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DESIGN-EXPERIMENT INVESTIGATIONS OF THE GAS ENGINE CONVERTED FROM THE TRACTOR DIESEL

Summary. An experience of foreign firms is analyzed in the article in relation to the re-equipment of transport vehicles diesels for work on natural gas, results of computer modeling of work cycle of gas engine and diesel are shown, features of the feed system of gas engine on the base of D-240 diesel are described and its load characteristic is presented.

Key words: gas engine, natural gas, compression ratio, diesel

INTRODUCTION

One of the tendencies, directed on reducing of the exhaust gas emissions of internal combustion engines and saving natural resources, is a transition into the alternative fuels. There are a lot of oil fuels substitutes for vehicles in existence nowadays. An expedience of introduction of every type of fuel is determined after the technical and economic indices of extraction or receipt of fuel, by charges on transport and saving, by presence of resources, by ecological indices, etc. But lately, ecological and economic indices predominate.

THE STATEMENT OF THE RESEARCH PROBLEM

Natural gas (CNG) is the most real for wide use, because it has a number of advantages in comparison with liquid fuel. CNG has higher octane number than the best sorts of petrol and it is possible to use it in engines with high compression ratio. As it enters the cylinders in the gaseous state, a rarefaction of motor oil is eliminated, even during the cold starting of engine, which multiplies the period of its service and diminishes the wear of engine details. In comparison with petrol, while working on the CNG, a more homogeneous mixture appears, the even distributing of mixture on cylinders takes place. It gives the possibility to use poor fuel-air mixtures.

Today, the use of gas engines is not wide. At small scales of production the conversion of liquid-fuel engines into gas-fuel ones with providing their maximum unifica-

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tion with the base liquid-fuel engines is more effective economically than the creation of original constructions.

It is easy to reequip petrol engines into gas ones using serial gas bladder-type equipment and all the ways of their re-equipment on gas fuel are technically solved. But in the case of re-equipment of petrol engines into gas ones, engine power decreases up to 18-22%. It is explained by less combustion warmth of gas-air mixture in comparison with petrol-air mixture and worse filling of cylinders with the fresh charge. It causes the weakening of hauling-dynamic qualities of the vehicle.

It is more rational to use the engines with high compression ratio, which were created on the basis of diesels. The replacement of diesels with engines which use CNG can improve the ecological situation. Another way of using CNG is the application of gas-diesel process. The gas-diesel is more profitable than diesel because it uses less liquid fuel. However, reliability of gas-diesel is lower than that of diesel. It is connected with the presence of the second feeding system, and with the possibility of the cooking pulverizers of sprayers through the substantial reduction of the cooling effect of fuel stream. Ecological indices of gas-diesel in the comparison with diesel do not get better. It is explained by not full replacement of diesel fuel by gas (the substitution makes only 40–70%). That’s why the use of gas-diesels is insignificant for the cities and regions with assured gas-supplying.

A full replacement of diesel fuel by gaseous fuel is carried out during the converting of a diesel into a gas engine with spark ignition. The discharge of harmful substances with the exhaust gases diminishes substantially. The creation by the leading world's firms of gas engines, that meet the hardest standards on the harmful discharge, testifies the advantage of this converting method.

ANALYSIS OF THE PREVIOUS RESEARCHES

The idea of re-equipment of diesel engine into a gas one with spark ignition arose recently. Now this problem is being worked over in many countries of the world. A construction and results of engine tests on natural gas, converted from diesel B 5.9 CUMMINS is considered in work [Kamel and Duggal 1994]. The conception of „an engine working on poor mixtures” with spark ignition and external mixture formation is used there. The use of poor mixtures secures a low NO_x emissions and high economy without increasing the thermal loading of engine details.

It is the row six cylinders engine, with working volume of 5.9 liters. Spark-plugs are approximately in the same position as sprayers in diesel. Electronic ignition system without a distributor is used in this engine. After compressor, the air is cooled down in the intercooler. The overflow valve of residual gases by turbine is foreseen in the supercharging system. The gas feeding system and the overflow valve of residual gases are operated by the electronic system.

The gas engine has the power of 143.4 kW at 2800 rpm. The reserve of torque is about 13%. By tests results of gas engine, the highest value of effective efficiency equals to 0.367 at 1800 rpm on the full-load curve. Without the oxidizing neutralizer engine satisfies the LEV requirements, and equipped with it – to the ULEV norms. The general run in exploitation equals to 160 000 km.

A gas engine on the basis of a row six cylinder diesel manufactured by NISSAN is considered in work [Yutaka Takada et al. 1994]. It develops the power 173 kW at 2100 rpm. The flat chamber of the „Texas Dog Dish" type is used instead of toroidal-cavity combustion chamber in that engine and the compression ratio is lowered from 18 to 11. Two spark-plugs are placed in every cylinder there. The base engine has no supercharging. The gas engine is equipped with gas-turbine supercharging with an intercooler. The temperature of exhaust gases of gas engine with excess air factor (α) equals 1 and got 100º higher, than in the base diesel, which according to the authors can lower the reliability of the engines. The maximum power fell by 20%. When α = 1.35 the temperature of exhaust gases in the gas engine is the same as in diesel, but the engine power is only 120 kW.

The torque and the power of gas engine achieved the same values as in a supercharged diesel. The gas engine worked on all the operating modes with α = 1.55. At the low loading of the gas engine, the temperature of exhaust gases was considerably higher than in the diesel. The CO and C_mH_n concentrations were higher in the case of gas feeding, but it was compensated by a considerably lower concentration of NO_x .

The German firms MAN and „Daimler Benz" converted diesels into gas engines. In the first case the compression ratio changed from 18 to 14. Consequently, the engine power was reduced from 117.6 to 95.6 kW. In the second case, the diesel and his gas analogue developed power to 126 kW and torque 600 and 640 N·m, correspondingly. The data about the exhaust gas emissions were not published [Grygoryev et al. 1989].

Gas engines are developed in MVRI (Russia) on the basis of KamAZ diesels. A gas engine without supercharging, which as well as the base diesel, developed power 143 kW at 2200 rpm with α = 1,15 [Lukanin et al. 2001] was created. The torque did not change, either. Compression ratio changed from 17 to 13. C_nH_m emissions diminished 1.9 times, *CO* – 2.2 times, and the content of NO_x in exhaust gas diminished from 15 g/kW·h to 12.3 g/kW·h.

Summing up the above-mentioned, the necessity arose to estimate the possibility of the converting diesels without supercharging, which were made by other factories of the CIS countries, and which are exploited in Ukraine, as well as the need to specify some results of previous researches, which are contradictory. With this purpose diesel D–240, which is widely used in the agricultural technique and road transport vehicles was re-equipped into the gas engine at the motor-car engines laboratory of the Lutsk state technical university.

METHOD OF RESEARCH

Analyzing a thermal coefficient of the useful effect and middle pressure of the Otto cycle it is clear, that in the duty cycle of gas engine it is expedient to realize the compression ratio that does not exceed 12. At the first stage of researches a mathematical model and program of gas engine work cycle computation for PC was worked out. It allows to define its power and economic indicators and to get the optimum values of construction parameters and of engine work cycle. Basic data are given in Table 1, and the results of computer design of duty cycle of gas engine and base diesel are given in Table 2. On the basis of these data the unfolded indicator-diagrams of gas engine and diesel (Fig.1) were made. The obtained results testify the possibility of work of the D-

240 engine on CNG. A reduction of mean effective pressure is related to reduction of mechanical efficiency; a reduction of effective fuel rate is conditioned by application of richer gas mixtures; a reduction of effective power is insignificant and related to reduction of volumetric efficiency and application of fuel with lower heat value.

Table 1. Basic data to computation of work cycle of the D-240 engine

Parameters	Value	
	Diesel	Gas engine
Compression ratio	16	12
Crankshaft speed, rpm	2200	2200
Excess air coefficient	1,5	1,2
Coefficient of combustion warmth use	0,77	0,85
Charge preheating, K	20	20
Intake end temperature, K	900	950
Lower combustion warmth of fuel, MJ/kg (MJ/m^3)	42,5	35
Mass part of carbon in the diesel fuel	0,87	-
Mass part of hydrogen in the diesel fuel	0,126	-
Mass part of oxygen in the diesel fuel	0,004	-
Mass part of methane in CNG	-	0,95
Mass part of nitrogen in CNG	-	0,04
Mass part of carbon dioxide in CNG	-	0,01

Table 2. Results of computer design of work cycle of the D-240 engine.

Parameters	Value	
	Diesel	Gas engine
Volumetric efficiency	0,77	0,71
Combustion end temperature, K	2318	2461
Combustion end pressure, MPa	6,8	7,4
Mean indicated pressure, MPa	0,842	0,835
Indicated efficiency	0,45	0,43
Indicator fuel rate, kg/(kW·h), m^3/(kW·h)	0,188	0,239
Middle pressure of mechanical charges, MPa	0,163	0,19
Mean effective pressure, MPa	0,679	0,645
Mechanical efficiency	0,81	0,77
Effective efficiency	0,36	0,33
Effective fuel rate, kg/(kW·h), m^3/(kW·h)	0,233	0,312
Computation effective power of engine, kW	59,1	56,2

The reequipment of diesel into the gas engine has become the second stage of researches. On the reequipped engine, spark-plugs BRISK L15YC are set instead the of sprayers (Fig. 2). The fuel pump of high pressure was reequipped for the fastening of distributor, a billow of which is driven into motion from the camshaft of pump; the electronic ignition with the inductive sensor in the distributor is set (Fig. 3). A gas mixer is set on the inlet collector on the base the K126-G carburetor with baffle fin for the gas feeding, and also gas reducing gears of high and low pressure and other gas equipment.

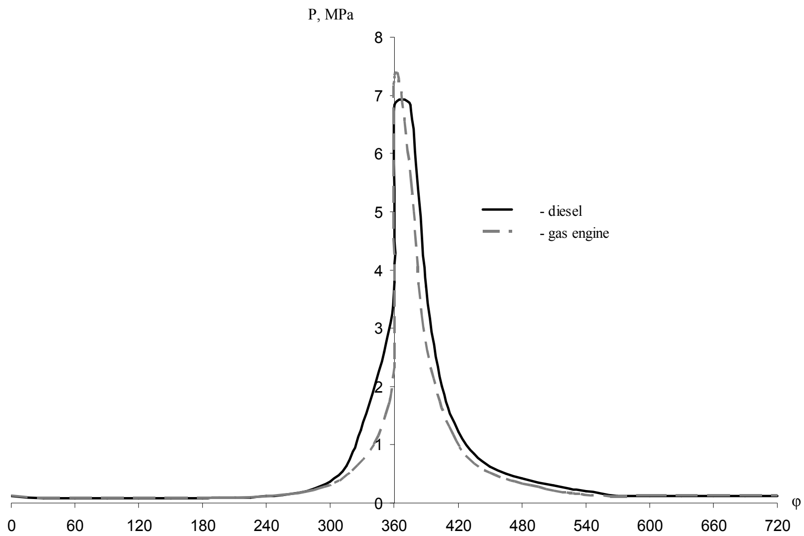

Fig. 1. Unfolded indicator-diagrams of gas engine and diesel

Compression ratio of gas engine is reduced from 16 to 12 by setting under the head of cylinders the block of 3 gaskets by the general thickness of 4,5 mm. That is a diesel was converted into the engine with spark ignition and external mixture formation. Reequipment of diesel into the gas engine was made with the possibility of its reverse converting into diesel.

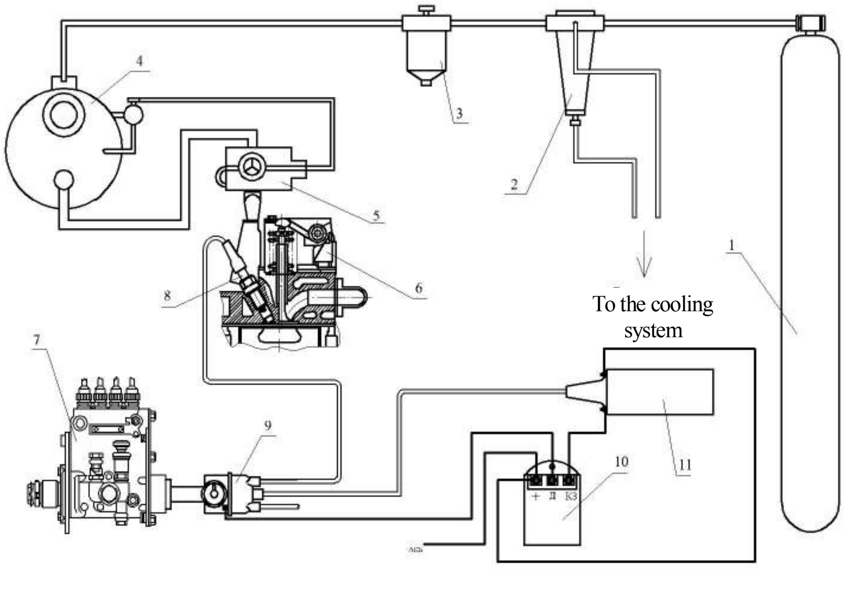

Fig. 2. Diagram of feeding and ignition systems of gas engine

The experimental tests of converted gas engine included the motor researches on the electric brake stand. The base of the stand is the balancer electric machine by power 40 kW and by the maximum brake power 77 kW at the rotor rotation speed 2000 rpm and the dynamometer with the scale of 0...50 kg.

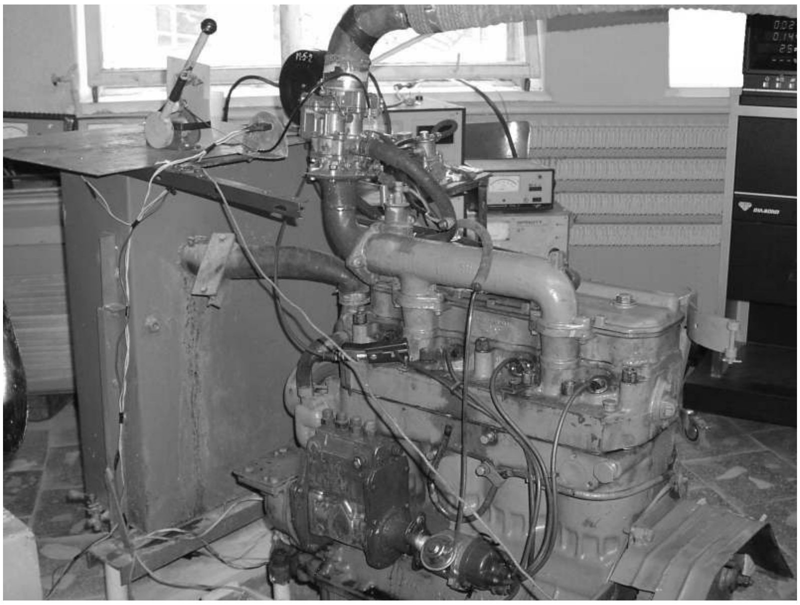

Fig. 3. Gas engine reequipped from diesel D-240

Rotational speed, air consumption, gaseous fuel consumption, residual gases temperature were measured. Emission of engine exhaust gas components such as CO, CO_2, C_nH_m and NO_x was measured by exhaust-gas analyzers. At the beginning of tests an optimum ignition advance angle was determined and set.

RESULTS OF THE EXPERIMENTAL RESEARCHES

The gas engine worked firmly on all modes. Its load characteristic got on crankshaft rotation speed 1400 *rpm* is shown in Fig. 4. On this mode the gas engine develops power approximately by 4% less than the D-240 diesel. Effective fuel rate is by 6.2% higher than in diesel, as the gas engine works on richer mixtures. The level of the troop landing CO and C_nH_m in the gas engine is less and there is no soot in exhaust gas, but NO_x concentration on the maximal loading mode is by 25% larger, than in diesel. However, there is the possibility of its reduction by the optimum adjusting of the systems of feed and ignition. D-240 diesel indexes are taken from the work [Zakharchuk 1996]. A noise during the work of gas engine is considerably lower than that of diesel.

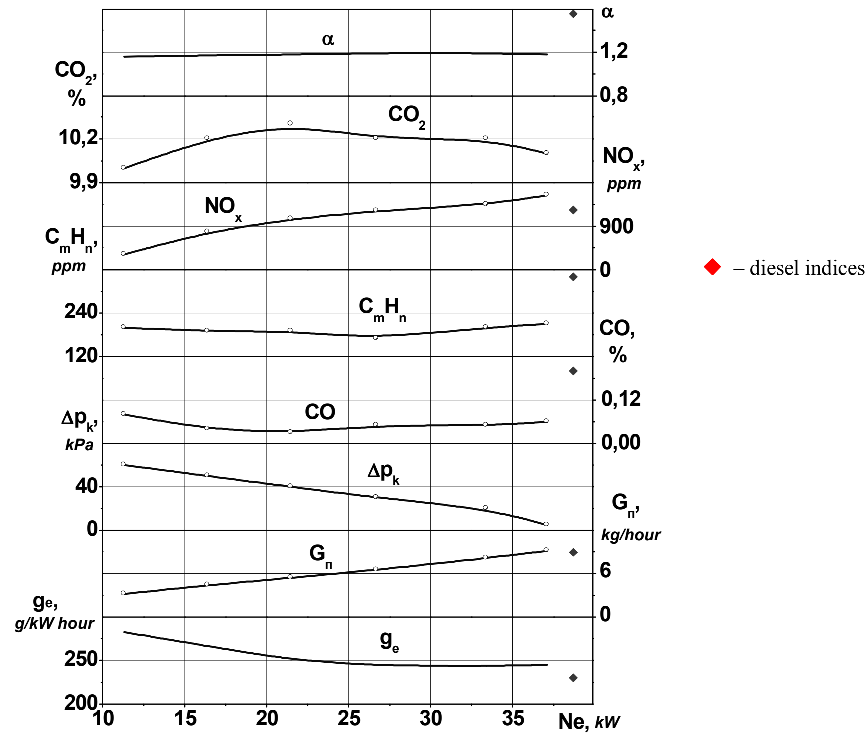

Fig. 4. Load characteristics of gas engine.

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The analysis of received results proves the expedience of the diesel convertion into gas engines. In particular, the setting of such engines instead of diesels in the city buses would considerably improve ecological situation in cities. The high power indices in gas engines, converted from diesels, are received due to the possibility of realization of large values of compression degree. In transitions, gas expenditure of the fuel-lubricant materials is twice diminished. The period of recoupment of investments on the converting is from 9 to 16 months.

The temperature of exhaust gases of a gas engine is higher in the comparison with diesel. Obviously, the final combustion temperature is higher, too. That is why the next stage of researches is an estimation of operating reliability of a converted gas engine. And the first step in this direction will be the removal of the indicator-diagram of a gas engine, its comparison with the computation diagram and with the diesel indicator-diagram.

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