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OZONIZATION INFLUENCE ON ENERGY AND ECOLOGICAL CHARACTERISTICS OF LOCOMOTIVE DIESEL ENGINE

Summary. The results of preliminary experimental research of ozonized fuel influence on working characteristics of diesel engine. The decrease of fuel consumption on 1,1% and exhaust opacity lessening of exhaust gases by working on ozonized fuel on 12-17% are discovered.

ВЛИЯНИЕ ОЗОНИРОВАНИЯ НА ЭНЕРГО-ЭКОЛОГИЧЕСКИЕ ПОКАЗАТЕЛИ ТЕПЛОВОЗНОГО ДИЗЕЛЯ

Резюме. Представлены результаты предварительных экспериментальных исследований влияния озонированного топлива на рабочие характеристики дизельного двигателя. Выявлено снижение расхода топлива на 1,1% и уменьшение дымности отработавших газов при работе на озонированном топливе на 12-17%.

1. INTRODUCTION

The jump of the world prices on oil and oil products, energy suppliers dependence of Ukraine caused a serious problem for the country's economy. Moreover threatening situation with ecology which requires immediate implementation of measures on lowering man-caused influence on environment actualized the search of alternative energy sources and ways of fuel combustion.

According to the information of academician N.P. Laverov, energy sources consumption in XX century has increased by 15 times and reached 15 billion toe per year (in which oil – 40%, coal – 27%, gas – 23%, atomic energy – 7%, renewable sources - water-power, solar, wind-power – 3%) [1]. As a result the cost of fossil fuel has considerably increased. According to energy prognosis of the USA administration the volume of primary energy sources consumption in the whole world will amount to 22 billion toe by 2025 by average annual rate of growth 1,9% (including in China – 3,5%, India – 3,2%). The natural gas share in the general structure of energy consumption will increase to 28,4% and atomic energy will decrease to 4,5% [1] (Fig. 1). Global energy crisis will grow and deepen and fossil fuel will be continuously rising in price (by inevitable instability of world prices), that it will extend economical borders of using renewable energy sources and increase their share in the structure of energy consumption.

According to the information of the World Bank if the rate of growth of fossil fuel consumption and the emission volume of CO_2 do not decrease, that by the beginning of XXII century the mean temperature on the Earth will increase by 3–7°C that it will be the cause of irreversible climate change (Fig. 2) [3]. The only significant reduction of fossil fuel use will let from 2020 to stabilize total volume of carbonic acid emission into the atmosphere and from 2050 gradually reduce atmosphere pollution. The modern energy revolution inseparably linked with and will take place simultaneously with ecological revolution, the energy sector will acquire noospheric character. That is why it is rightful to say about global energy and ecoloogical revolution of XXI century that will change the face of the Planet.

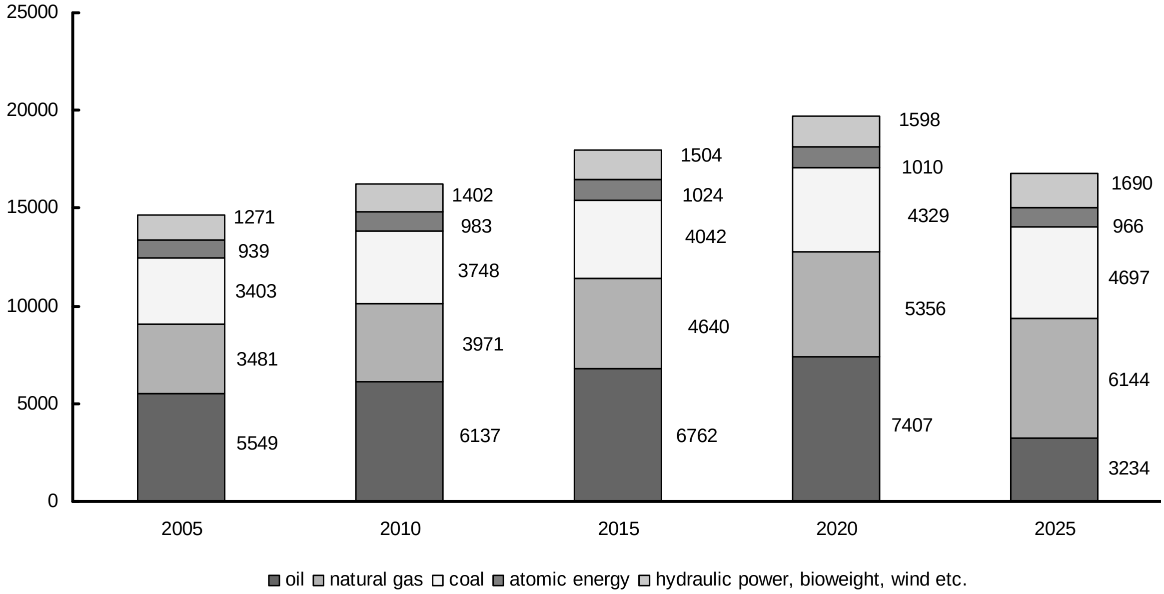

Fig. 1. The prognosis energy resources consumption in the world before 2025 (billon toe)
Рис. 1. Прогноз потребления энергетических ресурсов в мире до 2025 г., млрд. т у.т

As it follows from [4] the main pollution sources of ambient air are heavy industry and transport where railway transport also plays not the last role.

During the last century car engine and fuel which puts them in action were a powerful motivational factor in the policy of the leading world countries. If we take into consideration the limited nature of oil reserves and intensification of greenhouse effect in the atmosphere it won't be a surprise to get to know how much efforts are made to increase efficiency of internal combustion engine – the main oil consumer and nitric oxide source.

Railway transport as alternative to motor transport plays greater role in different spheres of the country's economy. Offering systemic advantages energy and ecological in particular it is important to provide new technical solutions by constructing rolling-stock with a view to rise comfort level, lowering noise and vibration, functioning reliability of all railway system and also above all implementation of resource-saving technology.

2. STATEMENT AND PROBLEM SOLVING

One of the complex of measurements aimed at energy and resource saving on a rolling-stock in general is the problem solving of using the energy of regenerative braking.

The offered way of using the energy of regenerative braking of diesel locomotive for the effectiveness increase of locomotive diesel engines by scientists of East Ukrainian Volodymir Dahl National University is of doubtless interest. During diesel locomotive breaking that is a frequent mode both for passenger locomotives and freight locomotives railway motors switch to the mode of generator work. At the same time a great amount of electric energy (exhaust) liberation takes place which is lead to the ozone generator where ozone is generated during the period of the whole process of braking and then diesel fuel is processed which differs more quality and effective combustion in cylinders of diesel locomotive. The suggested technical solution allows:

- to increase the process of fuel combustion,
- to use rationally and effectively exhaust electric energy, obtained in the result of thermodynamic braking of diesel locomotive,
- to increase efficiency of locomotive diesel engine,
- to increase economy of locomotive diesel engine,
- to provide for decrease to minimum harmful substances in discharge gas,
- to decrease calorific intensity and snuff formation of sleeve assembly parts of locomotive diesel engine.

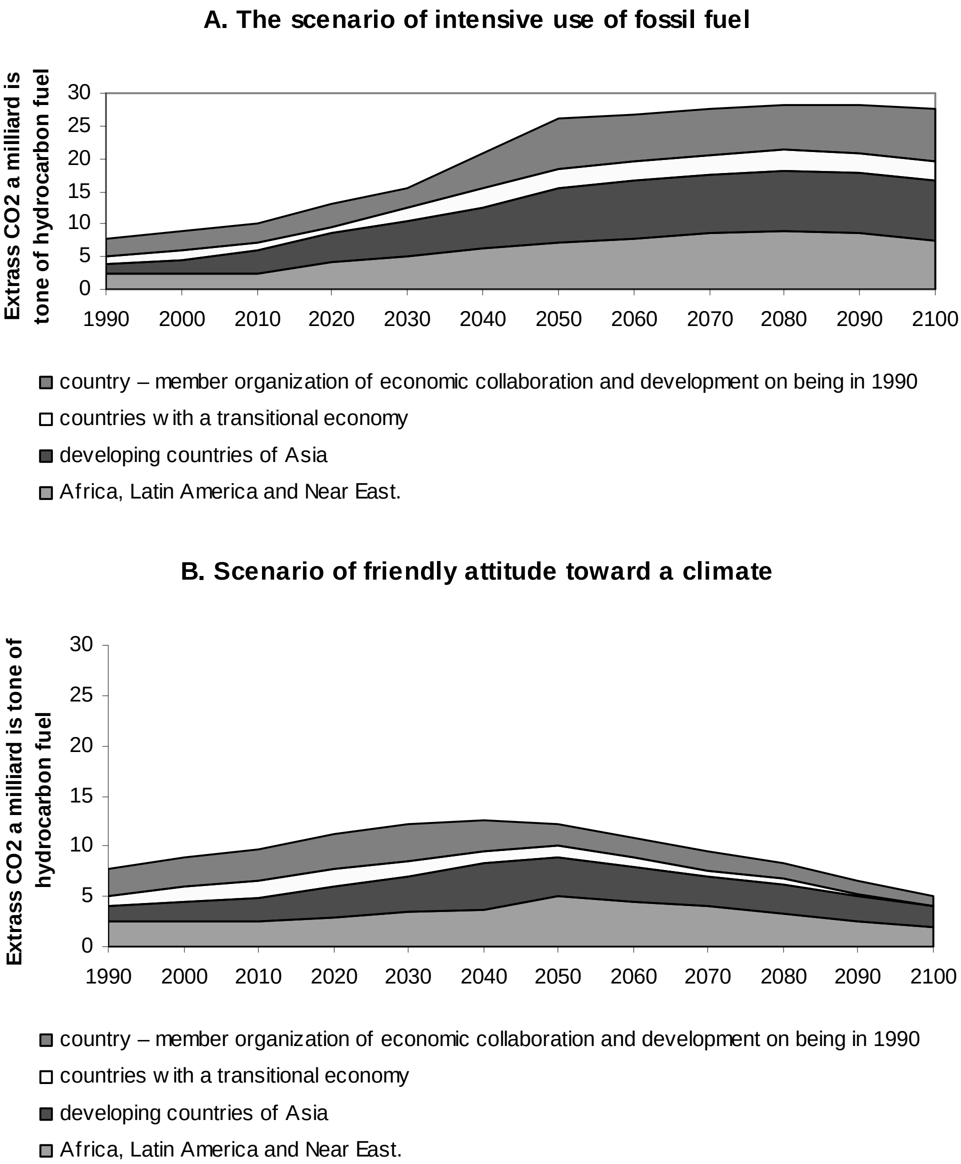

Fig. 2. The scenario of intensive use of fossil fuel and "friendly" attitude to climate (1990-2100)
Рис. 2. Сценарий интенсивного использования ископаемого топлива и "дружественного" отношения к климату (1990 – 2100 гг.)

Combustion process is a compound physicochemical process consisting of a range of interconnected physical and chemical stages: fuel evaporation, oxidant diffusion in zone of combustion and combustion materials in zone of fresh mixture, chemical reactions taking place in the flame front in zone of afterburning of fuel elements. The research of foremost scholars A. N. Voinov, V.K. Inozemtsev, V.V. Pomerantsev, N.N. Semenov and others for the basis of combustion process takes the conception of conversion, the speed of which influences the development of the process in general and diffusion conception, i.e. the speed of movement of front flame in the bulk of air-and-fuel mixture [5, 6, 7].

Viscosity, surface tension and density are referred to the physical properties of fuel influencing fuel stream dynamics and shallowness of spraying by other equal conditions. Average volumetric boiling point according to the characteristics of fuel distillation, critical temperature and phase transfer pressure of liquid fuel into steam and others are referred to the physical characteristics of fuel effecting the processes of its evaporation and burning.

Moreover hydrocarbon fuel content influences greatly on the processes of chemical kinetics. According to [8] hydrocarbon fuel content is presented in tab. 1.

The influence of dispensing of ozone and air mixture into fuel is basically connected with chemical adsorption and reactions of ozonolysis in liquid phase. The analysis of reactiveness of hydrocarbons can be done by constants of speed of ozonolysis reaction which are equal [9]:

for paraffin carbohydrates …...…………..... $10{,}5\cdot 10^{-2}…0{,}7$ l/(mole·s);
for naphthenetic carbohydrates …...………. $5\cdot 10^{-2}…0{,}32$ l/(mole·s);
for aromatic carbohydrates …...………..…. $3{,}4\cdot 10^{-1}…5\cdot 10^{-1}$ l/(mole·s).

Thus the most reactive aromatic carbohydrates will be mainly exposed to ozonolysis. The influence of ozone on the process of burning by its microaddition in fuel is explained by chain radical mechanizm of chemodecomposition of peroxide junctions which cause detonation in zone of burning.

The time of radical existence is limited that is why long-term storage of ozonized fuel leads to synthesis in its volume acids and decreases the ability to full burning.

According to [10] by ozonizing gasoline fuel the improvement of air-and-fuel mixture preparation for burning, evenness of burning in the whole front of flame are observed. The works on diesel fuel ozonizing by the analysis of the sources of literature have not been found.

For the verification of preliminary theoretical research [11, 12] the initial testing of ozonized fuel influence on working characteristics of diesel engine has been carried out.

The testing was carried out by charging characteristics on the test bench with swirl-chamber diesel engine 2Ч8,5/11 (fig. 3). Pulverizer РШ 6×2×25° with the pressure of fuel injection 15 MPa was set in the combustion chamber. The angle of advance of fuel injection was 10° before ODP.

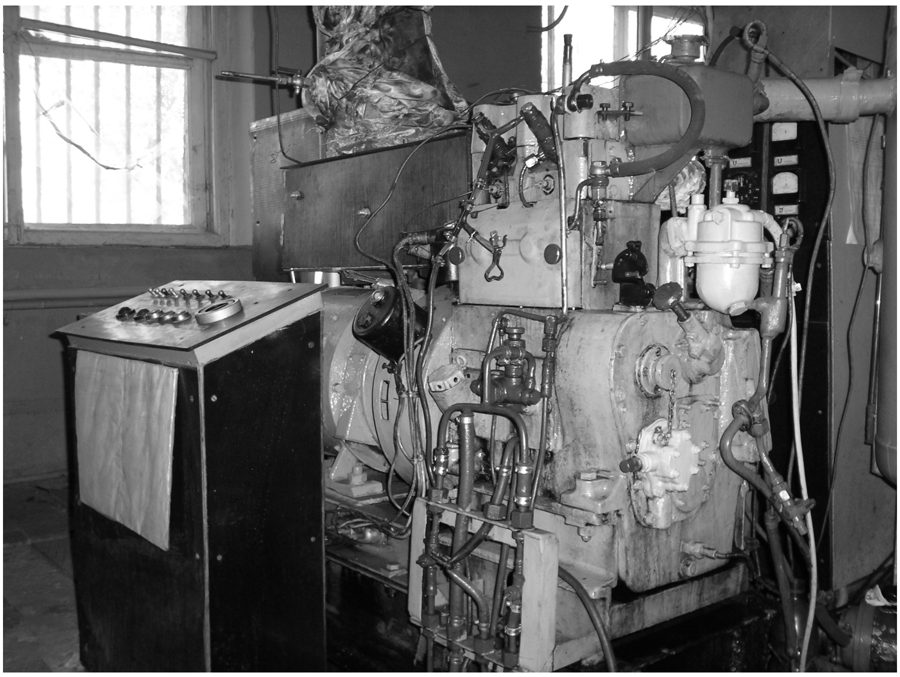

Fig. 3. General testing bench view
Рис. 3. Общий вид стенда

Table 1

Average statistical hydrocarbon diesel fuel content

№	Hydrocarbon Name	Hydrocarbon content, % volume
1	Aalkanes	32,49
2	Naphthenes	31,72
3	Indans, tetralins	6,69
4	Alkyl benzenes	11,65
5	Indenes or C_nH_{2n-10}	1,74
6	Naphthalene	0,59
7	Naphthalenes	7,11
8	Acenaphthenes, C_nH_{2n-14}	4,06
9	Acenaphthelenes, C_nH_{2n-16}	2,76
10	Ricyclic aromatics	1,18
11	Total of naphthenetics	33,46
12	Average from alkyl benzene	13,42
13	Average from naphthalenes	13,39

In the engine head (fig. 4) instead of the glow plug the connecting pipe is set in which chromel and copel thermopair with the diameter 1,5 mm. In the outlet branch the temperature of the burnt gas was fixed by a thermocouple. The thermocouples were previously jointly calibrated and selected according to their characteristics to control the state of valves and the influence of fuels on the combustion temperature in the swirl chamber.

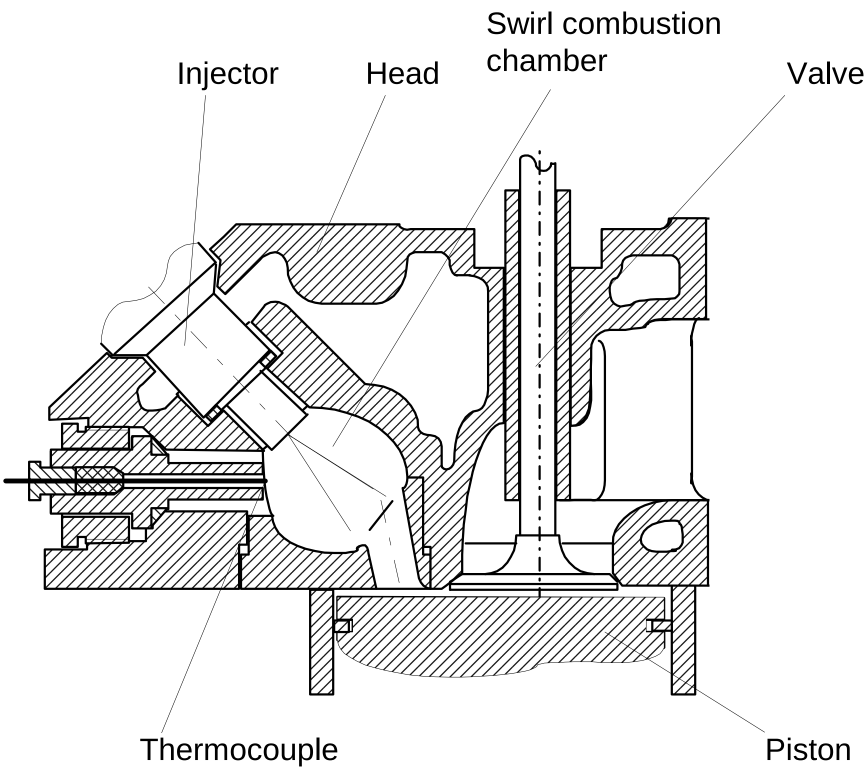

Fig. 4. The circuit of the chamber of combustion of diesel engine Ч 8,5/11
Рис. 4. Схема камеры сгорания дизеля Ч 8,5/11

Then after the engine warming-up when it was working on two cylinders at the time of damping-down, the fuel supply to one sprayer was cut off and the fuel delivery from the high-pressure pump was effected to the volumetric flask. After the restart, the rocking arm of a gas-distributing mechanism of dead cylinder was taken off on the working engine and the necessary loading was charged.

The test desk contains an oil-electrical engine, a loading device in the form of blocks with band resistances, an inlet system with a stabilizing container and the gas-meter РГ-40, the measuring of the fuel consumption АИР-50, the water system with an independent drive of the water pump and the outlet system. The temperatures of the burnt gases in the outlet branch and in the swirl combustion chamber were measured by chromel – copel thermocouples, the rotations of the engine crankshaft – by the standard tachometer and were duplicated by the frequency measuring meter Ф-5080. The air consumption was fixed with the gas-meter РГ-40. Exhaust opacity (N) was indicated on the gauge of exhaust opacity bench-top ИДС-3С. This gauge of exhaust capacity is a microprocessor device that provides automatic calibration and setting. The measuring result is presented in the form of simple average value, resulted from 20 current values of the exhaust opacity that have been measured during the measurement cycle (20 s). The device is licensed in Ukraine according to the certificate № UA-MI/1p-678-99.

The circuit of the experimental assembly for fuel ozonation is presented on fig 5. Testing was carried out with ozonator voltage U2 = 6 kV, the distance between ozonator electrodes was l = 5 mm, the ozonized fuel volume was V=2l, processing time – t = 25 min.

The results of the test are illustrated below (fig. 6-7).

While carrying out the statistical treatment of experimental data with a likelihood of 99% the reduction of the fuel consumption on the ozonized fuel was by 1.1%, and reduction of exhaust opacity by 12.29% and increase of performance index by 1.205% were revealed.

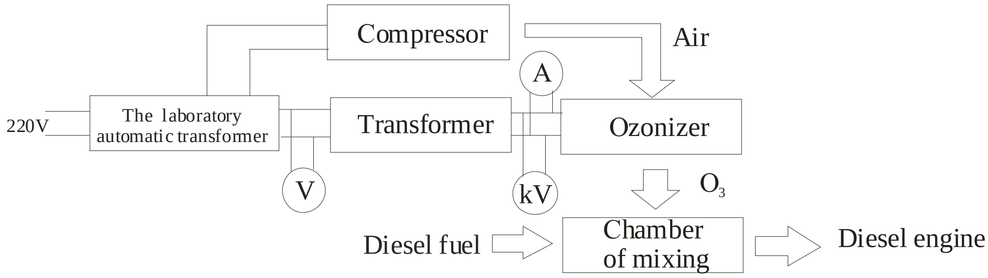

Fig. 5. Experimental setup for mixing diesel fuel and ozone
Рис. 5. Экспериментальная установка для смешивания дизельного топлива с озоном

Fig. 6. Dependence of fuel consumption from the time of diesel work: ♦ - on diesel oil; ▲ – on ozonized fuel
Рис. 6. Зависимость расхода топлива от времени работы дизеля: ♦ - на дизельном топливе; ▲ – на озонированном топливе

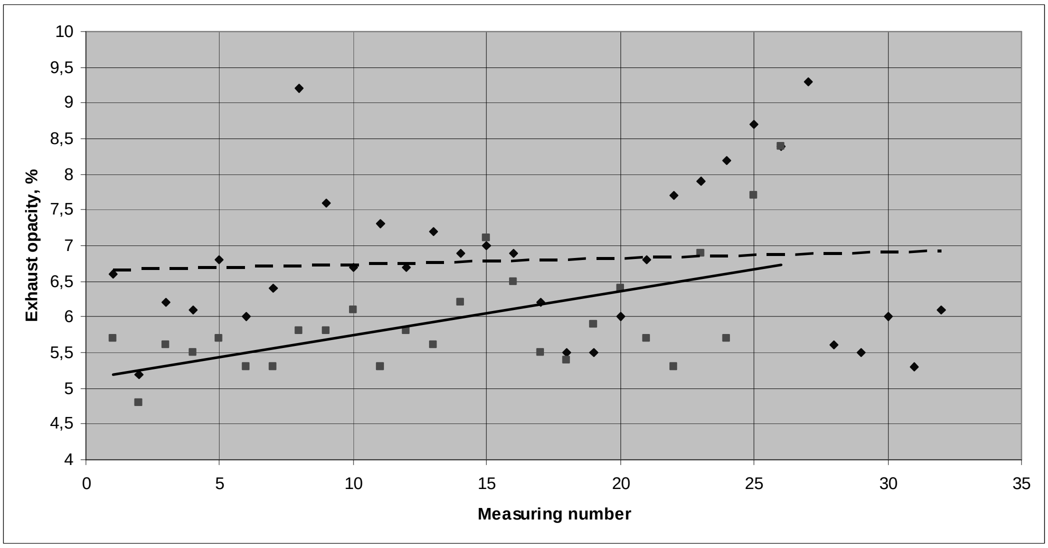

Fig. 7. Experimental data of exhaust opacity metering ♦ - on diesel oil; ■ – on ozonized fuel
Рис. 7. Экспериментальные данные замера дымности ♦ - на дизельном топливе; ■ – на озонированном топливе

3. CONCLUSIONS

As the preliminary experimental research shows there is some positive tendency of ozone usage as fuel additive. However, additional experimental research is necessary with showing up the influence on the flowing process of different factors such as concentration of ozone, time of influence on fuel etc.

Furthermore, it is interesting to reveal the influence of diesel air charge ozonation on its economy and ecological compatibility as well as ozone influence on bio-diesel fuel.

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