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Experimental Studies on Performance and Emission Characteristics of Fish Oil Methyl Ester and its blends at different injection opening pressures in a direct injection CI engine

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ABSTRACT
Biodiesel is one of the most versatile alternative fuel options for direct injection CI engine applications. In the recent research of biodiesel in India receives its attention towards fish oil based biodiesel. The present work aimed at production of biodiesel from the fish oil extracted from marine fish species by transesterification process which is used as fuel in direct injection CI engine to evaluate its performance, and emission characteristics at different injection opening pressures of 190bar, 200bar, 210bar. The different blends of fish oil biodiesel with diesel, B10, B20, B30, B40, B50 and B100 were used in the experiments and the results indicate that brake thermal efficiency were higher with B30 blend fuel than that of diesel at 210bar as compared at 190bar and 200bar. The brake specific energy consumption for B30 blend at 210bar shows better results than that of diesel. By considering these two performance parameters B30 blend at 210 bar injection opening pressure is taken as optimum. At full load for B30 fuel at 210bar injection opening pressure the emission results shows that there is increase in NO_x and CO_2 emission but reduction in CO and HC emissions by 20% and 15.55% respectively with reference to diesel fuel.

Keywords- Biodiesel, Emission characteristics, Fish oil, Injection Opening Pressure, Performance characteristics, Transesterification Process.

I. INTRODUCTION

Diesel engine is a popular prime mover for surface transportation, agricultural machinery and industries. In Indian agriculture sectors more than 6.5 million diesel engines are being used for various activities. Import of petroleum products is a major turmoil on our foreign exchange sources and with growing demand in future years, the situation is likely to become worse. Hence, it has become important to use suitable alternative fuels, which is indigenous [1]. For this the promising alternative is a biodiesel fuel which seems to be providing a better solution to all the present problems. Biodiesel can be produced using renewable resources such as vegetable oils (like corn seed oil, palm oil) and animal fats (like poultry fat, Fish oils) or used cooking oils from the food industry, restaurants or domestic kitchens.

The annual production quantity of marine fisheries in Taiwan amounted to 1540 thousand metric tons in 2011[2].During the manufacturing process of fish products, the viscera, fins, eyes, tails etc., is often discarded. The discarded parts of marine fish are frequently ground into fishmeal to provide food for livestock and have little economic value. However, the crude fish oil extracted from these discarded parts may provide an abundant, cheap, and stable source of raw oil to allow maritime countries to produce biodiesel and thus help to reduce pollutant emissions. Cherng-Yuan Lin et.al [4] transesterified fish oil to produce biodiesel. They used discarded parts of mixed marine fish species as the raw material to produce biodiesel. They reported that, commercial biodiesel from waste cooking oil, when compared with marine fish oil biodiesel had a larger gross heating value, elemental carbon and hydrogen content, cetane index, exhaust gas temperature, NO_x and O_2 emissions and black smoke opacity and a lower elemental oxygen content, fuel consumption rate, brake-specific fuel consumption rate, equivalence ratio, and CO emission.

Fuel injection pressure in diesel engine plays an important role in engine performance. Higher injection pressure decreases fuel particle diameter which aids in better formation of mixing of fuel to air during ignition period, as a result of which engine performance will increase. High-pressure injection in combination with small orifice can achieve lean combustion which allows better fuel atomization, evaporation and improved emissions [5].T. Hari Prasad et.al used artificial neural network (ANN) modeling of a diesel engine to predict the exhaust emissions of the engine [6]. They made the comparison between the acquired ANN predictions with the experimental results. From the experimental results, they concluded that there is a significant reduction in the CO, CO_2 and HC emission levels accompanied by an increase in NO_x level. A. Karthikeyan et.al [7] studied the diesel engine performance with fish oil biodiesel and its blends with diesel on a single cylinder, water cooled, four stroke diesel engine. They reported that Brake thermal efficiency of B60 blend and B100 was close to the brake thermal efficiency of diesel at all loads. However they also found that NO_x emissions of fish oil blends are slightly higher than that of diesel. Sharanappa G. et al.[8] tested methyl ester of fish oil on diesel engine to evaluate fish biodiesel as an alternative fuel. This present investigation aims at study of performance and emission characteristics of Fish oil Methyl ester and its blends in a direct injection CI engine at different injection opening pressures.

II. EXPERIMENTAL PROCEDURE

2.1 Biodiesel Production

Crude fish oil is used as the raw oil for the production of fish oil biodiesel. The filtered raw fish oil is mixed with methanol with constant stirring to undergo a transesterification reaction at 60^0 C for one hour. The mass ratio of the fish oil and methanol was set at 1:6, and to enhance the reaction 1% wt sodium hydroxide of the fish oil was added into the mixture as an alkali catalyst. After the transesterification reaction, the chemical product has to be kept for about an hour, by this time the chemical product was separated into two layers, crude biodiesel and glycerin, by virtue of the density difference between the two compounds. The crude biodiesel obtained was then water washed for five minutes, and the un reacted methanol, water, volatile compounds and other impurities were removed by heating it at around 100^0 C for 10 min. The resulting fish oil biodiesel was thereafter used as diesel engine fuel in the study.

2.2 Fuel Properties

The test fuel sample of fish oil biodiesel was obtained directly from Blue line Foods Pvt. Ltd, Mangalore, India, manufacturers of fish oil and fish meal. The physical characteristics of fish oil methyl ester are closer to diesel. The fish oil fuel properties were tested in our college laboratory and listed in Table 1.

Table 1 Properties of fish oil methyl ester and diesel

Parameters	Units	B100	Diesel
Density @ 28^0 C	Kg/m^3	891	812
Kinematic Viscosity @ 40^0 C	Cst	3.99	2.1
Flash Point	^{0}C	153	44
Fire Point	^{0}C	162	54
Calorific Value	kJ/kg	37815	43400

2.3 Experimental Setup

Fig.1 Photographic view of experimental setup

A single cylinder, four strokes, water cooled, compression ignition engine with a bore 80 mm and stroke of 110 mm and a compression ratio of 16.5:1 was used for the experimental work. The engine was rated for 5 HP at 1500 rpm with centrifugal governor to control the speed. The performance and exhaust emission tests were carried out in a constant speed, direct injection diesel engine. The engine specifications are represented in Table 2. The engine was loaded with electrical resistive load. Fuel consumption was volumetrically measured using measuring burette, the consumption was determined by measuring the time for the consumption of a fixed fuel volume. The air flow was measured using an orifice flow meter and the exhaust gas temperatures were recorded with chromel alumel thermocouples. The engine was started on neat diesel fuel and warmed up. The warm up period ends when the cooling water temperature was stabilized. The Kirloskar, engine is one of the widely used engines in agriculture tractor, pump sets, farm machinery and medium scale commercial purposes.

Table 2 Engine specification

SL NO	ENGINE PARAMETERS	SPECIFICATION
01	Machine supplier	INLAB Equipments. Bangalore.
02	Engine Type	TV1(Kirloskar, Four Stroke)
03	Number of cylinders	Single Cylinder
04	Number of strokes	Four-Stroke
05	Rated power	3.7KW (5 HP) @1500RPM
06	Bore	80mm
07	Stroke	110mm
08	Cylinder Capacity	553cc
09	Compression ratio	16.5:1
10	Loading	Eddy current dynamometer

2.4 Experimental Procedure

The engine was started by hand cranking with diesel fuel and it was allowed to run for few minutes to reach its steady state. The test fuels used during this program were neat fish biodiesel, a neat diesel fuel and blends of 10, 20, 30, 40, 50 percent biodiesel by volume in the diesel fuel. Selected properties for fuels are listed in Table 1.The engine was sufficiently warmed up and stabilized before taking all readings. The performance of the engine and emissions were studied at variable loads corresponding to the load at maximum power at an average speed of 1500 rpm. After the engine reached the stabilized working condition, load applied, fuel consumption, brake power and exhaust temperature were measured from which brake specific energy consumption and thermal efficiency were computed. The emissions such as CO, HC, CO_2 and NO_x were measured using an exhaust gas analyzer. These performance and emission characteristics for different fuel blends are compared with the result of baseline diesel.

III. RESULTS AND DISCUSSIONS

3.1 Performance Characteristics

The engine performances with fish oil biodiesel are evaluated in terms of brake thermal efficiency, brake specific energy consumption for different loading conditions. The results obtained pertaining to the performance of the engine is demonstrated with the help of suitable graphs.

3.1.1 Brake Thermal Efficiency

The variation of brake thermal efficiency with brake power for different fuels at different injection opening pressure are presented in Fig.2, Fig.3 and Fig.4. In all cases, it increases with increase in load. This was due to reduction in heat loss and increase in power with increase in load. From the above graphs we can say that the brake thermal efficiency of B30 is better than diesel by 2.98% at 210 bar injection opening pressure. But in 190 bar and 200 bar brake thermal efficiency of diesel fuel is better than the biodiesel fuels. Also there is an improvement in brake thermal efficiencies of biodiesel fuels with increase in injection opening pressure from 190 bar to 210 bar. The maximum thermal efficiency for B30 (28.96%) was higher than that of diesel at 210 bar injection opening pressure. The possible reason for increase in brake thermal efficiency at 210 bar may be complete combustion caused by better atomization and inherent oxygen in the biofuel which improves combustion characteristics.

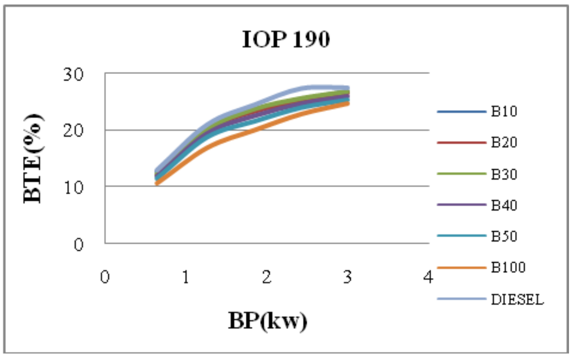

Fig.2 Variation of BTE % v/s Brake power at 190 bar

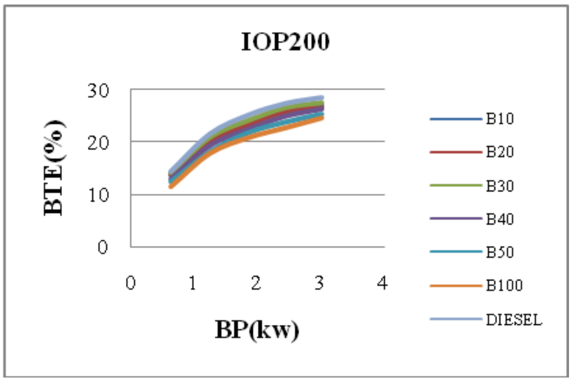

Fig.3 Variation of BTE % v/s Brake power at 200 bar

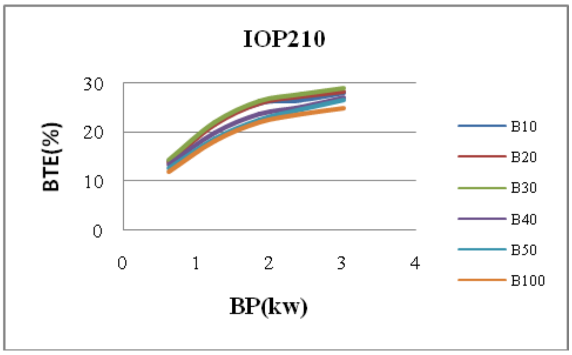

Fig.4 Variation of BTE % v/s Brake power at 210 bar

3.1.2 Brake Specific Energy Consumption

Brake specific energy consumption (BSEC) is an ideal variable because it is independent of the fuel.

Hence, it is easy to compare energy consumption rather than fuel consumption. The variation in BSEC with brake power at different injection opening pressures and for all fuel blends are presented in Fig.5, Fig.6 and Fig.7. In all cases, it decreased sharply with increase in percentage of load for all fuels. The main reason for this could be that percent increase in fuel required to operate the engine is less than the percent increase in brake power due to relatively less portion of the heat losses at higher loads. From above graphs we can say that the brake specific energy consumption of B30 fuel in comparable with diesel at 210 bar injection opening pressure, the difference being 6.02% higher for biodiesel fuel B30 than diesel fuel. In other injection opening pressures of 190 bar and 200 bar the difference is much lower with diesel fuel which has minimum brake specific energy consumption.

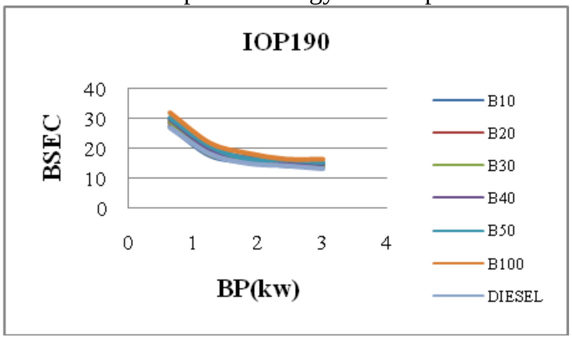

Fig.5 Variation of BSEC v/s Brake power at 190 bar

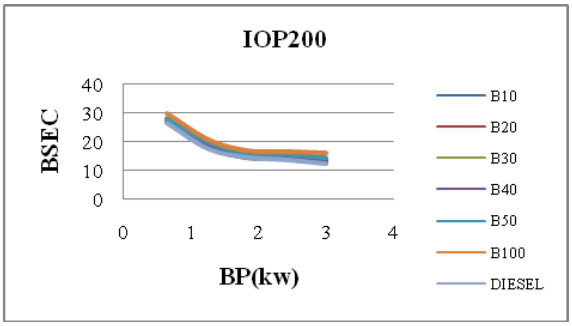

Fig.6 Variation of BSEC v/s Brake power at 200 bar

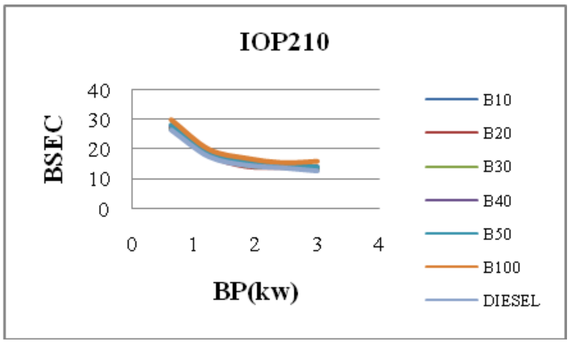

Fig.7 Variation of BSEC v/s Brake power at 210 bar

3.2 Emission Characteristics

3.2.1 Hydrocarbon emissions

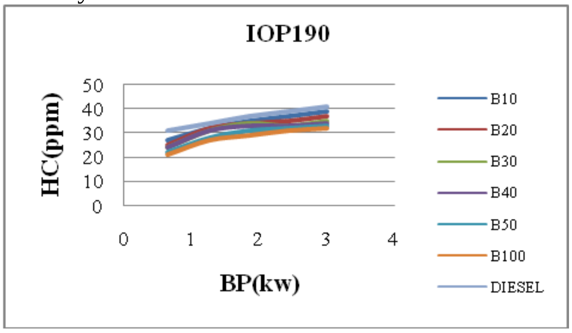

Fig.8 Variation of HC v/s Brake power at 190 bar

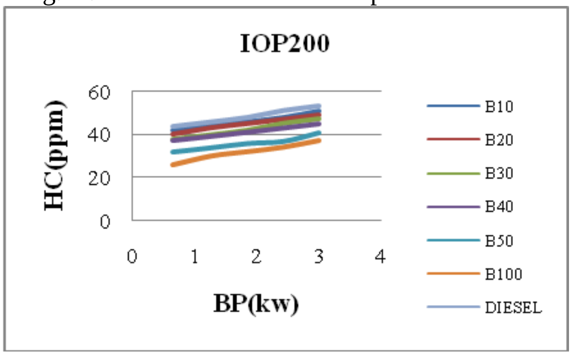

Fig.9 Variation of HC v/s Brake power at 200 bar

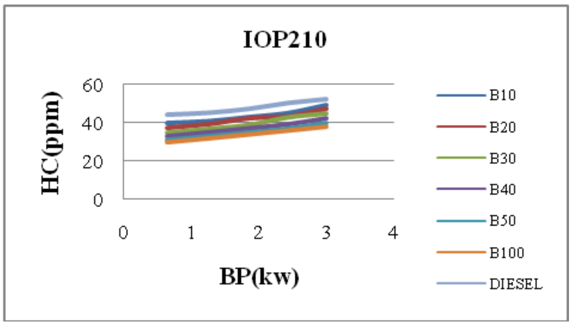

Fig.10 Variation of HC v/s Brake power at 210 bar

The hydrocarbon (HC) emission trends for blends of methyl ester of fish oil and diesel at different injection opening pressures are shown in Fig.8, Fig.9 and Fig.10. The reduction in HC was linear with the addition of biodiesel for the blends tested. The possible reason for the reduction of HC emissions with biodiesel is the oxygen content in the biodiesel molecule which leads to more complete and cleaner combustion. From the above graphs we can say that HC emission of biodiesel fuels is less than the diesel fuel at all injection opening pressures. The difference 15.55% which is maximum for B30 compared with diesel at injection opening pressure of 210 bar. The difference is much lower in case of 200 bar and 190 bar injection opening pressures.

3.2.2 Carbon monoxide

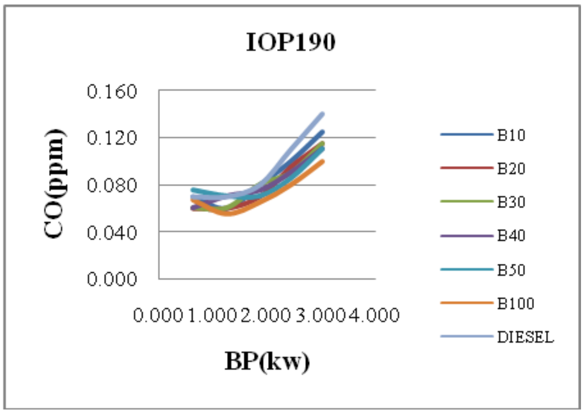

Fig.11 Variation of CO v/s Brake power at 190 bar

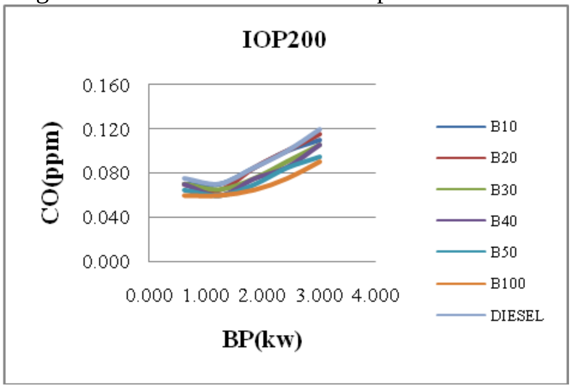

Fig.12 Variation of CO v/s Brake power at 200 bar

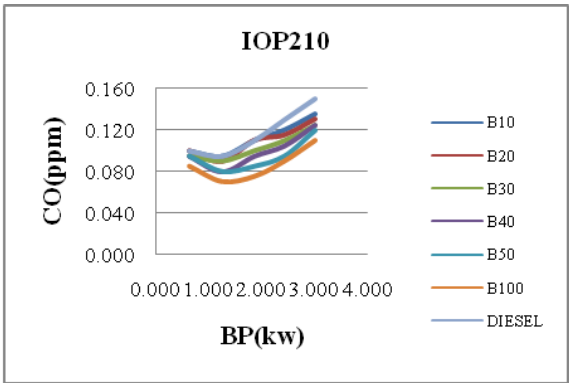

Fig.13 Variation of CO v/s Brake power at 210 bar

Variation of CO emissions with brake power at different injection opening pressures for different fuel is compared in Fig.11, Fig.12 and Fig.13. These lower CO emissions of biodiesel blends may be due to their more complete oxidation as compared to diesel. Some of the CO produced during combustion of biodiesel might have converted into CO_2 by taking up the extra oxygen molecule present in the biodiesel chain and thus reduced CO formation. It can be observed that the CO initially decreased with load and latter increased sharply up to full load. This trend was observed for all the fuel blends tested. Initially, at no load condition, cylinder temperature might be too low, which increase with loading due to more fuel injected inside the cylinder. At elevated temperature, performance of the engine improved with relatively better burning of the fuel resulting in decreased CO. From the above graphs we can say that carbon monoxide emission of B30 is lower diesel at all injection opening pressures. The carbon monoxide emission of B30 at 210 bar shows maximum difference of 20% reduction compared to diesel. In other injection opening pressures of 190 bar and 200 bar the difference is much lower with diesel fuel.

3.2.3 Oxides of nitrogen

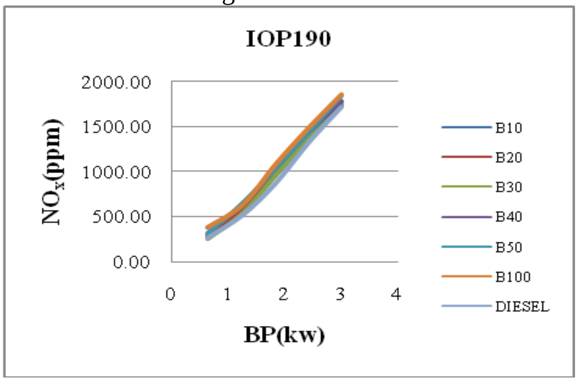

Fig.14 Variation of NO_x v/s Brake power at 190 bar

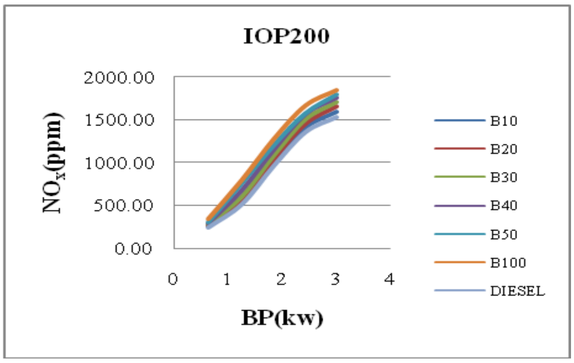

Fig.15 Variation of NO_x v/s Brake power at 200 bar

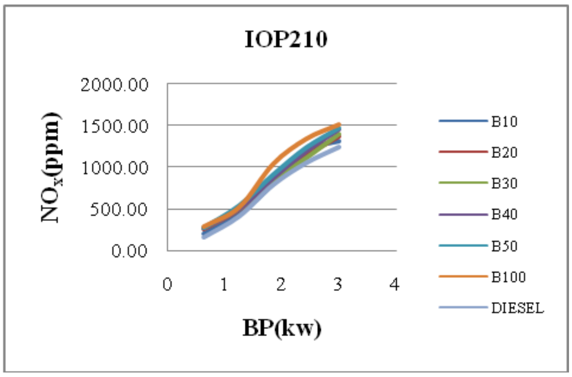

Fig.16 Variation of NO_x v/s Brake power at 210 bar

The variation of NO_x with brake power for different fuels at different injection opening pressures are presented in Fig.14, Fig.15 and Fig.16. The nitrogen oxides emissions formed in an engine are highly dependent on combustion temperature, along with the concentration of oxygen present in combustion products when compared with that of pure diesel. In general, the NO_x concentration varies linearly with the load of the engine. As the brake power increases, the overall fuel-air ratio increases resulting in an increase in the average gas temperature in the combustion chamber and hence NO_x formation, which is sensitive to temperature increase. From above graphs we can say that NO_x emission of B30 is higher than diesel in all injection opening pressures. The NO_x emission of B30 at 210 bar shows minimum difference of 12.99% than diesel. All other blends show much higher difference with diesel at all injection pressures. Also the difference for B30 is higher at injection opening pressures of 190 bar and 200 bar compared to 210 bar.

3.2.4 Carbon dioxide

The variation of carbon dioxide emission with brake power for diesel fuel and biodiesel blends is as shown in the Fig.17, Fig.18 and Fig.19. From the graphs it is observed that CO_2 emission increased with increase in load for all blends. The lower percentage of biodiesel blends emits less amount of CO_2 in comparison with diesel. Using higher content biodiesel blends, an increase in CO_2 emission was noted, which is due to the high amount of oxygen in the specified fuel blends which converts CO emission into CO_2 emission contents. From the graphs we can say that carbon dioxide emission of B30 is higher than that of diesel at all injection opening pressures. The carbon dioxide emission of B30 at injection opening pressure of 210 bar shows maximum increase of 8.23% than diesel. For the same biodiesel blend B30 the difference is lower at lower injection opening pressures.

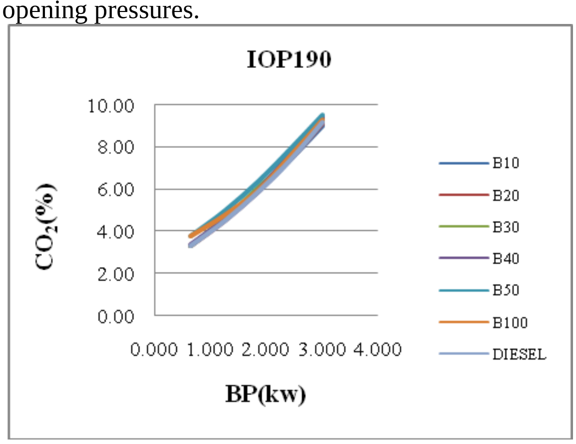

Fig.17 Variation of CO_2 v/s Brake power at 190 bar

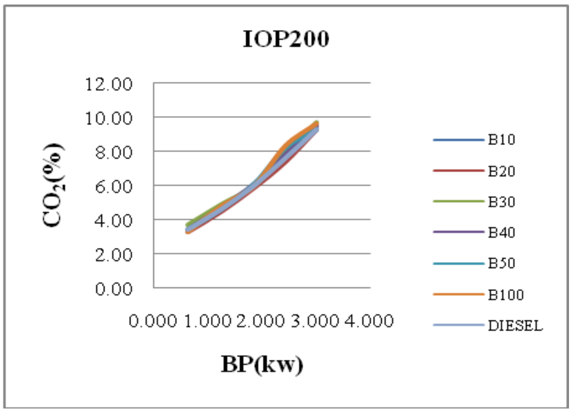

Fig.18 Variation of CO_2 v/s Brake power at 200 bar

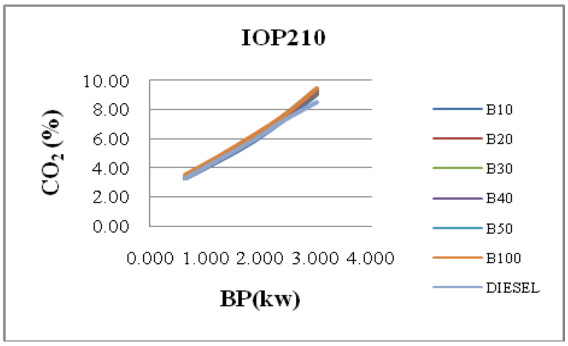

Fig.19 Variation of CO_2 v/s Brake power at 210 bar

IV. CONCLUSIONS

The conclusion derived from the performance and emission characteristics of single cylinder direct injection compression ignition engine by using diesel, fish oil methyl ester (B100) and its blends (B10, B20, B30, B40, B50) at different injection opening pressures (190bar, 200bar, 210bar) are summarized as follows:

- The properties like density, viscosity, flash and fire point of fish biodiesel under test are higher, and calorific value is lower, and are in the range of 92 - 97% that of diesel.
- The brake thermal efficiency of B30 fish oil biodiesel at 210 bar injection opening pressure is 2.98% higher than that of diesel. For the same blend at injection opening pressures of 190 bar and 200 bar gives thermal efficiency lower than that of diesel.
- The brake specific energy consumption of B30 fish oil biodiesel at 210 bar injection opening pressure is 6.02% higher than that of diesel.
- There is a gradual reduction in emissions like unburnt HC, CO of neat fish biodiesel and its blends at full load than that of diesel when test is conducted on single cylinder diesel engine.
- It was also observed that there is an increase in NO_x and CO_2 when neat fish biodiesel and its blends are tested in single cylinder diesel engine.
- From the above results we can conclude that B30 blend at 210 bar pressure has given better

performance in terms of brake thermal efficiency, brake specific fuel consumption and emission parameters.

REFERENCES

[1] Srinivasa Rao.P and Gopalakrishnan K.V , *Use of non-edible Vegetable oils as alternative fuels in Diesel Engines*, DNES project report no. *7/2/83, pp 292-297*, Indian Institute of Technology, Chennai, 1992.

[2] FAO, 2012, *The State of World Aquaculture and Fisheries* 2011. *126 pp.*

[3] Cheng-Yuan Lin, Rong-Ji Li, *Fuel properties of biodiesel produced from the crude fish oil from the soap stock of marine fish. Fuel Process Technology* 2009, *90,883-888*.

[4] Cheng-Yuan Lin, Rong-Ji Li, *Engine performance and emission characteristics of marine fish-oil biodiesel produced from the discarded parts of marine fish. Fuel Process Technology* 2009, *90,130-136.*

[5] Prashanth Karra and Song Charng Kong, *Diesel Emission Characteristics Using High Injection Pressure with Converging Nozzles in a Medium-Duty Engine*, SAE Paper Number, *2008-01-1085*.

[6] T. Hari Prasad, Member, IACSIT, Dr. K. HemaChandra Reddy and Dr.M.Muralidhara Rao, *Performance and Exhaust Emissions Analysis of a Diesel Engine Using Methyl Esters of Fish Oil with Artificial Neural Network Aid*, IACSIT International Journal of Engineering and Technology 2010 *Vol. 2,No.1*.

[7] Karthikeyan A., Prasad B. Durga, *Experimental Investigation on Diesel Engine Using Fish oil Biodiesel and its Diesel Blends*, International Journal of Applied Engineering Research , 2009, *Volume : 4, Issue : 7*.

[8] Sharanappa Godiganu, Rana Prathap Reddy, Ch.Suryanarayan Murthy, Performance *and emission characteristics of a Kirloskar HA394 diesel engine operated on fish oil methyl esters*. Renewable energy 2010, *35, 355-359*.

[9] Sehmus Altun, Husamettin Bulut, Cengiz Oner, *The comparison of engine performance and exhaust emission characteristics of sesame oil-diesel fuel mixture with diesel fuel in a direct injection diesel engine.* Renewable Energy *2008, 33, 1791-1795.*