to create pressure in the hydraulic brake drive and provides a follow-up action during braking (fig. 25.9).

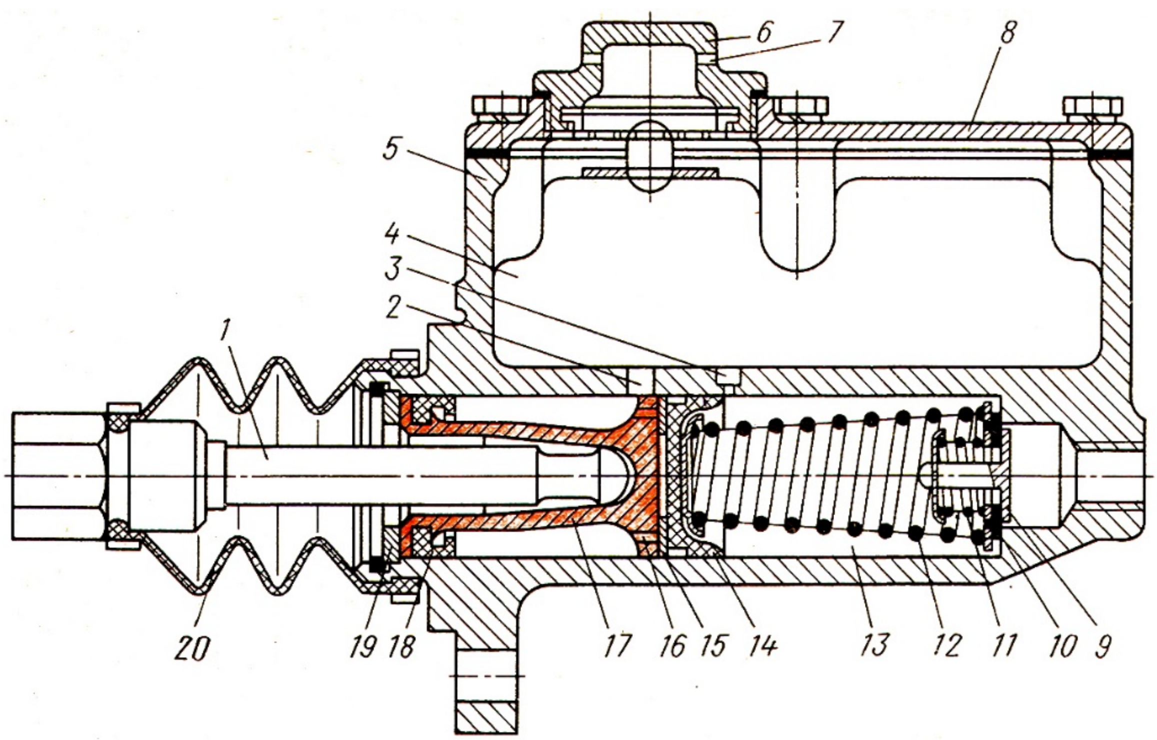

Fig. 25.9. **The main brake cylinder of GAZ-53a:** 1 - tappet head; 2 - bypass hole; 3 - compensation hole; 4 - hole; 5 - framing; 6 - screwed plug; 7 - holes; 8 - cover; 9 - bypass valve; 10 - check valve; 11 - spring; 12 - reset spring; 13 - cylinder; 14 - rubber cuff; 15 - annular valve; 16 - holes; 17 - piston; 18 - a sealing ring; 19 - retaining washer; 20 - case

25.3.2.3. Wheel brake cylinder

The wheel brake cylinder converts fluid pressure into a force that is transmitted to the brake shoes (fig. 25.10)

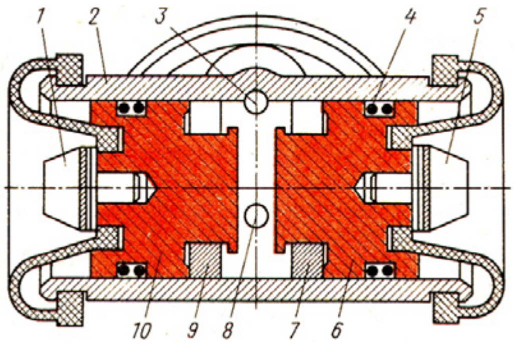

Fig. 25.10. **Wheel brake cylinder of the GAZ-24 "Volga" car:**
1, 5 - pushers; 2 - framing; 3 - upper port;
4 - cuffs; 6, 10 - pistons; 7, 9 - rings; 8 - bottom hole

25.3.3. Pneumatic drive

25.3.3.1 The principle of operation of the pneumatic drive (fig. 25.11)

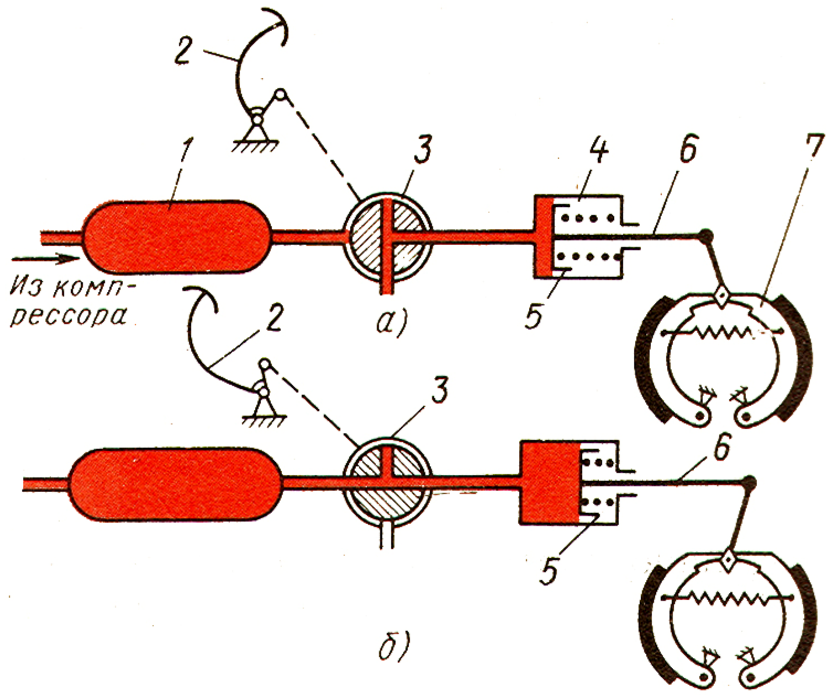

Fig. 25.11. **Diagram of the simplest pneumatic brake drive:** 1 - receiver; 2 - pedal; 3 - crane; 4 - brake cylinder; 5 - piston; 6 - stock; 7 - an expanding fist of a brake

The follow-up mechanism is designed so that the air pressure in the cylinder depends on the effort on the pedals (Fig. 25.12).

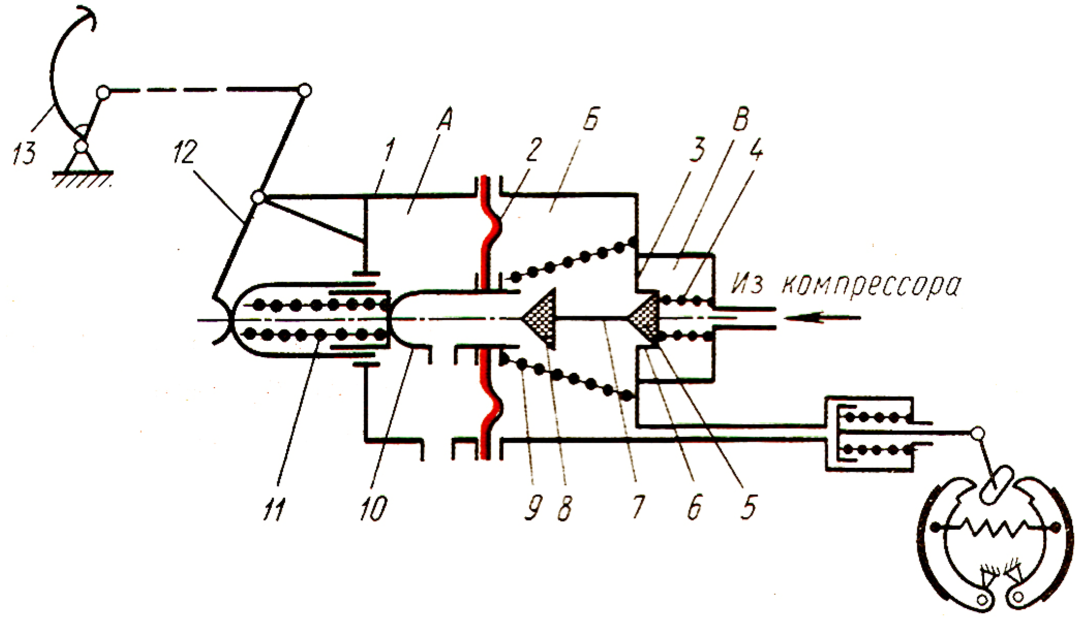

Fig. 25.12. **Diagram of a direct action follower:**
1 - framing; 2 - membrane; 3 - partition; 4 - spring;
5 - inlet valve; 6 - seating; 7 - rod; 8 - release valve; 9 - reset spring; 10 - seating;
11 - a glass of springs; 12 - lever; 13 – pedal

There are following mechanisms:
- of direct action;
- of reverse action.

Of direct action:

The diagram is shown when the mechanism is released. When the pedal 13 is pressed, the glass 11 moves through the lever 12, simultaneously with the seat 10, until the valve 8 separates the cavities "A" and "B". Further, moving to the right, opening the exhaust valve 5 on the left on the membrane, a force acts, depending on the effort on the pedal, and on the right, the air pressure in the cavity "B" and the brake cylinder. As the effort on the pedal increases, the air pressure in front of the diaphragm increases. Therefore, the follower sets the air pressure in the brake cylinder depending on the pedal force.

Of reverse action:

It changes the air pressure in inverse proportion to the driving force.

They establish the relationship between the efforts on the pedals and the drop in air pressure in the cavity "B" (Fig. 25.13).

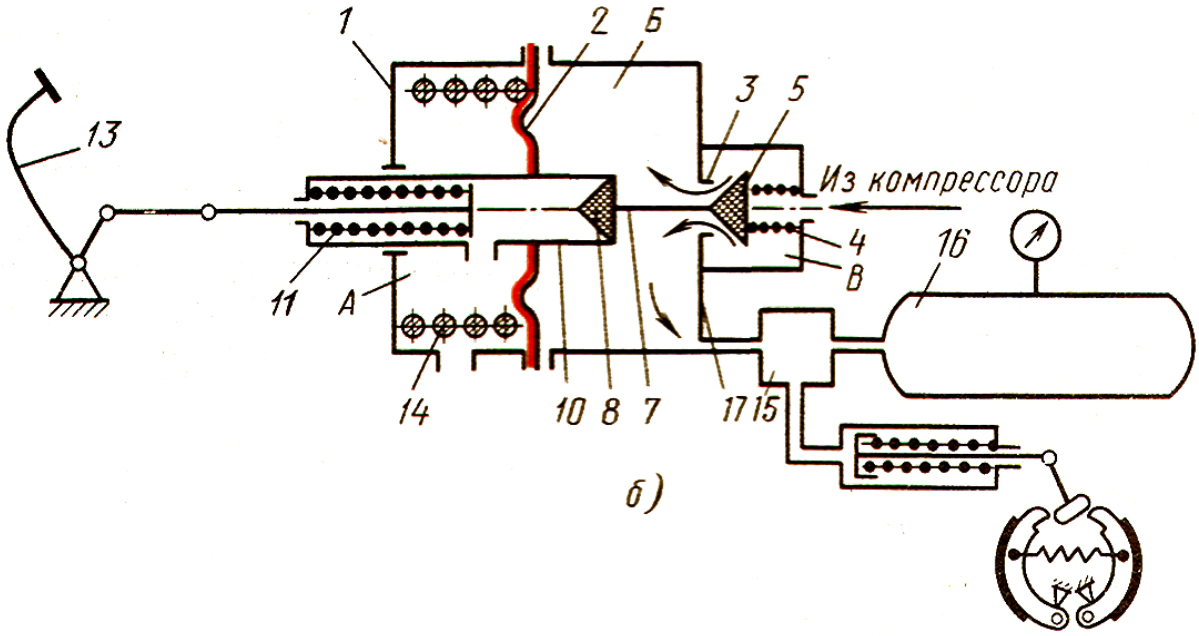

Fig. 25.13. **The follower of reverse action:**
1 - framing; 2 - diaphragm; 3 - saddle; 4 - spring; 5 - inlet valve;
7 - rod; 8 - outlet valve; 11 - balancing spring;
13 - pedal; 14 - balancing spring; 15 - air distribution device; 16 - air receiver; 17 - baffle

25.4. *Structural diagrams of the pneumatic brake drives*

The air in the compressor is heated, and then it is cooled in the pipelines. Moisture is released from it; therefore a filter is installed in the supply part of the drive (Fig. 25.14).

MAX excess pressure of 0.7 - 0.75 MPa, is automatically limited in the receivers.

At low temperatures, mixtures with moisture of alcohols form anti-freeze agents.

Safety valves allow air to move in one direction only.

If you divide the double-circuit drive (Fig. 25.15), you get a single-circuit one.

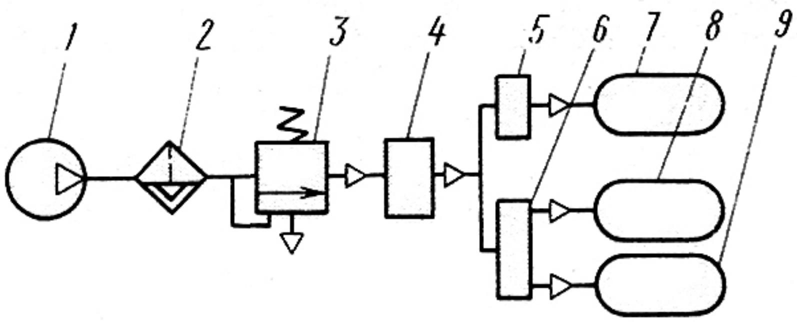

Fig. 25.14. **Block diagram of the power supply of the pneumatic brake drives:** 1 - compressor; 2 - filter-separators; 3 - regulator; 4 - alcohol aerator; 5, 6 - safety valves; 7, 8, 9 – receivers

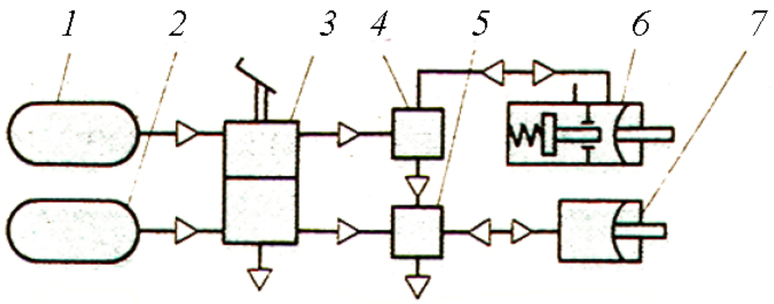

Fig. 25.15. **Double-circuit drive of the service brake system:** 13, 14 - receiver; 15 - brake valve; 16, 17 - valves; 18, 19 - brake chamber

25.5. The design of the elements of the pneumatic drive

25.5.1. Compressors

Typically, the pneumatic brake drives use a piston type compressor, with 1 or 2 cylinders. The compressor cooling and lubrication system is connected to the corresponding internal combustion engine systems.

25.6.2. Pressure regulator

The pressure regulator acts as a filter and safety valve and maintains a constant pressure in the system. At 700 - 750 kPa, air is vented into the atmosphere, and below 620 - 650 kPa, it is injected into the system.

25.6.3. Oil and moisture separators

Cars use a thermodynamic-type of the oil-moisture separator with an automatic condensate drain valve. Compressed air from the compressor enters the radiator of the moisture-oil separator, made in the form of a finned aluminum tube; then it is cooled during the movement and some condensate is released from it. Then, getting into the filter, the air passes along the guide discs, swirls and, changing the direction of movement, flows through the central tube to the pressure regulator. In this case, globules of fluid are thrown onto the walls of the framing, flow down and through the central hole in the membrane enter the sump. Under the action of air pressure, the diaphragm with the guide piston is lowered down; the valve is pressed against the seat.

When the pressure regulator sets the compressor to the idle state, the pressure above the diaphragm drops, it moves up, the valve opens and the condensate water is drained out.

25.6.4. Preventer from freezing

This device is installed behind the thermodynamic moisture-oil separators. They can be of the pump and evaporative type. The evaporative type preventer is equipped with a wick, part of which is in the alcohol bath. The air, passing by the wick soaked in alcohol, is saturated with its vapors. Moisture released from the air combines with alcohol vapors to form condensation water with a low freezing point.

25.6.5. Brake valve

A brake valve is a device that, in proportion to the pressure on the brake pedal, passes the required amount of compressed air into the pneumatic brake gear.

Brake valves can be:

- one-section;
- one-section combined;
- two-section;
- three-section.

Recently, brake valves are made with electronic control or electronic sensors for the movement of the follower elements of the brake valve, for combined brake drives, such as an electronic-pneumatic drive.

25.6.6. Brake chambers

Brake chambers are used to actuate the brake mechanisms of the wheels. Brakes are installed on all wheels. On the intermediate and rear axles, they are common to the working, parking and spare braking systems (Fig. 25.16).

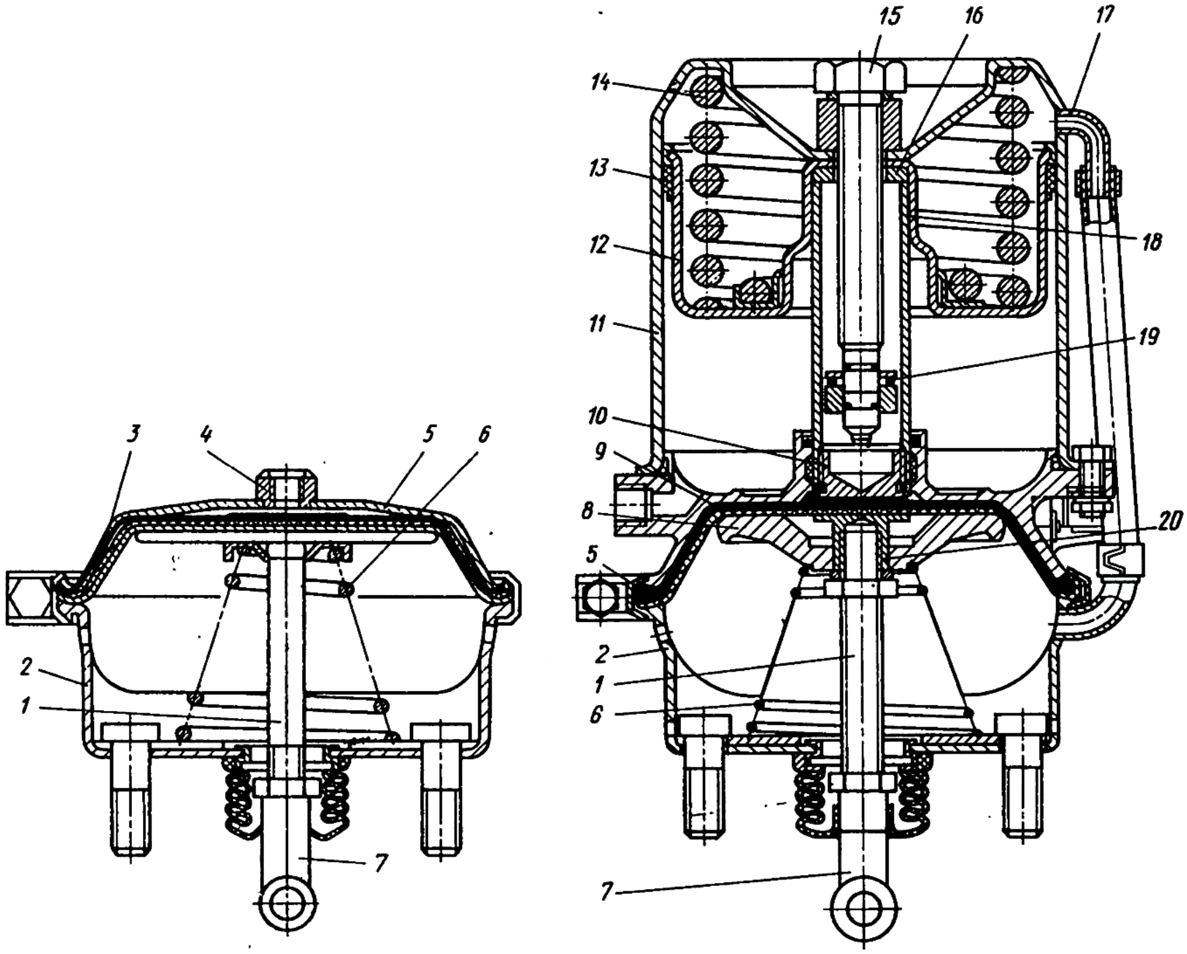

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Fig. 25.16. **Brake chambers:** a - normal; b - with spring brake; 1 - stock; 2 – framing; 3 - case cover;
4 - connector; 5 - membrane; 6 and 14 - springs; 7 - plug; 8 - disk;
9 - cylinder flange; 10- axial bearing; 11 - cylinder; 12 - piston;
13 - piston sealant; 15 - screw; 16 - thrust washer;
17 - drainage tube; 18 - pusher; 19 - bearing;
20 - cap nut

Brake chambers have a "TYPE" for example: Type 20 or Type 16. The numbers represent the active diaphragm area of the chamber in square inches. A brake chamber with a spring brake acts as a device that ensures the vehicle is held stationary in place during parking.

25.7. Combined brake drive

The combined brake drive can be:
- hydropneumatic (fig. 25.17);
- electrohydraulic;
- electro-pneumatic (fig. 25.18);
- electromechanical.

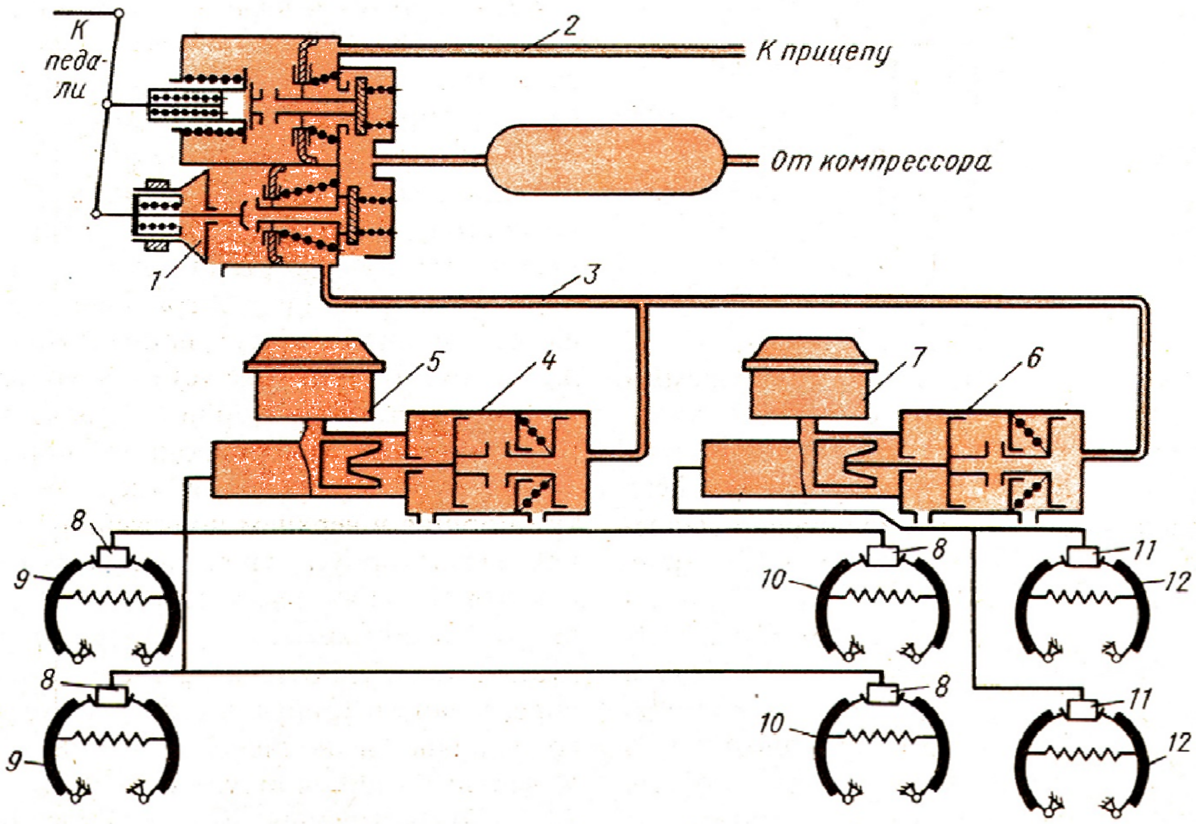

Fig. 25.17. **Brake drive diagram of the Ural-375 car:**
1 - brake valve; 2 - pipeline; 3 - pipeline;
4, 6 - pneumatic cylinders; 7 - brake cylinder;
8, 11 - brake cylinders 9, 10, 12 - pads

The most widespread today are electro-hydraulic and electro-pneumatic brake drives, which improve road safety and implement a number of functions that ensure the active safety of the vehicle.

The hydropneumatic brake gear is less commonly used and involves the advantages of hydraulic and pneumatic brake gears. Its only drawback is its bulkiness in comparison with the electro-pneumatic gear.

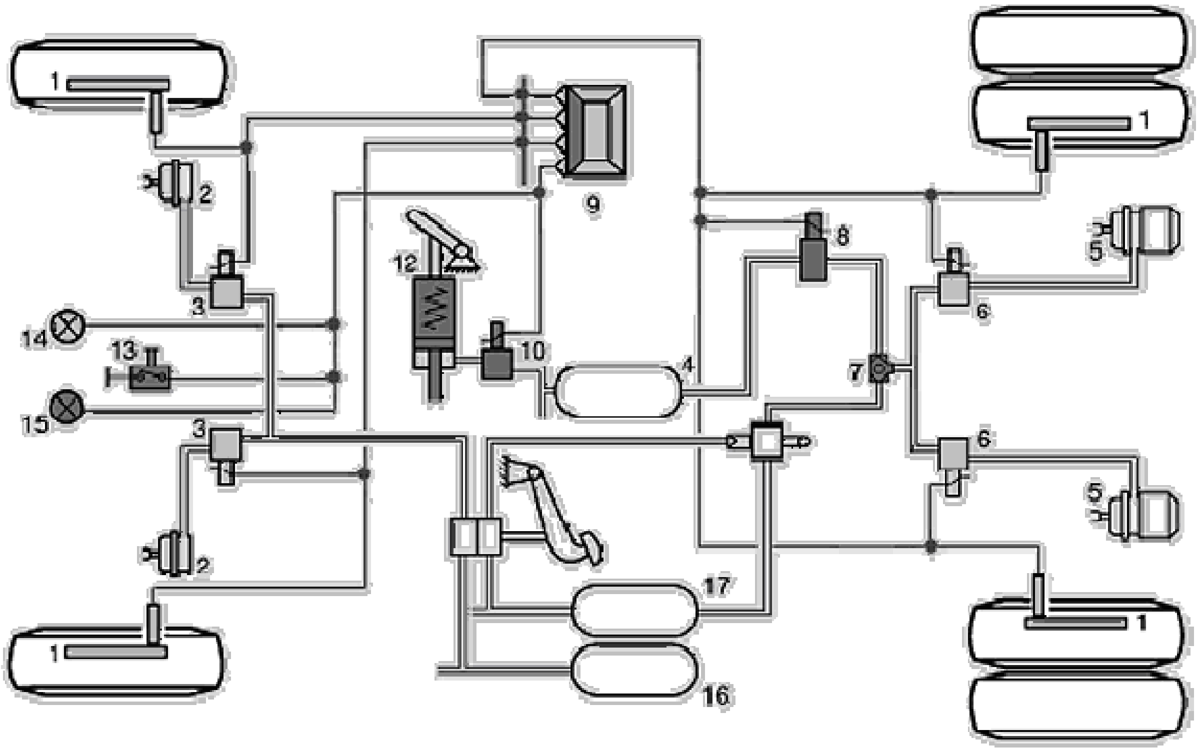

Fig. 25.18. **Electro-pneumatic brake drive diagram:**
1 - code wheel; 2 and 5 - brake chambers; 3 and 6 - ABS modulator;
4, 16 and 17 - receivers; 7 - two-line valve;
8 - differential valve; 9 - control unit;
10 - proportional valve; 12 - ASR working cylinder;
13 - switch; 14 - control lamp; 15 - ASR control lamp

References

1. Кисликов В.Ф., В.В. Лущик. Будова й експлуатація автомобілів. Київ: Либідь, 2018. – 400 с.

2. Скляров В.М., Волков В.П., Скляров М.В. Автомобільні двигуни. Особливості конструкції: навч. посібник – Харків: ХНАДУ, 2012. – 405с.

3. Омеличев А.А. Підручник з будови автомобіля. – Дніпро: Моноліт, 2019. – 288 с.

4. Білоус Б.Д., Ткачук П.П., Андрусик Ю.Ф., Білоус Н.Б., Онищенко В.В. Армійська техніка. Основи руху, будова, характеристика: навч . посібник. – Л.: Вид-во Національного університету «Львівська політехніка», 2007. – 536 с.

Test questions

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1. What is the main purpose of a service brake system?
2. What is the main purpose of the parking and spare brake systems?
3. What is the main purpose of the auxiliary retarder?
4. What is the basis of the parking brake mechanism?
5. What is the basis of the action of the auxiliary retarder?
6. What brake system is not related to the wheel braking devices?
7. What is the main purpose of a brake drive in the brake system of a car?
8. What is the main purpose of the brake mechanism in the brake system of a car?
9. What is the main purpose of the amplifier in the brake system of a car?
10. What is the main purpose of the brake separator in the brake system of a car?
11. What is the braking distance of a car?
12. What is meant by deceleration of a car?
13. What is a stopping distance?
14. What is meant by the driver's reaction time?
15. Which of the brake systems is the most effective?
16. Where are the brake mechanisms located?

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