Experimental Study Of Hydrogen In Internal Combustion Engines

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ABSTRACT

In this study, an experimental study on the performance of a spark ignition engine fuelled with hydrogen was performed at different speed and different loads. This present work was carried out on a Ford engine. This is a four-stroke cycle four-cylinder spark ignition engine with a bore × stroke of 80.6x88 mm and a compression ratio of 10:1. Experiments were made as 1500, 2000, 2500 and 3000 rpm. In experiments, cylinder pressures with crank angles were drawn. The experimental measurements give results in agreement with literature data

Keywords: Hydrogen, Gasoline, Engine, Cylinder Pressure

INTRODUCTION

Hydrogen has a wide flammability range in comparison with all other fuels. As a result, hydrogen can be combusted in an internal combustion engine over a wide range of fuel-air mixtures. A significant advantage of this is that hydrogen can run on a lean mixture. A lean mixture is one in which the amount of fuel is less than the theoretical, stoichiometric or chemically ideal amount needed for combustion with a given amount of air. This is why it is fairly easy to get an engine to start on hydrogen. Generally, fuel economy is greater and the combustion reaction is more complete when a vehicle is run on a lean mixture. Additionally, the final combustion temperature is generally lower, reducing the amount of pollutants, such as nitrogen oxides, emitted in the exhaust. There is a limit to how lean the engine can be run, as lean operation can significantly reduce the power output due to a reduction in the volumetric heating value of the air/fuel mixture [1].

Karim studied hydrogen as a spark ignition engine fuel [2]. Karim investigated hydrogen as a SI engine fuel. He conducted that there were excellent prospects to achieve very satisfactory S.I. engine operation with hydrogen as the fuel and most of the subject whether hydrogen could be obtained abundantly and economically remained yet to be answered satisfactorily.

Kahraman et al. studied experimentally on performance and emission characteristics of a hydrogen fuelled spark ignition engine [3]. They concluded that fast burning characteristics of hydrogen have permitted high speed engine operation, NOx emission of hydrogen fuelled engine is about 10 times lower than gasoline fuelled engine and less heat loss has occurred for hydrogen than gasoline.

Shudo and Yamada studied experimentally and numerically on hydrogen as an ignition-controlling agent for HCCI combustion engine [4]. They stated that hydrogen is an effective ignition controller for HCCI combustion of dimethyl ether and hydrogen makes the first heat release slower and delays the rise in temperature during the low temperature oxidation of dimethyl ether.

Al-Baghdadi investigated effect of compression ratio, equivalence ratio and engine speed on the performance and emission characteristics of a spark ignition engine using hydrogen as a fuel [5]. He stated that the variation in spark timing with hydrogen is very effective in controlling the combustion process and higher compression ratios can be applied satisfactorily to increase the power output and efficiency, mainly because of the relatively fast burning characteristics of the hydrogen–air mixtures.

HYDROGEN

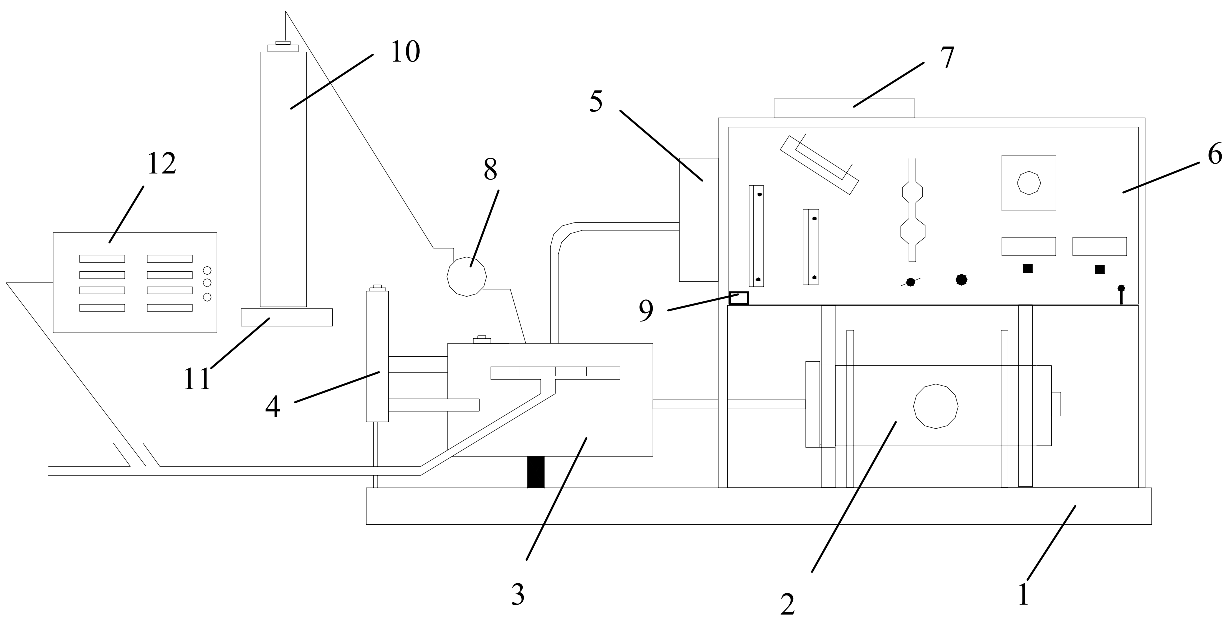
Flammability limits (possible mixture compositions for ignition and flame propagation) are very wide for hydrogen (between 4 and 75% hydrogen in the mixture) compared to gasoline (between 1 and 7.6%). This means that the load of the engine can be controlled by the air to fuel ratio, as for diesel engines. Nearly all the time the engine can be run with a wide open throttle, resulting in a higher efficiency.

Other advantage of hydrogen for SI engines is the high burning velocity. For near-stoichiometric mixtures (near $\lambda = 1/\varphi = 1$) the combustion is almost a constant-volume combustion, which increases the (thermodynamic) efficiency. Also the properties of lean hydrogen flames will cause flame acceleration due to cellularity and no turbulence enhancing methods have to be used (swirl ports, etc.). Again this increases the efficiency of the engine.

Furthermore, hydrogen has a high octane number and the compression ratio of the engine can be increased. This, of course, increases the efficiency. Finally the emissions of a hydrogen engine are very clean, only the noxious component NOx is emitted [6].

EXPERIMENTAL APPARATUS AND TEST PROCEDURE

The present study was conducted on a Ford gasoline engine. The engine is four-cylinder, four strokes, and spark ignition engine with a swept volume of 1800 cc. The general specifications of the engine are shown in Table 1. A Cussons-P8601 brand hydrokinetic dynamometer was used for the tests. The schematic view of the test equipments is shown in Fig. 1.



1-Engine Chassis, 2- Hydrokinetic Dynamometer, 3- Engine, 4- Engine Cooling Unit, 5-Air Tank, 6-Control Unit, 7- Main Fuel Tank, 8- Regulator, 9- Fuel Select Key, 10-Fuel Tank, 11-Digital Balance, 12-Exhaust Gas Analyzer, 13- Mass Flow meter

Figure 1. Experimental rig

Table 1. General specifications of the Ford-1.8 engine

Bore	80.6	mm
Stroke	88	mm
Compression Ratio	10:1	-
Exhaust valve opening	55	BTDC
Exhaust valve closing	50	ATDC
Intake valve opening	13	BTDC
Intake valve closing	227	ATDC
Intake valve radius	30	mm
Exhaust valve radius	28	mm

EXPERIMENTAL RESULTS

Figure2 shows that cylinder pressure versus crank angle for different engine speed for hydrogen. While engine speed increasing, ignition delay was decreasing and maximum peak pressure was obtained TDC. For 1200 rpm, maximum peak pressure was obtained 3^{o}CA after TDC.

There are some results of using hydrogen in the table 2.

Table 2. 100% H_2 Experimental Data's

Speed	1545	2000	2021	2022
Exhaust Manifold Temperatures	327	389	314	315
O_2 %	8,14	11,73	16,02	15,75
Torque(Nm)	17,73	25,45	25,45	34,61
Efficiency	26,44	21,64	23,48	29,75

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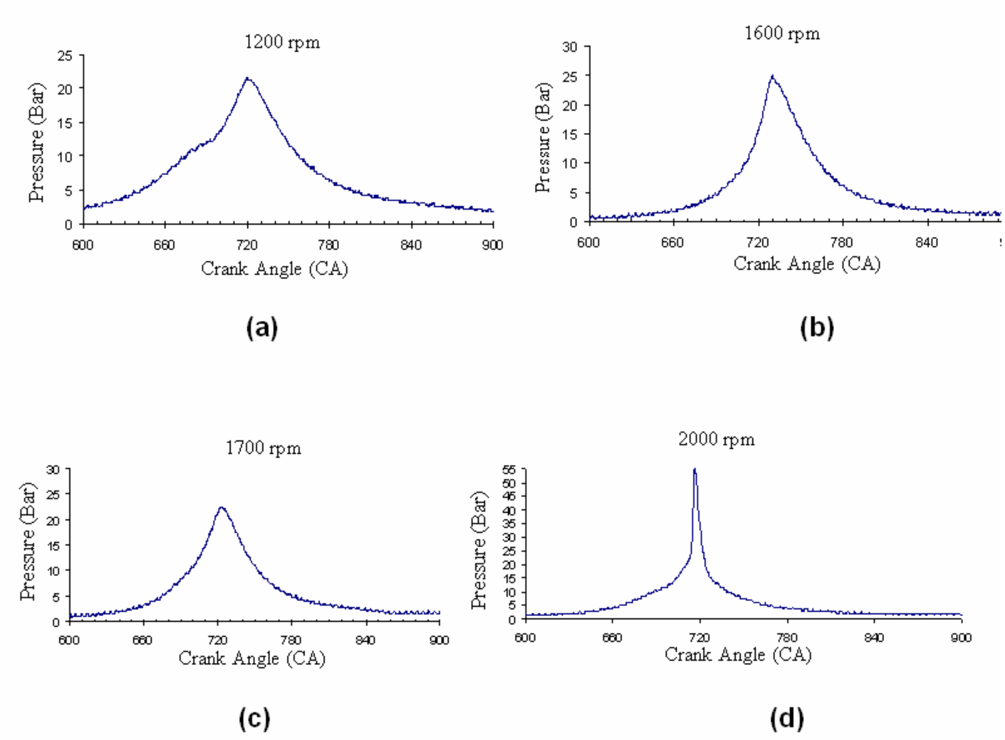

Figure 2 Variation of the pressure in the cylinder versus the CA for different rpm

Figure 3 gives the cylinder pressure versus crank angle for different loads and for 1500 rpm. The maximum peak pressure value is near the TDC. While the load is increased, the maximum peak pressure values are decrease.

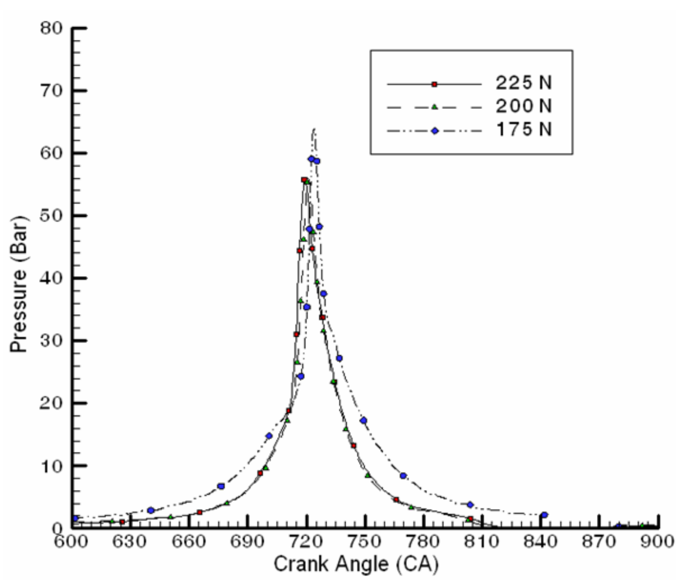

Figure 3. Cylinder pressure versus crank angle at 1500 rpm for hydrogen and different loads.

Figure 4 shows cylinder pressure versus crank angle for 2000 rpm and 160 N for hydrogen and gasoline. A pressure value of Hydrogen was higher obtained that pressure of gasoline. If the maximum peak pressure value of hydrogen is obtained about 3 ºCA after TDC, the same value for gasoline 15 ºCA after the TDC.

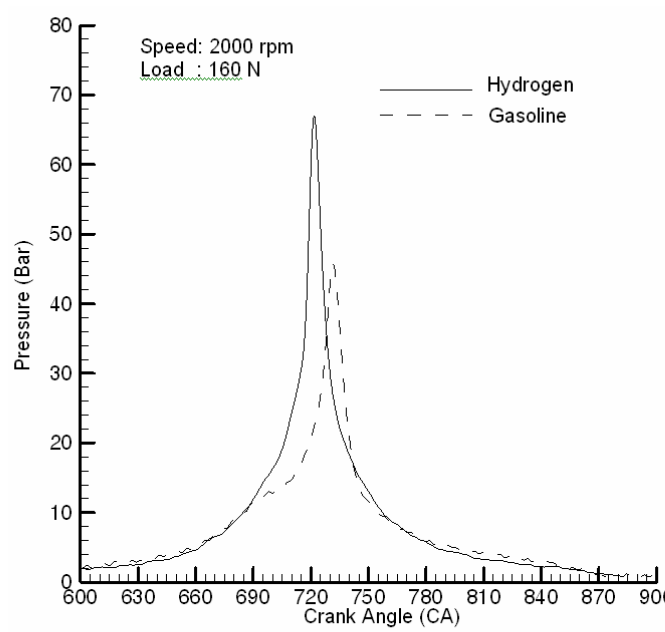

Figure 4. Cylinder pressure versus Crank angle at 2000 rpm for hydrogen and gasoline at 160 N.

Figure 5 shows that the cylinder pressure versus crank angle for hydrogen and gasoline for 2500 rpm. For same engine speed and different loads (150 N for hydrogen, 200 N for gasoline) the maximum pressure values in the cylinder is about 60 bars. The maximum peak pressure values are nearest the TDC for hydrogen than gasoline.

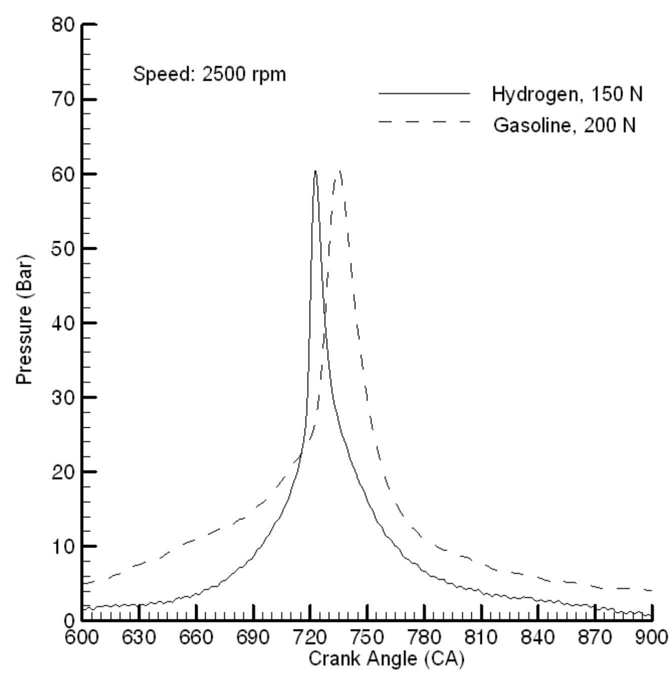

Figure 5. Cylinder pressure versus Crank angle at 2500 rpm for hydrogen (150 N) and gasoline (200 N).

Figure 6 gives the cylinder pressure versus crank angle for hydrogen and gasoline for 135 N at 3000 rpm. The maximum peak pressure values for the same engine speed and same load are obtained about 42 bar for gasoline and 55 bar for hydrogen. This values are observed 12 -13 ºCA after the TDC for gasoline and TDC for hydrogen.

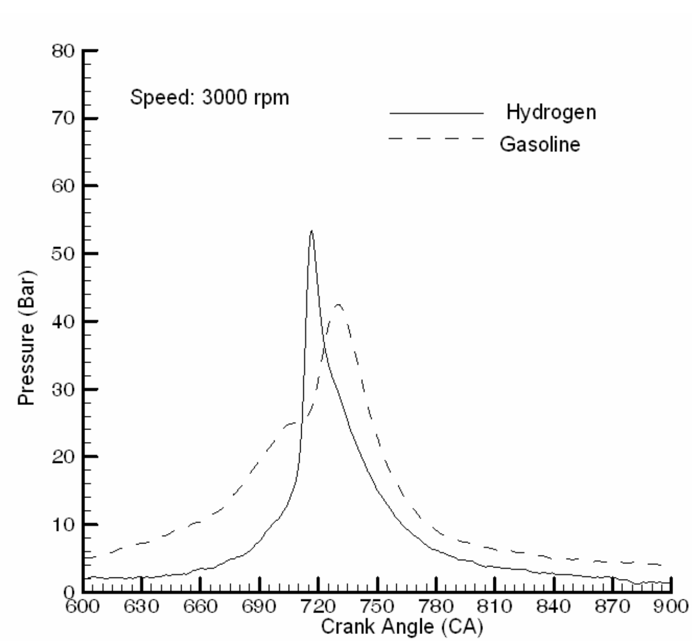

Figure 6. Cylinder pressure for hydrogen and gasoline at 3000 rpm and 135 N load.

CONCLUSIONS

The results of this study can be summarized as follow:

- While the hydrogen applied to SI engine, It was seen that back fire problem with 100 % H_2
- The results obtained from this study compared with the literature good agreement with experimental data is observed.
- While the load is increased, the maximum pressure values are come near the T.D.C.
- While the load is increased, the maximum pressure values are decreased. Because while the load is increased, temperature is increased and the flame is go ahead rapidly in the cylinder.

We can conclude that the hydrogen can use in internal combustion engines. Use of hydrogen in SI engines with injections is more suitable than the SI engine with carburetor because of back flash problem.

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