Література

1. Osetrov, O., Chuchumenko, B., Polivyanchuk, A. and Korohodskyi, V. (2021) "Mathematical Modeling and Computational Study of a Passenger Car Dynamics During Acceleration", 25th international scientific conference TRANSPORT MEANS 2021 6-8 October, 2021
2. Кравченко, С.С. Обґрунтування параметрів послідовної гібридної силової установки легкового автомобіля / О.О. Осетров, С.С. Кравченко, Б.С. Чучуменко // Двигуни внутрішнього згоряння – 2022. – № 1 . – С. 78-85.

Arsenii Buchok, Master, Pridneprovsky State Academy of Civil Engineering and Architecture, arseny.buchok.222@gmail.com
Tatyana Kolesnikova, Candidate of Technical Sciences, Associate Professor, Pridneprovsk State Academy of Civil Engineering and Architecture, tnk1403@ukr.net
Vitalii Herasymenko, Master, Pridneprovsky State Academy of Civil Engineering and Architecture, vgerasimenko08@gmail.com
Valentyn Babych, Master, Pridneprovsky State Academy of Civil Engineering and Architecture, babich060@gmail.com

ANALYSIS OF MODELING METHODS FOR CREATING A RODLESS INTERNAL COMBUSTION ENGINE WITH CYLINDER DEACTIVATION

Introduction.

Today, one of the most significant stimuli for the development of the automotive industry is the tightening of safety standards, which includes the environmental safety of vehicles. Over the past 40 years, engineers and researchers at leading automakers, together with the chemists who determine fuel technologies, have achieved many significant results

The development of a fundamentally new design of an internal combustion engine, despite its novelty, relies on already known operating processes and design solutions. Therefore, it is necessary to distinguish between the issues that require in-depth study and those whose solution can be obtained on the basis of already known results and methods from related engineering and scientific branches.

Improvement of the working process requires new designs of individual components and mechanisms in the internal combustion engine. As a rule, automakers rarely depart far from the established designs and introduce fundamentally new elements in limited quantities. This makes it possible to reduce time and money spent on improvement and development of the engine design and move to mass production in a shorter period of time.

One of the design schemes that create prospects for the realization of compression ratio control or cylinder deactivation by stopping the pistons is an engine with a crank-crank mechanism (CCM) of piston motion conversion [1].

In this paper the aim was to analyze and determine those modeling methods that meet the objectives of a comprehensive study in a minimum time of the design and operational processes occurring in a new crankless engine, up to the implementation of its control system and obtaining an assessment of the resulting effect of improvements.

Problem statement. When creating an internal combustion engine, the first important point is the working process in the engine cylinder. In principle, the scheme of the engine in the crank-crank mechanism is a conventional piston engine, which has lower mechanical losses and due to other kinematics slightly improved working process. Therefore, an in-depth study of the working process, for example, its modeling by methods of digital hydrodynamics or with the help of multizone models of turbulent combustion does not seem necessary. In addition, such methods are rather resource-intensive both in terms of computing power and modeling time.

Basic material. The exception may be cases when on the basis of design development a result has been achieved that makes it possible to realize a fundamentally new variant of the operating process. This is possible in the implementation of the engine with a variable compression ratio to realize ignition from the compression of a homogeneous gasoline mixture. Such ignition was observed during experimental studies in the two-stroke version of the crankless engine with variable compression ratio. A deeper study of the combustion process with compression ignition has been most actively studied during the last 20-25 years [2; 3]. But the realization of such methods of mixture ignition is usually considered on the basis of already worked out design solutions. Its modeling in an engine of fundamentally new design seems inexpedient.

However, one important aspect of the development of modern complex technical systems is the availability of such computer models that will allow the control system of an unconventional engine to be developed in the shortest possible time. This requires high-level dynamic models that have an acceptable simulation speed. High level models cannot always fully meet the research objectives. For example, engine models used for modeling in the design of vehicle control systems produce only the external performance of the internal combustion engine, such as effective power, effective torque, and fuel consumption. In the case of cylinder deactivation, the model must be based on the performance of a single cylinder, and in the considered variant of the study of working processes in the mechanisms of the engine with the CCM it is necessary to know the pressure in the cylinder, inertia forces, etc. Thus, descending to modeling at a lower level, for research and design purposes it is reasonable to stop at the description of working processes in the cylinder by a system of differential equations continuous in time [4]. Such a classical variant can be a compromise, allows to implement simulation modeling and meets the above requirements.

The second point to be emphasized is the study of working processes in a technical system, which is the engine. Obviously, when considering new designs, it is important to understand the interaction of individual elements, the forces that arise, and the time frames of interaction processes. For example, when the cylinder is disconnected by stopping the piston there will be a break in the kinematic connection in the CCM and it is important to know the time during which the transient process of stopping the piston or its connection will take place.

Modern mathematical methods and software products allow to perform geometric modeling of parts and units of the mechanism and to calculate by finite element methods the stresses and deformations occurring in the unit. But modeling of kinematic linkage breaking in available products is problematic. In addition, combining different systems within a single model is also often impossible. The finite element method is a low-level method. It is very specialized and resource-intensive. Of course, it can be used for topological optimization of a part or for strength analysis. But for strength analysis, it is necessary to obtain information on the effects of forces beforehand. For the study of the system as a whole, it is not reasonable to consider this method. In this case, it is better to use solid modeling systems. In this case, the amount of computational work is reduced due to the simplification of models.

Based on the set objectives, in particular, the assessment of the resulting effect and the creation of conditions for the development of the management system, the model should be comprehensive and simulation. Such models can be created in the Matlab Simulink environment. An important feature of this software is the integration of a large number of mathematical methods for solving general and specialized engineering and scientific problems.

The application of such products allows modeling at different levels the working processes in all systems of interest. Thus, simulation models of a 4-cylinder engine with a crank-coupling mechanism, the drive of the cylinder shutoff mechanism, the interaction of parts in the lock of the shutoff mechanism, etc. were obtained. Such models already at the preliminary stage of research allowed to evaluate a number of important points in the operation of mechanisms and systems.

An important aspect of modeling is the assessment of model adequacy. The more complex the model is, the more difficult it is to obtain universal dependencies working in all conditions.

It is necessary to pay attention to the fact that in order to obtain an adequate model, identification should be carried out on data reflecting different modes of operation of the modeling object. In addition, the part of data not involved in identification should be used for model verification. Thus, identification and optimization methods are an integral part of the methodology of engine development of a promising design.

It is necessary to dwell separately on the application of artificial intelligence. Artificial neural networks themselves are one of the types of models that require the application of identification methods. Here it does not make sense to single out any separate methods related to training or types of networks. Different artificial neural networks can be used in different tasks, from feedforward networks to deep RNN or convolutional networks, and different methods underlying the algorithms are used in training: back propagation of error, reinforcement learning and others. The important thing is that artificial neural networks in principle, solving their typical problems of regression and classification, can be applied to increase the speed of computation in modeling and debugging of high-level models in the process of preparation and development of the control system as surrogate models of engine systems.

The list of methods listed above is naturally not exhaustive and represents, in our opinion, the basis that allows us to achieve an acceptable result quite quickly in the development of a new design engine with cylinder deactivation: to create simulation models for research and debugging of individual assemblies and mechanisms and combine them into a common engine model to evaluate the effectiveness of the development and creation of the engine control system.

Conclusion

The conducted analysis allowed us to identify the main methods promising for modeling of the developed engine of a new design with cylinder deactivation: for obtaining simulation models, research and debugging of individual assemblies and mechanisms, obtaining a top-level model of the engine to assess the effectiveness of development and creation of a control system.

Literature

1. Mishchenko N.I., Khimchenko A.V., Yurchenko Yu.V., Suprun V.L. Kolesnikova

T.N. 8-Ye Lukaninskiye chteniya. Problemy i perspektivy razvitiya avtotransportnogo kompleksa, Moscow, MADI, 2019, pp. 410–422.

2. Duan X., Lai M.-Ch., Jansons M., Guo G., Liu J. Toplivo, 2021. vol. 285. P. 119142.

3. Bendu H., Murugan S. Obzory vozobnovlyayemoy i ustoychivoy energetiki, 2014, vol. 38, pp. 732-746.

4. Jung, L. Modeling of dynamical systems. - Englewood Cliffs, New Jersey: Prentice Hall PTR, 1994. - ISBN 0135970970