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IDENTIFICATION OF TECHNICAL STATE OF FUEL ENGINE APPARATUS ON THE GROUNDS OF MECHANICAL OPERATION SPEED IN PISTON-CONNECTING ROD SYSTEM

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Abstract

The following article presents technical state identification of fuel engine apparatus installed in ship combustion engine room on the grounds of mechanical operation of its piston-connecting rod system. Mechanical operation of piston-connecting rod system as the elementary assembly of fuel engine and energetic machine as well, is treated, according to J. Girtler, as the new physical quantity of [J·s]dimension. It expresses transformation of chemical energy delivered with fuel to the engine combustion chamber externally in form of work through the crankshaft torque. On the grounds of mechanical speed of piston-connecting rod engine operation, it is possible to assess the correctness of such elements as fuel pump, injector or their propulsion and tightness of the combustion chamber. At the same time one has to take into account the dependence of mechanical speed of piston-connecting rod system operation on such factors as engine load, revolution speed and the kind of fuel.

Keywords: *mechanical operation of piston-connecting rod system installed in ship combustion engine room, parameters characterizing dynamics of combustion in an engine, increasing speed of combustion gases pressure*

1. Introduction

To identify technical state of fuel apparatus in piston engine on the grounds of mechanical operation in the piston-connecting rod system, it is necessary to know accompanying processes like for example, the phenomenon of heat evolution in combustion chamber. Crank –piston system is a crank mechanism of the engine, enabling the change of reciprocating motion, carried out by the piston, into a rotational motion of the crankshaft.

This system is connected by means of piston rings with the assembly of cylinder liner and engine head. Such connection creates some kind of moving space, in which working process of the engine takes place [4]. Working process of the engine consists in heat evolution in the space over the piston, caused by fuel combustion. This increases pressure of the gases in the above mentioned space resulting in the movement of rings tightened piston, increasing the volume of the space. In this way chemical energy contained in the fuel, affects the elements of the piston-connecting rod system in the form of heat and work [5,9].

Piston-connecting rod system is a part of other functional systems of the engine. Evaluation of its operation enables the identification of the current technical state of fuel engine apparatus [1].

Below one can find a description of processes taking part during mechanical operation of the piston-connecting rod system, where a special attention is paid to thermo dynamical parameters, essential to identify technical state of fuel engine apparatus.

2. Mechanical operation of piston-connecting rod system in the high pressure engine

Mechanical operation of the piston is a transfer of energy in course of time, in the form of work by its neighborhood. The piston as a movable closure of the engine cylinder, transfers the power of gas pressure in the combustion chamber, to the connecting rod. These forces change in course of time in accordance with the indicator diagram. Besides, the piston is affected by inertial forces, caused by reciprocating movement of the piston and side forces from the connecting rod, as well as piston friction force against the walls of the cylinder liner. Fig.1 presents a diagram of forces affecting the piston, according to work [4].

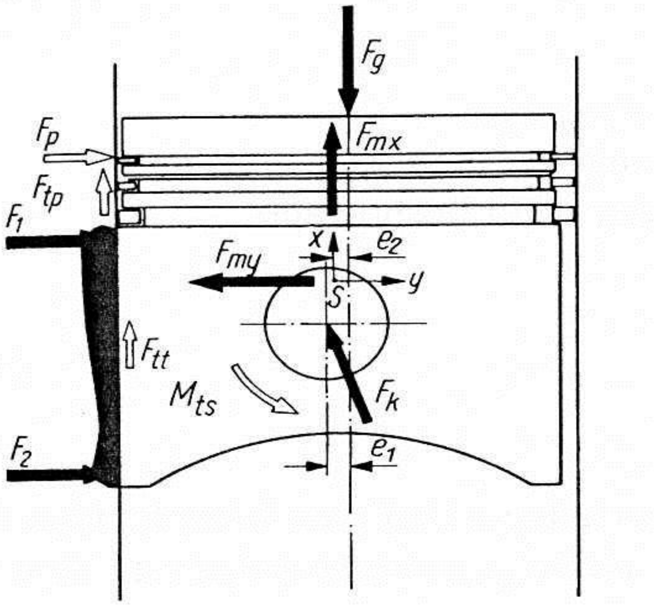

Fig.1. Forces affecting the piston [4]:F_g – gas force, F_{mx} – vertical component of inertial force, F_k – the force operating along the connecting rod axis, F_1 and F_2 – reaction of cylinder walls in the direction of "y" inadequately on upper and lower edge of leading part of the piston, F_{tt} – piston friction force against the cylinder walls, N- normal force, F_{tp} - friction force of the ring against the cylinder walls, M_{ts} – friction moment of piston pin

However, variability of the forces affecting the piston, is presented in fig.2. The above mentioned forces cause mechanical variables of operation in the piston-connecting rod system, whose dynamics depends on cylinder pressure, in particular, on the speed of its escalation.

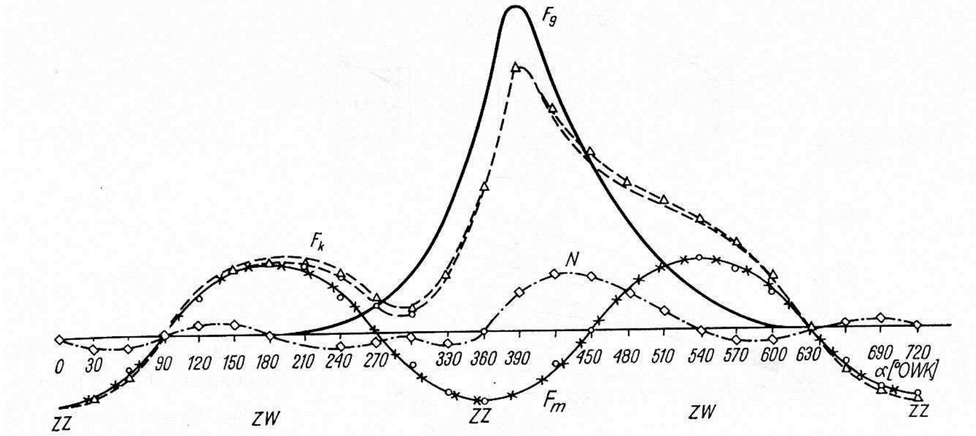

Fig.2. Variability of forces affecting the piston [4]: ZW- DMP, ZZ- GMP, symbols as in fig.1

Mechanical operation speed of the piston-connecting rod system, depends chiefly on the speed of pressure escalation, during combustion. This speed determines the loading conditions of crankshaft bearing and crank mechanism. It is also connected with a dynamics of heat emitting during combustion and depends on mass intensity of burning reaction. Besides the speed of mechanical operation increase, depends also on the volume change of combustion chamber during heat emitting. The speed of mechanical operation in the piston-connecting rod system of the engine can be determined indirectly by means of the pressure speed intensity in the cylinder, during combustion of fuel.

Approximate method which assumes that in the period of burning there is no heat exchange between the walls of combustion chamber and exhaust gases, allows us to determine the speed of gas pressure intensity by means of the following dependence[7]:

$$\frac{dp}{d\alpha} = \frac{\chi - 1}{V} \cdot W_d \cdot m_p \cdot \frac{dw}{d\alpha} - \chi \cdot \frac{p}{V} \cdot \frac{dV}{d\alpha} \qquad (1)$$

where:

W_d [J/kg] – combustible value of fuel,
m_p [kg/circulation] – fuel dose,
χ [-] – adiabatic exponent,
V [m^3] – volume of combustion chamber,
p [Pa] – pressure in combustion chamber,
α [^{0}OWK] – crank turn angle,
$\frac{dV}{d\alpha}\left[\frac{m^3}{^0OWK}\right]$ - speed of combustion chamber change,
$\frac{dw}{d\alpha}\left[\frac{1}{^0OWK}\right]$ - relative mass speed of reagents mass (burning subject to reaction in the time unit),
$\frac{dp}{d\alpha}\left[\frac{Pa}{^0OWK}\right]$ - speed of pressure intensity during combustion.

In dependence above, first part of equation presents the influence of heat emission and the second part- volume change of combustion chamber.

On the grounds of work [4] one can state that the speed of wear and tear of piston rings is dependent in a linear way on dynamics of combustion defined as the product of maximal speed of pressure intensity $\left(\frac{dp}{d\alpha}\right)_{max}$ and an increase of pressure until then $\left(\frac{dp}{d\alpha}\right)_{max}$.

Dependence between the speed of consumption expressed as tgα and the indicator of burning dynamics, has been presented in fig.3, according to work [4].

One should pay attention to the fact that mechanical operation of piston-connecting rod system of the engine, caused by gas pressure in the cylinder, is of dynamic character. The speed of pressure intensity as the parameter characterizing piston dynamics, according to work [4] equals to:

- for the engines with spark ignition from 0,2 to 0,4 [MPa/^{0}OWK],
- for the engines with self-ignition and direct injection 1 [MPa/^{0}OWK].

3. Diagnostic symptoms defining the correctness of work of fuel engine apparatus, on the grounds of mechanical speed operation in the piston-connecting rod system

Correctness control of fuel apparatus operation of an engine, can be carried out on the grounds of diagnostic parameters.

To achieve more correct results in operation of fuel engine apparatus, one can use the course of pressure changes on the grounds of indicator diagram. In this case diagnostic parameter achieved from an indicator diagram is nothing else but the speed of pressure intensity, in other words, an increase of pressure for one turn of the crankshaft or a pressure increase in a time unit.

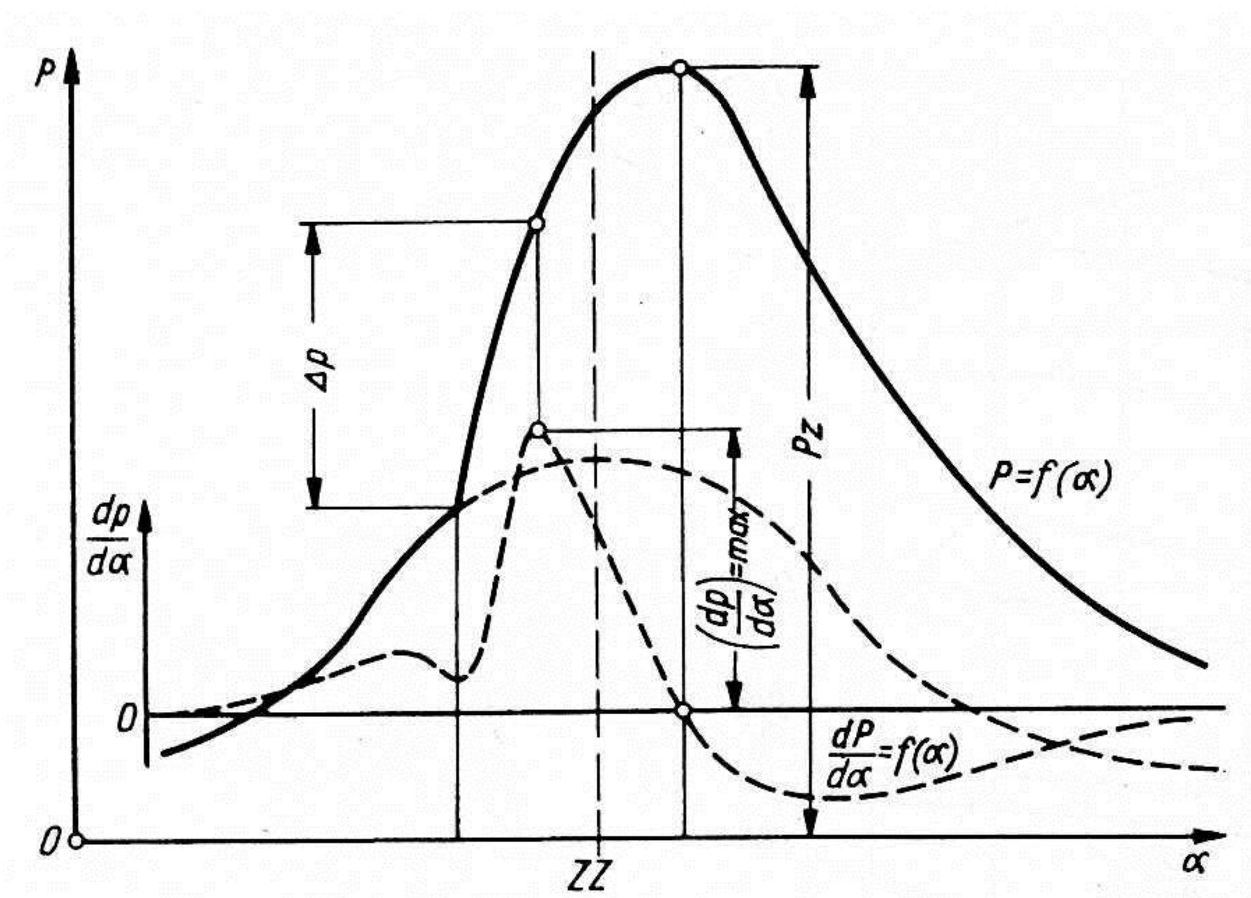

Fig.3. Parameters characterizing dynamics of burning process[4]; symbols as in text

The above parameter can be used to detect an incorrect work of such elements as: fuel pump, injector or their drive.

In order to determine diagnostic advantages of pressure intensity speed as a mechanical parameter of the piston-connecting rod system, special research by the Department of Marine Power Plant – Maritime Academy- Gdynia, was carried out. In order to carry out the research, the experimental combustion engine L22, made by the Warsaw Institute of Technology and the four – stroke combustion engine made by the Cegielski-Sulzer 3AL25/30, were used.

The L22 engine is equipped with some devices for fluent change of the injection advance angle, which allowed to determine the influence of the injection advance angle, on the changes of pressure intensity speed. Fig.4 presents a dependence of maximal pressure intensity speed on the injection advance angle. Results of the research cause deviations from the proper injection advance

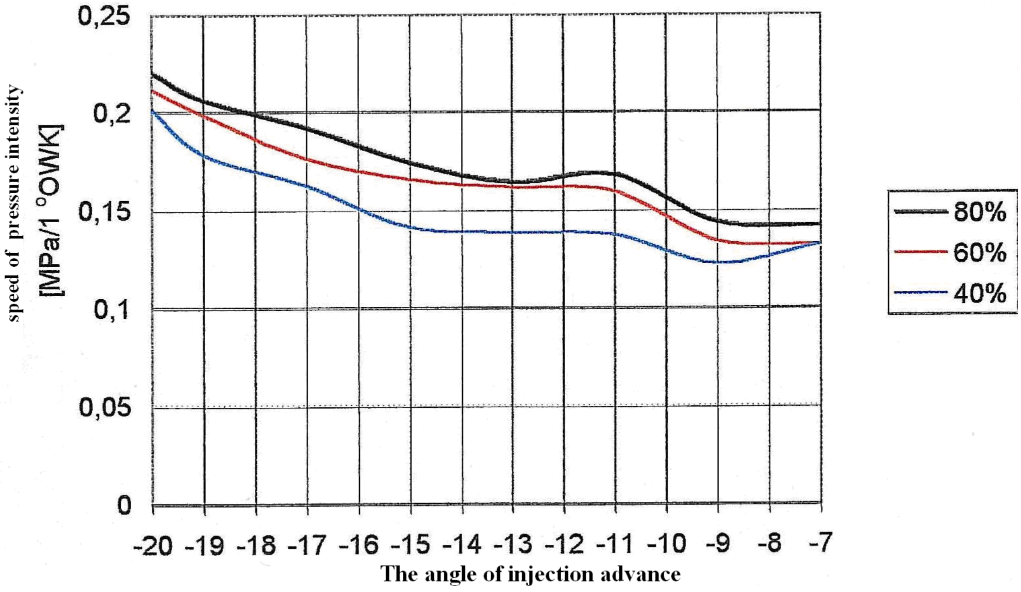

Fig.4. Dependence of maximal speed of pressure intensity on the injection advance angle at the engine load L22 40%, 60% and 80%

angle at different engine loading. This results in incorrect operation of the piston-connecting rod system. Maximal speed of pressure intensity will be too early if the angle is too big and too late when the angle is too small. Therefore too fast pressure speed intensity is the reason of the piston-connecting rod overloading. On the other hand, with too small angle, maximal speed of pressure intensity moves on to the expansion stroke which causes a drop in the efficiency of the engine operation. Such factors as injector sprayer with too much coke in it, faulty injection pump or too low pressure of the injector opening, influence negatively the operation of the piston-connecting rod system. The research on the change of maximal speed of pressure intensity was carried out on the engine 3AL25/30.

Fig.5 presents maximal speed of pressure intensity in cylinder No.2 of the engine 3AL25/30. Figure 5 shows the lack of ignition at the maximal speed of pressure intensity in the point where the ignition should occur and a pressure increase.

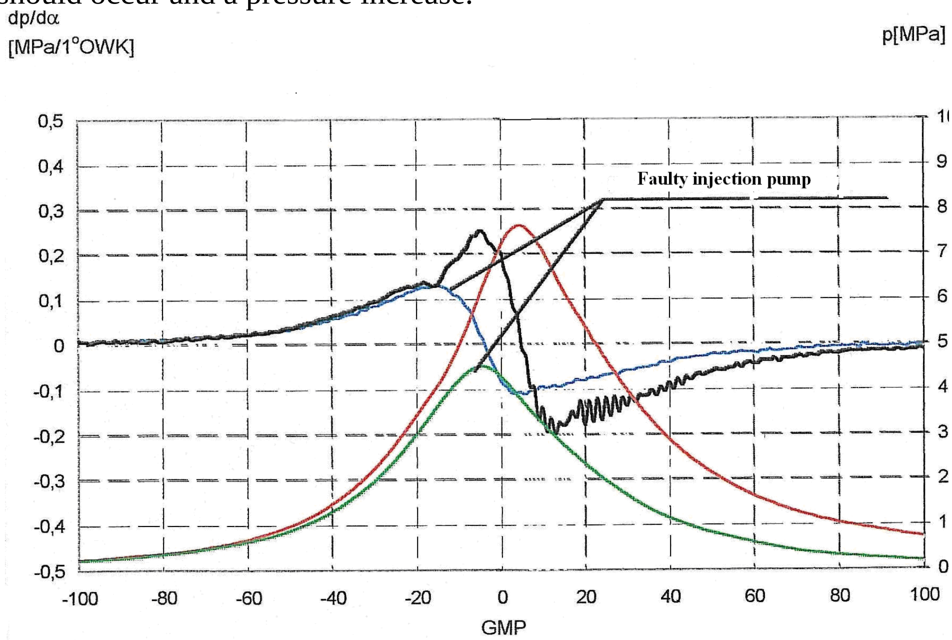

Fig.5. Faulty injection pump in cylinder No.2 of the engine 3AL25/30 at its load of 140 [kW]

On the other hand fig.6 shows the courses of maximal speed of pressure intensity in cylinder No.2 of the engine 3AL25/30 with too much coke in the injector openings of this cylinder. Fig.6

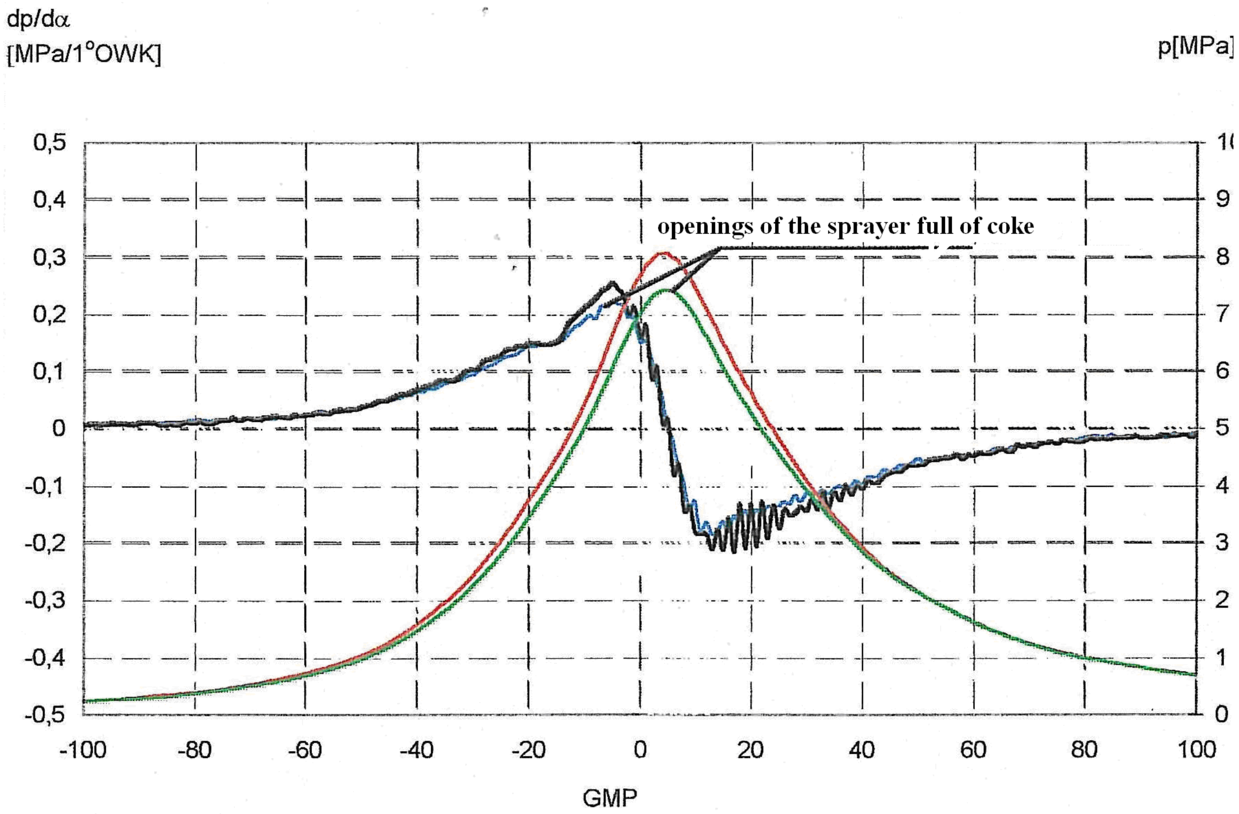

Fig.6. The course of maximal speed of pressure intensity in cylinder No.2 of the engine 3AL25/30 with coked openings of the injector and the load of 220[kW] in the function of the crankshaft turn

shows that such inefficiency of the injective reduces the maximal speed of pressure intensity and in the same way decreases the power of the engine at the same setting of the fuel fence.

Worsening of mechanical operation of the piston-connecting rod system is caused by the worse atomizing of the fuel in the combustion chamber and this results in the ignition delay. Worsening of the fuel injected into the cylinder is the cause of an increase of exhaust gases temperature [1,6].

The speed of pressure intensity changes its value depending on the mechanical speed of the piston-connecting rod operation [4,7,8].

Fig.7 shows maximal speed of pressure intensity in the cylinder of the engine 3AL25/30 at different loading and incorrectness of fuel apparatus operation in the second cylinder and leakages of its combustion chamber. Together with the speed of pressure intensity increase also:

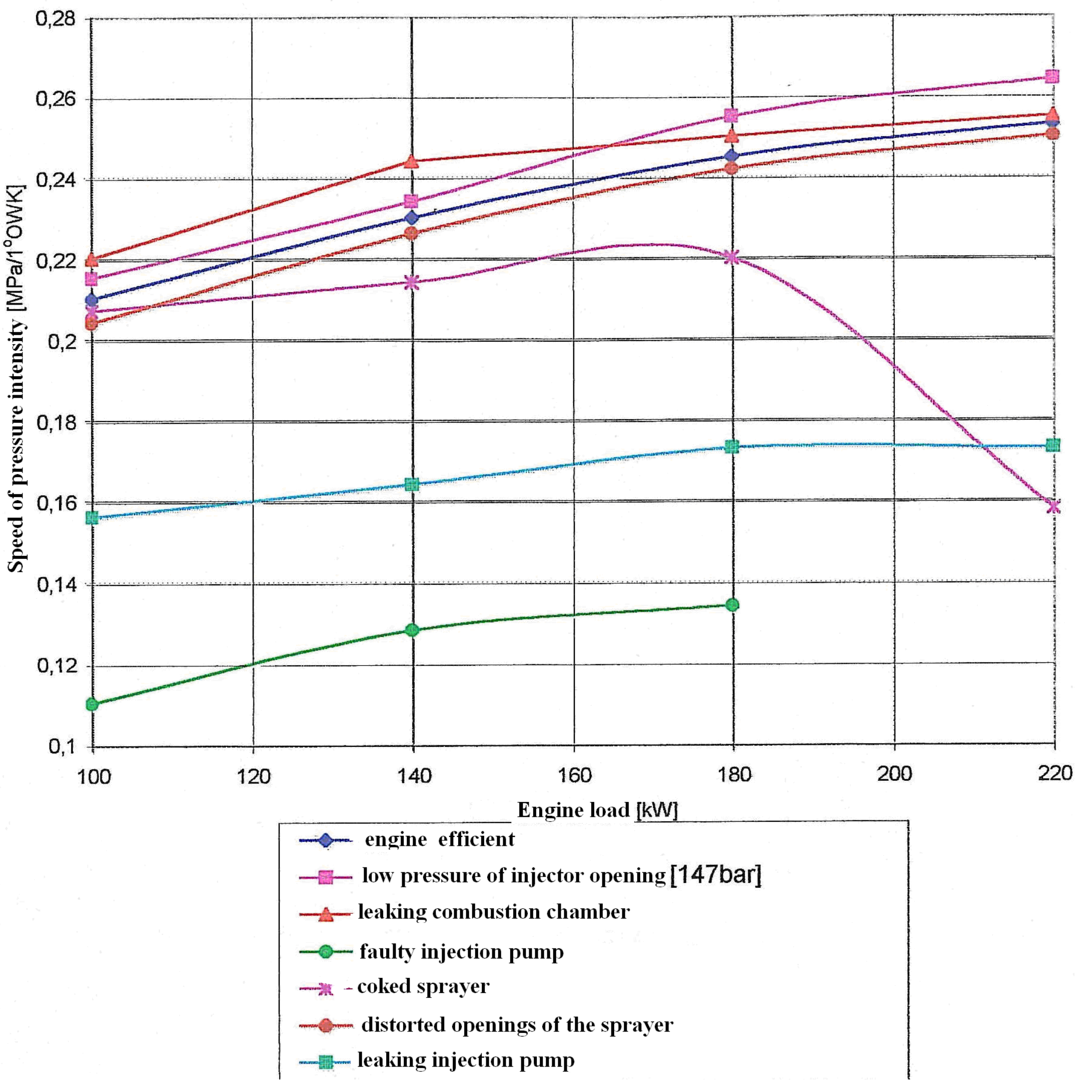

Fig.7. Speed dependence of pressure intensity in cylinder No.2 of the engine 3AL25/30 at its different loading: 100[kW], 140[kW], 180[kW] and 220[kW]

- temperature of gases,
- indicated medium pressure,
- maximal burning pressure.

The speed of pressure intensity changes its value in dependence on the mechanical speed of the piston-connecting rod system operation [7,8]. Fig.7 shows maximal speed of pressure intensity in the cylinder of the 3AL25/30 engine at its different loading and incorrectness of fuel apparatus operation in the second cylinder and leakages of its combustion chamber.

4. **Summary**

Basing only on the grounds of the speed pressure intensity one can determine only some irregularities of fuel engine operation. To identify precisely most irregularities it is necessary to take advantage of other diagnostic parameters. Irregularities of fuel engine operation are harder to detect if only one parameter is being used. Then it is necessary to verify other parameters like temperature of exhaust gases, indicated maximal pressure etc. [1,5].

The course of pressure speed intensity in engine cylinder depends also on such quantities as: engine load, revolution speed and the kind of fuel [4,5,8].

However, the efficiency of the engine depends to a great extent on the wear of piston rings which can be the reason of leakages in combustion chamber. Besides, material consumption of the piston-connecting rod system can cause changes of such parameters as:

- suction pressure,
- pressure of the final compression,
- combustion pressure,
- composition of exhaust gases[1,4].

The above parameters influence also the power and fuel consumption by the engine. To evaluate technical condition of the piston, rings and cylinder one can use such diagnostic parameters as:

- compression pressure,
- tightness of combustion chamber,
- suction pressure,
- the course of maximal speed of pressure intensity in the cylinder [6].

The operation of combustion engine has been determined as a delivery of necessary energy at a definite time which can be expressed in the form of the physical quantity with a measure unit called Joule · second [2].

Considering energetic values of combustion engines it is necessary to analyze their operation and not only their work. In operation analysis, except work, we also have to take into account the time of its realization [3].

During research as to estimate the piston-connecting rod system of combustion engine, it is possible to use characteristics of vibration signals. The knowledge of the vibration frequency of its own elements in the piston-connecting rod system of combustion engine, increases a precise defining of their technical state [6].

5. References

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