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RETURN COMPRESSION IN A PISTON AIR ENGINE

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Relevance. One of the current problems of modern automotive industry is the creation of economical and environmentally vehicles. One of the ways to increase these indicators is the use of hybrid cars, in which the additional engine operates in those modes where the internal combustion engine does not work effectively (starting from a standstill, acceleration modes, movement with small loads, in traffic jams). The use of hybrid engines allows not only to reduce fuel consumption, but also to significantly reduce emissions of toxic substances in exhaust gases.

The goal of the work is to study the influence of the parameters of the back compression process on the indicator parameters of a piston air motor.

To achieve the set goal, it is necessary to perform the following tasks: conduct computational studies of the working processes of the air motor, reveal the influence of the degree of reverse compression on its indicator indicators.

The Department of Internal Combustion Engines of the KhNADU continues research into evaluating the efficiency of various schemes of hybrid installations with an air motor, including schemes with various air distribution mechanisms [1]. In this regard, a detailed study of the working processes of air motors and the influence of individual parameters on their performance with a valve air distribution system is of particular practical interest.

Piston air motors were previously manufactured for special mining machines and were produced by specialized enterprises [1]. Radial piston air motors were widely produced in star cylinder design.

Table 1 contains data on four- and five-cylinder radial piston air engines that were mass-produced. In addition to the data on radial piston air engines, Table 1 also provides for comparison the parameters of a similar V l gasoline ICE 4Ch 9.2/9.2 car of class M 2 and converted from it air engines.

From the analysis of the data in Table 1, it can be concluded that piston air engines have low values of average piston speed c p = 1.6÷3.2 m/s and low average effective pressure pe = 0.23÷0.28 MPa in comparison with internal combustion engines (c p = 13.8 m/s and p e = 0.802 MPa). Air engines have a relatively low liter capacity N lpd = 3÷6 kW/l (N ldvs = 30.1 kW/l) and a higher specific metal content M N = 6.3÷15.1 kg/kW (M N = 2.45 kg/kW).

Domestic and foreign radial piston air motors and air motors of other types have a specific compressed air flow rate g i = 77÷93 kg/(kW h).

Such indicators are explained by losses associated with the imperfection of air motor designs (large pressure losses in air distribution elements, low degree of expansion, large air leaks, large dead volume, etc.).

For further calculation studies, a converted gasoline piston engine 4F 9.2/9.2 was selected. In a piston air engine with a valve air distribution is the ability to adjust the filling degree and the degree of back compression [1]. The adjustable filling degree and back compression allows for the use of a controlled change in the phases of air distribution, which opens up the possibility of optimizing the working process.

Air motors has other advantages:

- has the highest starting torque, which is 1.8 times the rated torque
- has the most favorable traction characteristics;
- allows overload;
- has low compressed air leaks (due to the high degree of sealing of the piston rings).

The air motors can be controlled both by the duration of the filling process and by changing the compressed air pressure at the inlet.

Analysis of works [1-4] shows that for a piston air motor the most appropriate is a six-process operating cycle.

The volume of the compression chamber of the air motor was left unchanged, equal to that of the combustion chamber of the internal combustion engine. The pressure of the compressed air at the inlet was p 1 =0.7 MPa. The speed of the air motor for calculations was n = 800 min -1. The degree of filling ε1 = 1.

For engines with a spool air distribution mechanism, the degree of reverse compression ε 3 is an unchanging design parameter. For air motor with electro-hydraulic valves, the degree of reverse compression ε 3 is a factor controlling the working processes. The degree of reverse compression ε 3 varies within wide limits. At ε 3 = 0, reverse compression is absent and the indicator work is maximum, while the consumption of compressed air increases significantly due to filling the volume of the combustion chamber when the piston is at TDC. The maximum value of the degree of compression ε 3 is obtained when the compression pressure p 4 does not exceed the pressure of filling with compressed air p 1.

Table 1. Radial piston indicators pneumatic pumps and gasoline engine 4 F 9.2/9.2

Indicators	Air motor brands				ICE 9.2/9.2	air motor 9.2/9.2
	P7.5-12	P16-25	P2.5-F1	P6,3-12		
Cylinder displacement (liters), V l , l	2,613	2,613	2,613	2,090	2,445	2,445
Compressed air pressure at the inlet, p 1 , MPa	0.4	0.5	0.5	0.4	–	0.7
Rated power, N e , kW	7.5	16	9.5	6.3	73.5	7.67
Nominal speed, n , min -1	750	1500	800	750	4500	800
Average piston speed, s p , m/s	1,625	3,250	1,733	1,625	13.8	2.45
Specific mass flow rate of compressed air, g , kg/(kWh)	83.2	92.8	77.3	80.9	fuel 0.307	6 1 ,2
Hourly air flow rate, G , kg/h	624	1485	734	510	fuel 22.6	156
Cylinder diameter, D , mm	101.2	101.2	101.2	101.2	92	92
Piston stroke, S , mm	65	65	65	65	92	92
Number of cylinders, z	5	5	5	4	4	4
Liter power, N l , kW/l	2.87	6.12	6.63	3.01	30.1	3.13
Specific metal content, M N , kg/kW	12.7	6.3	10.5	15.1	2.45	23.45
Average effective pressure, pe , MPa	0.229	0.245	0.272	0.241	0.802	0.185
Mass, M dv , kg	95	100	100	95	180	180

Table 2. Parameters of the working process of the air motor at p_1 =0.7 MPa, p_2 =0.12 MPa, ε_1 =1, ε_0 =1 and different ε_3

ε_3	n_c	L_i, k_J	P_i , MPa	N_i, kW	G_g, kg/h	g_i, kg/ kWh
0.1	1.32	0 , 31	0.51	2.56	157	61.3
0.2	1.32	0.293	0.479	2.42	151	62.2
0.3	1.32	0.277	0.453	2.29	145	63.2
0.5	1.32	0.244	0.399	2.01	133	6.55

The computational studies were conducted at fixed degrees of harmful space ε 0 and degree of filling ε 1 = 1. The calculation results are given in Table 2 and Fig. 1–4.

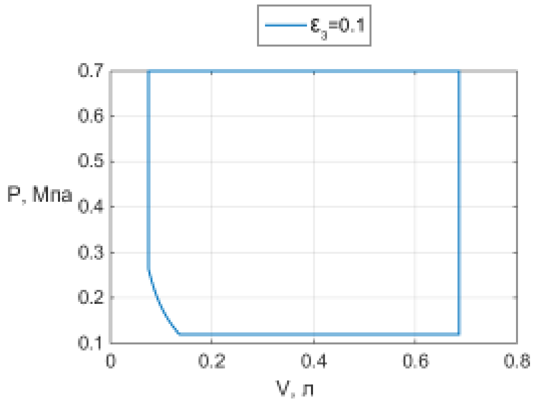

Figure 1 – Indicator diagram of the air motor when: ε3 = 0.1; L i = 0.2563 kJ ;
N i = 2.1184 kW; g i = 38.178 g/kWh;

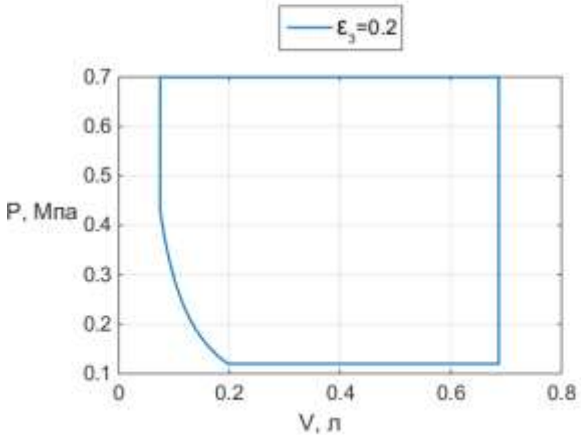

Figure 2 – Indicator diagram of the air motor when: ε3 = 0.2; L i = 0.248 kJ;
N i = 2.049 kW; g i = 36.516 g/kWh;

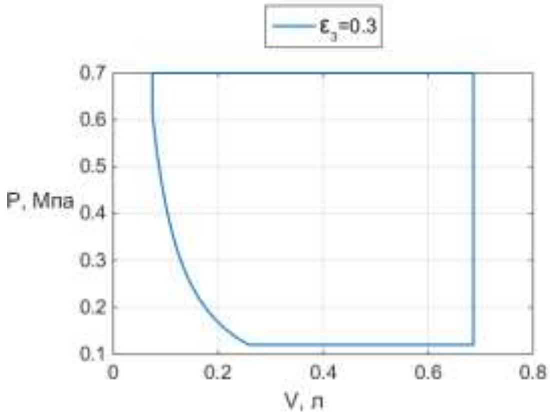

Figure 3 – Indicator diagram of the air motor when: ε3 = 0.3; L i =0.2397 kJ;
N i = 1.981 kW; g i = 34.738 g/kWh

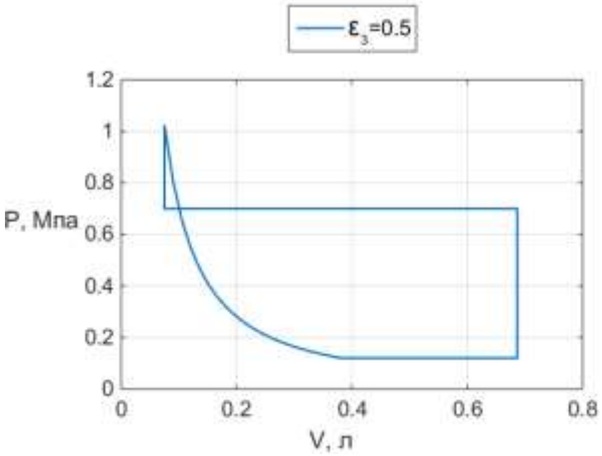

Figure 4 – Backpressure pressure exceeds inlet pressure

Algorithm was implemented in the program MatLab. According to the results of the research, the qualitative and quantitative picture of the working processes of the air motor was confirmed.

With an increase in the degree of back compression ε 3, the area of the indicator diagram and the indicator power N i decreased. At the same time, the hourly compressed air consumption G g decreased.

It should be noted that the graphs of the dependence ε 3 shown in Fig. 1–5, determined by the calculation method, are universal and suitable for any piston air engine, regardless of its parameters such as the dimensions of the working volume Vh, the cylinder diameter D, the piston stroke S , the crankshaft rotation frequency n and the temperature of the compressed air at the inlet T.

Conclusions

A computational study of the influence of the parameters of the back compression process on the indicator parameters of a piston air motor has been conducted.

The effect of reverse compression is revealed on air motor indicators. Calculated indicator diagrams are presented and mathematical dependencies are proposed, which are the basis of the calculation research methodology regarding the influence of the back compression process on the implementation of maximum work and minimum specific flow rate of compressed air.

The obtained calculation data allow us to reveal the processes taking place in the air engine and to assess the degree of efficiency of the air engine's working process. The obtained results indicate that the indicators of the converted air engine (the presence of the combustion chamber volume for operation in the ICE mode) are at the level of serially produced air motors.

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COMBINED OPERATION OF THE AIR ENGINE AND ICE OF THE COMBINED POWER PLANT OF A VEHICLE (CPU)

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For modern urban road transport, the use of environmentally friendly, including combined, power plants (PPUs) [1] is becoming relevant, when used in certain vehicle operating modes, it is possible to temporarily abandon the operation of the internal combustion engine (ICE) by replacing it with an alternative one included in the PPU.

Pneumatic motors (PM) when used as part of a CEU have a number of advantages compared to electric ones (simplicity and safety of design, lower weight of equipment when using modern materials, operation in conditions of explosion and fire hazard, absence of harmful electromagnetic radiation, no need to dispose of batteries, etc.) [2].

A combined power plant using a PD and an ICE provides for different layout schemes for placing units. When using a CEU on a vehicle, a combined scheme looks better, in which the PD and the ICE are located in the same housing, but work alternately by changing the operation of the intake, ignition (if available) and power supply systems. With such a scheme, the heat released as a result of the operation of the ICE is used to heat the compressed air and maintain the heat balance. The heat can be used from heated parts of the ICE, cooling and oil systems, exhaust gases, and heat accumulators.

During the operation of the power plant, two operating modes can be distinguished. The first is the PD operating mode at a rotation frequency of 0 - 800 min-1; the second is the ICE operating mode when the shaft rotation frequency