VISUALIZATION IN OF INSIDE CYLINDER PROCESSES IN GASOLINE DIRECT INJECTION ENGINE

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Abstract

Possibilities of improving power and achieving decrease in emission of toxic components of exhaust gases of combustion engines are conditioned by a more and more precise organization of the course of fuel injection and combustion process. A gasoline engine with direct injection into the cylinder of the firm Mitsubishi type 4G93GDI of 1800 cm^3 capacity constitutes the investigation object: The present work aims test bed with use of specialistic apparatus for visualizations of inside cylinder processes were discussed. By use of visualization observation was performed of the run of the fuel jet from the moment of injection, consequent by rebouncing of the fuel from the piston head, on to reaching under the gap between the electrodes of the ignition plug and flame spreading from the moment of ignition till the end of the combustion process.

1. Introduction

Possibilities of improving power and achieving decrease in emission of toxic components of exhaust gases of combustion engines are conditioned by a more and more precise organization of the course of fuel injection and combustion process. For optimization of the processes occurring inside the engine cylinder, analysis of changes of the basis initial parameters of the engine solely is not sufficient any more. For direct evaluation of the course of fuel injection, way of fuel-mixture formation and its combustion a possibility of visual evaluation of these phenomena becomes more and more necessary. There are a number of significant problems connected with recording pictures inside the cylinder of a combustion engine. To the crucial ones belong: high temperature and pressure of the working medium acting on the optical element of the measurement apparatus, too little room in the heads of up to date engines for access of optical insight into the cylinder and a high rate of change of the recorded phenomena. One of the examples of solution of this type of difficulties was given in this paper.

Moreover, visualizing systems of various firms were compared as concerns recording rate and frequency of picture sampling, definition of picture end optical sensitivity as well as possibility of storing pictures.

2. Investigation object

A gasoline engine with direct injection into the cylinder of the firm Mitsubishi type 4G93GDI of 1800 cm^3 capacity constitutes the investigation object: a 4-stroke, 4-cylinder, 16-valve with double distribution shaft in the head, constructed on the basis of an engine with multi-point indirect fuel injection, of the same volume. Modernization of the new feeding system includes:

- pump of high pressure of injection pressure $p_{wtr} = 5[MPa]$,
- shape of the piston head with a characteristic bowl permitting rebouncing of the fuel jet during work on stratified charges,
- vertical air ducts in the inflow collector,
- head of the engine equipped with two distribution shafts with 4-valves per cylinder,
- electromagnetic injector with an end permitting whirling of the injected fuel, mounted at an angle $\gamma = 36^0$ from the vertical cylinder axis.

The engine of the type 4G93GDI has a maximal torque M_{max}=147 [Nm} at rotational speed 3750 [rpm] and maximal engine power N_{max}=100 [kW] at rotational speed 5500 [rpm]. (Producer's data).

For visualization of this type of engine access of the measurement apparatus to the inside of the combustion chamber had to be made possible. So the head of the engine was subjected to some modifications: two openings of the same diameter $\varphi = 10[mm]$ at an angle measured from the bottom horizontal plane of the head were made (App.1), whereas, the angles between the two openings, measured in the cross plane of the head were $\varphi = 5$ and $\varphi = 7^0$. Choice of the value of these angles is decisive for recording processes occurring inside the cylinder, since they determine the area of visual control of the recorded pictures. Two sleeves were fixed in these openings, respectively one for the endoscope and the other for the stroboscope lamp. After adaptation of the head to the engine visualization was performed on a chassis test bed.

3. Test bed for visualization by use of apparatus of the firm AVL Engine videoscope 513 d

In order to perform visualization of the fuel injection and combustion process in the cylinder of the vehicle engine a chassis test bed was adopted.
The vehicle engine was equipped with an engine 4G93GDI and was placed on rollers of the chassis test bed permitting a precise reading of the values of loading and rotational speed of the engine.

Optical access to the combustion chamber is ensured by endoscope. This element is connected directly with the digital camera lens. Cooling of the endoscope is performed by a forced airflow between the sequence of lenses inside the endoscope. The firm AVL proposed endoscopes of diameter 7 and 4 [mm]. Endoscope of the diameter of 7 [mm] is characterized by a view angle 67^o, whereas the 4 [mm] diameter endoscope has a view angle of 80^0.
A digital camera CCD of the firm Pulmix of high definition of picture 768×482 points was adopted. The time of the exposure for combustion process recording is 60 [μs] (1/16000s). Of course longer exposition can also be applied e.g. for phenomena which are not light sources. Maximal frequency of measurement release is 12 [Hz]. Since consequent pictures are taken from different cycles of engine work the recording frequency of recording does not limit directly the angular distance of successive recorded expositions. Due to it the measurement

system performs storing of pictures of the phenomena occurring in the cylinder of the engine shifted with respect to one another by 0.1^o CA.

The way and scheme of the test bed was presented in Fig. 1.

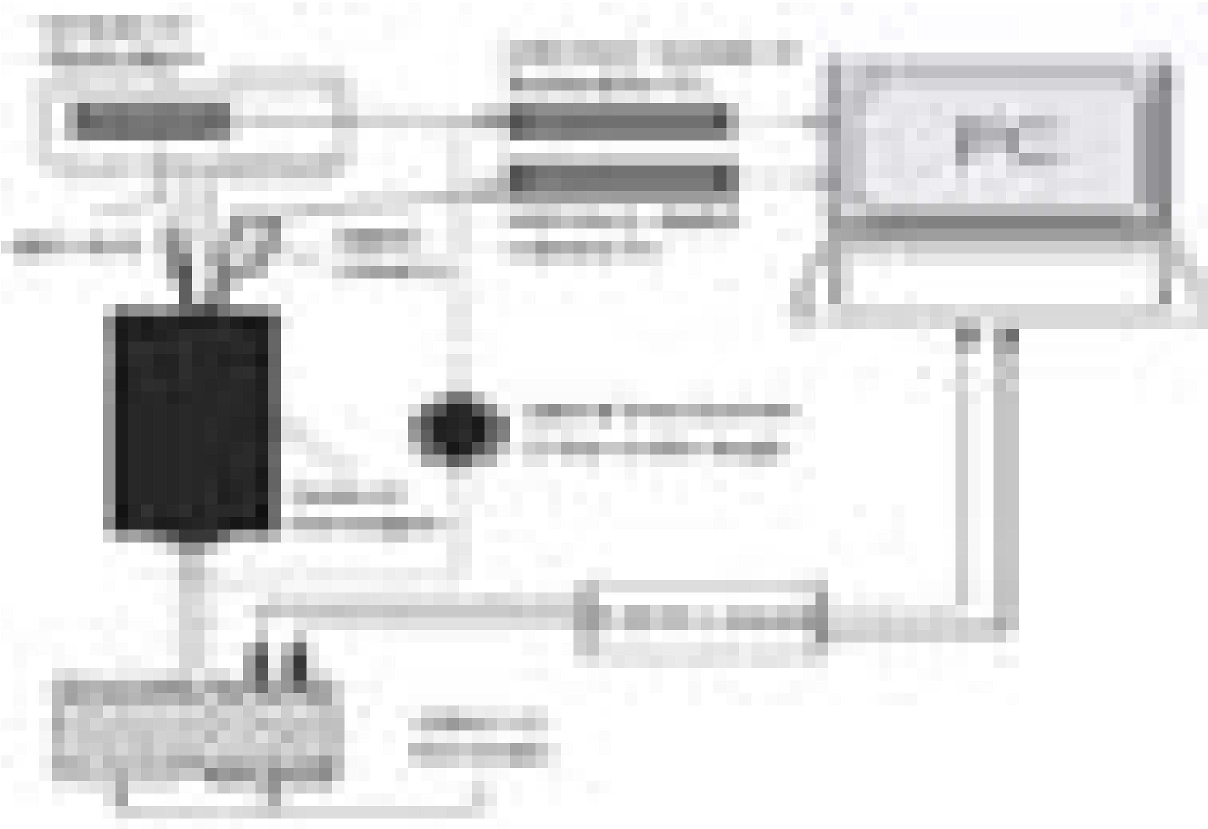


Fig. 1. Scheme of the measurement test bed for visualization on fuel injection and combustion process in a Mitsubishi GDI engine by use of AVL Engine Videoscope 513D

4. Investigation results

Respectively in point 4.1 was presented visualization of injection combustion process during engine work on stratified mixture.

In point 4.2 was presented visualization of the combustion way in the GDI engine during engine work on stratified mixture.

4.1 Visualization of injection combustion process during engine work on stratified mixture

The carried out visualization concerned the process of injection and combustion during engine work on stratified mixture. Recording was carried out for rotational speed of the engine 2400 [rpm] for partial load. The value of fuel consumption per unit was 238 [g/kWh]. Fuel injection took place for 78^0 CA before TDC.

Below, in the presented film frames (*Fig. 2a-2d*) chosen photographs concerning fuel injection into the cylinder of GDI engine.

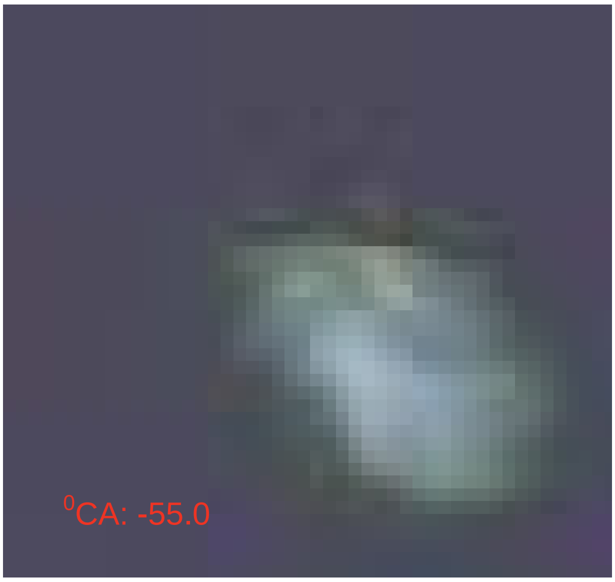
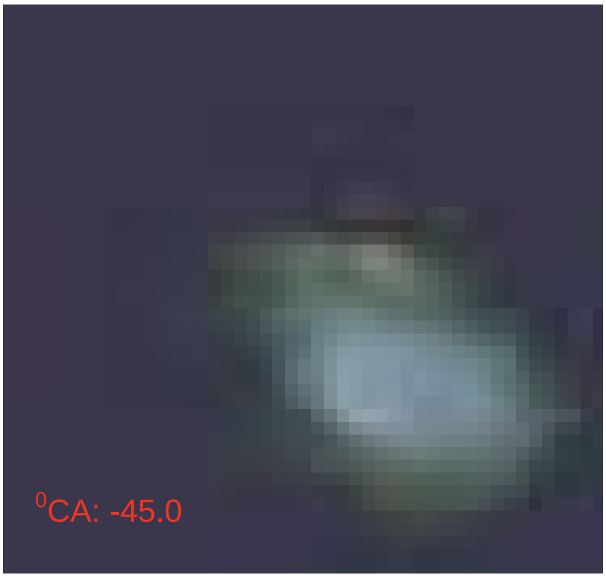


Fig. 2a. Photograph of injected fuel jet for 62 deg CA before TDC. There is small fuel dispersion on the other edges of the jet and its gradual evaporation. The fuel jet inside the core is very coherent

Fig. 2b. Photograph of injected fuel jet for 55 deg CA before TDC. In consequence of turbulence considerable evaporation of fuel has taken place, whereas a portion of the not evaporated part reaches the inclination of the piston head



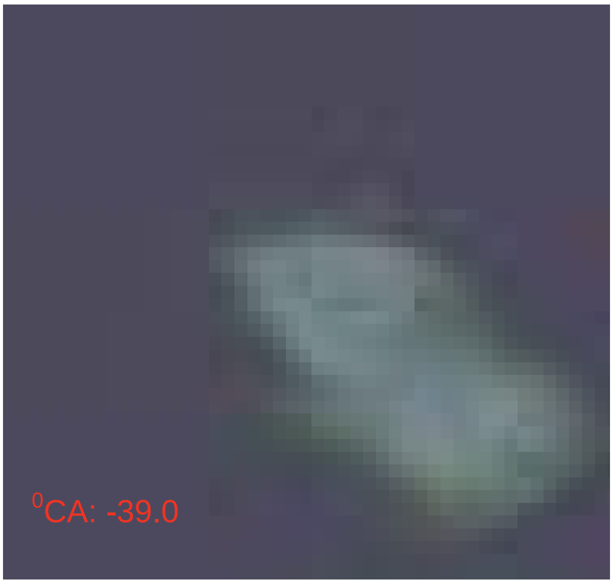


Fig. 2c. Photograph of injected fuel jet for 45 deg CA before TDC. Rebouncing of the injected fuel jet from the piston head takes place

Fig. 2d. Photograph of injected fuel jet for 39 deg CA before TDC. The fuel jet is directed by the curvature in the piston head towards the ignition plug

4.2. Visualization of the combustion way in the GDI engine during engine work on stratified mixture

The moment of ignition took place for 10 deg CA before TDC. *(Fig. 3a-3d).*

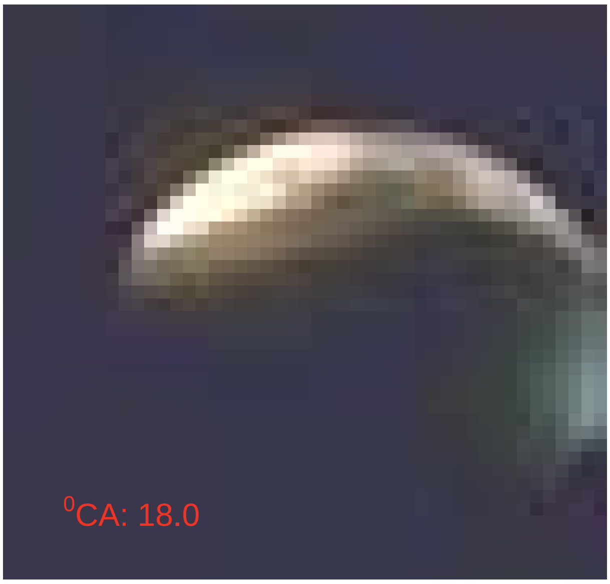


Fig. 3a.Moment of ignition took place for 10 deg CA before TDC. The photograph present the initial phase of flame development for 18 deg CA after TDC. High whirling occurring in the combustion chamber is clearly visible. This may be concluded from the character of the flame

Fig. 3b. Photograph of the further development of the flame for 20 deg CA after TDC. The flame spreads over the whole combustion chamber and the flame front moves towards the zone of expression

Fig. 3c. Photograph of a consecutive phase of stratified mixture combustion for 30 deg CA after TDC. High whirling inside the cylinder permits the flame to penetrate over the whole area of the engine cylinder

Fig. 3d. Photograph of the ending phase of stratified mixture combustion for 33 deg CA after TDC

5. Discussion.

1. The results of the carried out visualization are in form of files of the *avi* type. These are files designed for presentation of the record of particular frames in form of a moving picture.

2. Out of editorial reason the results of visualization are presented in this paper in form of individual film (frames snaps) succeeding one the other every certain crank angle.
3. The value of the angle for which consequent frames were presented are placed in the left bottom corner of an individual frame.
4. All the taken records store the pictures in function of the crank angle not from one but many cycles of engine work.

References

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