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A Study On The Effect Of Injection Pressure And Injection Timing On The Engine Performance And Emissions With Blends Of FOME As A Fuel For CI Engine

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ABSTRACT
Historically, fish have been seen as a promising source of protein and have been actively cultured by man for centuries, mainly for food. Recent soaring oil prices, diminishing world oil reserves, and the environmental deterioration associated with fossil fuel consumption have generated renewed interest in using fish oil as an alternative fuel. The present paper is focused on experimentally investigating the influence of injection pressure and injection timing on brake specific fuel consumption (BSFC), brake thermal efficiency (BTE), unburned hydrocarbon (UBHC), carbon monoxide (CO), oxides of nitrogen (NOx) and smoke opacity of a single cylinder compression ignition engine when the optimized blends of fish oil methyl ester (20%) are used as a fuel. Engine performance tests showed no major deviations in diesel engine combustion as well as no significant changes in the engine performance and reduction of main toxic emissions. Overall fish oil methyl ester (FOME) showed good combustion properties and environmental benefits.
Keywords: Fish, Injection Pressure, Injection Timing, Fish oil Methyl Ester (FOME), Performance, Emissions

I. INTRODUCTION

The depletion of oil resources and negative impact associated with the fossil fuels, there is a renewed interest in alternate energy sources. In this focus a much concentration is directed towards the production of bio diesel. Biodiesel is non – toxic, biodegradable, renewable fuel that can be produced from a range of organic feedstock including fresh or waste vegetable oils, animal fats, and oilseed plants. Biodiesel has significantly lower emissions than petroleum-based diesel when it is burned, whether used in its pure form or blended with petroleum diesel. Among many alternative fuels, vegetable biodiesel has been identified as one of the most promising substitute for diesel fuel. But the biodiesel from vegetable also has certain drawbacks like, growth duration, oil separation and extraction which resulted in fish biodiesel. Fish oil extracted from marine fish is rich in omega-3 polyunsaturated fatty acids. Eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) are the two most important components in omega-3 polyunsaturated fatty acids. The length of the carbon chain of fish oil is frequently greater than that of general vegetable oils, which are primarily composed of palmitic acid, oleic acid, linoleic acid and linolenic acid. The purpose of this research is to analyze the influence of injection pressure and injection timing on engine performance, combustion characteristics and emission parameters on comparison between blends of FOME with straight diesel and the final result is arrived at optimum injection timing during which minimum emissions, maximum performance and better combustion is achieved.

II. BIO DIESEL PRODUCTION

Biodiesels are manufactured through transesterification process, where triglycerides of fish oil are transferred to their corresponding monoesters by reaction of methanol in the presence of potassium hydroxide catalyst. This process has been widely used to reduce viscosity of triglycerides. Three consecutive and reversible reactions are believed to occur in the transesterification. The first step is the conversion of triglycerides to diglycerides, followed by the conversion of diglycerides to monoglycerides, and finally monoglycerides to glycerol, yielding one methyl ester molecule from each glyceride at each step, when methanol is used in the esterification. A catalyst and excess alcohol are used to increase rate of reaction and to shift the equilibrium to the product side respectively. During transesterification process, each mole of triglyceride is converted into a mole of fatty acids methyl esters (FAMEs) using three moles of methanol as shown in Fig.1.

Step 1:

CH_2 –$COOR_1$ Catalyst CH_2 –OH
CH-$COOR_2$ + CH_3 -OH CH-$COOR_2$ +
CH_3 –$COOR_1$
CH_2 –$COOR_3$ CH_2 –$COOR_3$
Triglyceride Methanol Diglyceride
Methyl ester
(Parental oil) (Alcohol)
(Biodiesel)

Step 2:

CH_2 –OH Catalyst CH_2 –OH
CH-$COOR_2$ + CH_3 -OH CH-$COOR_2$ +
CH_3 –$COOR_2$
CH_2 –$COOR_3$ CH_2 –OH
Diglyceride Methanol Monoglyceride
Methyl ester
(Alcohol)
(Biodiesel)

Step 3:

CH_2 –OH Catalyst CH_2 –OH
CH-$COOR_2$ + CH_3 -OH CH-OH +
CH_3 –$COOR_3$
CH_2 –OH CH_2 –OH
Monoglyceride Methanol Glycerol
Methyl ester
(Alcohol)
(Biodiesel)

Fig.1.Transesterification of oil to biodiesel.

III. PROPERTIES OF FISH OIL

The fuel properties of biodiesel from marine fish oil and ASTM No.2D diesel are presented in table 1. The acid number of a biodiesel can be used to indicate the content of free fatty acids of the fuel. The marine fish oil biodiesel is found to have large acid number due to the greater water content of the crude marine fish oil. The specific gravity of biodiesel is generally in the range between 0.86 and 0.90 and somewhat larger than that of the ASTM No.2D diesel, which is about 0.81-0.85. The flash point of the marine fish-oil biodiesel was 103^0C which is much higher than the flash point of ASTM No.2D diesel. Liquid fuel with a high flash point can prevent auto ignition and fire hazards at high temperatures during transportation and storage periods. The kinematic viscosity of the biodiesel is found to be larger than that of the ASTM No.2D diesel, hence it is inferred that the biodiesel from marine fish oil will have inferior injection and atomization performance, but offer lubrication and protection for the moving parts of an engine superior to those of the ASTM No.2D diesel. The biodiesel has a lower heating value than the ASTM No.2D diesel. Consequently, the biodiesel would require a feeding rate large than that of the ASTM No.2D diesel to achieve the same engine power output.

Table 1: Properties of FOME in comparison with ASTM No.2 diesel

Sl. No.	Property	Unit	FOME	ASTM No.2D diesel
1	Acid number	mg KOH/g	1.17	-
2	Specific Gravity	g/cm^3	0.86	0.83
3	Flash point	^{0}C	103	74
4	Kinematic Viscosity at 40^0C	cSt	7.2	3.4
5	Cetane Index		50.9	53.2
6	Carbon Residue	Wt.%	0.76	1.57
7	Heating value	MJ/kg	41.37	46.16
8	Element O	Wt.%	7.19	0

IV. EXPERIMENTATION

The experimental work carried out for the objectives, requires an engine test set-up adequately instrumented for acquiring necessary performance. Fish oil methyl ester blends (20%) and pure Diesel were used to test a TV1, Kirloskar, single cylinder, 4-stroke, water-cooled diesel engine having a rated output of 5.2 kW at 1500 rpm and a compression ratio of 17.5:1 under variable injection pressure and injection timing. The engine was coupled with an eddy current dynamometer to apply different engine loads. The experimental set-up and photographic views of engine are as shown in Fig. 2 and 3.

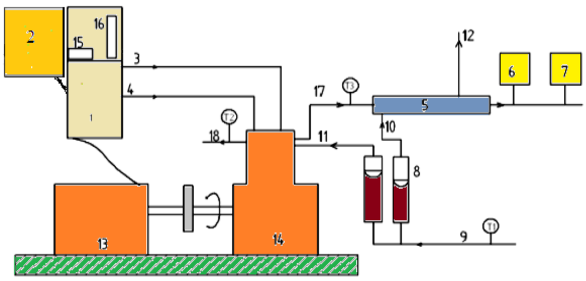

Fig. 2: Schematic diagram of the experimental set up

1 = Control Panel, 2 = Computer system, 3 = Diesel flow line, 4 = Air flow line, 5= Calorimeter, 6 = Exhaust gas analyzer, 7 = Smoke meter, 8 = Rota meter, 9= Inlet water temperature, 10= Calorimeter inlet water temp., 11= Inlet water to engine jacket, 12 =Calorimeter outlet water temp., 13 = Dynamometer, 14 = CI Engine, 15 = Speed measurement, 16 = Burette for fuel measurement, 17 = Exhaust gas outlet, 18 = Outlet water from engine jacket, T1= Inlet water temperature, T2 = Outlet water temperature, T3 = Exhaust gas temperature.

Fig.3: Photographic view of Diesel engine test rig

V. RESULTS AND DISCUSSION

1.1 Effect of Injection Pressure on Engine Performance

i. Brake thermal efficiency (BTE): Fig. 4 shows the variation of brake thermal efficiency for compression ratio of 17.5 with brake mean effective pressure (BMEP) at injection pressure of 180 bar 200 bar and 220 bar for methyl esters of fish oil. Brake thermal efficiency is increased with increase in BMEP due to reduced heat loss with increase in power and increase in load. **.**

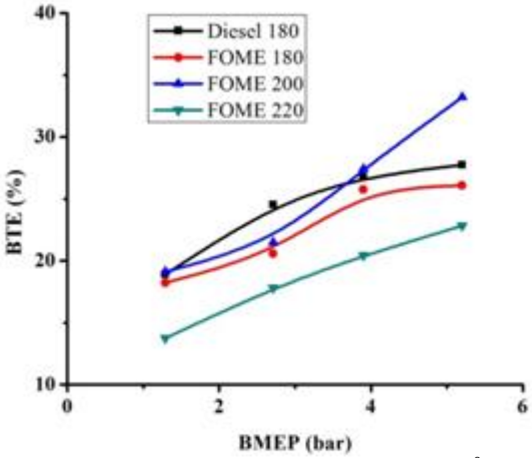

Fig. 4: Variation of BTE with BMEP at IT 27^0 bTDC for FOME.

ii. Brake specific fuel consumption (BSFC): Fig. 5 shows the variation of BSFC with BMEP at injection pressure of 180 bar 200 bar and 220 bar for methyl esters of fish oil. It can be seen that the BSFC for FOME is higher than diesel fuel, which was observed due to lower calorific value of bio diesel. It is found that the BSFC is decreased with increase in injection pressure to 200 bar. This may be due to the fact that, as injection pressure increases the penetration length and spray cone angle increases, so that at optimum pressure, fuel air mixing and spray atomization will be improved. The lowest BSFC for the fuel tested was found to be at 200 bar injection pressure.

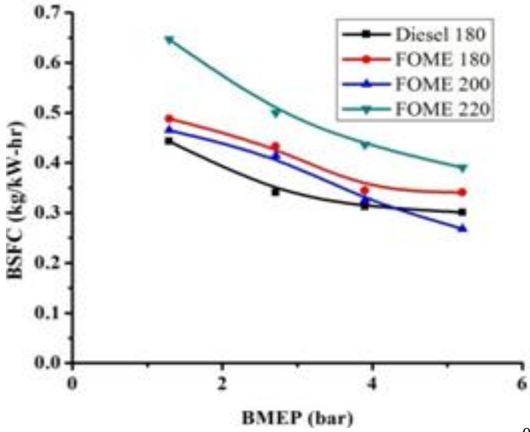

Fig. 5: Varitation of BSFC with BMEP at IT 27^0 bTDC for FOME

1.2 Effect of Injection Pressure on Engine Emissions

i. Unburnt hydrocarbons (UBHC): Fig. 6 shows the variation of UBHC with BMEP. The UBHC is increased with increase in BMEP. It is observed that the UBHC emissions for FOME are lower than the diesel fuel, indicating that the heavier hydrocarbon particles that are present in the diesel fuel increase UBHC emissions. The UBHC emission of methyl esters at full load is approximately 31 to 34% lower than the diesel value. The presence of oxygen in the fuel was thought to promote complete combustion that leads to lowering the HC emissions.

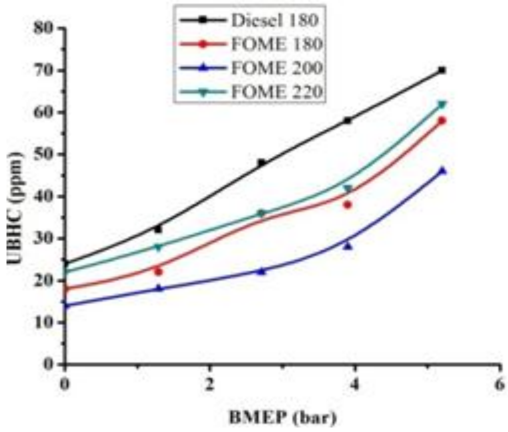

Fig. 6: Variation of UBHC with BMEP at IT 27^0 bTDC for FOME

ii. Carbon monoxide (CO): Variation of carbon monoxide (CO) with BMEP is shown in Fig.7. Carbon monoxide emissions from a diesel engine mainly depend upon the physical and chemical properties of the fuel. The bio diesel itself contains 11% of oxygen which helps for complete combustion. It is found that the amount of CO is decreased at part loads and again increased at full load condition for all fuels. This is common in all internal combustion engines since air-fuel ratio decreases with increase in load. The carbon monoxide emissions increase as the fuel air ratio becomes grater. The CO emission for fuels used at full BMEP is approximately 40 to 45% lower than the corresponding value for diesel.

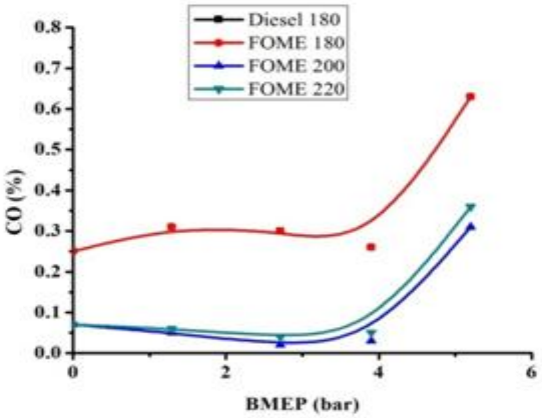

Fig. 7: Variation of CO with BMEP at IT 27^0 bTDC for FOME

iii. Oxides of Nitrogen (NO_x): Variation of NO_x with BMEP is shown in Fig. 8. The nitrogen oxides results from the oxidation of atmospheric nitrogen at high temperature inside the combustion chamber of an engine rather than resulting from a contaminant present in the fuel. Although nitrogen oxides are considered as major contributor for ozone formation and also reality of operating internal combustion engines. From the Fig. it is seen that the amount of NO_x is increased with increase in BMEP for all fuels this is because with increasing load, the temperature of combustion chamber increases and NO_x formation is a strongly temperature dependent phenomenon and is that the average NOx emission in the case of conditioned bio diesel is slightly higher than the diesel fuel. These higher NO_x emissions due to higher temperature of combustion chamber using conditioned bio diesel. NO_x emissions were lower at 200 bar injection pressure indicating that effective combustion was taking place during the early part of expansion stroke.

iv. Smoke opacity: Fig. 9 indicates the variation of smoke opacity with BMEP. It is found that the opacity is increased with increase in load. It also shows that the opacity variation is lower for conditioned bio diesel compared to diesel fuel.The average opacity at full load for methyl esters is 64% which is almost same when compared to that of diesel fuel.

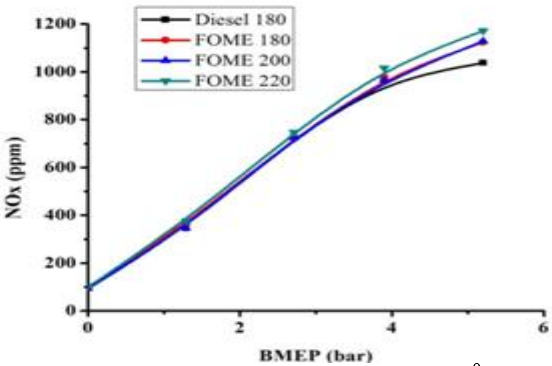

Fig. 8: Variation of NO_X with BMEP at IT 27^0 bTDC for FOME

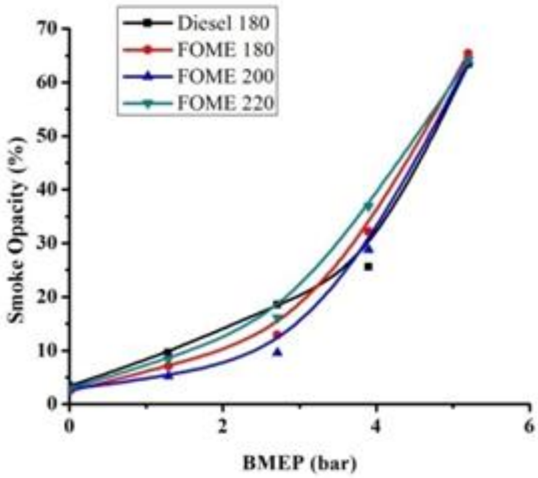

Fig. 9: Variation of Smoke Opacity with BMEP at IT 27^0 bTDC for FOME.

1.3 Effect of Injection Timing on Engine Performance at Optimised Injection Pressure of 200bar

i. Brake thermal efficiency (BTE): Fig.10 show the variation of brake thermal efficiency (BTE) with BMEP at various injection timing for methyl esters of fish oil. For FOME, the BTE is improved with increase in BMEP. Brake thermal efficiency increases when the injection timing is advanced. This is because starting the combustion earlier compensates the effect of slow burning. Combustion is slow with conditioned bio diesel on account of its high viscosity which leads to a poor spray and mixture with air. The maximum brake thermal efficiency occurred at the static injection timing of 30^0 bTDC which is selected as optimal. This is 3^0 more advanced than that of diesel.

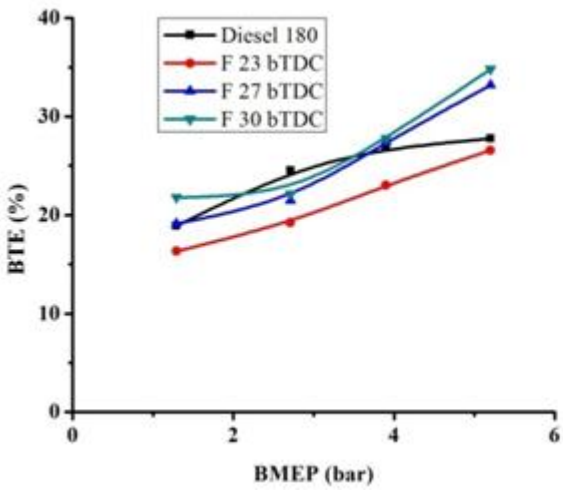

Fig.10: Variation of BTE with BMEP at IP 200 bar for FOME.

ii. Brake specific fuel consumption (BSFC): Fig. 11 show the variation of BSFC with BMEP at injection pressure of 180 bar 200 bar and 220 bar for methyl esters of fish oil. BMEP of a diesel engine directly relates to the brake power. It can also observed that advance of injection timing leads with lower BSFC this is due to optimum delay period and smaller amount of fuel during after burning.

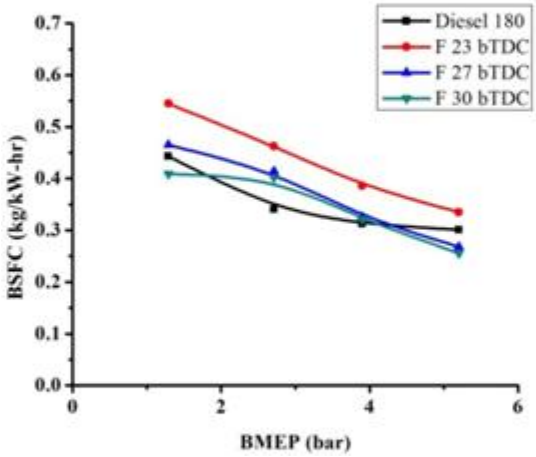

Fig. 11: Variation of BSFC with BMEP at IP 200 for FOME.

1.4 Effect of Injection Timing on Engine Emissions at Optimised Injection Pressure of 200bar

i. Unburnt hydrocarbons (UBHC): Fig. 12 show the variation of UBHC with BMEP. The UBHC is increased with increase in BMEP. The UBHC emissions for FOME bio diesel are lower than the diesel fuel by 34%. HC emission is lowest with the injection timing namely 30^0 bTDC is shown in Fig 12. This injection timing lowers the HC level at all loads due to improved combustion and use of over leaner fuel air mixtures as compared to other timings 23^0bTDC and 27^0bTDC and account improved brake thermal efficiency. The HC level at full load falls off from average 66 ppm with the timing of 23^0bTDC to average 46 ppm with the best injection timing of average 30^0bTDC.

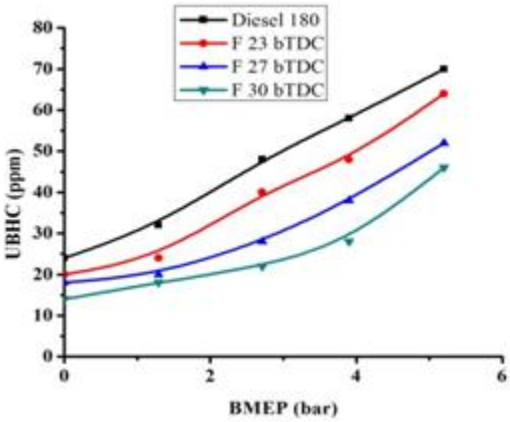

Fig. 12: Variation of UBHC with BMEP at IP 200 for FOME.

ii. Carbon monoxide (CO): Fig. 13 represents variation of CO emissions with BMEP. An increase in BMEP at any conditioned oil and injection timing at low load CO level increases and medium loads CO level decreases slightly. At all loads, at 30^obTDC injection timing condition of CO level is less about 10**%** volume compared with 23^obTDC and 27^obTDC. This is because of optimum delay period. At 23^obTDC and 27^obTDC injection timing, the timing required for proper mixing of air and conditioned bio diesel may not be sufficient, this will result high fuel consumption and exhaust level.

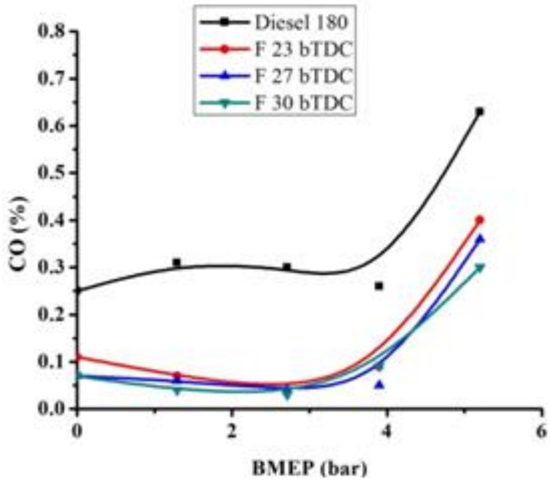

Fig. 13: Variation of CO with BMEP at IP 200 for FOME.

iii. Oxides of Nitrogen (NO_x): Variation of NO_x with BMEP is shown in Fig.14. it can observed that the NO_x emission level increases with advance the injection timing as expected due to increased cylinder gas temperatures. At full load the average increase of 1130 ppm at the injection timing of 23^0bTDC to 1160 ppm with the optimum timing of 30^0bTDC with conditioned bio diesel.

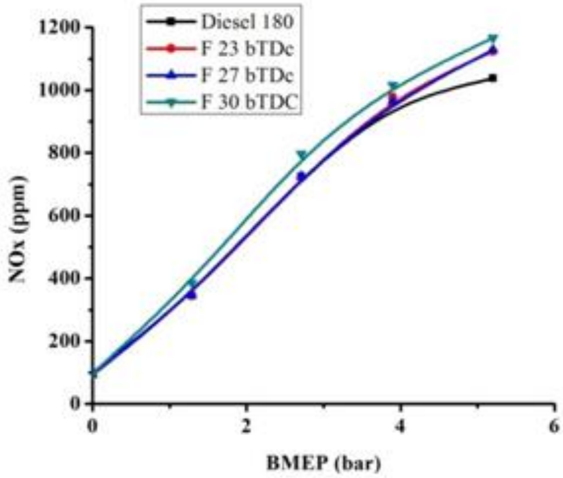

Fig. 14: Variation of NO_X with BMEP at IP 200 bar for FOME

iv. Smoke opacity: Fig. 15 indicates the variation of smoke opacity with BMEP. The opacity is increased with increase in load. It can be seen that the opacity is in significant variation with conditioned bio diesel compared to diesel fuel. The smoke level decreases as the injection timing is advanced, as is normal in diesel engines because of the dominance of the premixed combustion phase.

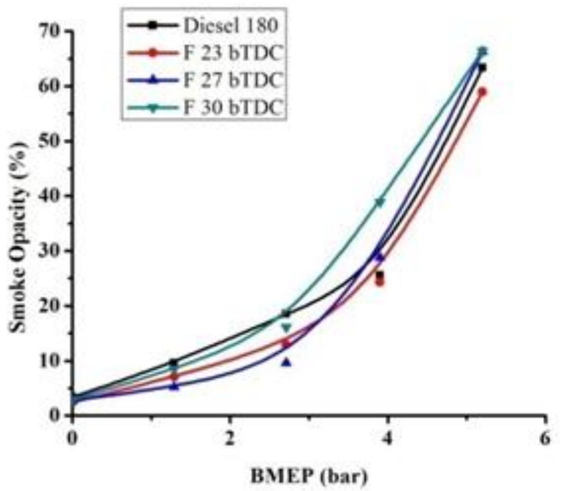

Fig. 15: Variation of Smoke Opacity with BMEP at IP 200 bar for FOME.

VI. CONCLUSION

From the present experimental results and discussions it can be concluded that a significant improvement in the performance and emissions, if the injector opening pressure and injection timing properly optimized (say 200 bar and 30^0bTDC), when a diesel engine is to be operated with conditioned Fish oil methyl ester (FOME). The comparison of methanol transesterified oils with diesel fuel in terms of performance and emissions shows acceptable results.

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