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An Experimental Evaluation of Performance and Emission Characteristics for Modified Diesel Engine Using Biofuel

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Abstract - **Combustion in the cylinder of a diesel engine has a critical effect on the efficiency of the engine and the contamination caused by the engine. In a diesel engine, combustion is controlled by means of fuel injection. Therefore, it is of great importance that the injection process of the fuel is controlled in a proper manner. Recently, the need to reduce CO2 levels has made increased fuel economy an urgent matter of concern for the researches. Use of the highly efficient diesel engine is expected to increase and measures against emissions such as soot are a major problem. Gasoline engines, on the other hand, are more sustainable in terms of exhaust emissions, and are steadily approaching the diesel engine in terms of fuel economy as well. We are also proposing various advanced system solutions in response to needs for automobile fuel economy, emissions and power. Oxygenated fuels like biodiesels have great impact on engine emission and performance. Biodiesel has become more prominent alternate fuel, for diesel engines on the basis of single fuel concept. Since, use of neat biodiesel on a large scale is raising certain difficulties and is being adopted in blended form with petro-diesel fuel and many a studies have confirmed B20 as a better blend with still HC and NOx emissions still on the higher side. In the present work experimental evaluation of single cylinder water-cooled diesel engine will be carried out by adopting B20 and B40 blends while studying the influence of fuel injection parameters to improve performance and emission characteristics. The investigation will be done to analyze the effect of brake specific fuel consumption and hydrocarbon emissions with B20 ,B40 and B100 fuels also the effect of fuel injection timing and fuel nozzle hole size will be studied on the performance and emissions of engines with biodiesel and diesel blends. Effect of retarded injection timings will be studied on NOx emissions. Biodiesel-diesel blends could extend the availability of petro-diesel fuel.**

Keywords: Biodiesel, Petro-diesel, Fuel injection parameters, Optimum engine operation

1. INTRODUCTION

With the socio-economic growth of the society, the energy requirement has increased multifold globally as the consumption pattern in a particular country depends upon the availability of energy resources. The various sectors that require energy from some sources are industry, transport, agriculture, domestic etc. Different energy sources are wood, coal, petroleum products, nuclear power, solar, wind etc. Out of these, the world surface transport depends primarily on petroleum fuels. The overbearing dependence on petroleum products and related economic and environmental problems have created disquieting situation. The diesel engine is frequently used in transportation, power generation and many miscellaneous applications including industrial and agricultural. The major pollutants from diesel engine are smoke, particulate matter (PM), carbon monoxide (CO), Nitrogen oxides (NOx) and unburnt hydro carbon (UBHC). Among different pollutants, the most significant are smoke and nitrogen oxides. For achieving this goal, two methods have been followed; adaptation of the engine to the fuel and adaptation of the fuel to the engine. Considering the large numbers of existing engines, the second strategy seems to be more apropos. Hence, there is a need to explore viable alternate fuel that can be used in compression ignition (CI) engines. Any such alternative should not only match the performance of diesel but also meet or exceed the current emission norms. Harvesting renewable energy has also become an important energy source worldwide. In general, biodiesel feedstock can be divided into four categories:

(1) Edible vegetable oil: Sunflower, Rapeseed, Rice bran, Soybean, Coconut, Corn, Palm, Olive, Pistachia Palestine, Sesame seed, Peanut, Opium Poppy, Safflower oil etc.

(2) Non-edible vegetable oil: Jatropha, Karanjaor Pongamia, Neem, Jojoba, Cottonseed, Linseed, Mahua, Deccan hemp, Kusum, Orange, Rubberseed, Sea Mango, Algae and Halophytes etc.

(3) Waste or recycled oil.

(4) Animal fats: Tallow, yellow grease, chicken fat and by- products from fish oil etc.

2. CURRENT SCENARIO OF BIODIESEL

The production of biodiesel has registered commendable increase during the past ten years. The consistent development in the production of biodiesel is shown in Fig. 1. The growth of Indian economy in 2009–2010 was estimated as 8.0% by quick estimate released on 31 January 2011 and 8.6% in 2010–2011 as per the advance estimates of Central Statistics Office (CSO) released on 7 February 2011. The combination of rising oil consumption and relatively flat production (Fig. 2) has left India increasingly dependent on imports to meet its petroleum demand.

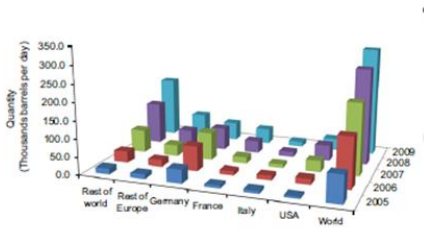

Figure 1: Production of biodiesel in world

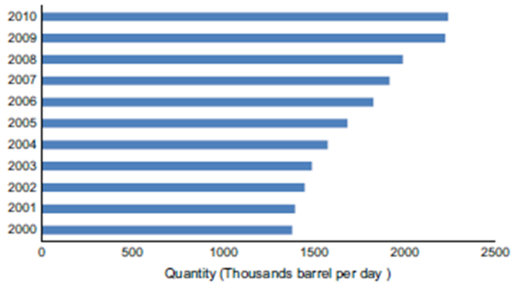

Figure 2: Difference between production and consumption of oil in India

India is one of the top 10 oil consuming countries in the world. The country's existing annual crude oil production is at about 32 million tonnes as against the demand of about 110 million tonnes. In India, bulk of the freight (over 60%) and passenger traffic (over 80%) is carried by road; and diesel and petrol contribute to 98% of the energy consumed in the transport sector. Oil imports during April– May 2007 were valued at US$ 9165.20 million and the oil import bill is expected to rise to $120 billion in 2011–2012. This fact is well established by the production and import data of edible oil (Fig. 3).

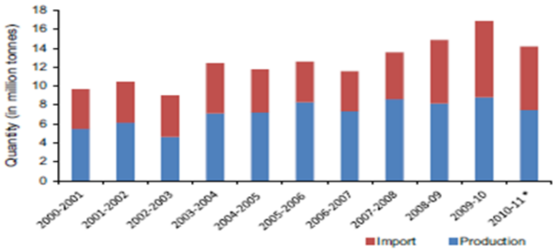

Figure 3: Production and import of edible oil in India

The possibility of commercial production of Jatropha, Karanja and Mahua has been explored for biodiesel.

3. PERFORMANCE AND EMISSIONS OF BIODIESEL FROM MAHUA

Mahua oil (MO) is non-edible oil which is widely available in India and neighbouring countries. The density and viscosity of mahua methyl ester were observed to be about 4 and 53% higher than that of diesel. Agarwal et al. (2012) investigated the performance and emission characteristics of linseed oil, mahua oil, rice bran oil and LOME and their blends in a stationary single cylinder, 4-stroke diesel engine and compared it with diesel. The results show that 30% mahua oil blend was not only most thermally efficient but also provided marginally better BSEC than other oil blends. However, smoke density was higher for mahua blends compared to diesel at lower loads. Raheman and Ghadge tested different blends of methyl ester of mahua oil (MOME) in a Ricardo E6 engine, the results enunciate that reduction in exhaust emis sions and BSFC together with increased BP, BTE made the blend of biodiesel (B20) a suitable alternative fuel for diesel. An engine testing was conducted on a single cylinder 4-stroke direct injection, constant-speed CI diesel engine using MO, MOME and B20 (20% MOME and 80% diesel) as fuels. It had been observed that the B20 blend gave higher efficiency (at higher loads) and MO gave lower thermal efficiency than diesel fuel. MOME gave lower smokeopacity but MO resulted in higher smoke emission among all fuels. 158 HP rated power, turbocharged, DI, water cooled diesel engine was run on diesel, methyl ester of mahua oil and its blends at constant speed of 1500 rpm under variable load conditions. The experiments show that the BSFC increased and BTE decreased with increase in the proportion of biodiesel in the blends. The amount of CO and HC in exhaust emission reduced, whereas amount of NOx increased with the increase in percentage of mahua biodiesel in the blends. Puhan et al have tested mahua oil ethyl ester (MOEE) in a four stroke naturally aspirated direct injection diesel engine and reported an increase in BSFC and a slight increase in BTE for MOEE compared to diesel. The emission of carbon monoxide, hydrocarbon, oxides of nitrogen and smoke were decreased by 58, 63, 12 and 70%, respectively. Puhan et al experimented with methyl ester (MOME), ethyl ester (MOEE) and butyl ester (MOBE) of Mahua oil in a 4 stroke, direct injection diesel engine. Total fuel consumption (TFC) for esters was higher than diesel. For methyl ester thermal efficiency was found to be better compared to other fuels while maximum exhaust temperature was recorded for MOME. In contrast to CO2 emission, CO and NOx emissions from all esters were lower than diesel. The authors concluded that the MOME was better fuel than other two esters in terms of performance and emission.

4. DISCUSSIONS

Poor cold flow properties, low volatility along with oxidative stability are main hurdles in the utilisation of SVO in diesel engine. The combined effect of high viscosity and low volatility of Seed oils are poor cold engine start up, misfire and ignition delay. To reduce these problems and to decrease viscosity, different methods have been adopted; namely, blending, micro emulsion, transesterification, preheating and pyrolysis (thermal cracking). Of these, transesterification is the most common method. Trans- esterification also improves the cold properties of biodiesel. Methanol is the most preferred alcohol used to produce biodiesel because of its low price, and its physical and chemical advantages, as it has polar and the shortest chain. Although, transesterification makes the fuel properties of Seed oils closer to diesel, the viscosity of the biodiesel remains still higher (about 2 times) than that of diesel. Further decrease in viscosity can be achieved through blending or heating.

4.1 EFFECT OF FATTY ACID ON PROPERTIES OF MAHUA BIODIESEL

The transesterification reaction of an oil or fat produces biodiesel fuel corresponding to the fatty acid profile of its parent oil or fat. Thus, biodiesel can be said to be a mixture of fatty esters with each ester component contributing to the properties of the fuel. In this section, discussion has been carried out about properties of biodiesel in relation with the fatty acid structure. Properties of biodiesel like ignition quality, cold flow, oxidative stability, viscosity, and lubricity are strongly influenced by the structure of its component fatty esters and the nature of its minor components. The cetane number of biodiesel derived from different feed- stock, reported in different literatures, ranges from 48 to 65. The variation in reported cetane number arises mainly due to chemical structure, oil processing technology and climate condition of the area where oil is collected. Wadumesthrige et al. have demonstrated that not only the composition of biodiesel influence cetane number. Further they tend to crystallise indefensibly with variation of temperature. Knothe et al. have shown that the reason for lower CN of some fatty compounds is due to the formation of low-CN compounds during pre-combustion, especially for more unsaturated esters. Biodiesel prepared from more saturated oil such as those prepared from tallow and used frying oil has higher cetane number. Calorific value is the most important property of a fuel which determines the energy value of it . Cold flow properties such as cloud points and pour points are the major problems associated with the use of biodiesel. The cold flow properties of biodiesel fuels depend on the feedstock (specific type of oil, fat or grease etc.) from which they are made and are a strong function of the level of saturated fat. Viscosity and density are two key fuel properties parameters required by biodiesel and diesel fuel standards. Pratas et al. Density is notable properties of fuel because injection systems, pumps, and injectors must deliver the amount of fuel precisely adjusted to provide proper combustion. Iodine number is a measure of the degree of unsaturation of the fuel.

Table 1 properties comparison between Mahua biodiesel and Pure Diesel

Fuel properly	Unit	Diesel	Mahua biodiesel
Kinematic viscosity at 40°C	cSt.	4.56	5.58
Specific gravity at 15°C		0.8668	0.8812
Flash point	°C	72	174
Fire point	°C	80	185
Pour point	°C	−18	4
Cloud point	°C	−3	12
Diesel index		50.6	51.4
Calorific value	kJ/kg	42850	42293

4.2. EFFECT OF BIODIESEL ON ENGINE PERFORMANCE AND EMISSION

In this work, performance and emissions of different biodiesel reported by different authors have been studied

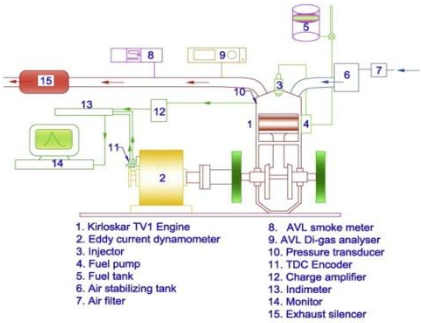

Figure 4: Engine Setup

Parameter	Specification
Engine model	Kirloskar TV-1
Engine type	DI, naturally aspirated, water cooled
Number of cylinders	1
Bore (mm)	87.5
Stroke (mm)	110
Displacement (cm^3)	661
Compression ratio	17.5
Maximu power (kW) at rated rpm	5.2
Rated rpm	1500
Injection pressure (bar)	220
Injection timing (°btdc)	23

Figure 5: Engine Specifications

4.2.1. PERFORMANCE

4.2.1.1. POWER

A group of authors agree that the engine power decreased with the utilisation of biodiesel. The reasons are less calorific value of biodiesel and inefficient combustion of biodiesel. Some authors also reported some power recovery and it is attributed to the higher density, higher bulk modulus and higher viscosity of biodiesel. High density results in injection of increased mass of fuel, while high viscosity reduces the leakage. However, the higher mass fuel flow for the methyl ester is not sufficient to compensate for the approximately 12.8% lower heating value compared to diesel fuel. It was also reported by some authors that there was no significant difference in engine power between biodiesel and diesel. The explanation is that engine delivers fuel on volumetric basis and biodiesel density is higher than that of diesel which supplies more biodiesel to compensate the lower heating value. Higher viscosity of biodiesel leads to larger spray droplet which enhances fuel spray penetration due to higher momentum, thus improving air–fuel mixing. In addition, in-built oxygen of biodiesel also benefits the combustion process. Therefore, the higher BSFC of biodiesel and improved combustion are the reasons for increase in the engine power.

4.2.1.2. BRAKE SPECIFIC FUEL CONSUMPTION

Most of the authors reported an increase in fuel consumption in case of biodiesel compared to diesel. This increase is due to combined effects of the higher fuel density, viscosity and low heating value of biodiesel. As the BSFC was calculated on weight basis, obviously higher densities resulted in higher values for BSFC as higher mass injection for the same volume at the same injection pressure. Also, the higher density of biodiesel has led to more discharge of fuel for the same displacement of the plunger in the fuel injection pump, thereby increasing the specific fuel consumption. In addition, the lower heating value of biodiesel requires that a larger amount of fuel to be injected into the combustion chamber to produce the same power.

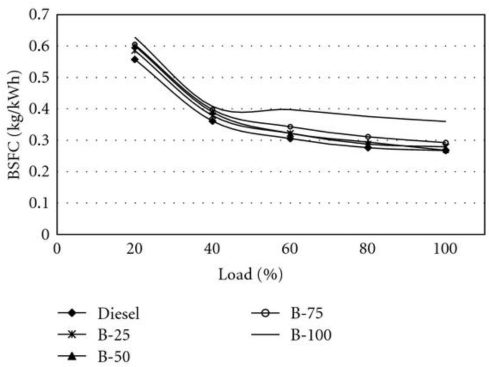

Figure 6: BSFC comparison between Mahua biodiesel blends and Pure Diesel

4.2.2. EMISSION

4.2.2.1. CO EMISSIONS

For the biodiesel, the CO emissions were less than for the diesel fuel. Canakci, Oner and Altun and Nabietal. found 18.4, 14.5 and 4% reductions in CO emissions respectively, when the engine was fuelled with B100.Thismaybeduetooxygencontentofbiodiesel and its blends. In addition, lower C/H ratio of biodiesel compare to diesel also reduces CO emission. However, the amount of decrease in CO emissions does not depend on biodiesel percentage in fuels. Biodiesel contain oxygen in their molecule that resulted in complete combustion of the fuel and supplied the necessary oxygen to convert CO to CO.

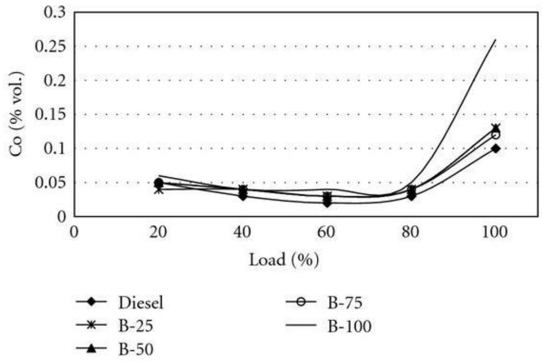

Figure 7: Comparison of Co emissions between diesel, Mahua biodiesel, and blends

4.2.2.2. NOX EMISSIONS

No unanimity regarding emission of NOx was found in the literature. Some of the literature reported less NOx emission with the utilisation of biodiesel. Oner et al. reported 38.4% reduction, while Sahoo et al. reported 4% reduction. The explanations given are higher cetane number and lower flash point of biodiesel as compared to diesel. Increasing cetane number reduces the size of the premixed combustion by reducing the ignition delay and hence lower NOx formation rate since the combustion pressure rises more slowly giving more time for cooling through heat transfer and dilution and leading to lower localized gas temperatures.

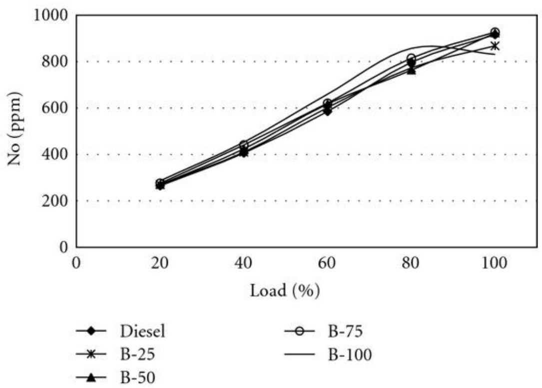

Figure 8: Comparison of no emissions between diesel, Mahua biodiesel, and blends

4.2.2.3. PM AND SMOKE

PM (particulate matter) is composed mainly of three components: DS (dry soot), sulphate and SOF (soluble organic fraction). The literature review shows that PM emissions were generally reduced with the use of biodiesel as compare to diesel; due to the oxygen contained in the biodiesel molecules, the low levels of sulphur content and higher cetane number. Particulate matters were formed in the locally rich regions of the heterogeneous mixture of fuel and air during combustion in the combustion chamber. Further mixing of air and fuel resulted in burning of particulate at the boundary of diffusive flame due to the high temperature and available oxygen at the region. The increase of oxygen content in the biodiesel which contributes to a complete fuel oxidation even in locally rich zones, led to a significant decrease in PM and smoke.

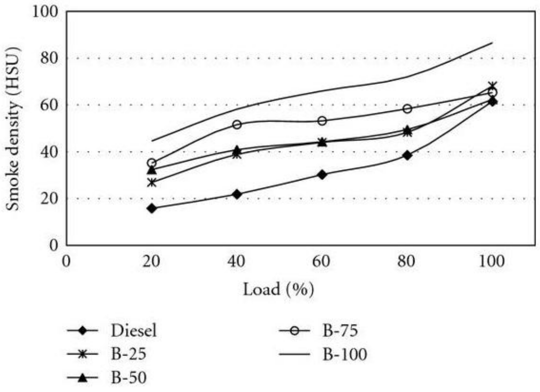

Figure 9: Comparison of smoke between diesel, Mahua biodiesel, and blends

4.3.2.4. HC EMISSION

Many previous studies have reported significant reduction in HC emission, however the reduction amount vary in the reported data. Kalligeros et al. reported that the addition of methyl esters contributed to a faster evaporation and more stable combustion, and hence, a decrease in HC in comparison to diesel. The oxygen contains and higher cetane number of biodiesel along with advanced injection and combustion timing reduces HC emission for biodiesel significantly.

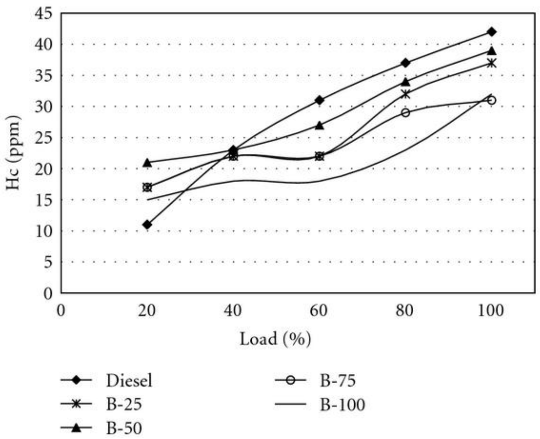

Figure 10: Comparison of Hc emissions between diesel, Mahua biodiesel, and blends

4.2.2.5. CO_2 EMISSION

CO_2 emissions of biodiesel are higher than that of diesel fuel. Presences of oxygen in biodiesel and relatively lower content of carbon in biodiesel for the same volume of fuel consumed are cited as there as on for higher emission of CO_2.

CONCLUSIONS

The properties of the Mahua biodiesel are similar to the diesel. However, the variation in the properties of this biodiesel causes variation in the nature of the performance and emission of the diesel engine. In-depth understanding of the relation exhibited between nature of the Mahua feedstock of biodiesel and performance and emission may pave way for a more detailed exploration of biodiesel in diesel engine. Furthermore, the effect of different types of engine is also an influential factor to be considered while evaluating the performance and emission of engine. Beside these factors, other factors, such as, difference in used diesel, the different measurement techniques or instruments etc., are also instrumental in providing fluctuating results.

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