PERFORMANCE OF DIESEL ENGINE RUN ON HYDROGEN AS SUPPLEMENTARY FUEL

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ABSTRACT

A study was conducted to assess the percent diesel replacement by hydrogen on a Kirloskar make 10 hp four stroke compression ignition engine using hydrogen as supplementary fuel. It was found that up to 60% of diesel could be replaced by hydrogen at 60% of rated brake load, beyond which excessive knocking started. At 80% of rated brake load, only 30% of diesel could be replaced by hydrogen beyond which excessive knocking started. At rated load, only 10% of diesel could be replaced by hydrogen beyond which the engine gave excessive black smoke. This might be due to incomplete burning of diesel and hydrogen due to shortage of air supply. At 60% of rated brake load, the flow rate of hydrogen was 12.82, 21.72, 29.10, 38.71, 47.50 and 76.58 lpm when 10, 20, 30, 40, 50 and 60 per cent diesel was replaced by hydrogen, respectively. At 80% of rated brake load, the flow rate of hydrogen was 15.09, 23.83 and 36.74 lpm when 10, 20 and 30 per cent diesel was replaced, respectively. At 100% and 110% of rated brake load, the flow rate of hydrogen was 16.53 and 19 lpm respectively at 90% diesel. From the long duration test, it was found that at 60% of rated brake load, replacement of diesel by 40% hydrogen was smoother and the power of the engine did not fall even after two hours of running. Thus, the diesel engine can be run on 60% diesel + 40% hydrogen at 60% of rated brake load without any detrimental effects.

Key words: Hydrogen fuel, Diesel engine, Performance, Supplementary fuel, Brake load.

INTRODUCTION

Presently, all the agricultural tractors and other heavy duty vehicles are powered by compression ignition (CI) engines using diesel fuel. Agricultural sector is next to transport sector in high speed diesel (HSD) fuel consumption in India. Due to its high demand, it has become scarce and costlier. Consequently, in India, oil prices have increased alarmingly and so is the oil import bill. It has, therefore, become imperative to make serious efforts to conserve and stretch the available reserve of the petroleum fuel. In this endeavour, it is essential to find out alternative fuels which may fully or partially replace HSD as engine fuel in future.

Hydrogen is seen as one of the important energy vectors of the present century. Hydrogen as a renewable energy source, provides the potential for a sustainable development particularly in the transportation sector. A hydrogen fuelled engine has substantially cleaner emission than other internal combustion engines. Due to wide flammability limits and high flame propagation speed of hydrogen, better efficiency is achieved (Verhelst et al. 2001, 2006).

MATERIALS AND METHODS

The study was conducted on a Kirloskar make 7.1 kW (9.6 BHP) air cooled four stroke constant speed diesel engine (Model DAF 10). To run the engine on dual fuel (i.e.) diesel and hydrogen, a minor modification was made by fitting an adaptor in the intake manifold of engine so that hydrogen gas could be mixed along with the incoming air (Gopal et al. 1982). In order to know the flow rate of hydrogen, a variable flow rotameter having flow rate capacity of 5 to 50 lpm (litres per minute) calibrated for three different incoming gas pressures of 0.5, 0.75 and 1 kg/cm² was used. Another rotameter having

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flow rate capacity of 50 to 500 lpm calibrated for three different pressures of 0.75, 1 and 1.5 kg/cm² was used. Both the rotameters had needle control valves which were used to control the flow rate of hydrogen to the engine.

After warming up the engine for about 20 to 25 minutes, the tests were conducted at no load, 20% (3.8 kg), 40% (7.7 kg), 60% (11.5 kg), 80% (15.4 kg), 100% (19.2 kg) and 110% (21.1 kg) of rated load with diesel fuel and diesel mixed with hydrogen gas in the following order (Goswami et al. 1994 and Manes et al. 1994).

a) 100% diesel run.

b) 10% hydrogen with 90% diesel

c) 20% hydrogen with 80% diesel
d) 30% hydrogen with 70% diesel
e) 40% hydrogen with 60% diesel
f) 50% hydrogen with 50% diesel
g) 60% hydrogen with 40% diesel
h) 70% hydrogen with 30% diesel
i) 80% hydrogen with 20% diesel
j) 90% hydrogen with 10% diesel

k) It was not possible to run at 100% hydrogen gas.

An eddy current dynamometer (Model SCR 70EC 3.6) having a capacity of 70 hp was used to load the engine. For the replacement of diesel with hydrogen, needle control valve of rotameter was used. For example, in an experiment to run the engine with 10% hydrogen and 90% diesel, the flow rate of hydrogen was so adjusted that the engine consumed only 90% of diesel as compared to the diesel when the engine was run on diesel only.

In the above experiments, the performance of the engine which did not allow higher level of diesel replacement with hydrogen gas (either due to knocking or pre-ignition or abnormal engine sound), the experiments were discontinued at that particular level of hydrogen blend (Senthil Kumar et al. 2003).

RESULTS AND DISCUSSION

The flow rate of hydrogen (lpm) at various percentage of diesel replacement (on volume basis) at different brake loads when run on dual fuel (diesel + hydrogen) is graphically represented in Fig 1. Throughout the study, the brake load was kept constant at 20%, 40%, 60%, 80%, 100% and 110% of full load (corresponding torque i.e., 0.907, 1.838, 2.745, 3.676, 4.584 and 5.037 kg-m was kept constant at various percentage of diesel replacement by hydrogen). The flow rate of hydrogen required to obtain the necessary replacement of diesel was measured.

At no load, 20% and 40% of rated brake load, it was possible to replace the diesel by almost 90% with hydrogen. But replacing the diesel by more than 70% with hydrogen at no load and at 20% of rated load, there were problems like pre-ignition or erratic running of engine. However, at 40% of rated load replacing the diesel by more than 70% with hydrogen was comparatively smoother. Up to 60% of diesel was replaced by hydrogen at 60% of rated brake load, beyond which excessive knocking started. At 80% of rated brake load, only 30% of diesel could be replaced by hydrogen beyond which excessive knocking started. At rated load, only 10% of diesel could be replaced by hydrogen beyond which the engine gave excessive black smoke. This might be due to incomplete burning of diesel and hydrogen due to shortage of air supply (Lambe et al. 1990).

At no load, the flow rate of hydrogen was 9.07, 15.26, 21.75, 28.06, 34.23, 36.82, 40.84, 45.89 and 68.01 lpm at 10, 20, 30, 40, 50, 60, 70, 80 and 90 per cent diesel replacement respectively. At 20% of rated brake load, the flow rate of hydrogen was 9.58, 17.78, 23.33, 30.25, 35.27, 39.77, 44.11, 47.89 and 77.52 lpm at 10, 20, 30, 40, 50, 60, 70, 80 and 90 percent diesel replacement respectively. At 40% of rated brake load, the flow rate of hydrogen was 12.14, 19.22, 25.44, 33.14, 40.29, 46.47, 69.24, 75.23 and 80.89 lpm at 10, 20, 30, 40, 50, 60, 70, 80 and 90 per cent diesel replacement respectively. At 60% of rated brake load, the flow rate of hydrogen was 15.09, 23.83 and 36.74 lpm at 10, 20 and 30 per cent diesel replacement respectively. At 80% of rated brake load, the flow rate of hydrogen was 16.53 lpm at 10 per cent diesel replacement.

At 110% of rated brake load, the flow rate of hydrogen was 19 lpm at 10 per cent diesel replacement.

Long duration tests were conducted at 60% of rated brake load. It was found that at 60% of rated brake load, replacement of diesel by hydrogen by about 40% was smoother and the power of the engine did not fall even after two hours of running. The exhaust gas and engine oil temperature were
also under the limit. But, when the replacement of diesel by hydrogen was increased to 50%, the engine delivered constant power for about an hour after which the power dropped sharply. Also, when the replacement of diesel by hydrogen was increased to 60%, the engine delivered constant power for 10 minutes after which the power dropped sharply. The drop in power after an hour and 10 min at 50 and 60% diesel replacement, respectively may be due to overheating of engine which was reflected by high exhaust temperature. Thus, it is very clear that the engine can be run on 60% diesel + 40% hydrogen at 60% of rated brake load without any detrimental effects.

CONCLUSION

1. At no load, 20% and 40% of rated brake load, it was possible to replace the diesel by almost 90% with hydrogen. But replacing the diesel by more than 70% with hydrogen at no load and 20% of rated load created problems like pre-ignition or erratic running of engine. At 40% of rated load, replacing the diesel by more than 70% with hydrogen was comparatively smoother.

2. Up to 60% of diesel was replaced by hydrogen at 60% of rated brake load, beyond which excessive knocking started. At 80% of rated brake load, only 30% of diesel could be replaced by hydrogen beyond which excessive knocking started. At rated load, only 10% of diesel could be replaced by hydrogen beyond which the exhaust manifold gave excessive black smoke. This might be due to incomplete burning of diesel and hydrogen due to shortage of air supply.

3. From the long duration test, it was found that at 60% of rated brake load, replacement of diesel by 40% hydrogen was smoother and the power of the engine did not fall even after two hours of running. Thus, the diesel engine can be run on 60% diesel + 40% hydrogen at 60% of rated brake load without any detrimental effects.

4. At 60% of rated brake load, the flow rate of hydrogen was 13.94, 21.35, 30.19, 48.00 and 75.88 lpm at 90, 80, 70, 60, 50 and 40 percent diesel respectively. At 80% of rated brake load, the flow rate of hydrogen was 15.28, 24.64 and 38.23 lpm at 90, 80 and 70 percent diesel respectively, at fuel injection timing of 23° B.T.D.C and fuel injection pressure of 180 kg/cm² where the brake thermal efficiency was found to be maximum. At 100% and 110% of rated brake load, the flow rate of hydrogen was 16.53 and 19 lpm respectively at 90% diesel.
REFERENCES


