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Performance and Emission Analysis of Supercharged IDI Diesel Engine Fuelled with Waste Cooking Oil Biodiesel

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Abstract:
Waste cooking oil is used for the replacement of diesel fuel in an IDI engine with super charging. An additive like hydrated methanol has brought total changes in the combustion propensity. This paper uses inexpensive waste cooking oil biodiesel with an additive to satisfactorily replace the diesel fuel with advantages. 6% hydrated methanol with waste cooking oil biodiesel created advantages like reduction in NO_x, smoke and exhaust temperatures. There are performance benefits in augmenting the thermal efficiency of the engine and specific fuel consumption decrease.

Keywords: Indirect Injection (IDI); Performance and Emissions; Waste cooking oil biodiesel (WCOBD)

I. INTRODUCTION

Biodiesel application in internal combustion (IC) engines is increasing day by day due to the fact that biodiesel emits much lesser tail pipe emissions than conventional diesel fuel. The major advantages of using biodiesel in pure or blend in conventional diesel engines is that: biodiesel possess improved properties like oxygen content, cetane value, latent heat etc. which helps in improve the combustion efficiency. On the other hand the production cost of biodiesel from raw oil is more expensive and sometimes the availability of the raw oil is limited due to the climatic changes. Now the search for biodiesel with lesser cost and improved properties than conventional diesel fuel is a vital point for any researcher. Meanwhile, an enormous amount of used cooking oil is being wasted around the world by dumping. These disposed oils will lead to many environmental issues, so proper utilization of these oils is a matter of concern. Literature on used cooking oils reveals that [1-2] biodiesel produced from waste cooking oil is gaining a momentum in most of the developed countries as a cheaper alternative to diesel fuel. There are many processes for making of waste cooking oil biodiesel (WCOBD) but transesterification [3-4] is widely followed process. Muralidharan et al. [5] conducted experiments on a single cylinder four stroke VCR engine fuelled with WCOBD and its blends with neat diesel to evaluate its performance, emission and combustion characteristics. Fuel blends of 20%, 40%, 60% and 80% were used at a compression ratio of 21:1 with an engine speed of 1500 rpm for different loading conditions. It was observed that the brake thermal efficiency of the blend B40 increased. A. Abu-Jrai [6] NOx emissions were increased with the use of cooking oil methyl ester compared to neat diesel fuel whereas the same got reduced when the engine is equipped with EGR. Lin et al. [7] tested Ultra Low Sulphur Diesel (ULSD) with waste cooking oil biodiesel (WCOBD) on the Heavy Duty Diesel Engine (HDDE) reported that due to better combustion efficiency of the WCOBD blends, the particulate matter (PM) emissions were decreased. M A Kalam et al [8] used waste cooking oil derived from palm oil and coconut oil was blended with pure diesel in the proportion of 5%WCOBD and 95% pure diesel and was used in a multi-cylinder vertical diesel engine. Due to the presence of 92% of highly saturated fatty acids in coconut oil compared with that of 50% of palm oil, the exhaust temperatures are higher, HC and CO was reduced. Hribernik and Kegl [9] presented a paper on the experimental research on the influence of WCOBD on fuel injection and combustion process of an IDI diesel engine. From the experimental results no operational problems were encountered with the application of neat diesel fuel with WCBD blend up to 75% and the engine ran smoothly, no reduction in power output was observed. From the literature it is found that used cooking oils can be used as an alternative fuel to diesel fuel. In this paper an attempt was made to evaluate the performance and emissions aspects of an IDI supercharged diesel engine fuelled with used cooking oil methyl ester and an additive. Supercharged engine means excessive Oxygen supply and cooled combustion. Waste Cooking oil is to dump only not to utilize for any purpose. Now this is being used for biodiesel conversion. And finally the additive is to improve the combustion properties to nullify the bad effects of the biodiesel.

II. METHODS AND MATERIALS

Raw used cooking oil was collected from the local restaurants and it is esterified and then transesterified into biodiesel by two stage transesterification process. Few samples of waste cooking oil biodiesel (WCOBD) fuel were tested for its properties. Table.1 represents the characterization of WCOBD in comparison with standard diesel fuel.

III. EXPERIMENTATION

Engine tests were performed on a supercharged IDI diesel engine at five discrete part load conditions (No load, 0.77kW, 1.54kW, 2.31kW and 2.92kW) by maintaining fixed speed of 1500rpm. The technical specification of the engine is represented in the Table.2 and an Eddy current dynamometer was used for loading purpose. The engine is supercharged with a 350 Watt air blower as shown in fig.1. While supercharging 9% output power increase was observed at a constant speed of 1500 rpm [10-12]. Different percentages of hydrated methanol from 2% to 10% with an increment of 2% were used as an additive in waste cooking oil biodiesel (WCOBD). The different percentages of hydrated alcohol were injected directly into the suction end of the combustion chamber with an electronically controlled secondary fuel injector at a pressure of 3bar as shown in the Fig.1. AVL gas analyzer (AVL DIGAS-444N) and AVL smoke meter (AVL 437C) were used to measure the tail pipe emissions. The performance and emission results obtained were compared with a neat diesel fuel.

Table.1.Fuel characterization

S.No	Properties	Diesel Fuel	WCOBD
1	Density (kg/m^3)	830	875
2	Viscosity (cSt)	2.75	4.4
3	Cetane Index	47	55
4	Heating Value (kJ/kg)	43000	38500
5	Latent Heat (kJ/kg)	250	290
6	Oxygen (% by Wt)	0	12

Table.2. Specifications of IDI engine

S.No	Specification	Factor
1	Bore (mm)	86
2	Stroke (mm)	77
3	Compression Ratio	24:1
4	Stroke Volume (cm^3)	447.3
5	Max Torque (Nm) at 2200 rpm	18.7
6	Injection Pressure (bar)	142 to 148

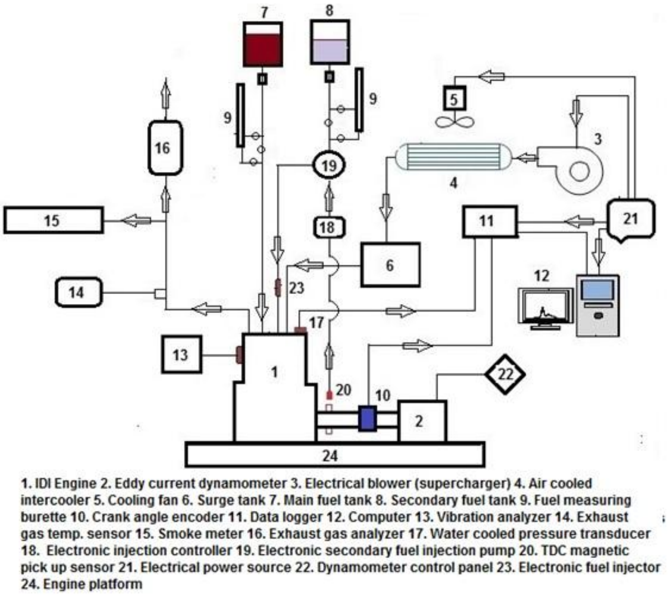

Figure.1. IDI engine test rig.

IV.RESULTS AND DISCUSSION

Performance Analysis

Various performance analyses like cylinder pressure, brake thermal efficiency, fuel consumption and tail pipe emissions like HC, CO, CO_2, NOx and smoke were measured for all the fuel samples at different loads. The combustion pressure data has been collected by the data logger at every degree of the crank revolution and is presented in Figure.2 at maximum load. Neat Diesel fuel operation exhibits maximum peak pressure this may be due to its higher heating value. It can be observed that neat biodiesel fuel and other combination of additive in biodiesel exhibits pressure almost equal to the neat diesel fuel and the band width of combustion is more in the case when additive is introduced to the biodiesel which is obviously due to high cetane value of the biodiesel. It can be concluded that with the additive percentage the combustion is being delayed and the share of combustion of the fuel is confined to the main combustion chamber.

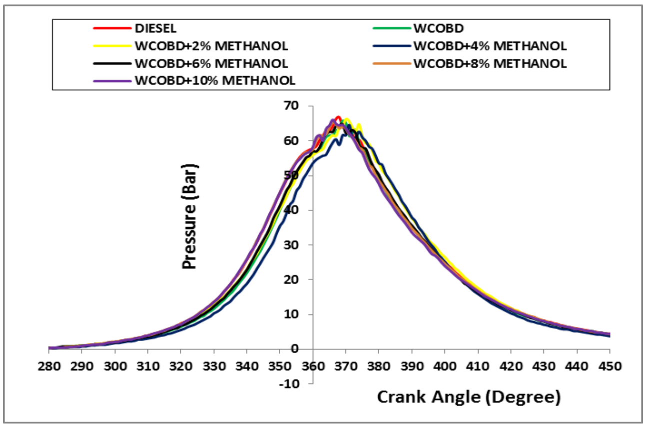

Figure.2 Pressure Verses Crank angle at 2.92 kW Load

Figure.3 represents the brake thermal efficiency (BTE) verses break power for biodiesel and its additive with respective diesel at different loads. It was found that BTE of biodiesel and its blends are higher than neat diesel at maximum and 3/4th maximum loads. The maximum BTE for 4% and 8% additive in biodiesel is 10.25%, 10.18% higher than neat diesel at 3/4th maximum load. For 6% additive the BTE at maximum and 3/4th maximum load is 6.5% and 8% more than diesel fuel. This may be due to the excess oxygen in the biodiesel and the supercharging effects helps in the complete combustion.

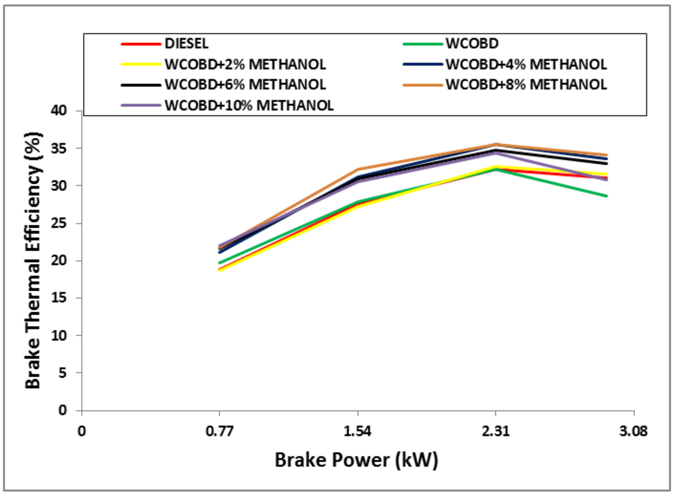

Figure.3. BTE Verses Brake Power

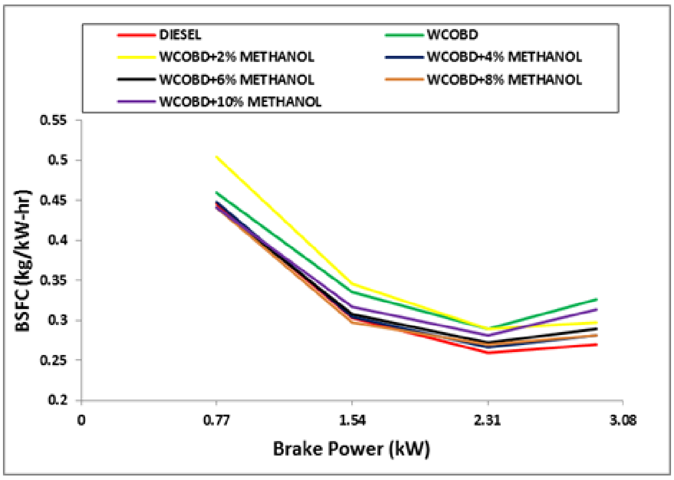

Figure.4. BSFC Verses Brake Power

The specific fuel consumption for various biodiesel additives and neat diesel fuel is represented in the figure.4. It is observed that for all combination of additive in biodiesel the fuel consumption is higher than neat diesel under various loading conditions. This may be due to the high viscosity, density and low heating value of the biodiesel fuel.

Emission Analysis

The unburnt hydro carbon (UHC) emissions for diesel and biodiesel with additive are represented in the figure.5. It can be observed that UHC emissions are more for all the biodiesels with additive compared to diesel fuel, and these emissions are lower at maximum and 3/4th maximum loads. Figure.6 represents the carbon monoxide (CO) emissions for diesel and biodiesel with different percentage of additive methanol. Normally alcohol increases CO and HC emission in the presence of water. Anyhow, this can be dismissed as minor change when compared to the advantage it has gained through the reduction of NO_x etc. There is 50% reduction of CO at maximum load for neat biodiesel compared to neat diesel fuel operation from figure 6.

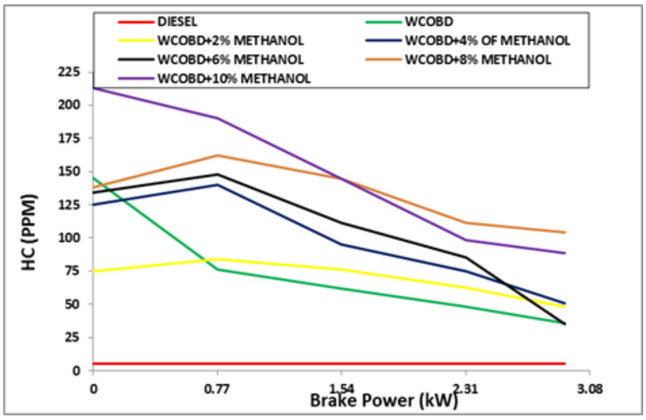

Figure.5. Hydrocarbon emission Verses Brake Power

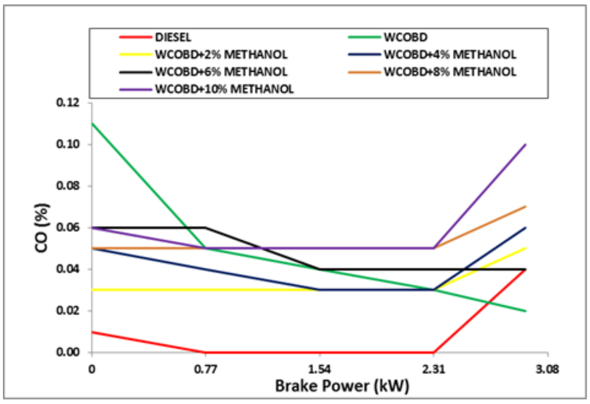

Figure.6. Carbon monoxide emission Verses Brake Power

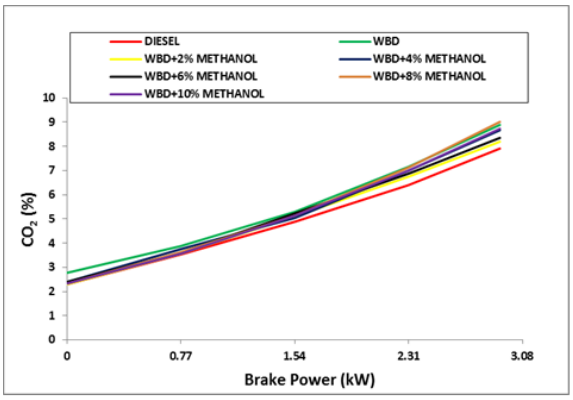

Figure.7. Carbon dioxide emission Verses Brake Power

Figure.7 represents the carbon dioxide (CO_2) emissions at varying loads. These emissions are increased with load for neat biodiesel and biodiesel with different additive combinations. It can be observed greater relief in the case of NOx, smoke and exhaust gas temperatures when implemented the new fuel combinations. 15.86% and 46.75% of NOx reductions are observed in the case of 6% additive methanol in biodiesel with respective to diesel fuel at maximum and 3/4th maximum load as represented in figure.8. 75.69% and 66.91% reduction in smoke levels are observed in the case of 6% additive in biodiesel at maximum and 3/4th maximum loads as represented in figure.9. 13.05% and 5.72% of exhaust gas temperature reduction was observed for 6% additive in biodiesel compared to diesel fuel. These benefits are attributed to the low temperature combustion and complete combustion of the new combo fuel when the engine was supercharged.

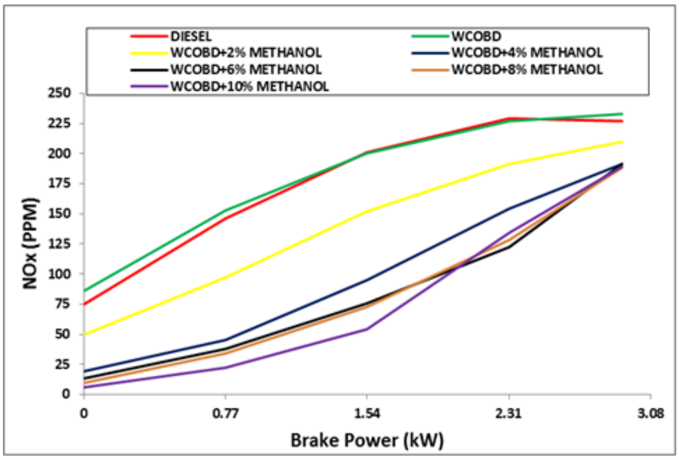

Figure.8. NOx emission Verses Brake Power

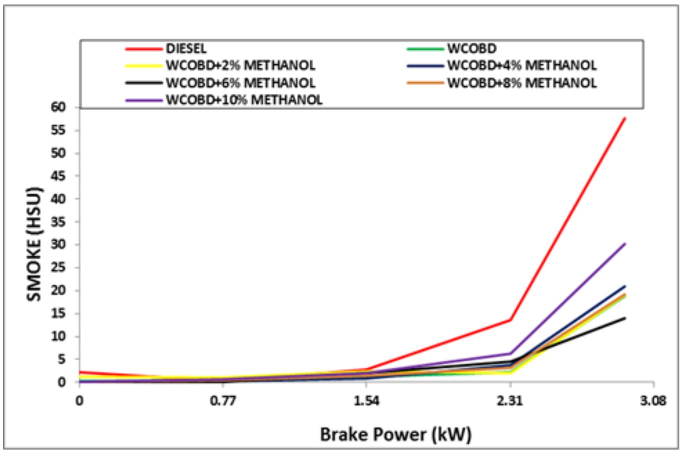

Figure.9. Smoke emission Verses Brake Power

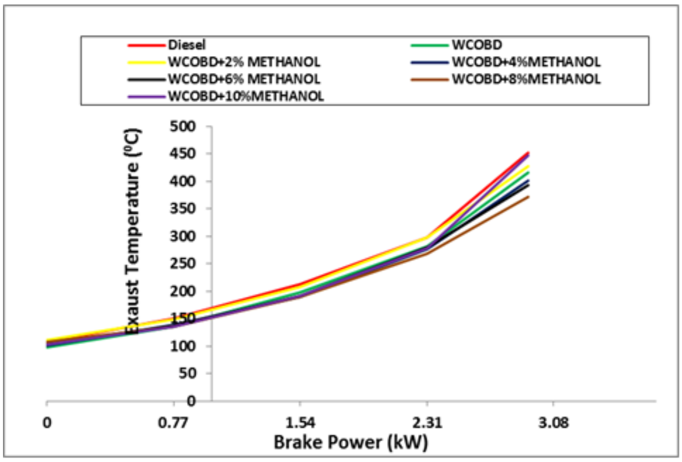

Figure.10. Exhaust gas temperature Verses Brake Power

IV.CONCLUSIONS

In the present investigation, the performance and emission characteristics of a supercharged indirect injection diesel engine fuelled with waste cooking oil methyl esters with different percentage of hydrated methanol additive have been discussed and compared with neat diesel fuel. Results of the present work are summarized as follows:

- Waste cooking oil methyl ester with different percentages of hydrated methanol was tested successfully in supercharged IDI engine without any engine modifications except the secondary injection of additive and super charging.
- Peak pressures were attained almost equal to the diesel fuel for all the biodiesel combo fuels in the presence of super charging.
- Better BSFC and BTE observed in the case of new fuel combination.
- Improved NOx and smoke emissions was achieved in the case of new fuel combination.

Hence finally it is recommended of totally replacing the diesel fuel with the new combo fuel from the aforesaid advantages, clean combustion can be best assured with the waste cooking oil biodiesel and 6% hydrated methanol.

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