THE USE OF HYDROGEN IN A DIRECT INJECTION SPARK IGNITION ENGINE

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Abstract: This paper aims to reveal the benefits of using hydrogen to ensure burning of lean gasoline-air mixtures in direct injection SI engines.

1. INTRODUCTION

The use of hydrogen for lean mixtures was studied by the authors first on SI engines with carburetor. These studies were then developed on direct injection SI engines.
One of the major achievements was the construction of a device able to produce hydrogen on board of the vehicle (fig. 1).

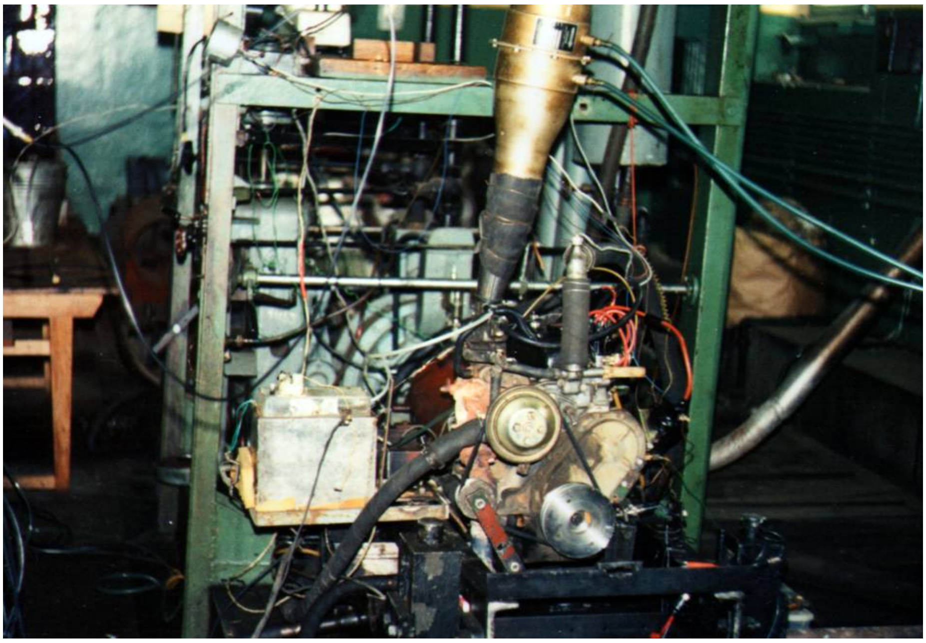


Fig.1 Device for producing hydrogen on board of the vehicle

The device produces, through electrolysis on a mixture of water and methanol, in accordance with chromatographic analyses, 0,2% CH_3OH volumes, 1,03% H_2 volumes, 20,4 % 0_2 volumes and 78,6% N_2 volumes.
By introducing a small quantity of hydrogen in the cylinder it is possible to initiate the burning of lean gasoline-air mixture. The aim of using hydrogen in SI engines is to reduce consumption and emissions.

2. TEST BED PRESENTATION

In accordance with the international standards the running characteristics have been obtained on the fluid brake stand by comparison with the same engine
The scheme of the measurements device is presented in figure 2.

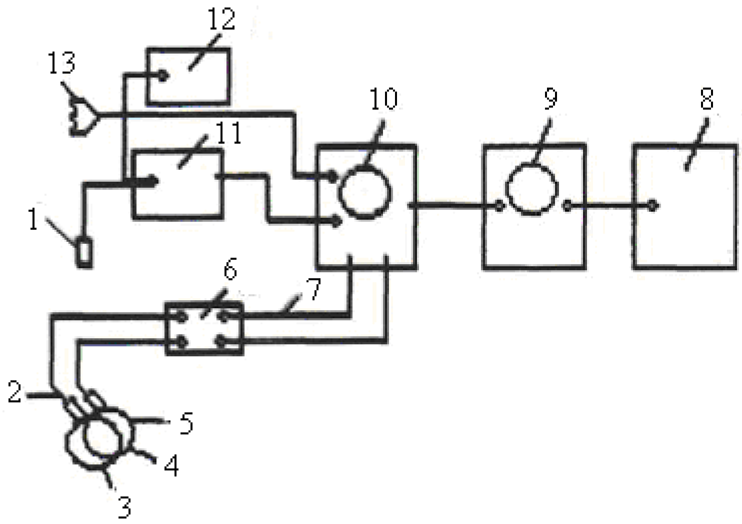


Fig.2 measuring device for raising the indicated diagram

1. KISTLER 601 piezoelectric transducer for measuring the pressure in the cylinder. Response 16,7 pc/bar.
2. Inductive transducers type AVL.
3. Denticulate disk for angle marking.
4. Denticulate disk for releasing the oscilloscope time.
5. Engine crank axle.
6.Time base control unit AVL-4004.
7. Oscilloscope input for angle marking.
8. Oscilloscope input for external sweeping. 8.Tektronix oscilloscope type 5113.
9. X-Y Riken recorder.
10. Nicolet digital oscilloscope.
11. Tektronix oscilloscope type 5113.
12. Load amplifier AVL-3059.
13. Calibration unit AVL-3054.
14. Inductive transducer to indicate the moment of ignition.

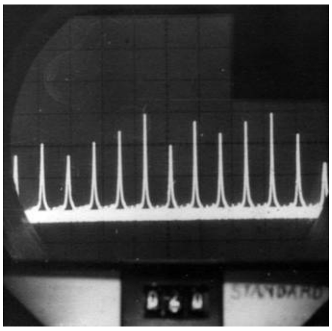
3. EXPERIMENTAL RESULTS

It had bean studied the engine characteristic comparatively under standard condition and with lean mixtures and hydrogen addition under different operating conditions of the engine, respectively. The envisaged research program has been carried out by recording the following parameters:

- parameters concerning the specific real quantities of the engine;
- parameters concerning the specific indicated quantities of the engine;
- coefficient concerning the parameters of the combustion process;
- quantities concerning the level of the emissions in the exhaust gases;

The correlation of the measured pressure depending on the rotation angle of the crankshaft as well as the opening of the inductive transducers type A.V.L. firmly mounted on the cylinder block is made by those transducers which are taking over the impulses from two coaxial disks mounted on the crankshaft.

The denticulate disk obtained through milling-work marking the angle has been made with a 20° RAC division, and near the upper dead centre has been made symmetrically every 5° in order to accurately pursuit the detachment points.



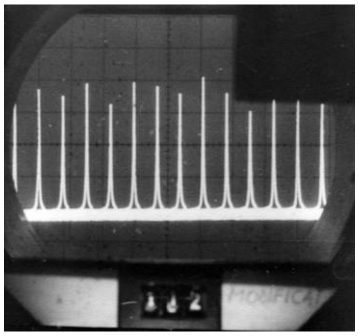


Fig. 3.a. Cyclical dispersion at 100% loading without hydrogen addition

Fig. 3.b. Cyclical dispersion at 100% loading with hydrogen addition

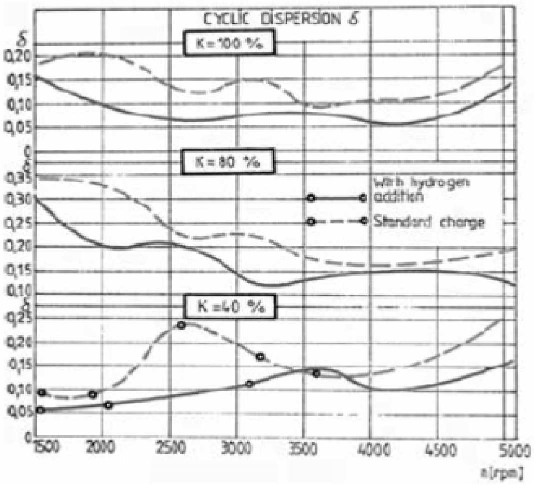


Fig. 3c The cyclical dispersion

The diagram, the cyclical dispersion as well as the other values which characterize the quality of the combustion processes have been made according to the scheme in Fig.3.
By hydrogen addition in lean mixture, the induction-time is shorter, because more active centres exist and so the reaction rate increases. This is very well shown by the cyclic dispersion *δ.*

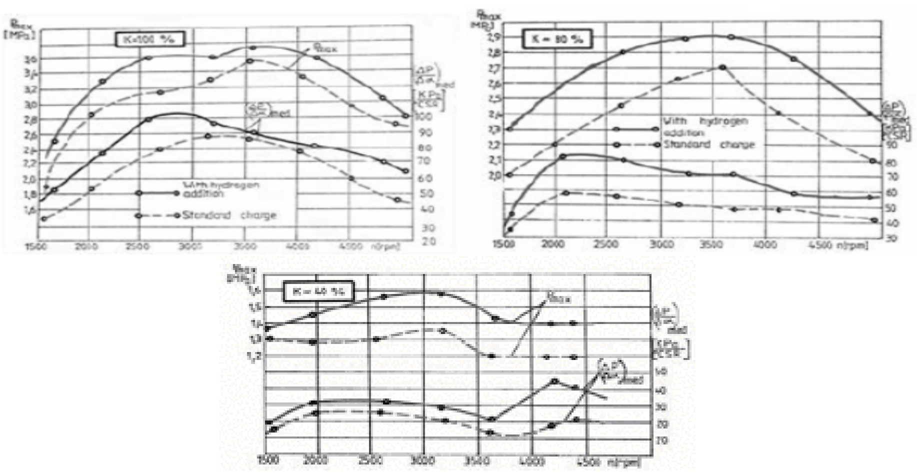
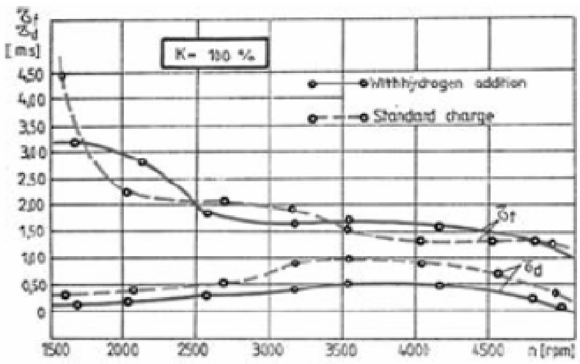
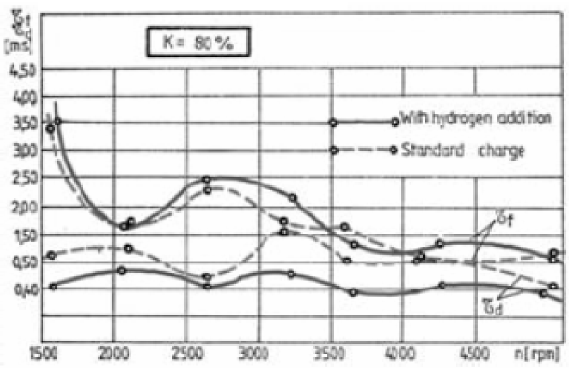


Fig. 4 The variation of pressure with the load

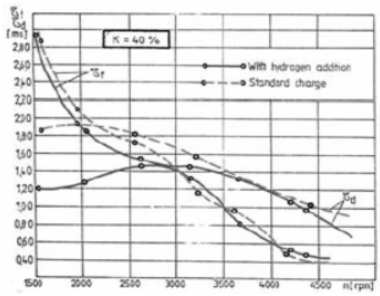
From the measurements results an increase of the pressure in the cylinder, a step-up in power by 5-7% respectively, and a reduction of the fuel consumption of between 12-15% (fig. 4).
Another stage has been the testing of the engine on the car at stabilized speeds on the track as well as in highway traffic.
So, at the average speed of 72 km/h, on a 250 km distance, in street traffic we have obtained a fuel consumption of 5,3 l/100 km, at a loading of 50% from the maximum permitted load.
The dynamic parameters have also been improved. Thus from 0-100 km/h we got to a 18,3" timing compared to the 22" obtained without our device.
The influence of hydrogen addition in lean mixtures on the combustion phases and process parameters was determined by investigating the delay of the fast combustion phase τ_d with the crankshaft rotation speed.
At low crankshaft revolutions values (under 2500 rpm) the top pressure decrease is caused mainly by the considerable increase of the fast combustion phase duration, the point in which the top pressure occurs moving towards the expansion stroke (Fig. 5). As the crankshaft revolution increases, the initial phase $\Delta\alpha_d$ (in degrees of crankshaft revolutions) will be longer because the delay to the fast combustion phase does not vary with the crankshaft revolution. So the top pressure peak will move towards the expansion stroke. For small rated loads (*K=40%*) this fact is not so evident, because as the revolution increases the fast combustion time decreases (Fig.5.c).



a.



b.



c.

Fig. 5 The variation of pressure with the crankshaft revolution

4. MATHEMATICAL MODEL

Because the improvement of engine's parameters with hydrogen addition, it is interesting to make a theoretical study of the burning process by developing a mathematical model.
This mathematical model was developed using AVL's FIRE Program. The program was useful especially for investigating the delay of the fast combustion phase τ_d .

The major problem was to simulate the formation of active centres that initiate the burning process.
To validate the model there were made two comparisons between the calculated values and the measured values for:

- the pressure in the cylinder during the burning process (Fig. 6)

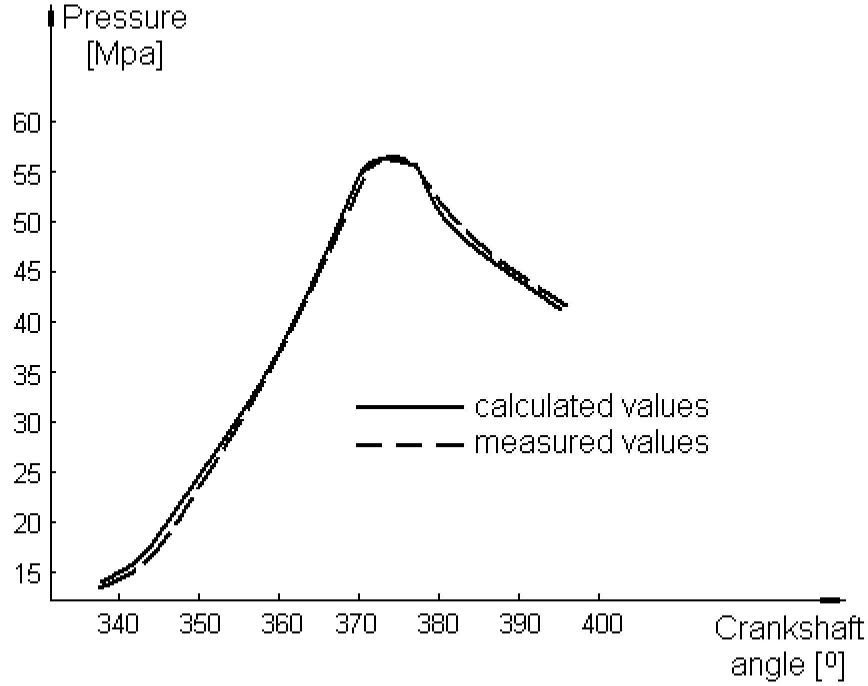


Fig. 6 Comparison between calculated and measured cylinder pressure

- fuel consumption (fig. 7)

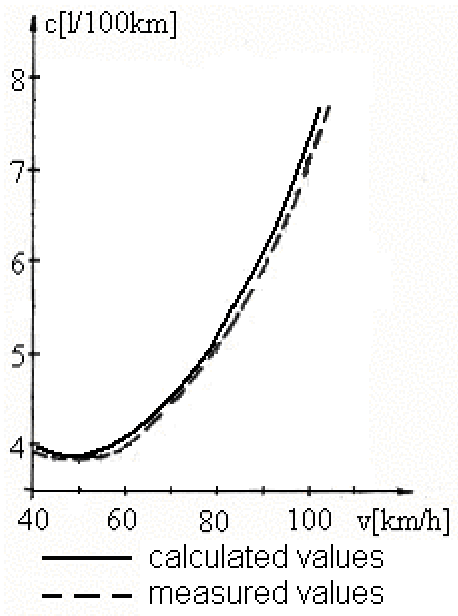


Fig. 7 Comparative consumption diagrams

In both figures one can see that the calculated values are close to the measured ones. The difference between those values were under 5%.

5. CONCLUSION

The conclusions are made observing the diagrams for the rated load *K=80%* and for the full load *K=100%* between 2000 and 4500 rpm.

The pressures are in these cases clearly higher for the hydrogen addicted engine although the mixture is leaner. We expect that even better results could be obtained if an optimum correlation is acquired between the addicted hydrogen quantity, the lean mixture quality and the spark timing. So the cyclic dispersion could be reasonably diminished for lower rated loads, with direct mechanical, energetically and economical implications.

By using AVL FIRE simulation program one can determine the variation of the hydrogen amount which must be introduced in the cylinder regarding load and rotation speed so that consumption and emissions should be reduced to minimum values.

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