ANALYSIS OF INCREASE IN GENERAL EFFICIENCY OF SPARK IGNITION ENGINE WITH DIRECT FUEL INJECTION

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Abstract
The paper presents a thorough analysis of general efficiency of Gasoline Direct Injection Engine. The article gives a description of the measurement test bed, and the performed investigations which aimed at proving increase in general efficiency of the engine GDI. The results of the performed investigations are presented in form of two-dimensional diagrams. Analysis of the obtained results permits to state that in a certain range of rotational speed and at loading during work on stratified mixture increase in efficiency takes place.

Introduction
Constructors of fuel engines face higher and higher requirements concerning ecological problems and increase in engine performance at a simultaneous decrease in fuel consumption. These requirements can be satisfied due to recognition of the phenomena occurring in the engine cylinder, choice of adequate optimal parameters of the fuel injection process, as well as determination of the geometrical shape of the combustion chamber and piston head. All these parameters influence significantly improvement of fuel engine performance and raise of its efficiency. The later one is, first of all, connected with changes introduced in feeding: adequate regulation of the fuel-air mixture in dependence on rotational speed and load; so, combustion of lean mixture in a fuel engine with direct fuel injection has significant influence on the increase in efficiency at a simultaneous decrease in exhaust gas toxicity and fuel consumption.
This kind of feeding systems shows that, apart from the advantage of very lean mixture combustion, petrol engines with direct injection have a number of other positives:
- higher power than in other spark ignition engines with multi-point fuel injection.
The constructors aim is to get increase in general efficiency and not only in one of the constituting it partial efficiencies; hence a thorough analysis of the above mentioned factors, deciding about its real value, is absolutely justified.

Investigation object
A petrol engine with direct fuel injection into the cylinder Mitsubishi type 4G93GDI of cylinder capacity 1800 cm³. A four stroke, four cylinder, 16-valve with a double camshaft in
the head, constructed on the basis of an engine with multi-point indirect fuel injection of the same cylinder capacity. Modernisation of the new feeding system includes:
- pressure pump of injection pressure $P_{inj}$ 50 [bar]
- shape of the piston head with a characteristic bowl which permits rebounding of the fuel jet during work on stratified charges
- vertical air channels in the inflow collector
- the engine head equipped with two camshafts with 4-valves cylinder
- electromagnetic injector with an ending permitting whirl of the injected fuel, mounted at an angle $36^\circ$ from the vertical cylinder axis.

Fig. 1. Scheme of the measurement post for determination of general engine GDI efficiency
Test bed for engine 4G93GDI

For determination of general efficiency of a fuel engine with direct fuel injection test bed investigations were performed. Their aim was to state the speed and load characteristics of the examined engine. On their basis the general efficiency of the fuel engine with direct fuel injection can be determined. A roller undercarriage test bed equipped with an electrically controlled water brake whose maximal breaking moment is 150 [Nm] was adopted as a test bed for determination of speed and load characteristics of the engine. A scheme of the measurement stand was shown in fig. 1.

Results of test bed investigation

Results of test bed investigations were presented in graphical form in two-dimensional diagrams. With regard to a significantly decreased unitary and hourly fuel consumption within the range of rotational speed 750-2700 [rpm] caused by engine work in the mode of fuel-air mixture stratified (\( \phi = 1.5 \), 2.1 in dependence on the rotational speed and load of the engine) the diagrams were to be accomplished by an additional characteristics of unitary fuel consumption.

In order to achieve it diagrams of unitary fuel consumption were drawn within the same range of rotational speed 750-2700 [rpm] in the same way as for an engine working on homogenous mixture (\( \phi = 1 \)). In consequence of it the value of unitary fuel consumption does not show the characteristic transition from one mode of work to the other. Fig. 2, 4 shows diagrams of unitary fuel consumption in function of rotational speed of engine GDI and fig. 3, 5 shows diagram of general efficiency in function of rotational speed of engine GDI.

![Graph of unitary fuel consumption in function of rotational speed of engine GDI for fuel power](image)

Fig. 2. Diagram of unitary fuel consumption in function of rotational speed of engine GDI for fuel power
Fig. 3. Diagram of general efficiency in function of rotational speed of engine GDI for full power

Fig. 4. Diagram of unitary fuel consumption in function of rotational speed of engine GDI for ¾ power
Fig. 5. Diagram of general efficiency in function of rotational speed of engine GDI for fuel ¾ power

Conclusions

The performed test bed investigations, aiming at proving the increase in general efficiency of the engine GDI of cylinder volume 1800 cm$^3$ with direct fuel injection, permit to formulate the following conclusions:

- engine GDI with direct fuel injection into the cylinder during work on stratified mixtures (injection during compression stroke) shows a unitary and hourly decrease in fuel consumption by about 20%
- the value of the coefficient of air excess during work on heterogeneous mixture increases to the value 2.2, this giving evidence of a very lean charge in the engine cylinder
- lamination of charge depends mainly on the rotational speed of the engine and its load and remains unchanged to 2300-2700 [rpm]
- the characteristic moment of transition from the working mode of the engine on heterogeneous mixture to the working mode on homogenous mixture is noticeable in form of a rapid jump of unitary fuel consumption by about 50 [g/kWh] on all characteristics of partial powers for full power, ¾, ½, ¼ of the effective power respectively
- during work on idle gear a drop of rotational speed by about 650-700 [rpm], in connection with it a drop of fuel consumption is noticeable
- the value of the maximal torque 172 [Nm] at 3750 [rpm] and maximal power 95 [kW] as well as of advantageous runs in function of rotational speed indicate to a great elasticity of the engine with this kind of feeding system
- evident increase in general efficiency of the petrol engine GDI by about 15% in determined
- the range of rotational speeds which increase in general efficiency occurs is within the limits 750-2700 [rpm].