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PERFORMANCE ANALYSIS OF CATALYTIC FUEL REFORMER IN CI ENGINE

Thangarasu P*

Department of Mechanical Engineering, Annamalai University, Annamalai Nagar, Tamilnadu, India

A R T I C L E   I N F O

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A B S T R A C T

In this study, Waste engine oil (WEO) was selected as an alternative fuel for compression ignition (CI) engine. WEO was thermally cracked with alumina catalyst in the catalytic fuel reformer (CFR). The gas obtained from the CFR was allowed through the inlet manifold of the engine. The experimental investigation was conducted in a single-cylinder DI diesel engine and the performance and emissions were compared with that of the diesel fuel. At maximum engine load, the brake thermal efficiency of Al_2O_3 400 increased about 18.27% than that of diesel fuel. Exhaust gas emission of Al_2O_3 400 at maximum load contained 75% lower CO emissions, 36.18% lower HC emissions, 59.89% lower NOx emissions and 63.98% lesser smoke emissions as compared to that of fossil diesel fuel. This study concludes that environmentally hazardous waste material such as waste engine oil is recycled and converted into a useful resource and serves as an alternative source of fuel for CI engine.

INTRODUCTION

Alternate fuel is one of thrust area in the researcher's mind. Waste to energy generation not only generating the energy and also minimize the waste disposal. Therefore researchers are focussing on alternate fuel from the waste resources. USEPA in 1996 [1] stated that one litre of used engine oil is enough to contaminate one million gallon of fresh water. Used engine oil also increases the pollution threats to humans, animals, vegetation and the environment [2–6]. 40 million metric tons of lubricating oil was used in different sectors all around the world. Automobile sector uses the major consumption. About 60% of the oils used in lubricating are generated as waste. Used engine oil contains metals and heavy polycyclic aromatic hydrocarbons that could contribute to chronic hazards including mutagenicity and carcinogenicity [7].

Around 60% of the production becomes waste. Less than 45% of available waste oil was collected for recycling and the remaining 55% was either misused or discarded by the end user in the environment [8–12]. Different approaches are studied to convert waste engine oil into useful products. Two main processes have been proposed during their combustion and pyrolysis. In the combustion process, the waste engine oil was used as fuel and some of the more toxic components have been removed from the oil. In the pyrolysis process, the solid adsorbents were used in fluidized bed reactor, in which the heavy metals are trapped in the solid bed. In these conditions, pyrolysis causes the demetalization of the waste oil and theoretically the final product is a useful one. A wide range of catalytic materials have been tested in the pyrolysis process. But the use of expensive catalysts may increase the economy of the process. Since catalysts cost is the key factor of catalytic cracking, the search for cheap catalysts is of primary interest.

Alumina, Al_2O_3 is a major engineering material. It offers a combination of good mechanical properties and electrical properties leading to a wide range of applications. Its high hardness, excellent dielectric properties, refractoriness and good thermal properties make it the material of choice for a wide range of applications. In its largest scale application, alumina is the catalyst in the

The objective of this study is to use the WEO as alternate fuel in the gaseous form through the intake air manifold to the CI engine and analyze the performance and emission characteristics of the engine.

MATERIALS AND METHODS

The CFR is used to convert the WEO into gaseous state. The alumina catalyst is placed in the reactor of the CFR and it was first heated to the temperature of 200^oC. Reformed gas is sent to the combustion chamber via intake manifold to analyze the performance of the engine. The combustion and emission characteristics of the engine are analyzed. The same procedure is repeated with the

Corresponding author:* **Thangarasu P
Department of Mechanical Engineering, Annamalai University, Annamalai Nagar, Tamilnadu, India

CFR temperature set to 400°C.

Catalytic fuel reformer

A CFR is designed and fabricated with suitable dimension which would convert the WEO into hydrocarbon fuel. The reformer is installed with the experimental setup. The system consists of several components such as fuel tank, control panel, reactor, thermocouple, stirrer, condenser and fuel storage tank. The fuel tank is used to supply WEO into the reformer. The reformer of the system had a cylindrical shape with an inner diameter of 15cm and a length of 45cm. The reformer is designed and fabricated to heat the WEO immersed with the catalyst. It includes an electrical heating unit which can be used to heat the WEO and catalyst to a temperature up to 1000°C. The electrical heater panel consists of a resistance heater and a voltage control to adjust the heating rate. The heating control is performed by the control panel. The stirrer is used to mix the WEO with the catalyst uniformly and also to distribute the temperature uniformly. The temperature in the reformer is measured by a thermocouple.

Engine test rig setup

The experimental investigation was carried out on a Kirloskar TV-I, single cylinder, four stroke DI natural aspirated diesel engine under different loads at a constant speed of 1500 rpm. The schematic representation of the experimental setup is shown in Figure 1. The test engine is directly coupled with an eddy current dynamometer for making power measurements. Separate fuel tanks are used for supplying diesel and WEO to the test engine. The engine specifications are given in Table 1.

Table 1 Specification of the Engine

Type	Four stroke, Kirloskar make, compression ignition, direct injection, constant speed, vertical, water cooled
Number of cylinder	One
Bore	87.5 mm
Stroke	110 mm
Compression ratio	17.5 : 1
Rated power	5.2 kW
Rated speed	1500 rpm
Dynamometer	Eddy current
Injection pressure	220 bar
Injection timing	23° bTDC
Injection type	Mechanical pump – nozzle injection system
Nozzle type	Multi hole
Number of holes	3

The Chromel Alumel (k-type) thermocouple in conjunction with a digital temperature indicator was used to measure the exhaust gas temperature. AVL 444 di-gas analyzer is used to measure NOx, HC and CO emissions in the exhaust. The accuracy of the instrument is ±1 ppm. Smoke was measured by an AVL 43 smoke meter. A probe is used to receive the sample of exhaust gas from the engine.

Initially, experiments are carried out using diesel fuel. All the experiments are conducted at the rated engine speed of 1500 rpm. All the tests are conducted by starting the engine with diesel fuel only. Then the CFR is switched on. The temperature of the reformer is set to 200°C and it took

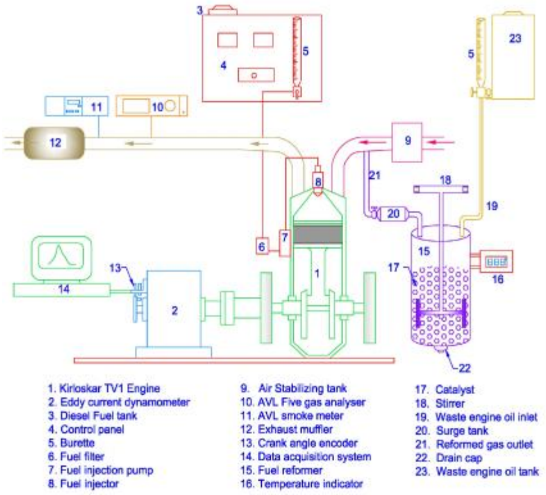

Figure 1 Schematic View of Experimental Setup

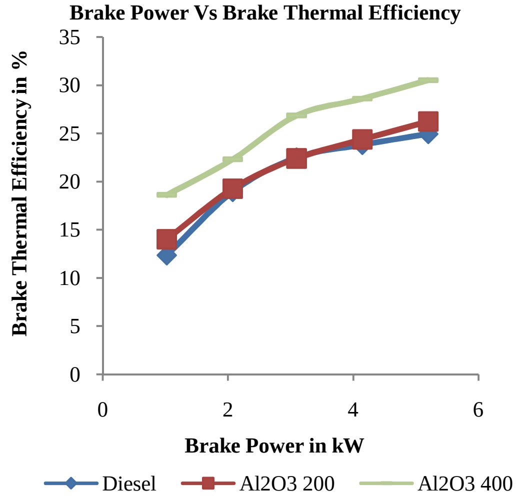

Figure 2 Brake Power against Brake Thermal Efficiency

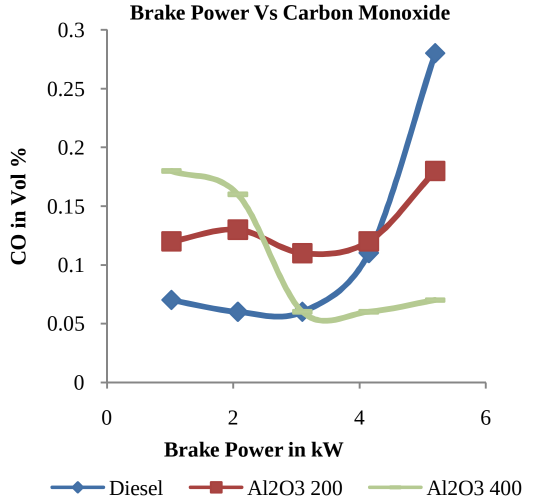

Figure 3 Brake Power against Carbon Monoxide

15 to 20 mins to reach around 80°C. From 80°C, the reformer started to produce the gas. The produced gas is allowed to the combustion chamber via intake air manifold. The experiments are conducted three times at each load to ensure the repeatability of the readings. In each trial, the engine is made to run for 20 mins to reach the steady-state condition. The same procedure is repeated with the temperature of CFR set to 400°C.

RESULTS AND DISCUSSION

Performance analysis

Brake thermal efficiency

Figure 2 shows the effect of brake power on brake thermal efficiency. It is seen from the graph that when load increases brake thermal efficiency also gradually increases. This is due to the increase in brake power; It can be noticed that the thermal efficiency for Al_2O_3 400 is higher than that of Al_2O_3 200 and diesel fuel. The brake thermal efficiency for Al_2O_3 400 at high load is 18.27% higher compare with that of diesel fuel and Al_2O_3 200.

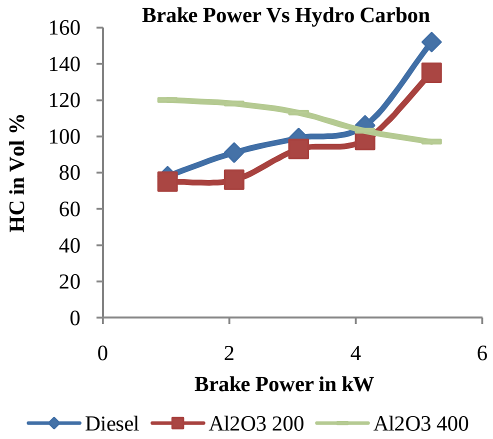

Figure 4 Brake Power against Unburned Hydrocarbon

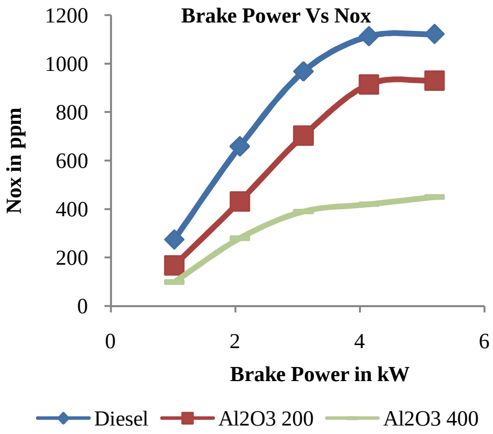

Figure 5 Brake Power against Oxides of Nitrogen

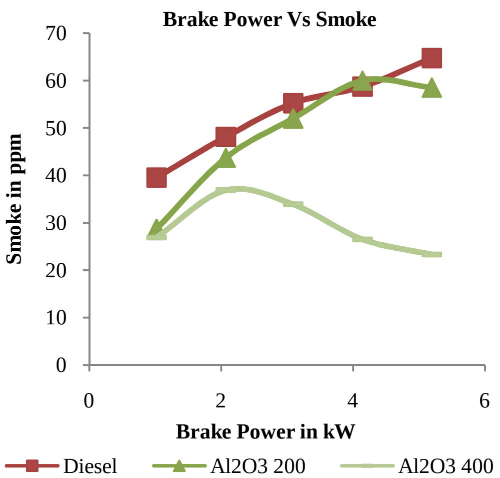

Figure 6 Brake Power against Smoke Density

Emission analysis

Carbon monoxide emission

The variation of carbon monoxide emission with brake power is shown in Figure 3. It is observed from the graph that the maximum percentage reduction at final load is 75% for Al_2O_3 400 compare to that of diesel fuel.

This reduction in CO emission may be because of improvement in the combustion of air-pyrolysis gas mixture due to fine fuel droplets.

Hydrocarbon emission

Figure 4 shows the variation of hydrocarbon emission with brake power of the engine for diesel fuel, Al_2O_3 200 and Al_2O_3 400. Hydrocarbon emission is mainly due to incomplete combustion. The hydrocarbon emission level at final load for Al_2O_3 400 is 36.18% higher than that of diesel fuel.

Oxides of nitrogen emission

The main factor to facilitate and accelerate the reaction between oxygen and nitrogen to increase NOx formation is temperature. The variation of NOx emission with brake power of the engine is shown in Figure 5.

It is observed from the graph that oxides of nitrogen for Al_2O_3 400 shown maximum reduction when compare to that of diesel fuel and Al_2O_3 200. At maximum load Al_2O_3 400 shows 59.89% lesser emission compare to that of diesel fuel.

Smoke emission

The variation of the smoke emission with brake power is presented in Figure 6. The smoke emission increases with an increase in engine loads. The amount of fuel per unit time increases as load increases and consequently smoke emission increases. The smoke emission level of Al_2O_3 400 shows 63.98% lesser than that of the diesel fuel. This may be due to the higher oxygen content present in the Al_2O_3 400.

CONCLUSION

An experimental investigation has been conducted to investigate the performance and emission of conventional diesel fuel, Al_2O_3 200 and Al_2O_3 400. The present study is conducted in a single cylinder, four stroke, air cooled, direct injection diesel engine with a minor modification in the engine. The CFR is installed and the output of the system is supplied to the combustion chamber through the intake air manifold. alumina is used as the catalyst in the reformer and the load test is conducted with two different temperatures of the system, viz. 200°C and 400°C. Waste engine oil is used as the fuel for the CFR. Based on the experimental results, the following conclusions have been drawn.

- The CFR can be used with a very minor modification in the intake air manifold of the engine. Al_2O_3 400 shows the optimum result compared to that of diesel fuel and Al_2O_3 200.
- Al_2O_3 400 shows the higher brake thermal efficiency of 18.27% at final load, when compare to that of diesel fuel.

- The maximum carbon monoxide reduction of 75% is for Al_2O_3 400 compare to that of diesel fuel at final load.
- Al_2O_3 400 shows the maximum unburnt hydrocarbon emission reduction of 36.18% at final load, when compare to that of diesel fuel.
- NOx emission reduction is of 59.89% for Al_2O_3 400 compare to that of diesel fuel at the final load.
- The maximum smoke density reduction of 63.98% is for Al_2O_3 400 compare to that of diesel fuel at final load.
- On the whole, Al_2O_3 400 shows better performance compare to diesel fuel and Al_2O_3 200.

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