ANALYSIS AND ASSESSMENT OF GAZ-DIESEL CYCLE EFFICIENCY

АНАЛИЗ И ОЦЕНКА ЭФФЕКТИВНОСТИ ГАЗОДИЗЕЛЬНОГО ЦИКЛА

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Abstract: *The paper dwells on peculiarities of operation of engine running on gaseous fuel that envisages the influence of the period of impeding spontaneous combustion on the operation of engine with the dependence on dosing of fuse. Simultaneously, there is considered the influence of changeability of the air-excess coefficient on the engine load when using the different gaseous fuels, as well as its influence on the efficient operation of engine, improvement of ecological and economic parameters, with account for improving geometrical parameters of engine. There are given the analysis and comparison of the efficient characteristics of the ideal cycle of diesel engine when running on liquid and gaseous fuel.*

KEY WORDS: GAS DIESEL; GASEOUS FUEL; EXCESS AIR COEFFICIENT; IDEAL CYCLE.

1.Introduction

Reciprocating internal combustion engines are mostly used as power-generating equipment of bothland and marine as well as of other transport purposes. Most of them use the oil-origin liquid fuels of various fractions and composition. At the same time, the possibility of the use of gaseous and bio-fuels in power-generating equipment should be noted as well. The high-capacity vehicles, tractors, river and sea crafts and special-purpose devices are mostly equipped with diesel engines, which run on diesel or oil fuel. Diesel fuel, petrol, kerosene and others pertain to the group of oil products, which are produced from crude oil by way of rather complicated technological processing. The amount of fuel produced by using the existing technological processes does not exceed 45%. This is explained by fact that the energy inputs on vehicles are growing continuously. All this causes oil and oil products shortages that fosters significant increase of fuel prices. At the same time, oil is a valuable product for the chemical industry, and besides, there exists the trend of its wide application in industrial microbiology as well.

Despite permanent shortages and expensiveness of liquid fuel, the use of gaseous fuels is restricted in reciprocating internal combustion engines that requires carrying out some specific studies.

It should be also noted that during the world oil crisis, the direct injection diesels were widely applied in diesels used in both light vehicles and trucks. Acceleration of this process was also fostered by adoption of a new legislation in the developed countries, which restricts the permissible amount of toxic substances in exhaust emissions and noise level. The light vehicles manufacturer companies were forced to engage actively in research works, which envisaged improving ecological parameters of engine. By the same period, various studies have been carried out already, including studies on the single-cylinder devices carried out by a number of companies (Daimler-Benz, Audi, Volkswagen, Ford, etc.). The direct injection diesel engines have been developed for vehicles. For example: a four-cylinder Audi with useful capacity of 1,4 l, as well as an experimental low=noise diesel LDX developed by AVL Company, which was equipped with a mechanical pump duse [1].

Meeting the growing demands for transport power, providing with cheap and environmentally safe fuel, and at the same time, for more effective use of natural resources, it is necessary to find the ways to enhance fractional composition of oil and alternative types of fuel.

2. Preconditions and means for resolving the problem

One of the ways of increasing efficiency of liquid fuel is implementing the gas-diesel cycly in the internal combustion engines, where the basic fuel is a natural gas, but the working mixture ignition is made by diesel fuel (ignition fuze dosage). In this case, the torch power of fuel mixture ignition fuze is significantly higher than in the engines with spark-plug ignition that significantly effects on the course of working process. The use of a gas-diesel working process reduces consumption of operating liquid fuel by 80-90%, smoking of the exhaust – by 3-4 times, the amount of carbon oxides – by 85-90%, the amount of nitric oxides – by 50-60%. The advantage of the gas-diesel engines also consists in fact that the engine can swith to the use of diesel fuel or vice-versa without stopping and reducing power. So, gas as a fuel of engine, au naturel, is the best one among the oil-origin fuels. Its use provides high technical and economic parameters. natural gas is characterized by high anti-detonant degree, favorable conditions for mixture formation and by the best ignition property of mixture with air.

During gas fuel conversion of the existing engines, their ignition is made by the ignition system, which uses a spark plug or by small dose of the detonative liquid fuel. Up until now, the mixture self-ignition at the end of the compression process had not been used in the engines running on a gas fuel, which is used in diesel engines. The main difficulty in implementing the self-ignition cycle consists in fact that gaseous fuel is characterized by high ignition temperature, which for natural gas is 650-700 ^{0}C and considerably exceeds the diesel engine's self-ignition temperature (320-380^0 C) [2]. Thus, in case of using the gas as a fuel, it is necessary to provide pre-dosed injection ofdetonative fuel at the end of compression with some advance, the amount of which should not exceed 15-20% that will enable us to use the series-production diesel engine without changesin compression degree and design.

The diesel engines running on the liquid oil-origin and compressed natural gas fuels differ from one another by the operation principle. In case of natural gas, there is no need to install the evaporator in front of engine, which causes reduction of the amount of new charge inletting into the cylinder, i.e. decreases the coefficient of charge and engine power correspondingly. At the same time, operation of diesel engine on methane is more stable than on propane, in this case the probability of detonation combustion, at the same magnitude of excess air coefficient, depends on the angle of advance of fuze injection, and increasing fuze dosage causes stability augmentation of the combustion process. In this case,numerous combustion sources will be created for self-ignition of working mixture. Ignition of pre-dosed fuze depends on a cetane number of diesel fuel, which has a significant effect on the diesel engine parameters. When assessing the gas fuel, it is necessary to take account for fact that reliable and efficient operation of engine may be achieved by high anti-detonant degree of gas fuel and by proper quality regulation of working mixture, which should correspond to the selected operation mode of engine.

The analysis of thermodynamic cycles of reciprocating internal combustion engines has shown that the closer is a real cycle of diesel engine to heat supply cycle at a constant volume (V=const), the higher is its efficiency, since in this case, there are no additional heat losses due to performing isobaric operation. Hence, high magnitude of the efficiency of large-size slow-running diesels (Table 1) is achieved by high degree of isochoric growth of pressure.

Operation of gas-diesel engine, which is characterized by the geometric parameters of basic engines becomes like operation of engine with heat supply at a constant volume (V=const), i.e. the engine cycle running on petrol, where the cutoff ratioρ=1, and mixture formation mostly occurs outside the cylinder in a special-purpose mixer by regulating the quality of mixture. In this case, the compressor-less (Trinkler) diesel and gas-diesel cycles are shown in Fig.1, which shows the diesel cycle PV on the diagram asaczz^{1}ba curve, but the gas-diesel cycle – as aczz^{11}ba curve, therefore the gas-diesel cycle becomes like a heat supply cycle at a constant volume (V=const). In this case, for the analysis of cycle efficiency we shall use the following formulas for calculating thermal efficiency:

$$\eta_{t_1T} = 1 - \frac{1}{\varepsilon^{\kappa-1}} \frac{\lambda\rho^{\kappa}-1}{\lambda-1+K\lambda(\rho)}, \quad \eta_{t_1 0} = 1 - \frac{1}{\varepsilon^{\kappa-1}}$$

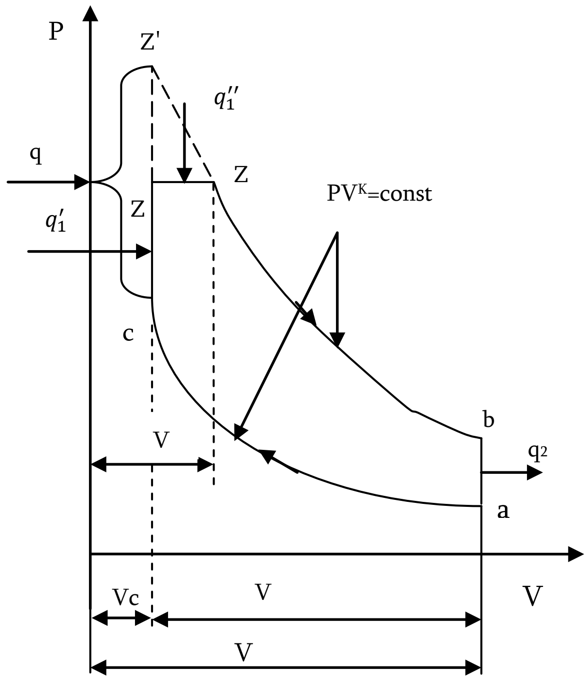

***Fig1.** Compressor-less (Trinkler) diesel and gas-diesel cycles*

Comparison of above shown cycles has shown that in the conditions of the same geometric parameters, the gas-diesel cycle is more efficient, than the compressor-less diesel cycle. Comparing them in TS coordinate system better shows the advantage of the gas-diesel cycle (Fig. 2) that means that in case of implementing the gas-diesel cycle the larger amount of heat will be converted into the useful operation, since in TS coordinates, the area Abz^{11}ba is larger than the aczz^{1}ba area.

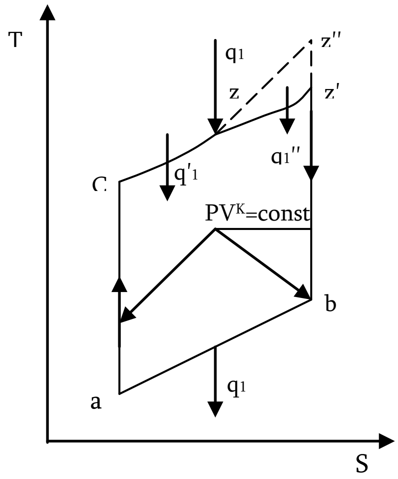

***Fig. 2.** The advantage of the gas-diesel cycle*

3. Conclusion

As is also well-known, the diesel engine represents the engines with a larger volume, that means that power developed by a unit work volume is lower in comparison with engines running on petrol. This is explained by high magnitude of the excess air coefficient $\alpha = 1{,}30\text{-}1{,}36$ at a nominal mode of engine. During operation with the gas-diesel cycle at the mode corresponding to the nominal power, the excess air coefficient should be$\alpha = 1$. In this case, the engine's work volume will be completely used profitably and, at the same time, we won-t have such amount of heat, which is required for heating of the excess air.

So, the above described analysis has shown that when implementing the gas-diesel cycle, the engine's efficiency and ecological parameters are improved.

4. Literature

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