ANALYSIS OF A CATALYTIC FUEL REFORMER USING ZEOLITE CATALYST IN A DIESEL ENGINE

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ABSTRACT
The present study involves an empirical examination of a catalytic fuel reformer implemented in a diesel engine, utilising a zeolite catalysts. The attempt is made to study the recycle and reuse the Waste Cooking Oil (WCO) as an alternative fuel for diesel engine. For this purpose the WCO is cracked in the catalytic fuel reformer by using the catalyst zeolite. The output of the catalytic fuel reformer is in the gaseous form which is condensed using water cooled condenser. The oil obtained after condensing the reformulated gas is named as WCOZ. To know the suitability of using the WCOZ as alternate fuel for IC engines, the different properties of WCOZ are determined. Experimental results concluded that the performance and emission level are better than those of diesel fuel. This research presents the performance of catalytic converters manufactured from zeolite for the reduction of gas emissions of a CI engine. Hence an environmentally unfriendly WCO can be recycled into a useful resource and serves as an alternative source of fuel for diesel engine.

Key words: Waste cooking oil, Zeolite, Catalyst, Hazardous, Fuel Reformer

1.Introduction

The main problem today is the emission of harmful gases from automobiles which affects the environment in several ways. Nitrous oxide is the main threat to the environment such as global warming, ozone depletion, and acid rain [1]. The exhaust emissions include nitrogen oxides (NO_x), hydrocarbons (HC), carbon monoxide (CO), carbon dioxide (CO_2), and particulates. Therefore, many countries have emission regulations such as EURO emission standards and Bharat stage emission standards for Indian cars. Currently, there are several techniques which are implemented to reduce the emissions from an exhaust gas including SCR using urea [2-3].

The conventional catalytic methods used to reduce NO_x automobile exhaust gases are categorized into (i) decomposition reactions, (ii) nonselective catalytic converter and (iii) selective catalytic converter [4-5]. The selective catalytic reduction is used to reduce certain emission gases such as NO_x, HC, CO, and CO_2. Emission control of NO_x is less prominent in lean-burn engines such as diesel engines as it operates in highly oxidizing conditions. The conversion of NO_x into less harmful gases such as N_2 is possible with three-way catalytic converters in spark ignition engines because gasoline engines work in rich-burn conditions [6-7]. The desire to improve fuel consumption and lower emissions of CO_2 is supposed to surge the demand of diesel engines. Therefore, it is important to develop a system that can reduce NO emission from lean-burn engines. Though the traditional three-way catalytic converter does not control NO_x emission in oxygen-rich conditions, hydrocarbons are generally used to selectively reduce NO_x emissions as it acts as a reducing agent [8-9]. However, in a lean-burn engine, the hydrocarbon is not present in required quantities to complete decomposition of NO_x. Therefore, there is a need to develop a system that can reduce NO_x emissions from lean-burn engines [10].

Composite honeycomb consisting of microporous zeolite 5A is developed with many potential applications. The cordierite structure of zeolite 5A can be used in diesel engines in order to reduce NO_x emissions in lean-burn conditions [11-12]. Zeolites are a group of minerals that consists of calcium, sodium, and potassium. One of its properties is that they can be readily dehydrated and rehydrated. They can be used as molecular sieves and powders. They are microporous minerals generally used as catalysts and commercial adsorbents. Zeolite has the property of absorbing impurities.

2. Zeolite Catalytic Fuel Reformer

A zeolite catalytic fuel reformer is a type of catalytic reformer that uses a zeolite catalyst to convert hydrocarbon fuels into more valuable products. Zeolites are a type of microporous crystalline material that have a high surface area and a specific pore structure. This makes them ideal for catalyzing a variety of reactions, including catalytic reforming. In a zeolite catalytic fuel reformer, the hydrocarbon fuel is first vaporized and then passed over the zeolite catalyst. The catalyst causes the fuel to undergo a series of reactions, including dehydrogenation, isomerization, and aromatization. These reactions convert the fuel into more valuable products, such as hydrogen, gasoline, and jet fuel. Zeolite catalytic fuel reformers are used in a variety of applications, including refineries, petrochemical plants, and power plants.

3. Experimental Setup

The Kirloskar TV-I is a single-cylinder, four-stroke, direct injection (DI), naturally-aspirated diesel engine that is subjected to varying loads while maintaining a constant rotational velocity of 2000 rpm in the laboratory. Figure.1 shows a schematic of the experimental setup. Eddy current dynamometers evaluate power output by connecting directly to the test engine. Both diesel and spent cooking oil are transported to the test engine in their own dedicated fuel tanks. Details the engine configurations noted in Table.1.

Figure.1: Photographic View of the Experimental Setup

Table.1: Technical Specifications of the Engine

Details	Specifications
Engine	Kirloskar, four stroke water cooled, Single Cylinder, VCR
Stroke	110 mm
Bore	87.5 mm
Capacity	661 cc
Power	5.2 kW
Speed	2000 RPM
Compression Ratio	12-18 or 17.5:1
Injection system	Common rail direct injection with open ECU
Injection timing	23^{o} before TDC
Injection pressure	300 bar
Dynamometer	Eddy current dynamometer
Dynamometer Arm	185 mm
Method of Cooling	Water
Combustion Chamber	Hemispherical Open Type
ECU	Model Nira i7r

4.RESULTS AND DISCUSSION

4.1 Performance Analysis

4.1.1 Brake thermal efficiency

Figure.2 shows the variation of brake thermal efficiency with brake power for diesel fuel, zeolite 200 and zeolite 300. Brake thermal efficiency increases with increase in engine loads. It is observed from the graph zeolite 200 and zeolite 300 shows higher brake thermal efficiency when compare to that of diesel fuel. At low load, there is no significant change in the thermal efficiency, whereas at maximum load, zeolite 200 shows remarkable increase in the thermal efficiency. Whereas zeolite 300 shows higher thermal efficiency for all loads and the maximum percentage increase of 14.44% is for zeolite 200 and zeolite 300 compare to that of diesel fuel.

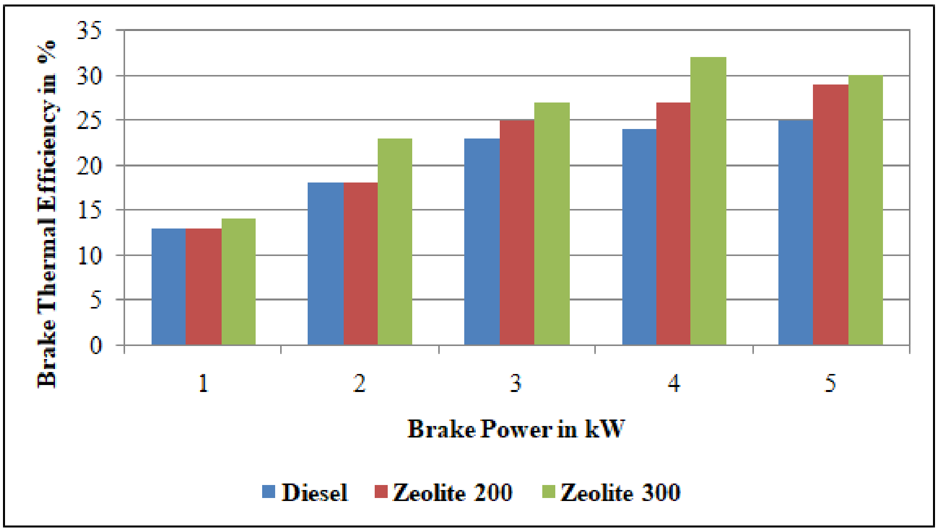

Figure.2 Brake Power against Brake Thermal Efficiency

4.2 Emission analysis

4.2.1 Carbon monoxide emission

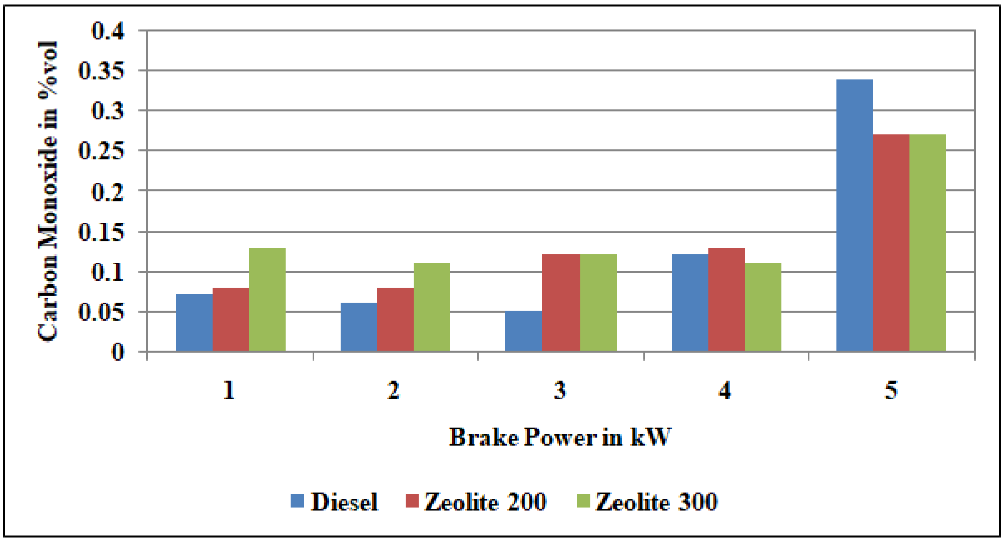

Figure.3 Brake Power against Carbon Monoxide

The variation of carbon monoxide emission with brake power is represented in the figure.3. The CO emission level for diesel fuel varied from 0.07 % vol. at low load to 0.28 % vol. at maximum load, for zeolite 200 it varied from 0.08 % vol. at low load to 0.27 % vol at maximum load and varied from 0.13 % vol. at low load to 0.33 % vol. at maximum load for zeolite 300. It can be observed from the graph that there is no significant difference between zeolite 200 and diesel fuel. Whereas zeolite 300 shows remarkable increase of 46.15% at low load and 15.15% at maximum load compare to that of diesel fuel.

4.2.2 Hydrocarbon emission

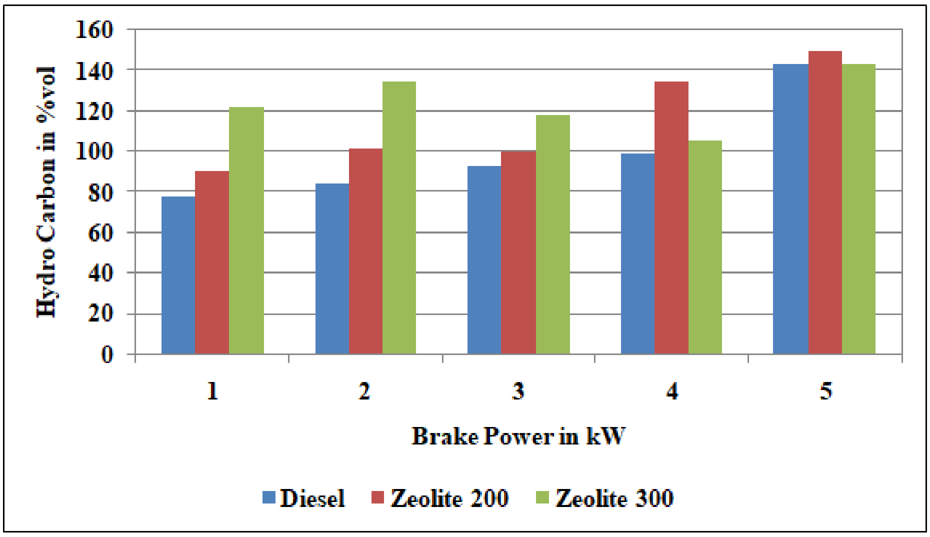

Figure.4 Brake Power against Unburned Hydrocarbon

Figure.4 shows the variation of hydrocarbon emission with brake power. The HC emission level of diesel fuel varied from 78 ppm at low load to 152 ppm at maximum load, for zeolite 200 it varied from 90 ppm at low load to 158 ppm at maximum load and varied from 123 ppm at low load to 152 ppm at maximum load for zeolite 300. Compare to diesel fuel at low load, zeolite 200 and zeolite 300 shows higher HC emission. Whereas at maximum load zeolite 200 is slightly higher than that of diesel fuel and zeolite 300 is equal to that of diesel fuel.

4.2.3 Oxides of Nitrogen Emission

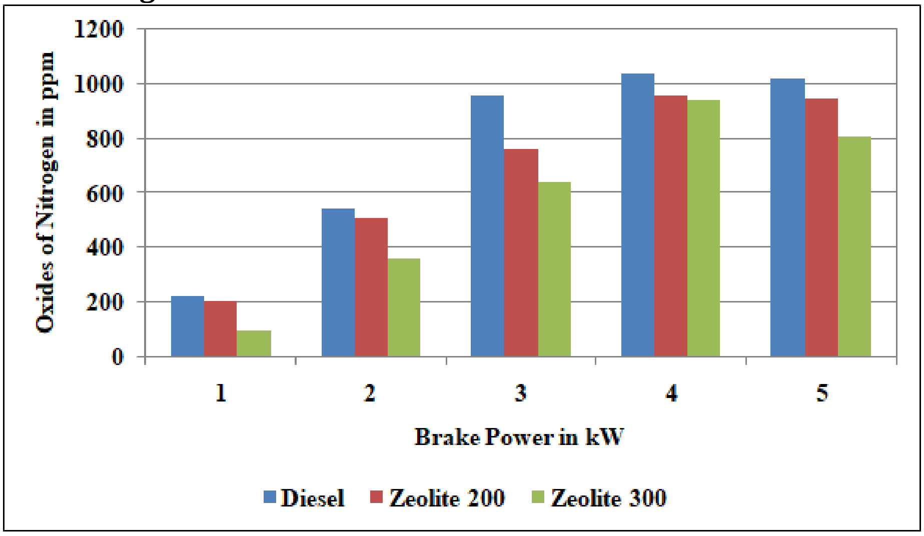

Figure.5 Brake Power against Oxides of Nitrogen

The variation of oxides of nitrogen with brake power is shown in figure.5, NOx emission increases with increase in load. The NOx emission for zeolite 200 and zeoilte 300 are compartively lesser than that of diesel fuel. At maximum load the NOx emission for diesel fuel is 1122 ppm, for zeolite 200 is 942 ppm and 858 ppm for zeolite 300. The maximum percentage reduction of 23.52% for zeolite 300 compare to that of diesel fuel. Similarly zeolite 200 shows 16.04% of reduction in NOx emission compare to that of diesel fuel.

4.2.4 Smoke Emission

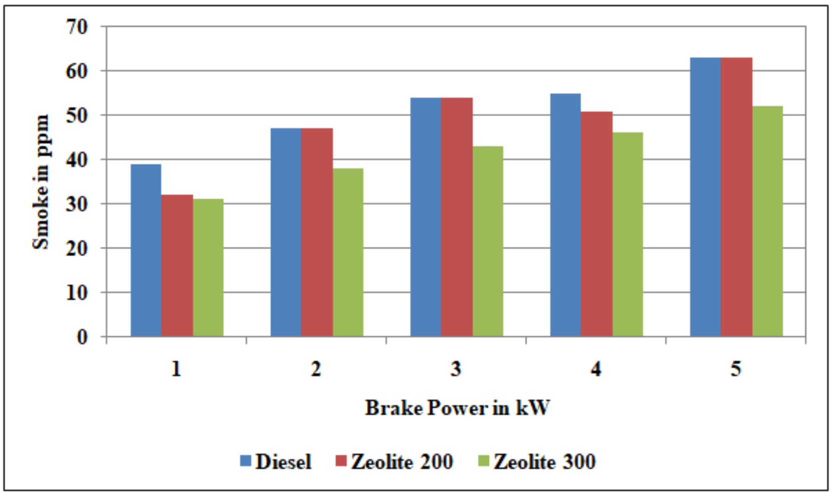

Figure.6 Brake Power against Smoke Density

The variation of smoke density with brake power is presented in the figure.6. From the graph it is revealed that there is no significance change in the smoke density between diesel fuel and zeolite 200. Whereas zeolite 300 shows remarkable reduction compare to that of diesel fuel and zeolite 200. At maximum load the smoke density is 64.7 HSU for diesel fuel, for zeolite 200 is 65.5 HSU and for zeolite 300 is 59.7 HSU. The maximum percentage reduction of 7.72% is for zeolite 300 compare to that of diesel fuel at maximum load.

5. Conclusion

Diesel, Zeolite 200 and Zeolite 300 have all had their performance and emissions tested experimentally. The current investigation is carried out in a slightly modified single-cylinder, four-stroke, air-cooled, direct-injection diesel engine. Installation of the CFR is complete, and the system's output is piped into the combustion chamber through the intake air manifold. The reformer's catalyst is Zeolite, and the load test is performed at both 200°C and 300°C system temperatures. Used cooking oil waste serves as the CFR's fuel source. The following conclusions have been drawn from the experimental data.

- Zeolite 300 shows the higher brake thermal efficiency for all loads and 14.67% at maximum load, when compare to that of diesel fuel.
- NOx emission reduction is of 23.52% for zeolite 300 compare to that of diesel fuel at the maximum load.
- Unburnt hydrocarbon emission level of zeolite 200 and zeolite 300 is higher at low load, when compare to that of diesel fuel. Whereas at maximum load HC emission level for zeolite 300 equals to that of diesel fuel.
- On the whole, zeolite 300 shows better performance compare to diesel fuel and zeolite 200.

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