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IMPROVING THE PROCESS OF FILLING CYLINDERS WITH AIR BY MODERNIZING THE INTAKE MANIFOLD

Purpose. To increase the mass flow rate of air through a forced diesel engine of type 6 Ch 15/15 by modernizing the design of the intake manifold.

Methodology. A comparative numerical study of the conditions for filling cylinders with air for different design variants of the intake manifold when the engine is operating at rated power is carried out. The problem is considered in a three-dimensional non-stationary formulation. To describe the boundary conditions, the results of the calculation of the working process are additionally used, namely, the pressure pulsation in front of the intake valves during the cylinder filling process.

Findings. It has been established that using newly designed intake manifolds can increase the mass flow rate of air through the engine cylinders by 9 %. In operation, this will allow one, with minimal redesign (only the intake manifolds are upgraded), to improve engine operating conditions, primarily to increase engine power, increase effective efficiency, and improve torque characteristics, especially at partial load conditions. This will increase the maneuverability of the vehicle and improve its consumer qualities.

Originality. The study made it possible to investigate the influence of the intake manifold design on the conditions of cylinder filling with air and to develop scientific and practical recommendations for improving the technical and economic performance of the engine, especially with an increase in its level of boost.

Practical value. Improving the conditions for filling the cylinders with air will increase the mass flow rate and cycle fuel supply and, accordingly, enhance the power of a forced diesel engine, increase the effective efficiency, and improve its performance.

Keywords: *diesel engine, intake manifold, filling process, mass airflow*

Introduction. Improving the design of modern transport engines is a highly complex and costly process [1, 2]. Refining the design of existing engines also requires considerable time, primarily when experimental research methods are used [3].

The development of modern numerical methods [4], implemented in software complexes, allows comparative numerical experiments to be carried out with minimal expenditure of time and resources [5, 6]. This approach significantly reduces the time required to develop a new design and refine an existing one [7].

A distinctive feature of the numerical methods and software complexes used is their dependence on the accuracy and adequacy of the boundary conditions (BC) described in the problem and, accordingly, on the experience of modelling specialists [8, 9]. Therefore, to increase the accuracy of the results obtained, it is necessary to use an approach in which the results of experimental studies and calculations (our own and those of other authors) are used to verify mathematical models.

Performing a series of test calculations is necessary to set up a mathematical model and select specific semi-empirical coefficients. The results obtained are analysed, and the values of the varied parameters are refined to approximate the experimental results.

Improvements in methods and approaches to mathematical modelling of mixing and combustion processes make it possible to increase the accuracy and informativeness of research results into complex physical and chemical processes [10, 11].

Recently, as a rule, when creating a new engine design or its components, an approach is used whereby a series of comparative numerical experiments are carried out, the research results are analysed and summarised, and then, for the best design option, comparative non-engine and engine tests are carried out.

Using non-motorised stands for static blowing of engine intake manifolds with compressed air allows for a quick assessment of the influence of design factors on hydraulic resistance and, accordingly, the perfection of the intake manifold design.

The results of non-engine experiments can also be used to verify the mathematical model of air flow in the intake manifold.

However, given the complexity of gas-dynamic processes in the intake manifolds of V-shaped engines, the research should consider the effect of pressure fluctuations in front of the intake valves, which occur when a full-size engine is running. Therefore, even engine tests on a single-cylinder installation do not provide all the information needed to assess the conditions for filling the cylinders with fresh air.

Final tests must be carried out on a full-size engine, which allows all factors affecting the cylinder filling process to be considered.

Improving the conditions for filling the cylinder with fresh air allows you to increase the mass of air entering the engine cylinders, accordingly, it increases the cycle fuel supply and, subsequently, the level of its forcing [12]. This will improve the engine's consumer qualities and increase its manoeuvrability for the vehicle [13].

Literature review. Many automotive companies focus on improving their internal combustion engines' environmental and technical-economic performance.

To this end, more sophisticated engine control systems are used, with the installation of additional sensors (for example, a second oxygen concentration sensor in the exhaust gases – after the catalytic converter, or a sensor that signals the movement of the car on uneven surfaces, which causes additional vibrations of the car and engine).

New materials, alloys, and new designs are also used, such as bimetallic cylinder blocks (made of magnesium alloy with an aluminium alloy frame), significantly reducing the engine's weight and fuel consumption.

Car manufacturers are also trying to optimise the thermal state of the engine and the entire engine compartment (to reduce fuel consumption and improve environmental performance) by using various controllable flaps and deflectors.

Reducing toxic emissions from exhaust gases can be achieved in various ways, mainly by using hybrid power plants, the organisation of efficient internal combustion engines running on biofuels, and the refinement of existing internal combustion engine designs (when running on standard hydrocarbon fuels). The latter method is the most complex and costly.

Another current trend is to reduce carbon dioxide emissions, which can be achieved in power plants by lowering oil fuel consumption and/or reducing their share when using biofuels [14].

This approach requires changing the engine settings (when using biofuels within the range of up to 20%), and at higher concentrations, it is necessary to adjust the control program of the electronic engine control unit and, possibly, make changes to its design.

For transport diesel engines with a wide range of applications, with a mechanical high-pressure fuel pump and without electronic control, such as the 6Ch 15/15 engine, the most appropriate approach to increasing the level of forced induction of the internal combustion engine and improving its technical and economic performance is to increase the mass flow of air (by modernising the design of the intake manifold and/or using gas turbine supercharging).

Today, many research papers are devoted to studying the influence of the intake manifold design on the conditions of filling the cylinders with fresh air [15, 16]. As a rule, these studies are devoted to the use of wave phenomena in the intake manifold (resonance supercharging) or to reduction of the hydraulic resistance of the flow part of the intake manifold by reducing the roughness of the inner surface and 3-D profiling of the manifold channels [17].

The implementation of such approaches allows (within certain limits) for effective improvement of the conditions for filling the cylinders with fresh air, but radical changes can be achieved either by using gas turbine supercharging or by ensuring a normal air pressure level in the intake manifolds, which will provide better conditions for filling the cylinders.

A distinctive feature of 6Ch 15/15 transport diesel engines is the very limited volume of the engine and transmission compartment, which imposes certain restrictions on the design of the engine intake manifolds. Therefore, searching for rational ways to modernise the existing design of the intake manifolds of such engines is an extremely difficult and important task.

Unsolved aspects of the problem. As can be seen from the results of the literature review, choosing a way to increase the mass flow of air through the engine cylinders, taking into account the design features of the internal combustion engine and the vehicle, is a highly complex and relevant scientific problem, and its solution will improve the technical, economic and environmental performance of the engine with minimal changes to its design.

Purpose. The work aims to increase the mass flow of air through a forced induction diesel engine of the 6Ch 15/15 type by modernising the design of the intake manifolds.

To achieve this goal, the following tasks were set and solved in the work:

- to conduct a literature and patent search on approaches to modernising the intake manifolds of transport internal combustion engines to increase the mass flow rate of air;
- to form the geometry and calculation grid for the intake manifold (basic and modernised design);
- to calculate the working process of the studied diesel engine at rated mode for further description of the boundary conditions in the sections of the intake manifolds connected to the intake ports of the cylinder heads;
- to calculate the air flow process in the intake manifold of the basic and modernised designs in a three-dimensional unsteady setting;
- to analyse the results obtained and evaluate the mass air flow through the intake manifolds of a V-shaped transport diesel engine (6Ch 15/15);
- to form conclusions and recommendations on increasing the mass flow rate of air through the engine cylinders by modernising the intake manifolds.

The object of the study is the filling process of a V-shaped transport diesel engine (6Ch 15/15) operating at rated power with $Ne = 223$ kW at a crankshaft speed of $n = 2{,}600$ min^{-1}.

Methods. The brief technical characteristics of the 6Ch 15/15 diesel engine are given in Table 1.

For the comparative computational study, the geometry and flow section of the intake manifolds of the standard and modernised designs were formed (a pipe was added between the outer elbows for the *3rd* and *6th* cylinders, which provides a gas-dynamic connection between the intake manifolds). The boundary conditions of the gas dynamics problem were described, and comparative calculations of the air flow process in the intake manifolds were performed in a non-stationary three-dimensional setting.

The geometry of the flow part of the intake manifolds (standard and modernised design) for comparative numerical research was formed using CAD complexes in a three-dimensional setting. For further numerical modelling, the 3-D geometry was adapted (plugs were installed in it at certain inlet and outlet sections of the intake manifolds), which sealed (closed) the internal volume of the flow part from the environment. Then,

Table 1

Brief technical characteristics of the base diesel engine 6Ch 15/15

No.	Parameter	Unit of measurement	Value
1	Nominal power, *Ne*	kW	223
2	Rotational speed corresponding to nominal power mode, *n*	min^{-1}	2,600
3	Cylinder diameter, *D*	mm	150
4	Piston stroke, *S*	mm	150
5	Compression ratio, ε	–	15.8
6	Cylinder firing order	–	1l-1p-2p-2p-3l-3p
7	Working volume	l	15.9
8	Overall dimensions (*L* × *W* × *H*)	mm	791 × 1,150 × 748

the boundary conditions of the gas flow problem were described at these inlet and outlet sections.

The geometry of the flow part of the intake manifolds of the standard design is shown in Fig. 1, and that of the modernised design is shown in Fig. 2 [18].

A calculation grid (initial) was formed for comparative numerical modelling, which describes the geometry of the flow part of the standard and modernised intake manifolds, shown in Figs. 3 and 4.

In refining the mathematical model to describe the air flow process in the flow part of the engine intake manifolds, the com2putational grid was refined in areas with sharp changes in geometry and near solid walls.

Description of boundary conditions for comparative design study. For further numerical modelling, when describing the boundary conditions of the gas dynamics problem, boundary conditions were set at the inlet to the flow section of the intake manifold – pressure and temperature (environmental parameters) and at the outlet of the flow part, air pressure fluctuations arising during the movement of the intake valves (the dependence was obtained from the results of calculating the working process of a 6Ch 15/15 diesel engine in an identical mode) – Fig. 5, and the type of boundary conditions is shown in Fig. 6 and Table 2.

The pressure fluctuations of fresh air at the outlet of the flow part of the intake manifolds were set taking into account the order of cylinder operation (Table 1).

For the second row intake manifold, the boundary conditions and the method of their description in the

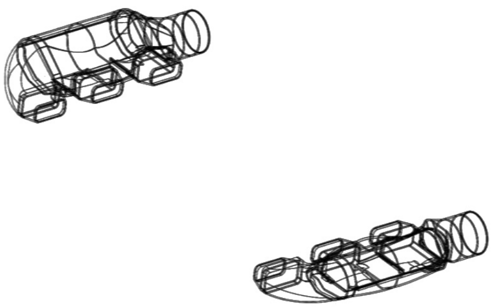

Fig. 1. 3-D geometry of the flow section of the intake manifolds of the standard design

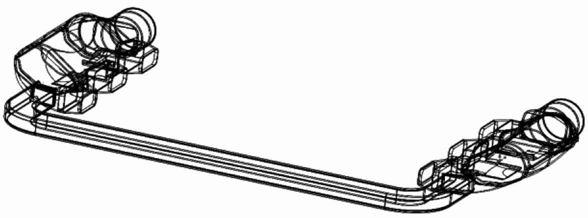

Fig. 2. 3-D geometry of the flow section of the intake manifolds of the modernised design

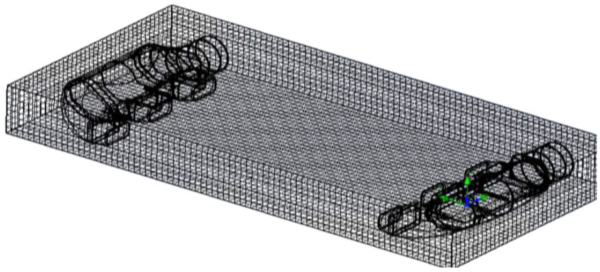

Fig. 3. Initial calculation grid describing the configuration of the intake manifold of the standard design

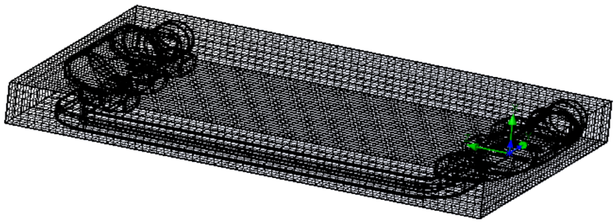

Fig. 4. Initial calculation grid describing the configuration of the intake manifolds of the modernised design

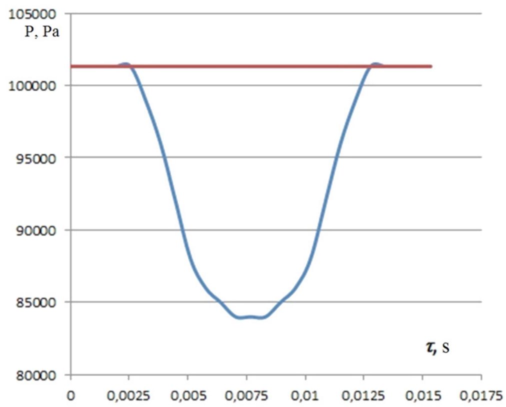

Fig. 5. Change in boundary conditions during air flow at the outlet of the intake manifold channels during cylinder filling (mode with Ne = 223.7 kW, at n = 2,600 min^{-1})

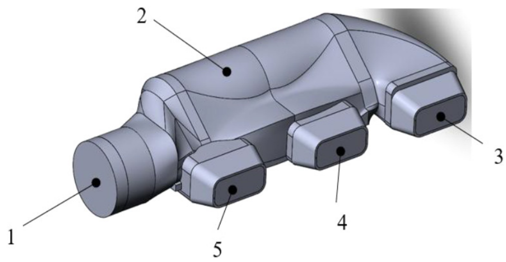

Fig. 6. Diagram of boundary conditions at the inlet and outlet of the manifold channels during cylinder filling

Table 2

Values of boundary conditions at the inlet and outlet of the intake manifold channels during cylinder filling

No.	1	2	3	4	5
Parameter	Approximate environment, Ro, To	Roughness, wall temperature	Ideal wall*	Ideal wall*	Ideal wall*
Note		According to drawings and operating conditions	Pressure pulsations at the outlet (Figs. 5, 6)		

* *variable parameter (depending on the order of cylinder operation)*

problem were identical (considering the sequence of cylinder operation).

Equations of the mathematical model describe the fresh air movement process in the intake manifolds' flow section. In this work, the following mathematical models and equations were used for comparative numerical modelling of the fresh air flow process in the flow section of the intake manifolds of the diesel engine under study.

A standard k-e turbulence model was used to describe the turbulent air flow process in the intake manifolds' flow part.

The Navier-Stokes equations

$$\rho\left(\frac{\partial \nu_i}{\partial t}+\nu_k\frac{\partial \nu_i}{\partial x_k}\right)=-\frac{\partial p}{\partial x_i}+ \\ +\frac{\partial}{\partial x_k}\left\{\eta\left(\frac{\partial \nu_i}{\partial x_k}+\frac{\partial \nu_k}{\partial x_i}-\frac{2}{3}\delta_{ik}\frac{\partial \nu_i}{\partial x_i}\right)\right\}+\frac{\partial}{\partial x_k}\left(\zeta\frac{\partial \nu_l}{\partial x_l}\delta_{ik}\right), \quad (1)$$

where η is the dynamic viscosity coefficient; ζ is the volumetric viscosity; δ_{ik} is the Kronecker delta; $i = 1,2,3$; t is time; ρ is density.

Continuity equation

$$\frac{\partial \rho}{\partial t}+div(\rho\vec{u})=0, \quad (2)$$

where $\vec{u}$ is the gas velocity.

For numerical modelling of unsteady turbulent flow, it is necessary to average the Navier–Stokes equations over time, while the pulsating quantity. φ is averaged according to the following dependence

$$\overline{\varphi}(\vec{x},t)=\frac{1}{T}\int_{t T/2}^{t+T/2}\overline{\varphi}(\vec{x},\tau)d\tau, \quad (3)$$

and the pulsating component (φ')

$$\varphi'(\vec{x},t)=\varphi(\vec{x},t)-\overline{\varphi}(\vec{x},t).$$

Models of k–ε turbulence

$$\begin{cases}\frac{\partial}{\partial t}(\rho\cdot k)+\frac{\partial}{\partial x_i}(\rho\cdot k\cdot\overline{u}_i)=\frac{\partial}{\partial x_j}\left[\left(\mu+\frac{\mu_t}{\sigma_k}\right)\frac{\partial k}{\partial x_j}\right]+ \\ \quad +G_k+G_b-\rho\cdot\varepsilon-Y_M+S_k, \\ \frac{\partial}{\partial t}(\rho\cdot\varepsilon)+\frac{\partial}{\partial x_i}(\rho\cdot\varepsilon\cdot\overline{u}_i)=\frac{\partial}{\partial x_j}\left[\left(\mu+\frac{\mu_t}{\sigma_\varepsilon}\right)\frac{\partial \varepsilon}{\partial x_j}\right]+ \\ \quad +G_{1\varepsilon}\frac{\varepsilon}{k}\left(G_k+C_{3\varepsilon}\cdot G_b\right)-C_{2\varepsilon}\cdot\rho\frac{\varepsilon^2}{k}+S_\varepsilon.\end{cases} \quad (4)$$

where k, ε are density and dissipation rate of turbulent vortices.

Presentation of the primary material and obtaining scientific results. A comparative numerical study was performed in a three-dimensional unsteady setting in Cartesian coordinates.

The results of a comparative calculation of the air flow process in standard and modernised intake manifolds of a diesel engine are shown below (Figs. 7–11).

First, the air flow process in the flow part of the intake manifold of the base design was considered. For the intake manifold of the basic design, the distribution of air flow velocity is shown in Fig. 7.

The results shown (Fig. 7) indicate that the maximum flow velocity values are observed in the area where the intake manifold connects to the channels in the cylinder head, with the flow velocity reaching 140 m/s. In the central part of the intake manifold, the flow velocity varies from 20 to 60 m/s, and at the inlet, it ranges from 10 to 15 m/s.

The distribution of the air flow velocity (in the form of diagrams in cross-section) for the intake manifold of the base design is shown in Fig. 8.

As can be seen from the results shown in Fig. 8, due to the viscous friction of the air against the walls of the flow part of the intake manifold, the flow velocity near the solid walls decreases to almost 0 m/s, and in the central part it varies from 27 to 55 m/s.

The visualisation of the air flow velocity distribution (in the form of flow lines) for the intake manifold of the new design is shown in Fig. 9.

For the intake manifold of the modernised design, an increase in air flow velocity is observed where the intake manifold connects to the channels in the cylinder head, with the flow velocity reaching 151 m/s (in individual calculation cells). In the central area of the intake manifold, the flow velocity varies from 30 to 65 m/s, and at the inlet, within 15–20 m/s.

The air flow velocity distribution (in the form of diagrams in cross-section) for the intake manifold of the new design is shown in Fig. 10.

Fig. 10 shows the distribution of air flow velocity in the cross-section of the intake manifolds of the new de-

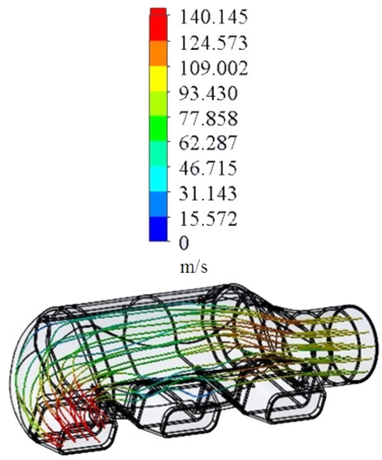

Fig. 7. Air flow velocity distribution for the intake manifold of the base design, m/s

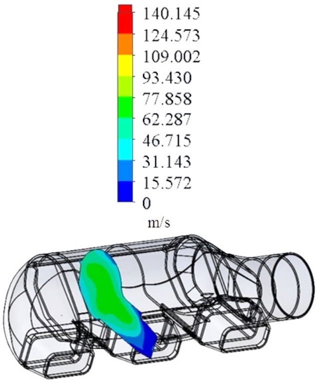

Fig. 8. Air flow velocity distribution for the intake manifold of the base design, m/s (in the form of diagrams in cross-section)

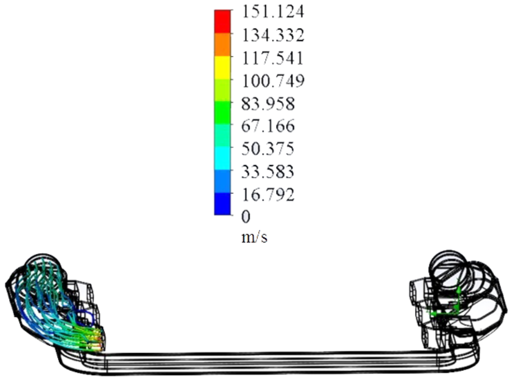

Fig. 9. Air flow velocity distribution for the intake manifold of the modernised design, m/s (in the form of flow lines)

sign by a vertical plane. Depending on the order of cylinder operation, the air flow velocity in the extreme elbows of the intake manifolds changes (the elbow of the *3rd* right cylinder from 16 to 65 m/s), and in the elbow of the *3rd* left cylinder it is almost equal to 0 m/s, since at this moment the intake valves are closed.

A connecting pipe between the outer elbows of the intake manifolds (3L and 3P cylinders) of the new design improves the conditions for filling the cylinders with fresh air. This is due to reduced hydraulic resistance during air pulsations in the intake manifolds of the engine cylinders' left and right rows.

The graph of air mass flow pulsation in the intake manifolds of a 6Ch 15/15 diesel engine at rated power is shown in Fig. 11.

As can be seen from the results shown (Fig. 11), when air flows through the intake manifold of the base design during engine operation, there is an air deficit in the elbows, which are connected to the channels in the heads of the *5th* and *6th* cylinders, which worsens the technical, economic and environmental performance of the engine. These phenomena are explained by the occurrence of pressure pulsations in the flow parts of the left and right row intake manifolds when the intake valves are opened and closed, as well as by local hydraulic resistance and a lack of air in the outer cylinders (especially the *3rd* right cylinder).

For the intake manifolds of the new design, there is an improvement in the conditions for filling the cylinders with fresh air (especially for the *2nd* left, *2nd* right, *3rd* left and *3rd* right). A slight decrease in air mass flow is observed in the *1st* right cylinder (Fig. 11), but overall, the air mass flow through the intake manifolds of the new design increases by almost 9 %.

Such local unevenness in air flow through certain cylinders of a multi-cylinder, especially a V-shaped engine, can be reduced using pipes (elbows) of different lengths. Or by using intake manifolds with variable geometry of the flow part. This makes it possible to achieve an efficient process of filling the cylinders with fresh air in almost all engine operating modes.

The generalised results of the comparative calculation study are presented in Table 3.

Thus, as can be seen from the results presented (Fig. 11 and Table 3), the modernisation of intake manifolds has a positive effect on the conditions for filling the cylinders with fresh air, which in operation will increase the adequate power of the engine and improve its technical, economic and environmental performance.

Using 3-D modelling technologies to conduct comparative numerical experiments allows for a quick assessment of the impact of design and operating factors on the operating conditions of individual engine components, parts, and the engine.

The approach considered in the study to assess the impact of design factors (intake manifold options) on the conditions for filling the cylinder with fresh air showed that the solutions proposed by the authors allow for effective improvement of the cylinder filling

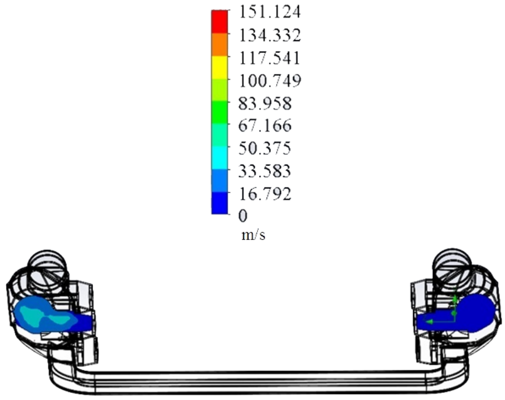

Fig. 10. Air flow velocity distribution for the intake manifold of the modernised design, m/s (in the form of diagrams in cross-section)

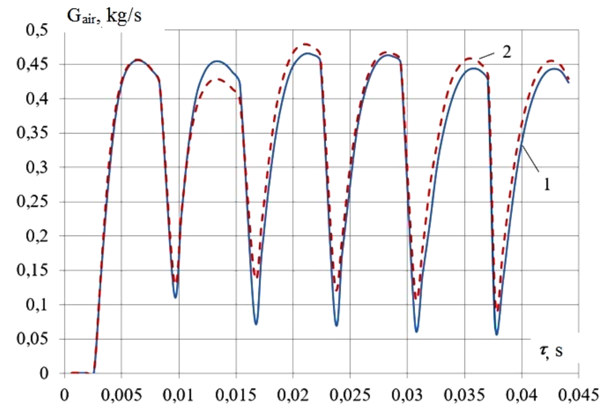

Fig. 11. Pulsation of mass air flow in the intake manifolds of a 6Ch 15/15 diesel engine at rated power

1 – basic design; 2 – modernised design

Table 3

Summary results of the comparative computational study

Basic design						
No. of cylinders	1L	1P	2L	2P	3L	3P
Air mass flow rate, kg/s	0.44	0.452	0.465	0.463	0.444	0.44
New design						
No. of cylinders	1L	1P	2L	2P	3L	3P
Air mass flow rate, kg/s	0.441	0.428	0.479	0.467	0.457	0.45

conditions and are a promising approach to solving the problem.

To further improve the process of filling cylinders with fresh air, it is necessary to study the influence of the intake manifold design on different operating modes, not only on the nominal power mode.

Conclusions. The goal of the work has been achieved. Using 3-D modelling technologies, the influence of the new design of intake manifolds on increasing the mass flow of air through the engine cylinders was analysed.

A literature and patent search was conducted on approaches to modernising the intake manifolds of transport internal combustion engines to increase the mass flow of air, a design option was selected that allows improving the filling conditions with minimal changes to the design of the intake manifolds, which will make it possible to implement the proposed design in the limited space of the vehicle' s engine and transmission compartment.

The geometry and calculation grid for the intake manifold (basic and modernized design) were formed.

The presented study calculates the working process of a diesel engine at nominal mode. The description of boundary conditions in the intake manifold sections connected to the intake channels of the cylinder heads is carried out using a method where the model describes the change in air pressure when the intake valves are opened/closed.

Comparative numerical studies of the air flow process in the intake manifolds of the basic and modernized designs in a three-dimensional unsteady state setting were carried out, considering the order of cylinder operation. Based on the calculation results, the change in velocity and pressure of the air flow in the flowing part of the intake manifolds of the standard and modernized designs and pressure fluctuations at the inlet to the intake manifolds during engine operation in the studied mode were determined.

As a result of a comparative numerical study, the change in mass air flow through the intake manifolds of a V-shaped transport diesel engine (6Ch 15/15) of the basic and new designs was evaluated. As can be seen from the results, the use of a pipe connecting the intake manifolds of the *3rd* left and *3rd* right cylinders is an effective design solution that allows for a 9 % increase in air mass flow.

An increase in engine efficiency will be observed (within a certain range) with an increase in crankshaft speed. These phenomena are associated with an increase in the inertia of the fresh air flow as the crankshaft speed increases.

When the engine is operating at reduced crankshaft speeds (e.g. 1,200–2,000 rpm), the advantages of using the connecting pipe of the proposed design will be less significant. To overcome this disadvantage, it is necessary to increase its diameter, or use connecting pipes of a different design (larger volume), or use intake manifold designs with an adjustable flow section (depending on the engine operating mode).

In further work, the authors plan to consider the effect of crankshaft rotation speed (operating factors) on improving the conditions for filling cylinders with fresh air and various design options for connecting pipes.

In the future, it is planned to place the pipes in several options: above the engine, in the plane of the cylinder heads and below the engine. The choice of the best option for the placement of connecting pipes, their dimensions (length, configuration and diameter) and the possibility of installation in the engine compartment will ensure an increase in the mass flow of air through the engine and, accordingly, increase its power when adjusting the cycle fuel supply.

Also, considering international experience, further work is planned to study the effect of other options for the design of intake manifolds on changes in air mass flow and conditions for filling the cylinders of a V-shaped diesel engine.

As can be seen from the study, the use of turbocharging for the engine in question is a very promising way to increase the mass flow of air and, accordingly, increase engine power. However, in practice, this can lead to uncontrolled growth in maximum combustion pressure and increased rigidity of the process, which negatively affects the engine's service life and reliability.

The search for promising ways to increase the power of transport engines while ensuring high technical, economic, and environmental performance and engine life is an up-and-coming area of research [19, 20].

As can be seen, this is promising for transport engines, which require increased power while reducing their weight and size. Increasing the litre power of a vehicle's engine allows for greater manoeuvrability and, thus, better performance. It also allows for greater speed when travelling on different types of terrain and overcoming certain obstacles (ditches, fords, etc.).

For further improvement of the air supply system, it is necessary to profile the inlet channels in the cylinder heads, reduce the roughness of the internal surfaces of the flow part, and install additional sensors (mass air flow) and a control system that will allow one to organise a change in the geometry of the flow part of the inlet manifolds, depending on the engine operation mode.

This will reduce hydraulic losses at the intake. Similar measures should then be taken to minimise hydraulic losses at the exhaust.

Combining such solutions and approaches will improve the process of filling the cylinders with fresh air. However, with an increase in the mass flow rate of air through the cylinders, the air velocity in the cylinders themselves will increase, which at certain speeds can lead to its over-swirling and, accordingly, to the deformation of the fuel flames during injection.

This can lead to a local decrease in the excess air coefficients (in direct contact with neighbouring fuel flares) and a decrease in the completeness of fuel combustion. This process (disruption of the mixture formation process due to the over-swirling of fresh air in the engine cylinder) is accompanied by a sharp deterioration in the internal combustion engine's environmental, technical, and economic performance.

To avoid such side effects, it is necessary to take a comprehensive approach to refining the engine design and coordinate the velocity of fresh air in the cylinders with the trajectories of fuel flames during diesel fuel injection.

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Поліпшення процесу наповнення циліндрів повітрям шляхом модернізації впускного колектору

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Мета. Збільшення масової витрати повітря крізь форсований дизельний двигун типу 6 Ч 15/15 шляхом модернізації конструкції впускного колектору.

Методика. Проведене порівняльне чисельне дослідження умов наповнення циліндрів повітрям для різних конструктивних варіантів виконання впускного колектору при роботі двигуна на режимі номінальної потужності. Задача розглядається в тривимірній нестаціонарній постановці. Для опису граничних умов, додатково, використовуються результати розрахунку робочого процесу, а саме – пульсація тиску перед впускними клапанами в процесі наповнення циліндра.

Результати. Встановлено, що при використанні впускних колекторів нової конструкції вдається збільшити масову витрату повітря крізь циліндри двигуна на 9 %. В експлуатації це дозволить, з мінімальною переробкою конструкції (модернізується тільки впускні колектори), поліпшити умови роботи двигуна, в першу чергу збільшити потужність двигуна, підвищити ефективний ККД та поліпшити характеристику крутного моменту, особливо на режимах часткового навантаження. Це дозволить підвищити маневреність транспортного засобу і поліпшить його споживацькі якості.

Наукова новизна. Дослідження дозволило вивчити вплив конструкції впускного колектору на умови наповнення циліндрів повітрям та розробити науково-практичні рекомендації з підвищення техніко-економічних показників двигуна, особливо зі зростанням рівня його форсування.

Практична значимість. Поліпшення умов наповнення циліндрів повітрям дозволить збільшити масову витрату повітря і циклову подачу палива та, відповідно, підвищити потужність форсованого дизельного двигуна, збільшити ефективний ККД і покращити його експлуатаційні показники.

Ключові слова: *дизельний двигун, впускний колектор, процес наповнення, масова витрата повітря*

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