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THE ENERGY EFFICIENCY ANALYSIS OF DIESEL ENGINES OF OIL AND GAS TECHNOLOGICAL TRANSPORT CONVERTED IN TO ALTERNATIVE FUELS

АНАЛІЗ ЕНЕРГОЕФЕКТИВНОСТІ ДИЗЕЛЬНИХ ДВИГУНІВ НАФТОГАЗОВОГО ТЕХНОЛОГІЧНОГО ТРАНСПОРТУ КОНВЕРТОВАНИХ НА АЛЬТЕРНАТИВНІ ВИДИ ПАЛИВА

The development experience of foreign and domestic specialists of converting diesel engines into monogas with spark ignition was studied. Disadvantages and advantages of use as motor gas fuel for diesel engines are analyzed. Ways of converting diesel units of the oil and gas industry to liquefied and compressed gas fuels according to various schemes are formulated.. Modelling of the energy efficiency of diesel units of the oil and gas industry during the conversion of diesel drives to the use of alternative fuels was performed. It has been found that when converting diesel engines of power drives of the oil and gas industry to gas motor fuel, it is possible to ensure torque, fuel consumption, and power indicators that are practically identical to the similar indicators of diesel engines before their conversion to gas. It has been established that when converting diesel units of the oil and gas industry to gas motor fuel, when converting diesel engines to a propane-butane mixture, in comparison with natural gas, it will be possible to provide better fuel, power, and environmental characteristics. It is *proved that the simulation results are in good agreement with the practical results already obtained on automobile and technological transport.*

***Keywords**: alternative fuel, diesel engine, drilling rig, gas refurbishment, energy efficiency.*

Досліджено досвід розробок закордонних і вітчизняних фахівців в напрямку конвертації дизельних двигунів у моногазові з іскровим запалюванням. Проаналізовані недоліки та переваги використання в якості моторного газового палива для дизельних двигунів. Сформульовані шляхи переобладнання дизельних агрегатів нафтогазової галузі на зріджені та стиснуті газові палива за різними схемами. Виконано моделювання енергоефективності дизельних агрегатів нафтогазової галузі при конвертації дизельних приводів на використання альтернативних палив. З'ясовано, що при конвертації дизельних двигунів силових приводів нафтогазової галузі на газомоторне паливо можна забезпечити показники крутного моменту, витрати палива, потужності практично тотожні аналогічним показникам дизельних двигунів до їхньої конвертації на газові. Встановлено, що при переобладнанні дизельних агрегатів нафтогазової галузі на газомоторне паливо при конвертації дизельних двигунів на пропан-бутанову суміш, у порівнянні з природним газом, вдасться забезпечити кращі паливні, потужнісні та екологічні характеристики. Доведено, що результати моделювання добре узгоджуються з практичними результатами, які вже одержані на автомобільному та технологічному транспорті.

***Ключові слова**: дизельний двигун, альтернативні палива, технологічний транспорт, енергоефективність, переобладнання на газ.*

Problem's Formulation

Oil reserves in the bowels of the Earth are constantly decreasing. According to the most optimistic forecasts, with the existing volumes of explored reserves and volumes of production, humanity will have enough oil for about 50 years. Gas engine fuels are the second energy resource as a fuel after oil. Currently, gas is used as motor fuel in most countries of the world. Currently, gas fuels are most widely used in Argentina and Brazil. The low price and good environmental indicators contribute to the expansion of the use of gas as a motor fuel.

Studying the development experience of domestic and foreign specialists shows that diesel engines converted to gas have high traction-dynamic and fuel-economy characteristics, and in terms of environmental safety, they are even significantly superior to basic diesel engines. This gives reason to assert that in order to solve the complex problem of reducing the rate of consumption of liquid petroleum fuels, the share of power drives with gas engines should be significantly increased, and for this, among other measures, technologies for converting existing diesel power drives into gas engines should be developed for the oil and gas industry. At the same time, diesel power drives converted into gas engines will simultaneously ensure a reduction in fuel and lubricant costs and reduce the negative impact of engines on the environment.

Gas as a motor fuel for diesel power drives has a number of advantages:

lower costs for gas fuel compared to diesel fuel, since gas fuel is, on average, 30—40 % cheaper than diesel fuel;

– there is practically no soot formation, which increases the engine resource by 1.5—2.5 times;

– on average, the periodicity of replacing motor oils and oil filters is doubled;

– better mixture formation is ensured, a more homogeneous combustible mixture is prepared, which is more evenly distributed among the engine cylinders, combustion pressures increase more smoothly, which extends the life of the engines;

– the gas engine warms up to operating temperature faster, due to which the wear of the cylinder-piston group and fuel consumption are reduced;

– condensation of fuel vapors on the walls of the cylinders, washing of the oil film and dilution of the engine oil are practically excluded;

– more complete fuel combustion is achieved, therefore the toxicity of exhaust gases is significantly reduced;

– engine noise is reduced;

– it is much more difficult for staff to steal gas from filled cylinders than diesel fuel.

The widespread use of compressed and liquefied gas fuels in diesel engines in our country is restrained due to:

– lack of serial production of diesel engines running on compressed and liquefied gas fuels;
– decrease in the duration of operation of equipment at one gas filling station in comparison with oil fuel;
– worse starting properties of gas engines in winter;
– increasing the weight and size parameters of equipment when installing gas equipment;
– the need for infrastructure costs for transportation and refueling of engines with compressed and liquefied gas fuels;
– the negative experience of converting diesel engines to work in gas-diesel mode due to their low efficiency and high prices for gas-diesel equipment.

Despite the mentioned shortcomings, in connection with the trend of constant growth in the cost of diesel fuel and the introduction of increasingly strict standards for the toxicity of exhaust gases, the use of compressed and liquefied gas fuels in diesel engines in the world and in our country will only increase in the future.

Analysis of recent research and publications

The creation of monogas engines by the world's leading companies, which already meet the most stringent standards of toxic emissions in exhaust gases, shows the significant advantages of converting diesel engines to gas engines with spark ignition.

Such well-known world concerns as Cammins, MAN, Scania, Iveco, Mercedes-Benz and others, which have already developed gas engines for buses and trucks based on diesel engines, are working in this direction [1].

Similar works are also carried out in the countries of the post-Soviet space. This is how a diesel engine manufactured in Minsk was converted to run on natural gas [2]. In the MMZ-245.12 diesel engine, spark plugs were installed instead of injectors and a non-contact transistor ignition system was installed. A SG-250 gas mixer and two high- and low-pressure Saga-7B gas reducers were installed on the intake manifold. To avoid detonation in the engine, the compression ratio was reduced from 16.0 to 12.0 units due to the boring of the combustion chamber in the piston.

The Sammins Corporation conducted research on a gas engine based on the Cammins QSL9 diesel engine [3]. The engine was equipped with an ignition system and gas equipment with electronic control and had a maximum specific gas consumption of 0.24 m^3/kWh. The gas engine was equipped with a regular turbocharger and an exhaust gas neutralization system. The convertible engine in terms of emissions of harmful substances with exhaust gases met the requirements of the UNECE Regulations up to the EURO-6 level and reduced CO_2 emissions by 30 % compared to the basic diesel engine. The power system with electronic control automatically provided the composition of the gas-air mixture to ensure the achievement of optimal indicators of fuel economy, power and toxicity of exhaust gases.

The KamAZ automobile corporation converted the KamAZ-740 eight-cylinder diesel engine into a gas engine under Euro-5 environmental standards with spark ignition and quantitative regulation of the gas-air mixture supply to the intake system [4]. For example, such engines are installed by the automaker on the KamAZ-6520PG dump truck with a carrying capacity of 18 tons, which is designed for the transportation of various construction loads. The car's fuel system consists of 13 compressed gas cylinders, the total volume of cylinders is 1120 liters or 224 m^3 of compressed natural gas at a pressure of 20 MPa. The range of the car is 450 km (maximum load) or 700 km (empty). In the converted engine, spark plugs with individual coils are installed in the nozzle holes, and the combustion chamber in the piston is bored so that the compression ratio is reduced from 17.0 to 12.0 [5]. The engine intake system is equipped with an original air-gas mixer and two air-gas mixture dispensers for each row of cylinders. Stand; and running tests of the created engine were performed. The convertible gas engine has almost the same energy performance as the base engine.

It should be noted that the reduction of the compression ratio in the converted gas engines under consideration was performed, as a rule, due to the boring of the combustion chamber in the piston of the basic diesel engine [6]. However, experimental studies show that even small changes in the geometry of the combustion chambers in the pistons lead to significant changes in the flow of heat, gas, and mass transfer processes. Optimizing the shape of the combustion chamber of a convertible engine requires serious calculation and experimental work to ensure energy, economic and environmental indicators and is a rather complex scientific and technical task.

There is experience in converting diesel engines to gas engines in Ukraine as well. The analysis of the developments of Ukrainian organizations shows that some experience has been gained in the conversion of several types of diesel engines, which are installed on vehicles and agricultural machines, into gas engines.

So at the Institute of Mechanical Engineering Problems named after A. N. Podhorny of the National Academy of Sciences developed the technology of converting diesel engines into gas engines and created a working model of a gas engine based on the D-21 diesel engine [7], which had a nominal power of 18.4 kW. The developed technology provided for a maximum focus on the use of serial gas equipment and elements of ignition systems and a minimum of changes in the engine design. Fuel economy at rated power is 11 % worse than the base diesel engine. Emissions of nitrogen oxides and carbon oxides have decreased in exhaust gases, and soot is completely absent. The compression ratio was reduced to 9.5 by boring the combustion chambers in the pistons.

Also, specialists from the Institute of Mechanical Engineering Problems, together with the employees of the Kharkiv National Automobile and Road University, developed the conversion technology and created a working model of a gas engine based on a six-cylinder YaMZ-236 diesel engine [8]. A feature of this development is the creation of an original ignition system of increased energy, which was supposed to provide the engine with good starting characteristics in conditions of negative temperatures. Engine conversion made it possible to reduce emissions of harmful substances, on average, by 1.5—2 times.

At the Lutsk National Technical University, the Belarusian-made D-240 diesel engine was converted into a gas engine [9]. The peculiarity of the technology of conversion of this diesel engine into a gas engine was that the reduction of the compression ratio to 12.0 was achieved due to the installation of three gaskets between the head and the cylinder block with a total thickness of 4.5 mm. It should be noted that such a conversion technology is not possible for engines with a gear camshaft drive.

Formulation of the study purpose

It should be noted that so far only a little experience has been gained in the direction of conversion of diesel engines to gas engines. The analysis of its results shows that for the conversion of diesel engines to gas engines in the oil and gas industry, many problems of a scientific, technical and commercial nature have yet to be solved. The scientific and technical problems are as follows:

– it is necessary to study the energy efficiency of diesel engines in the oil and gas industry when they are converted to alternative fuels;

– it is necessary to study the ways of improving the working processes of convertible gas engines in order to increase their economy, power and reliability;

– necessary development for the conversion of diesel engines into gas modern electronic ignition systems with computer control to optimize the processes of ignition advance angles;

– it is necessary to improve technologies for reducing the compression ratio of convertible diesels in order to reduce the cost of conversion and increase the degree of unification;

– the development of multi-fuel systems is desirable, which would allow to ensure the operation of convertible engines both on gas and, in case of possible interruptions with the delivery of gas fuel, in backup diesel mode, albeit with a slightly reduced power.

Conversion of diesel equipment to compressed and liquefied gas fuels can be carried out according to the following options: diesel engines are converted to work in gas-diesel mode or diesel engines are converted to monogas engines with spark ignition with a reduced, compared to diesel engines, compression ratio. Conversion of diesel engines to work in gas-diesel mode is not very advisable, because for such engines, diesel fuel consumption remains for ignition of the fuel-air mixture (according to real data — up to 50 %), which significantly worsens the economy of converted power drives. Therefore, the purpose of this article is theoretical research on the energy efficiency of diesel power drives in the oil and gas industry when converting diesel engines to use monogas fuels.

Presenting main material

The piston engine of the power drive of the mobile unit of the oil and gas technological transport is an energy-converting system in which the chemical energy of the fuel is transformed into work. An oxidizer (oxygen from the air) and an energy carrier are supplied to the input of this system, in our case it is diesel fuel, compressed natural gas or a liquefied propane-butane mixture. The incoming material flow is characterized by the heat supplied to the engine cylinders Q_n, which can be obtained by complete oxidation of the fuel. The heat is transformed into the work of gases $A_к$, which is perceived by the engine pistons.

The energy efficiency of engines is evaluated by the thermodynamic coefficient of effectiveness η_i, which is determined by the ratio of the useful work $A_к$ obtained on the crankshaft of the engine to the added heat Q_n obtained as a result of the combustion of the fuel-air mixture

$$\eta_i = \frac{A_к}{Q_n} = \frac{Q_n - Q_в}{Q_n}, \quad (1)$$

where $Q_в$ — amount of removed heat, kJ.

The quantities of heat supplied to the engine cylinders during the combustion of the fuel-air mixture and heat removed (through the cooling system, with combustion products, etc.) are determined by the temperatures of the working process

$$Q_n = mC_{v.p.c.}(T_z - T_c), \quad (2)$$

$$Q_в = mC_{v.п.з.}(T_b - T_a), \quad (3)$$

where $C_{v.p.c.}$, $C_{v.п.з.}$ — isochoric heat capacities, respectively, of the working mixture, and combustion products; T_z, T_c, T_b, T_a — temperatures, respectively, of the working fluid at the end of the combustion, compression, expansion and intake processes.

Temperatures of the working body at the end of the combustion, compression and expansion processes for diesel engines can be calculated as follows:

$$T_c = T_a \varepsilon^{n_{.1}-1}; \quad (4)$$

$$T_z = \frac{\lambda \rho T_c}{\mu}; \quad (5)$$

$$T_b = \frac{T_z}{\rho^{n_{.2}-1}}, \quad (6)$$

where λ — measure of pressure increase e; ρ — measure of subsequent expansion; μ — coefficient of molecular change of the working mixture, ε — measure of compression; n_1 — the average value of the index of compression polytropy; n_2 — the average value of the expansion polytropy index.

Due to the measure of compression and polytropes of compression and expansion, the ratio between the pressures of the working body at the end of the compression, combustion, and expansion processes is determined

$$P_c = P_a \varepsilon^{n_{.1}}; \quad (7)$$

$$P_z = \frac{P_c \cdot T_z}{T_c}; \quad (8)$$

$$P_b = \frac{P_z}{\varepsilon^{n_{.2}}}. \quad (9)$$

The added heat Q_n can also be defined as the product of the cyclic fuel supply $q_ц$ and the lower heat of combustion of the fuel H_u

$$Q_n = H_u q_ц. \quad (10)$$

Lower heat of fuel combustion H_u one kg of diesel varies between 41—42 MJ, one kg of compressed natural gas — 35—36 MJ, and one kg of liquefied propane-butane mixture — 43—46 MJ [10].

Cyclic fuel supply $q_ц$ determined by the amount of air G_{air}, which entered the engine per unit of time

$$q_ц = \frac{G_{air}}{l_0}, \quad (11)$$

where l_0 — theoretically required amount of air for burning one kg of fuel.

This value can be found from the stoichiometric equations for the oxidation of carbon and hydrogen found in the fuel. The content of carbon, hydrogen and the theoretically necessary amount of air for the combustion of one kg of fuel are shown in Tabl. 1.

Table 1. The content of carbon, hydrogen and the theoretically required amount of air for burning one kg of fuel [11]

Fuel	Carbon content C, %	Hydrogen content H, %	Theoretically, the required amount of air for the combustion of one kg of fuel l_0, kg
Petrol	85-86	14-15	14,7-14,9
Diesel fuel	86,5-87,5	12-13	14,3-14,5
Compressed natural gas	76,5-77,5	22,5-23,5	15,5-16,0
Propane-butane liquefied gas	81,5-82,5	17,5-18,5	15,5-15,7

But in real combustion processes, the fuel-air mixture has a composition that differs from the theoretically required amount. The actual quantity of air for burning one kg of fuel is taken into account by the coefficient of excess air α. Therefore, taking into account the real "fuel-air" ratio the cyclic fuel supply $q_ц$ is determined by the formula

$$q_ц = \frac{G_{air}}{\alpha \cdot l_0}. \quad (12)$$

When $\alpha = 1$ the mixture is called normal or stoichiometric, when $\alpha > 1$the mixture is called depleted, when $\alpha < 1$ — enriched. Gasoline engines work on both lean and rich and stoichiometric mixtures. Diesel engines work exclusively on lean mixtures. For example, the average values of the coefficient of excess air α for four-stroke low-pressure diesel engines of power drives of drilling rigs vary between 1.5 and 1.7.

The working processes of gas engines are quite close to the corresponding processes of gasoline engines. But unlike gasoline engines, the peculiarity of the combustion processes of gas engines is that they work on lean mixtures, just like diesel engines. For example, the average values of the coefficient of excess air α for four-stroke gas engines operating on methane vary between 1.05—1.8, and for a propane-butane mixture — between 1.05—1.7 [12].

Substitute (12) into (10) and analyze such an indicator as the lower specific heat of combustion of the fuel-air mixture $\frac{H_u}{l_0}$

$$Q_n = \frac{G_{air}}{\alpha} \cdot \frac{H_u}{l_0}. \quad (13)$$

The lower specific heat of combustion of the fuel-air mixture $\frac{H_u}{l_0}$ will be:

– for diesel fuel – 2,828—2,937 $\frac{MJ}{kg\ air.}$;

– for a propane-butane mixture – 2,739—2,968 $\frac{MJ}{kg\ air.}$;

– natural gas – 2,250—2,258 $\frac{MJ}{kg\ air.}$.

As can be seen from the above calculations, the lower specific heat of combustion of the fuel-air mixture $\frac{H_u}{l_0}$ is approximately the same for diesel fuel and propane-butane mixture. And the lower specific heat of combustion of the methane-air mixture is significantly lower than the lower specific heat of combustion of the mixture $\frac{H_u}{l_0}$ of air and diesel fuel.

From (13), it is obvious that with the lower specific heat of combustion of the fuel-air mixture being approximately the same for diesel fuel and the propane-butane mixture $\frac{H_u}{l_0}$, the amount of added heat Q_n will depend on the amount of air G_{air} that entered the engine per unit of time and the coefficient of excess air α.

The amount of air G_{air} entering the engine depends on several components. First, it is determined by the working volume of the engine V_{work}, that is, the volume released by the piston when it moves from top dead center to bottom dead center. Secondly, the amount of air entering the engine G_{air} depends on the density of the fuel-air mixture ρ_{mix}. Thirdly, the amount of air G_{air} is determined by the fill factor. Then the amount of air entering the engine $\eta_{нап}$ can be determined from the expression

Then the amount of air G_{air} entering the engine can be determined from the expression

$$G_{air} = V_{work} \cdot \rho_{mix} \cdot \eta_{нап}. \quad (14)$$

Taking into account (1) and (10—14), the useful work $A_к$ obtained on the crankshaft of the engine can be written as

$$A_к = \frac{\eta_i}{\alpha} \cdot \frac{H_u}{l_0} \cdot V_{work} \cdot \rho_{mix} \cdot \eta_{нап}. \quad (15)$$

To evaluate the energy efficiency of internal combustion engines, the useful work $A_к$ is attributed to the unit of the working volume of the engine V_{work}. The resulting indicator is called the average indicator pressure P_i

$$P_i = \frac{\eta_i}{\alpha} \cdot \frac{H_u}{l_0} \cdot \rho_{mix} \cdot \eta_{нап}. \quad (16)$$

Substituting (2—9) into (16) after a number of transformations for a cycle with mixed heat supply of diesel engines, we obtain

$$P_i = \frac{P_c}{\varepsilon - 1}\left[\frac{\lambda}{n_2 - 1}\left(1 - \frac{1}{\delta^{n_2 - 1}}\right) - \frac{1}{n_1 - 1}\left(1 - \frac{1}{\varepsilon^{n_1 - 1}}\right) + \lambda(\rho - 1)\right]. \quad (17)$$

The most important indicators that affect the average indicator pressure P_i in internal combustion engines there is pressure at the end of the compression process P_c and engine compression measure ε. A particular feature of diesel engines of power drives of drilling rigs is their relatively low values of the engine compression measure ε and pressure dependent on it at the end of the compression process P_c.

The values of compression ratios of the most common diesel engines of power drives of drilling rigs are given in Tabl. 2.

Table 2. The value of compression ratios of the most common diesel engines of mobile technological installations in the oil and gas industry

Engine model	Power, kW	Working volume, l	Engine compression measure,
B2-500TK-C4 TMX	330	38,88	14,0
71H12A PZL-Wola	404	26,64	14,5
Caterpillar 3508	507	34,53	13,0
6ЧН 21/21 - CA 30	482	43,60	14,0
6ЧН 21/21 - CA 10	460	43,06	13,5
Cummins KTTA19-C525	392	19,00	13,9
ЯМЗ-8504.10-02	368	25,86	14,0

The compression ratios of modern gas engines, which for gas fuels are calculated for the average octane value of 115, are in the range of 12—13. Therefore, the deformation that will need to be carried out during the conversion to gas fuel of the most common diesel engines of power drives of oil and gas technological transport will be relatively small. On average, the compression ratio of diesel engines of power drives of oil and gas technological transport will need to be reduced by one or two units, and in some models of low-pressure diesel engines, there will be no need to reduce the compression ratio at all. This is the fundamental difference between the conversion of diesel engines of power drives of oil and gas technological transport from, for example, high-pressure automobile diesel engines, where the compression measure ranges from 16.5 to 22.

Calculations show that the average indicator pressures P_i for four-stroke low-pressure diesel engines of power drives of drilling rigs will vary within 0.72—1.11 MPa, and the average indicator pressures P_i for diesel engines converted to gas fuel, power drives of drilling rigs will be in the range of 0.68—1.05 MPa. Moreover, it should be noted that the average indicator pressures P_i for diesel engines converted to gas fuel will be significantly higher than the average indicator pressures P_i for gasoline engines converted to gas fuel, in which, usually, the degree of compression is not increased during the conversion, being limited only to the installation of gas cylinder equipment. Especially large reductions in indicator pressures and, accordingly, power are observed for gasoline engines of trucks, where the compression ratio, on average, is in the range of 6.5—7.0.

Substituting (15—17) into (1) after a series of transformations, we obtain

$$\eta_i = \frac{P_i l_0 \alpha}{H_u \rho_{mix} \eta_{нап}}. \quad (18)$$

Let's analyze the component dependencies (18).

Such quantities as the density of the fuel-air mixture ρ_{mix} and fill factor $\eta_{нап}$ during converting diesel engines, the power drives of oil and gas technological transport practically do not change, since the intake system of the engines will remain almost unchanged, and therefore the resistance of the intake system will practically not change.

Theoretically the required amount of air l_0 for the combustion of one kg of diesel fuel varies within 14.8—14.9 (we take it as 100 %), one kg of compressed natural gas — 15.5—16.0, that is, on average 6 % more, and one kg of liquefied natural gas propane-butane mixture — 15.5—15.7, i.e. 5.5 % more on average.

The lower heat of combustion H_u of fuel of one kg of diesel varies within 41—42 MJ (we take it as 100 %), one kg of compressed natural gas — 35—36 MJ, that is, on average, 14.5 % less, and one kg of liquefied propane-butane mixture — 43—46 MJ, that is, on average, 7 % more.

Average indicator pressures P_i for four-stroke low-pressure diesel engines of power drives of oil and gas technological transport will vary within 0.72—1.11 MPa (taken as 100 %), and the average indicator pressures P_i for diesel engines converted to gas fuel, power drives of oil and gas technological transport will be in the range of 0.68—1.05 MPa, i.e., on average, 5 % less.

Average values of the coefficient of excess air α for four-stroke low-pressure diesel engines of power drives of drilling rigs vary in the range of 1.5—1.7, the average values of the coefficient of excess air α for four-stroke gas engines running on methane, they vary within 1.0—1.8, propane-butane mixture — within 1.0—1.7.

The calculations show that the thermodynamic efficiency coefficient of four-stroke diesel engines of power drives of oil and gas technological transport is, on average, within the range of 0.38—0.42 at the average values of the excess air coefficient α. When converting diesel engines of power drives of oil and gas technological transport to a propane-butane mixture, their thermodynamic efficiency will be, on average, 0.35—0.41, and when converting diesel engines of power drives of oil and gas technological transport to natural gas, their thermodynamic efficiency will be will be equal to, on average, 0.27—0.32 at the average value for gas engines of the coefficient of excess air $\alpha = 1{,}4$.

Conclusions

The following conclusions can be drawn from the above calculations:

– when converting diesel engines of power drives of oil and gas technological transport to gas motor fuel, it is possible to ensure that the indicators of power, torque, and fuel consumption are practically similar to the corresponding indicators of basic diesel engines before conversion;

– conversion to gas fuel of low-pressure diesel engines of power drives of oil and gas technological transport is a much more energy-efficient and technically less complicated process compared to conversion of high-pressure car engines;

– when converting diesel engines of power drives of oil and gas technological transport to gas motor fuel, when converting diesel engines to a propane-butane mixture, it will be possible to provide better indicators of power, torque and fuel consumption, compared to converting diesel engines of power drives of oil and gas technological transport to natural gas;

– values $\frac{P_i \cdot l_0}{H_u}$ for diesel and gas engines (especially when converting to propane-butane) are very close to each other and the main factor that will affect the power, torque and fuel consumption of the engine is the excess air ratio. In other words, extremely much during the conversion will depend on the configuration of the gas engine power system. Thus, if the fuel equipment and ignition system of a gas engine are not properly adjusted, its fuel economy and power characteristics will be significantly worse than the similar indicators of basic diesel engines before conversion. And vice versa, with the optimal configuration of the power system, it will be possible to even achieve better fuel economy and power characteristics compared to the corresponding indicators of the basic diesel engines of power drives of drilling rigs before conversion.

The given theoretical calculations and calculations are in good agreement with the practical gains that have already been made in road transport during the conversion of diesel engines to gas engine fuel. For example, as already mentioned, the MAN D2066LF diesel engine (Fig. 1) was converted into a gas engine with spark ignition and quantitative regulation of the gas-air mixture supply to the intake system at the MAN automobile corporation.

In particular, such engines are installed by the automaker on the MAN TGA 440PG chassis and dump truck. Stand and running tests of the created engine were performed at the MAN corporation. It has been established that the convertible gas engine has practically the same fuel economy and power characteristics as the basic diesel engine. For example, methane consumption for a MAN TGA 440PG dump truck, on average, ranges from 32 m^3 (empty vehicle) to 45 m^3 (maximum load).

Diesel fuel consumption under the same conditions for a similar dump truck MAN TGA 440 with a diesel engine ranged from 30 to 42 liters of diesel fuel. The capacities of both engine modifications (diesel and gas) were the same and amounted to 210 kW.

Fig. 1. Gas cylinder system of the MAN TGA 440PG car

There is experience in the use of converted car diesel engines into gas engines in Ukraine as well. For example, at KrAZ, the KrAZ-5401K2 model (Fig. 2) is produced with a 6-cylinder Mercedes-Benz M906LAG engine running on methane, with a capacity of 205 kW (279 hp). The car's fuel system consists of cylinders for compressed gas in the amount 9 pieces. The total volume of cylinders is 1155 liters of compressed natural gas at a pressure of 20 MPa. The power of the basic diesel engine is 207 kW.

Fig. 2. KrAZ-5401K2 car with gas cylinder equipment

For this car, the car manufacturer also carried out road tests of the car and found that the methane consumption for the KrAZ-5401K2 4x2 car, on average, is 35 m3 of gas. Diesel fuel consumption under the same conditions for a similar car KrAZ-N12.2 4x2 on diesel fuel was, on average, 32 liters.

The given examples show that automakers have already managed to develop models of diesel engines that can be converted to gas fuel. Moreover, it was possible to keep the capacity of the convertible engines at the same level as that of the basic diesel engines. And gas consumption for convertible car engines increased by 7—10 % despite the fact that the cost of one cubic meter of methane is, on average, 30—40 % less than the cost of one liter of diesel fuel.

Therefore, conversion of existing low-compression diesel engines of power drives of oil and gas technological transport, which are currently operated in the oil and gas industry, is a technically possible and economically profitable task.

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