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Experimental Investigation of the Effect of Hydrogen Blending on the Concentration of Pollutants Emitted From a Four Stroke Diesel Engine

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Abstract

The problem of pollutants emitted from internal combustion engines becomes increasingly important since it affects directly and indirectly human life on earth through air pollution, global warming, acid rains.. etc. The concentration of these pollutants must be reduced. One approach to reduce these concentrations is by blending hydrogen gas with hydrocarbon fuels used in internal combustion engines. In this paper an experimental research is carried out to study the effect of hydrogen blending. A four stroke air cooled diesel engine is used in this program. The engine is run at different loads, speeds and hydrogen blending percentages. It is found that increasing the blending percentage reduces the emitted concentration of carbon oxides and smoke. However it is found that nitrogen oxides concentration is increased with increasing hydrogen blending percentage due to higher cylinder temperatures. The results showed that 10% hydrogen blending reduces smoke opacity by about 65%, increases the nitrogen oxides concentration by about 21.8% and reduces CO_2 and CO concentrations by about 27% and 32% respectively. This trend is found at all tested speeds and loads.

. Keywords**:** Diesel engine, Hydrogen Blending, Hydrogen Fuel, Pollution

1. Introduction

It is well recognized worldwide that the internal combustion engines are a major contributor of environmental pollutants such as carbon oxides, nitrogen oxides, un burnt hydrocarbons and soot in case of diesel engines. Huge quantities of these pollutants are added to the atmosphere causing air and other types of environmental pollution. This problem becomes a major concern of scientists, researcher, politicians and ordinary people all over the world. Solutions must be sought for this problem since it causes global warming in addition to air pollution.

A lot of research work has been carried out over the years to find possible solutions for this problem, i.e. reducing the amount of these pollutants emitted from the internal combustion engines. Different possible techniques are used. One of theses techniques is by using alternatives fuels other than hydrocarbon fuels which contain less or no carbon atoms such as alcohols, bio-fuels, hydrogen, ..etc. These alternative fuels can be used either pure or blended in certain percentages with conventional fuels.

Al-Baghdadi [1] developed a mathematical model to simulate the operation of a four stroke spark ignition engine fueled with gasoline, ethanol and hydrogen either pure or blended. It was found that ethanol can be used as a supplementary fuel up to 30% of gasoline in modern spark ignition engines without major changes, and it improves the output power and reduces the NOx emissions of a hydrogen supplemented fuel engine. The hydrogen added improves the combustion process, especially in the later combustion period, reduces the ignition delay, speeds up the flame front propagation, reduces the combustion duration, and retards the spark timing. Blending of ethanol and hydrogen with gasoline reduces CO concentration but increases NO_x concentration in the exhaust gases. Also blending with hydrogen and ethanol improves combustion process and increases heat release rate.

Takemi C et al [2] investigated the use of methanol as an auxiliary fuel in diesel engine. The effect of auxiliary fuel proportion and timing of injection of auxiliary fuel and main fuel on engine performance and pollutants emission was studied. It was found that with 5% energy substitution of total energy input combustion process took place without misfiring and knocking. The combustion process was smokeless, smoother, with low NO_x emission and less noise than combustion with diesel fuel.

Shahad and Al-Baghdadi [3] developed a computer program to study the effect of equivalence ratio, compression ratio and inlet pressure on performance and NO_x emission of a four stroke supercharged hydrogen engine. The results showed that acceptable NO_x emission, high engine efficiency and lower sfc compared with gasoline operation mode.

The effect of hydrogen air enrichment medium with diesel fuel as an ignition source on performance of a stationary diesel engine was studied experimentally by Saravanan and Nagarajan [4]. They found that hydrogen air enrichment increased engine efficiency and reduced specific energy consumption. Also it resulted in lower smoke level and particulate and NOx emission.

Mihaylov and Barzev [5] carried out an experimental study to evaluate the influence of the addition of hydrogen oxygen mixture (obtained from electrochemically decomposed water) to the inlet air of a single cylinder direct injection diesel engine. The result showed improvement in combustion process efficiency due to better combustion characteristics of hydrogen.

Shahad and Abdul Haleem [6] performed an experimental investigation on a single cylinder spark ignition engine to study the effect of hydrogen blending on pollutants emission and engine performance. They found that hydrogen blending improves engine efficiency until a blending ratio of 20% by mass. They also found that hydrogen blending reduces CO_2, CO and particulate emissions but increases NO_x emission.

2. Experimental Rig

The experimental work is carried out on a test rig consists of the following parts; the engine unit, the hydrogen fueling system and the pollutants concentration measuring system as shown in figure 1.

The engine unit consists of a single cylinder compression ignition engine type Lumberdini with the following specifications (CR=18, stroke= 68 mm, bore=78 mm and a clearance volume of 19.2 cm^3). A data acquisition system type SAD/END is used to acquire , record and process the results.

The hydrogen fueling system consists of a hydrogen bottle, two pressure reduction valves to reduce the hydrogen pressure to 2 bars, a hydrogen flow meter and an injector. The injector is mounted on the inlet pipe at 10 cm from the engine with an angle of 45^o with the direction of injection. The hydrogen injection timing is controlled by an electronic control unit designed for this purpose.

The pollutants concentration measuring system consists of the following parts;

1- Exhaust gas analyzer type IMR 1400 to measure NO and NO_x concentration.
2- Smoke meter type MOD.SMOKY to measure the smoke concentration.

ORSAT apparatus to measure CO_2, CO, and O_2 concentrations.

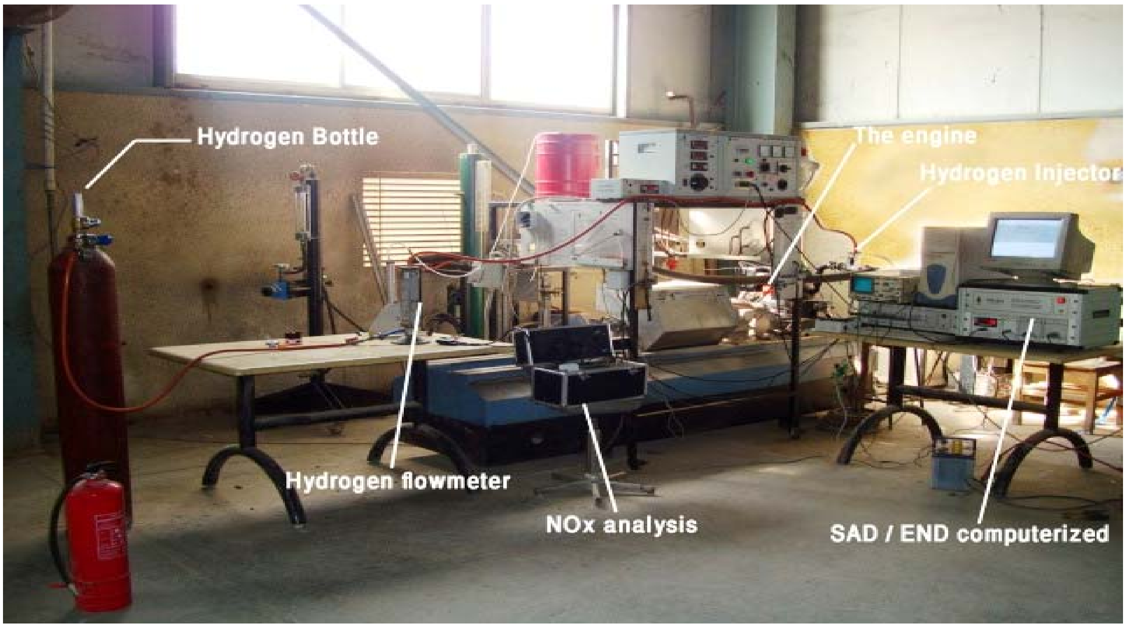

Figure 1. The test rig

3.Results and Discussion

A test program was designed to cover different speeds, loads and hydrogen blending ratios. Three different speeds was chosen namely 1000, 1250 and 1500 rpm. The load range was varied from no load to 80% of full load and the hydrogen blending ratio was varied from zero (pure diesel) to 10% (by mass) of the injected diesel fuel.

Figure 2 shows the variation of carbon dioxide concentration in the exhaust gases at different blending ratios and loads for an engine speed of 1000 rpm. It shows that hydrogen addition reduces CO_2 concentration at all loads. It must mentioned that two factors affect the concentration of CO_2 in the exhaust; the reduction of the carbon atoms in the cylinder charge which reduces the CO_2 concentration and the improvement of combustion process which increases the CO_2 concentration. The net effect is a reduction in concentration.

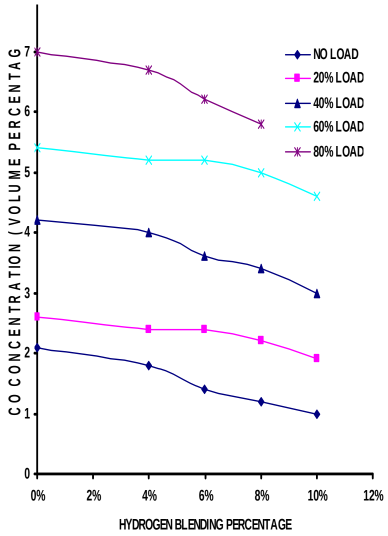

FIG (3) VARIATION OF CO CONCENTRATION WITH HYDROGEN BLENDINGPERCENTGE FOR DIFFERENT LOADS AT 1000 RPM

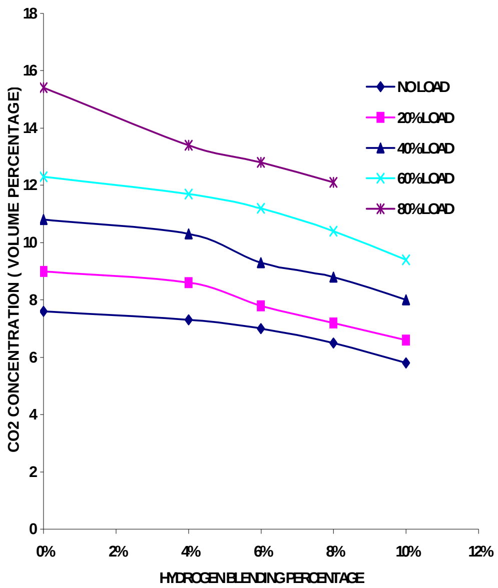

FIG (2) VARIATION OF CO2 CONCENTRATION WITH HYDROGEN BLENDING PERCENTAGE FOR DIFFERENT LOADS AT 1000 RPM

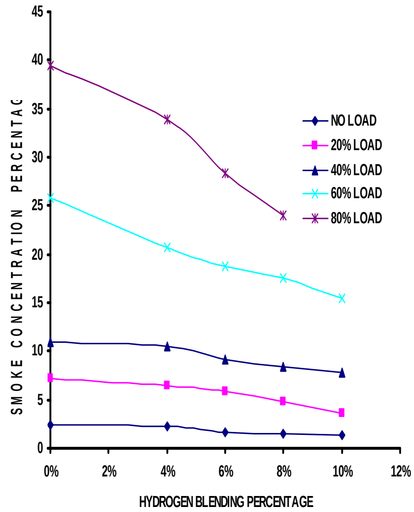

FIG (4) VARIATION OF SMOKE CONCENTRATION WITH HYDROGEN BLENDING PERCENTAGE FOR DIFFERENT LOADS AT 1000 RPM

Figure 3 shows that the concentration of carbon monoxide decreases with increasing hydrogen blending ratio for all loads and at the constant speed of 1000 rpm. This is due to better combustion process.

Figure 4 shows the effect of hydrogen blending on smoke concentration at different loads for an engine speed of 1000 rpm. It is well known that smoke is a major draw back of diesel engines. The fig shows that the hydrogen blending reduces smoke concentration. The effect is more noticeable at high loads where diesel smoke is very high. This due to better combustion process which is the effect of the presence of hydrogen in the mixture.

Figure 5 shows that the concentration of oxygen in the exhaust gases decreases as the load is increased and increases with hydrogen blending ratio since the added hydrogen consumes less air than the replaced diesel fuel. The results are at an engine speed of 1000 rpm.

Figure 6 shows the variation of NO_x concentration with hydrogen blending ratio at different loads for an engine speed of 1000 rpm. The fig shows that the concentration of NO_x generally increases with hydrogen blending ratio for all loads. This is due to the improvement of combustion process caused by the presence of hydrogen in the fuel mixture which leads to higher cylinder temperature. It is very well known that the NO_x formation reactions are highly temperature dependent. The decrease in the concentration of NO_x in the exhaust for 80% load at 6% hydrogen blending and more is probably due to the deterioration of combustion process at high loads.

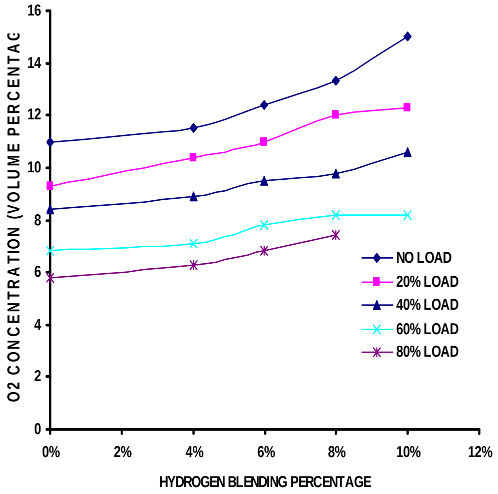

FIG (5) VARIATION OF O2 CONCENTRATION WITH HYDROGEN BLENDING PERCENTAGE FOR DIFFERENT LOADS AT 1000 RPM

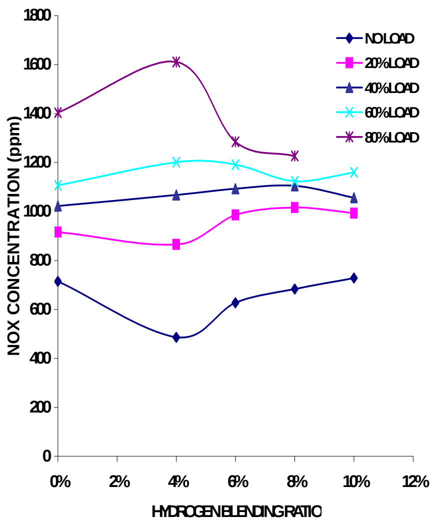

FIG (6) VARIATION OF NOX CONCENTRATION WITH HYDROGEN BLENDING RATIO FOR DIFFERENT LOADS AT 1000 RPM

The concentrations of all above mentioned pollutants are measured at other engine speeds namely; 1250 and 1500 rpm. Figure 7 shows that the concentration of CO_2 decreases with the increase of speed at fixed load and hydrogen blending ratio while the concentration of both CO and O_2 increase. This shows that the combustion process is deteriorating with speed which is a characteristic of compression ignition engines.

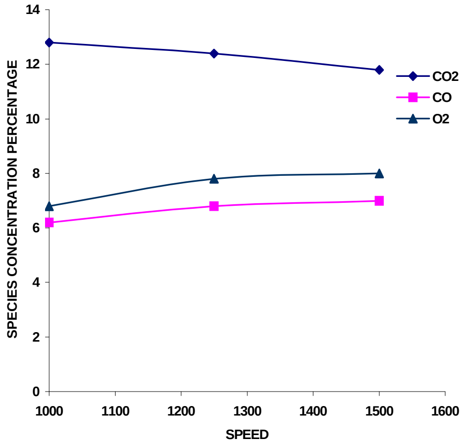

Fig (7) EFFECT OF SPEED ON SPECIES CONCENTRATION AT 80% LOAD AND 6% HYDROGEN BLENDING RATIO

Figure 8 shows that the smoke concentration increases with speed due to incomplete combustion of fuel which leads to the formation of smoke and low cylinder temperature.

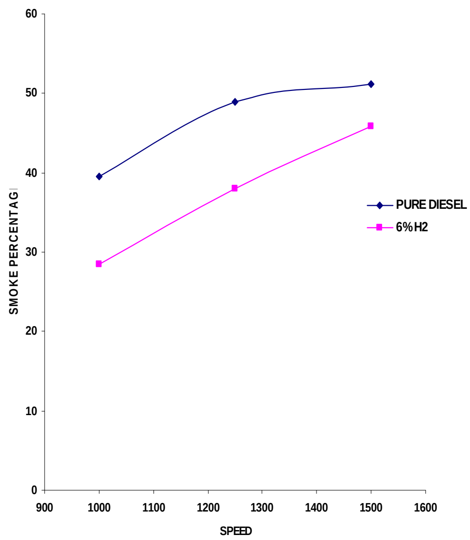

FIG (8) VARIATION OF SMOKE CONCENTRATION WITH SPEED FOR PURE DIESEL AND 6% HYDROGEN BLENDING RATIO

This result is reflected in figure 9 which shows that the NO_x concentration decreases with speed since the NO_x formation is highly dependent of temperature.

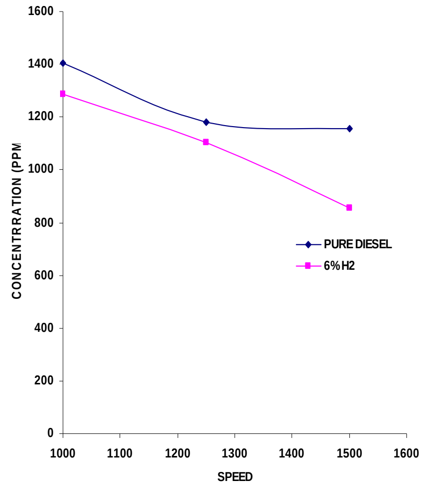

fIG (9) VARIATION OF NOx CONCENTRATION WITH SPEED FOR PURE DIESEL AND 6% HYDROGEN BLENDING RATIO

Figure 10 shows the variation of CO_2, CO and O_2 concentrations with speed at 80% load for pure diesel fuel. The fig shows that O_2 concentration increases with speed due to deterioration of combustion process while the concentration of CO_2 decreases for the same reason.
The results of the present study are compared with the results of ref. [7]. The comparison shows good agreement in trends.

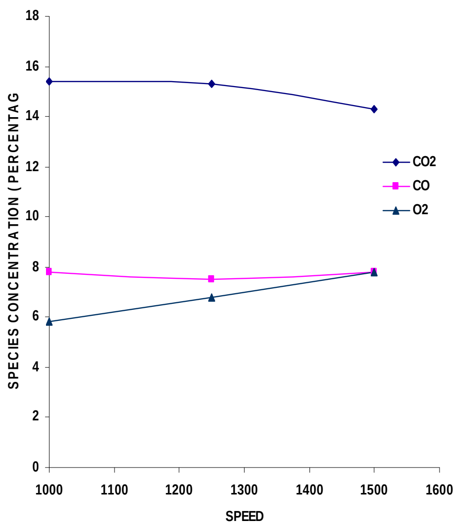

FIG (10) VARIATION OF CO2, CO AND O2 CONCENTRATIONS WITH SPEED FOR PURE DIESEL AND 80% LOAD

4. Conclusions

It can be concluded that:
1-The addition of hydrogen to the diesel fuel improves the combustion process.
2-The improvement of combustion process led to reducing pollutants concentrations.
3-The addition of hydrogen to diesel fuel shows a noticeable decrease in smoke levels specially at high loads. However the effect of speed on smoke levels is still significant even with the addition of hydrogen.

References

1-Maher A.R. Sadiq Al-Baghdadi, "A simulation model for a single cylinder four stroke spark ignition engine fueled with alternative fuels". Turkish J. Eng. Env. Sci, Vol. 30, No. 6, 2006.
2-Takemi, C. Noboru, M and Tadashi, M, "Smokeless, low NO_x and low noise diesel combustion with methanol as a main fuel".1981, SAE paper No. 811375.
3-Shahad H. A. K. and Al-Baghdadi, M. A. R., "A prediction study of a spark ignition supercharged hydrogen engine". Energy Conversion and Management, Vol. 44, No. 20, 2003.
4-Saravanan, N. and Nagarajan, G., "An experimental investigation of hydrogen enriched air induction in a diesel engine system". Int. J. of Hydrogen Energy, Vol. 33, No. 6, 2008.
5-Mihaylov, M. and Barzev, K., "Investigation of the effect of hydrogen addition on performance and exhaust emission of a diesel engine". FISITA World Automotive Congress, 23-27 May, Barcelona, Spain, 2004.
6-Haroun A. K. Shahad and Samir M. Abdul Haleem, (2009), "Experimental investigation of using hydrogen blending to improve performance and to reduce pollutants emission of a spark ignitions engine". Nuclear and renewable Energy Resources Conference With International Participation. 28-29 Sept., Ankara, Turkey.
7- Saravasnan N. and Nagarajan G., "An experimental investigation on DI diesel engine with hydrogen fuel". Renewable Energy Journal, Vol. 33, No. 2, 2008, 415-421.