INVESTIGATION ON PERFORMANCE AND EMISSIONS OF A CFR IN CI ENGINE USING RED MUD CATALYST

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ABSTRACT
The incresing fuel demand, prices and environmental impacts are the major concern associated with conventional fossile fuels. To overcome all these, the hunt for sustainable, non toxic , renewable and low cost alternative fuels is the need of the hour. The present investigation is aimed to reduce the emission and to improve the performance of diesel engine, the fuel reformer technique has been employed. In this connection an attempt is made to study on performance and emissions of a Catalytic Fuel Reformer (CFR) in CI engine using red mud catalyst. Experimental results concluded that the performance and emission level are better than those of diesel fuel. The engine shows that the red mud 300 shows higher BTE is 7.44% than red mud 200 at full load than diesel fuel under full load. Red mud 300 shows 13.14% decrease in carbon monoxide compared to diesel fuel at maximum load, slight reduction of NOx emission for red mud 300, whereas red mud 200 shows remarkable reduction upto 75% of the load and almost equal to that of diesel fuel and red mud 300 at the maximum load.

Key words: Waste cooking oil, Red mud catalyst, Hazardous, Fuel Reformer

1.Introduction

Red mud, which is a major solid waste derived from the aluminum industry, has been producing in huge quantities over the decades. At present, most of the red mud is treated for landfilling, which brings a heavy burden to the environment. At the same time, Bayer red mud is considered hazardous due to its strong alkalinity value pH is 10–12. Therefore, utilization of red mud has become the focus of study and an urgent issue all over the world. Since red mud contains 20–50% of Fe_2O_3 and large amounts of stable materials such as SiO_2, Al_2O_3 and TiO_2, it is a potential alternative catalyst in waste water and exhaust cleaning [1–5], which provides a cost-effective route of controlling waste by waste.

However, the large-scale catalysis application of red mud is limited because of its alkalinity [6], mainly originating from Na and Ca, and their oxides can cause sintering in the catalyst and reduce the catalytic activity [7]. Recently, Li et al. [8] developed a ball milling and acid-base neutralization method to reuse red mud as an efficient Fe-Ti/Si-Al denitration catalyst free of alkali. Cao et al. [9] reported an approach that used hydrochloric acid to treat red mud followed by alkali precipitation, by which the alkaline reduced and the CO catalytic oxidation performance is improved. Besides, for the first time, Lamonier et al. [10] compared the denitration performance of raw red mud and Cu-doped red mud, improving the activity of red mud. After that, Rajanikanth et al. [11,12] used red mud as a NOx adsorbent, which is arranged after the plasma purifier in the tail gas treatment module of a biodiesel engine, and the results showed that in this system, most exhausted NO_2 can be converted. Nevertheless, few studies have involved red mud deNOx catalyst in coal-fired flue gas processing.

Selective Catalytic Reduction of NOx with NH_3 is the most efficient method that has been applied in many thermal power plants for flue gas denitrification, while its technical core is the SCR catalyst with high efficiency and stability. So far, the commercial SCR deNOx catalyst is $V2O_5$-WO_3/TiO_2, but it suffers problems such as high manufacturing cost, heavy metal loss and secondary pollution caused by volatility at high temperature. From this, the development of low-cost and environment-friendly catalysts that replace V-Ti-based ones has attracted much attention in the energy and environment engineering field. Till now, some progress has been made in iron-based metal oxides catalysts. On the other hand, various metal oxide wastes that include red mud, red mud and aluminum dross are inexpensive materials that can be directly used in catalyst preparation, among which the red mud contains abundant effective iron oxides and thereby is valuable in research on SCR deNOx catalyst. Therefore, a systematic study is needed to assess the feasibility of red mud for SCR deNOx in coal-fired flue gas processing.

2. Fuel Reformer of Red Mud Catalyst

Red mud is the waste by-product of the Bayer process used to extract pure Al_2O_3 from bauxite ores for the production of aluminium metal. Disposal of red mud waste is a major issue to the environment, it associates with considerable safety hazards problems like space requirement and pollution created by red mud waste. Red mud mainly contains Fe_2O_3 and considerable amount of SiO_2, Al_2O_3 or TiO_2, hence it is necessary to develop a technology for the recovery of at least some of the important chemicals.

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

It is seen from the Figure.2 that when load increases brake thermal efficiency also gradually increases. It is observed from the graph that red mud 200 and red mud 300 shows higher brake thermal efficiency at all loads compared to that of diesel fuel. The variation of the brake thermal efficiency is from 12.246% at low load to 25.12 % at maximum load for diesel fuel. Red mud 200 varied from 13.16% at low load to 27.56% at maximum load, which is 2.44% higher than that of the diesel fuel in the maximum load. The variation of brake thermal efficiency for red mud 300 is 17.66% at low load to 32.6% at maximum load. This is 7.44% higher than that of diesel fuel due to a higher combustion rate.

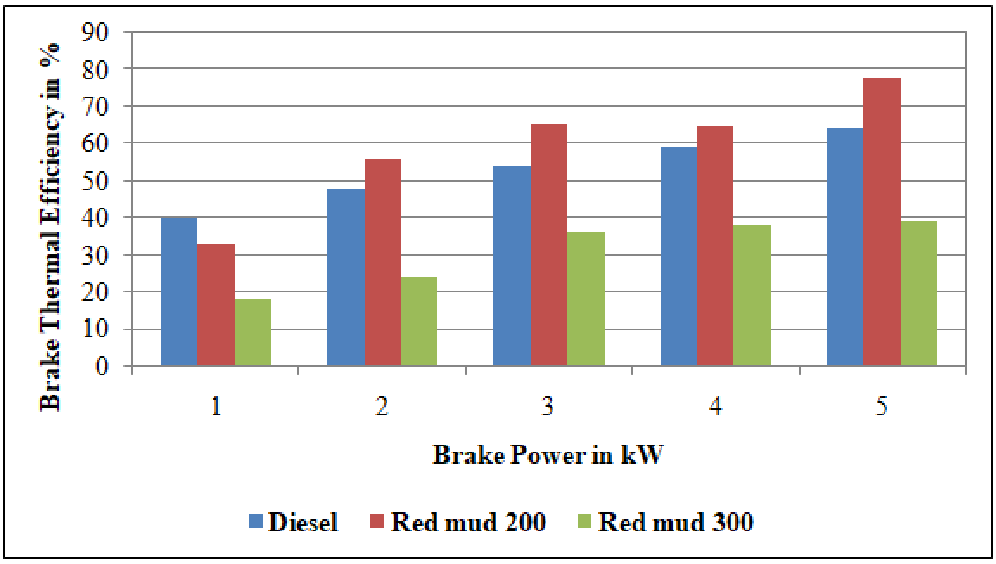

Figure.2 Brake Power against Brake Thermal Efficiency

4.2 Emission analysis

4.2.1Carbon monoxide emission

The variation of carbon monoxide emission with brake power is shown in figure.3. Carbon monoxide emission is mainly due to fuel to air equivalence ratio and in-cylinder temperature. The carbon monoxide emission varies from 0.07 % vol at low load to 0.27% vol at maximum load for diesel. For red mud 200, it varied from 0.06% vol at low load to 0.23% vol at maximum load. It varied from 0.25 % vol at low load to 0.08% vol at maximum load for red mud 300. The results revealed that carbon monoxide emission of red mud 200 is lower than that of diesel fuel. But carbon monoxide emission for red mud 300 increases in the initial load and reduces in the maximum load.

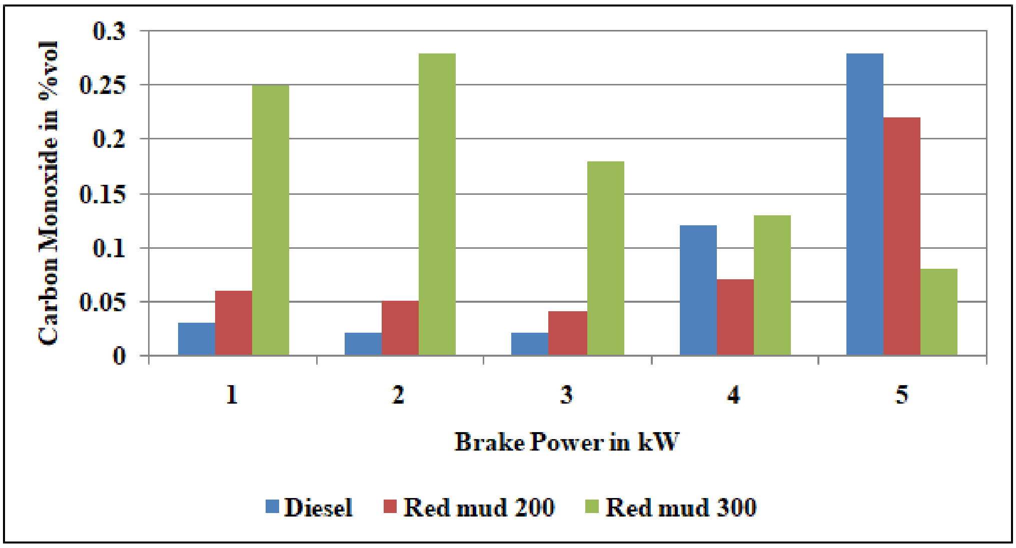

Figure.3 Brake Power against Carbon Monoxide

4.2.2 Hydrocarbon emission

Hydrocarbon emission with respect to brake power for diesel, red mud 200 and red mud 300 is shown in figure.4. Variation of hydrocarbon emission depends on load and fuel composition of the engine. Hydrocarbon emission for diesel fuel varied from 82ppm at low load to 151ppm at maximum load. The variation of hydrocarbon emission for red mud 200 is from 81ppm at low load to 147ppm at maximum load. For red mud 300, it varied from 314ppm at low to 144ppm at maximum load.

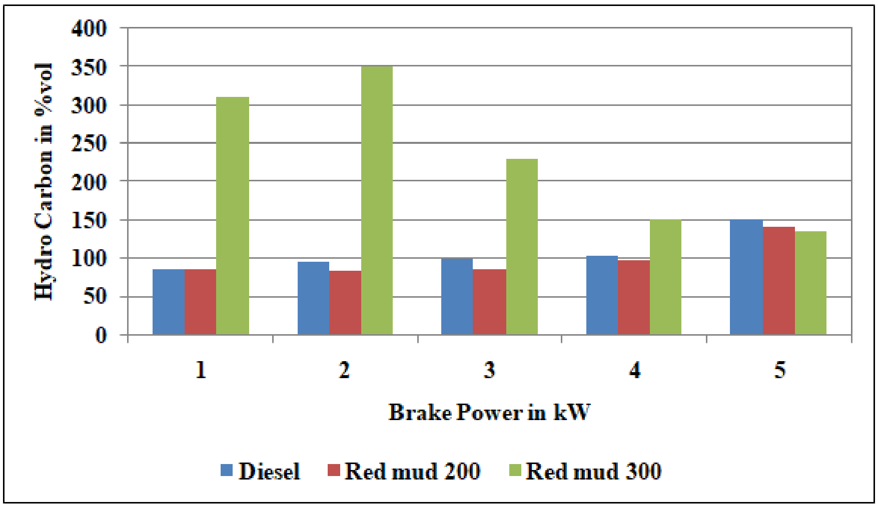

Figure.4 Brake Power against Unburned Hydrocarbon

It is observed from the graph that the hydrocarbon emissions for red mud 200 reduced slightly compared to that of diesel fuel. It showed complete combustion because of its gaseous form, whereas hydrocarbon emission for red mud 300 increased in the low load and at maximum load it decreased by 17.22%. This is likely due to the excess gas produced in the catalytic fuel reformer at 300^{o}C.

4.2.3 Oxides of Nitrogen Emission

The variation of NOx emission with brake power of the engine is shown in figure.5. Overall combustion temperature is higher, which increases the NOx emission for the case of red mud 300. In the case of red mud 200, it shows lesser NOx emission for the entire load of the engine compared to that of red mud 300 and diesel fuel. It is evident that the heat release characteristics of red mud 200 are lesser than that of red mud 300, which indicates lower combustion temperature for red mud 200. The gas-air mixture propagates a number of multi-site ignitions that will lead to further reduction in the combustion temperature and as a result NOx emission is significantly lower for red mud 200 in the range of no load to 75% of load.

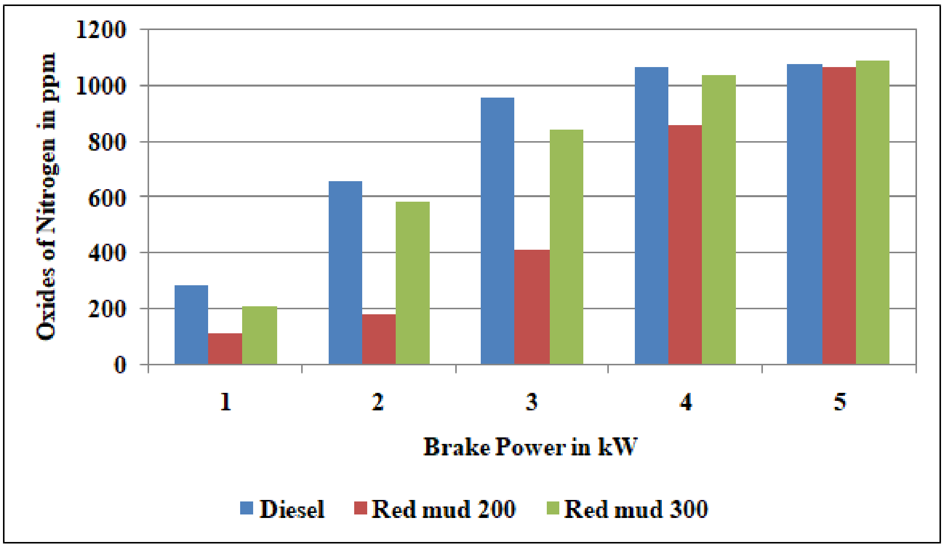

Figure.5 Brake Power against Oxides of Nitrogen

4.2.4 Smoke Emission

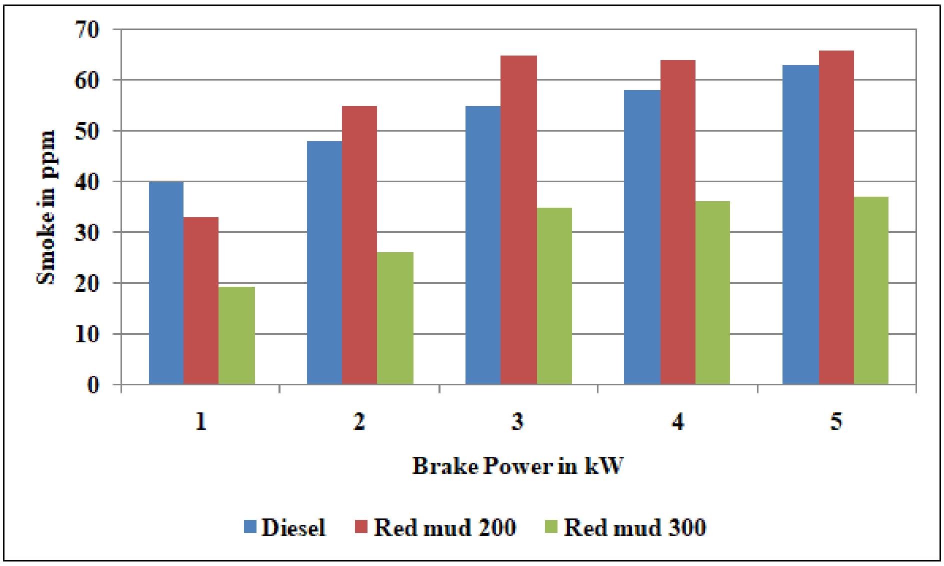

Figure.6 Brake Power against Smoke Density

The variation of the smoke density with brake power is presented in figure.6. It is seen from the graph that the smoke density is reduced at all loads for red mud 300. But for red mud 200 the smoke density is slightly increased in the medium load and beyond that the same trend as that of diesel fuel at the maximum load. This is due to the incomplete combustion that happened in the medium load. But red mud 300 showed a remarkable reduction of 41.86% in the smoke density at the maximum load. This is likely due to the effective and complete combustion because of the gas produced at 300oC from the catalytic fuel reformer.

5.Conclusion

Diesel, Red mud 200 and Red mud 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 red mud, and the load test is performed at both 200^{o}C and 300^{o}C system temperatures. Used cooking oil waste serves as the CFR's fuel source. The following conclusions have been drawn from the experimental data.

- Red mud 300 shows the higher brake thermal efficiency of 7.44% at maximum load, when compare to that of diesel fuel.
- There is slight reduction of NOx emission for red mud 300, whereas red mud 200 shows remarkable reduction upto 75% of the load and almost equal to that of diesel fuel and red mud 300 at the maximum load.
- Red mud 300 shows the maximum unburnt hydrocarbon emission reduction of 17.22% at maximum load, when compare to that of diesel fuel.
- On the whole, red mud 300 shows better performance compare to diesel fuel and red mud 200.

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