Performance Analysis of CIDI Engine Using Fish Oil Methyl Ester as Biodiesel

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Abstract— Recently, biodiesel has recognized as a suitable renewable alternative fuel in the place of petro-diesel in unmodified diesel engine. The fish waste from the aqua industry per year was projected to be over a millions of tons with no use. In this research work, the biodiesel was prepared using fish oil that was extracted from fish wastes. Then the experimental analysis was carried-out to assess the performance of direct injection (DI) diesel engine at rated speed of 1500 rpm at different loads using fish oil methyl ester (FOME) and its diesel blends (B20, B40, B60 and B100) as fuel. The test results recorded lower brake thermal efficiency (BTE), slightly higher brake specific energy consumption (BSEC), and moderately higher exhaust gas temperatures (EGT) from the engine when FOME and its blends used as fuel than that of diesel fuel at all engine loads. Finally, the research analysis revealed that fish oil methyl ester can be used as fuel in the diesel engine without any modifications in the engine and B20F biodiesel blend can be considered as a suitable alternative fuel to replace the diesel fuel.

Index Terms—Biodiesel, Fish Oil Methyl Ester, Performance, CIDI Engine

I. INTRODUCTION

Indeed, energy resources are the single significant factor for economic growth and human well-being. Fossil fuel resources are substantially located in few geographic locations, non-renewable, toxic, and polluting. The tremendous demand for fossil fuels, the diminishing fuel reserves and hazardous effect on the environment have encouraged the researchers and scientific community to search for an alternative renewable fuel to substitute the diesel fuel. In the recent times, plant based biodiesels are considered as an alternative for petro-diesel due to their chemical properties which have been similar to pure diesel. The physical properties of the fuel such as viscosity, volatility and flash point also affect the combustion process, thereby engine performance. The vegetable oils in neat form or as a diesel blend can be used in diesel engine without any modifications in the engine for all blend ratios. But it is not preferable for prolonged period which was raising severe problems such injector coking, piston ring sticking and thickening of the lubricating oil in the test engine [1-3]. The biodiesel that was produced by transesterification with lower alcohols such as ethanol, methanol as fuel resolves all mentioned issues. Currently, many nations are encouraging the blend of biodiesel as alternative to petro-diesel to promote rural employment and economic growth, to develop a long term replacement renewable fuel, to minimize the dependency on the petroleum imports and to increase the energy security [4].

The source for biodiesel production is chosen according to the availability in each region or country, physico-chemical properties, production cost and transportation. Any fatty acid source may be used to prepare biodiesel, but most research articles have reported soybean as a biodiesel source [5]. The common fatty acids found in vegetable oils and animal fats. Generally, the most abundant vegetable oil in a particular region is the most common feedstock. Thus, soybean oil is the largest source of vegetable oil in the United States, while rapeseed (canola) and sunflower oils are the largest source in Europe. Similarly, palm oil in Southeast Asia (mainly Malaysia and Indonesia) and coconut oil in the Philippines are the largest source of vegetable oil [6-8]. However, the cost of the biodiesel mainly depends on the expenditure incurred to produce the feedstock and its availability. The production cost of the plant based biodiesel feedstock is much higher than petro-diesel especially in its commercialization due to intense use of farm labor, plant costs and providing watering facility. Moreover, the present oilseeds production system is raising eco-concerns because the plants required massive amount of fertilizers and pesticides for high yielding. The crop rotation and/or with diverse crops certainly mitigate the negative impacts and enhance biodiversity. However, it reduces the quantity and production rate which may raise concerns about the sustainability of continuous production of biodiesel due to lack of feedstock. For all these reasons, biodiesel feedstock from industrial wastes such as fish oil from aqua industry byproducts and waste cooking vegetable oil from food industry waste is highly desirable as it is abundantly available with less price and moreover no other further usage [9]. Therefore, fish oil from fish industry wastes was selected for the present research study as biodiesel feedstock to evaluate its performance characteristics of direct injection diesel engine in terms of brake thermal efficiency (BTE), brake specific energy consumption (BSEC) and exhaust gas temperature (EGT).

II. MATERIAL AND METHODS

The crude fish oil was collected from the local vendor to prepare the biodiesel. The fish oil can be used directly in unmodified diesel engine in its pure form, but it creates engine problems such as severe carbon deposits, injector choking and piston ring sticking in the diesel engine [10,11]. This is because the higher viscosity, density, and lower cetane number of the fish oil. Generally, pre-heating/pyrolysis, blending/dilution, micro-emulsion and transesterification processes are the most commonly used methods to reduce the viscosity and to bring the combustion properties of the oil closer to that of petro-diesel fuel. As shown in Figure 1, in transesterification process, triglycerides (vegetable oil/fat) react with ethyl/methyl alcohol in the presence of a catalyst (potassium hydroxide/sodium hydroxide) and produce ethyl/methyl ester of oil, which is called biodiesel and glycerol as by-product. In this work, biodiesel in the form of fish oil methyl ester (FOME) was prepared using methyl alcohol in the presence of sodium hydroxide through transesterification process.

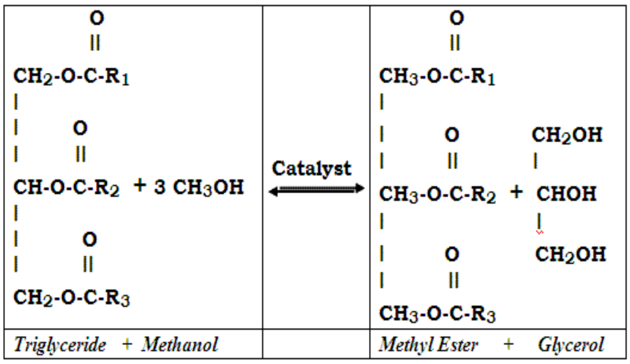


Fig. 1 Transesterification Process

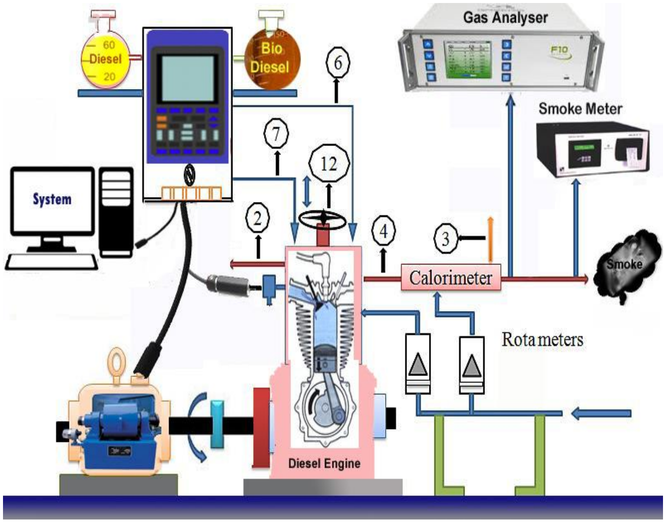
The properties of fish oil methyl ester (FOME) adhere to the ASTM standards and its properties along with mineral diesel are presented in the Table 1.

Table 1. Properties of Diesel and Biodiesel

Fuel Property	Units	ASTM Standards	Diesel	FOME
Kinematic Viscosity @ 40^{0}C	CST	D445	3.52	5.89
Flash Point	^{0}C	D93	49	165
Density @ 15^{0}C	kg/m^3	D1298	837	876
Calorific Value	kJ/kg	D4868	42850	3800
Cetane Number	--	D613	50	52
Carbon Residue	% by mass	D4530	0.1	0.47
Total Sulphur	% by mass	D5453	0.01	0.05
Ash Content	% by mass	D1119	0.01	0.03

III. EXPERIMENTAL SETUP

In this experimental study, a 3.7 kW, single cylinder, 4-stroke, water cooled compression ignition direct injection (CIDI) engine was used and the setup is presented in Figure 2. The test engine was connected to eddy current type dynamometer. The engine specifications are given in Table 2.



Nomenclature:
2: Outlet engine Jacket Water Temperature (^{0}C);
3: Inlet water temperature (^{0}C);
4 & 6: Exhaust Gas Temperature before and after Calorimeter (^{0}C);
12: Pressure Transducer

Fig. 2 Experimental Setup

The tests were carried-out from quarter to full load conditions at various biodiesel-diesel blend combinations rated injection pressure of 200 bar. While the engine reached the stabilized working condition, a series of experiments were conducted on a diesel engine using fish oil methyl ester (FOME) as fuel and brake thermal efficiency (BTE), brake specific energy consumption (BSEC), and exhaust gas temperatures (EGT) were determined.

Table 2. Specifications of Test Engine

Engine Make:	Kirloskar AV1, India
Engine Details:	DI, Single Cylinder, Four stroke, Water cooled
Bore & Stroke:	80 × 110 mm
Rated Power :	3.7 KW (5 HP) at 1500 rpm
Injection Pressure:	200 bar
Compression Ratio:	16.5:1
Dynamometer:	Eddy Current

IV. RESULTS AND DISCUSSION

The engine's performance analysis was carried-out when fueled with fish oil biodiesel for different test conditions at constant rated speed of 1500 rpm and the results are presented in this section.

A .BRAKE THERMAL EFFICIENCY (BTE)

The Figure 3 shows the variation of brake thermal efficiency (BTE) with engine load for different biodiesel blends and diesel fuel. The diesel has highest BTE than all tested fuels and biodiesel in its neat form has the lowest BTE. The B20F has comparable BTE with diesel and has highest BTE when compared all biodiesel blends. The engine performance in terms of BTE has decreased by about 22% when neat biodiesel used in engine than that of diesel fuel due to lower calorific value of the biodiesel. The BTE has increased along with the increase of load for tested fuels and for every 20% addition of biodiesel content in the blend decreases the BTE at the rate of 7%. The B20F blend was suitable replacement of diesel fuel in among all the tested fuels followed by B40F blend.

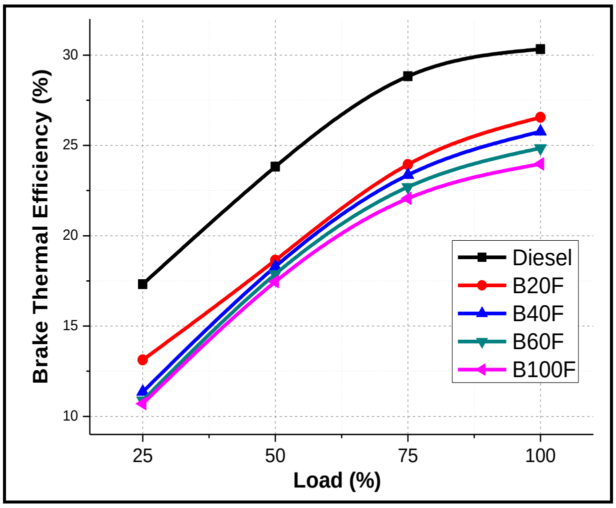


Figure 3: BTE vs. Engine Load for different fuels

B. BRAKE SPECIFIC ENERGY CONSUMPTION

The variation of BSEC for all tested biodiesel blends with varying engine loads at rated speed of 1500 rpm is illustrated in Figure 4. The brake specific energy consumption of the engine with fish oil biodiesel at all loads is higher than diesel fuel. This is due to higher density and lower calorific value of biodiesel. It observed that the BSEC has increased with increase of biodiesel content percentage and the petro-diesel has shown lowest among all the tested fuels. The neat biodiesel has shown highest BSEC throughout the engine load range and B20F blend has shown the lowest BSEC when compared to all others blends of biodiesel. At lower engine load conditions the BSEC is higher and gradually decreasing when load is increasing. At full load condition, it is noticed that the BSEC is lowest for all fuels. As percentage of biodiesel content increased, an increase in BSEC was observed.

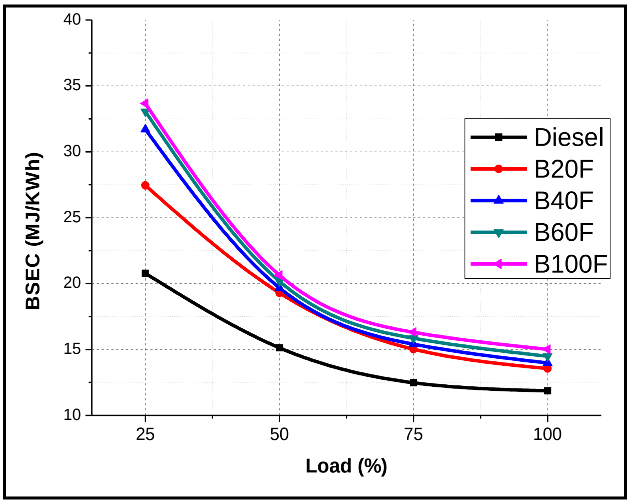


Figure 4: BSEC vs. Engine Load for different fuels

C. EXHAUST GAS TEMPERATURE

The variation of exhaust gas temperature with varying load conditions is presented in figure 5. The engine has emitted lowest exhaust gas temperature (EGT) with diesel fuel and the neat biodiesel has released highest EGT from the engine The EGT increased with the increase of engine load and the engine has released highest at full load condition. The increase in EGT was observed with the increase of biodiesel percentage in the blend and every addition of 20% biodiesel in the blend, an increase by rate of 2.25% was noticed with the blends. In among all the blends of biodiesel, B20F has closest EGT to petro-diesel fuel when compared all biodiesel blends.

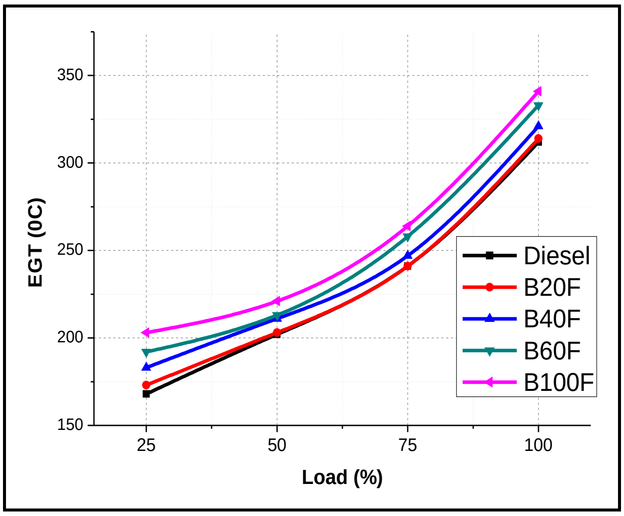


Figure 5: EGT vs. Engine Load for different fuels

V. CONCLUSION

The experimental investigation on performance of a single cylinder, 4-stroke, and water cooled CIDI engine using fish oil methyl ester (FOME) and its diesel blends as biodiesel have revealed that the B20F and B40F biodiesel blends have comparable performance in terms of brake thermal efficiency (BTE) and can be used as supplementary bio-fuel in compression ignition engine without any modifications in the engine. The brake specific energy consumption (BSEC) of the engine is significantly higher with biodiesel for the same power developed and the exhaust gas temperature (EGT) from the test engine is moderately higher with biodiesel for the same power developed when compared with diesel fuel.

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