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An investigation on the Performance and Emission characteristics of a Direct Injection Diesel engine using Safflower oil and Milk Scum oil as a Biodiesel

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Abstract: - Biofuels are developing kind of fuel whose origin is biomass. Among them, much different kind of fuels can be found: bio ethanol, bio butanol, biodiesel, vegetable oils, bio methanol, pyrolysis oils, biogas, and bio hydrogen. This thesis work is focused on the production of biodiesel, which can be used in diesel engines as a substitute for mineral diesel. Biodiesel is obtained from different kinds of oils, both from vegetable and animal sources. However, vegetable oils are preferred because they tend to be liquid at room temperature. And emits less pollutant.

An attempt has been made to produce biodiesel from Safflower Oil and Milk Scum Oil meeting with international standards. The mixture of Safflower Oil -Milk Scum Oil meeting with methyl ester was used as a new fuel in the present work.

The performance and emission test were carried out in a single cylinder direct injection compression ignition engine. The HC, CO and CO2 emissions were found to be less than that of neat diesel fuel except NOx. Break Thermal Efficiency of biodiesel and its blends was found to be less than diesel fuel, Exhaust Gas Temperature, Break Specific Fuel Consumption for biodiesel and its blends were found to be higher than diesel fuel. **.**

Index Terms: - Safflower oil, Milk scum oil, Biodiesel, Performance, Emission characteristics.

I. INTRODUCTION

Gradual depletion of world petroleum reserves, increase in crude oil prices and impact of environmental pollution have motivated the scientific community all over the world to look for sustainable alternative fuels. This results in renewed focus on vegetable/plant oils and other lipid sources. Several researchers have made systematic efforts to use plant oils and their esters (biodiesel) as fuel in CI engines [1-4].

It had been reported that major problem associated with straight vegetable oil (SVO) as petro diesel substitute in CI engine were its high viscosity, low volatility and presence of polyunsaturated character [4]. These problems are due to large molecular mass and chemical structure of vegetable oils .It was observed that due to polyunsaturated character, in long term operations, vegetable oils normally introduced the formation of gums, the formation of injector deposits [5], ring sticking as well as in compabality with SVO can be minimized by any one of the following process Viz, pyrolysis micro emulsification, dilution or Transesterification [7]. The processed vegetable oil can be used in any existing CI engine without any modification [8-9].

The use of non-edible vegetable oil as compared to edible oil is very significant in developing countries because of tremendous demand for edible oil as food and they are far too expensive to be used as fuel at present [7-11]. In the present investigation biodiesels of safflower oil and scum oil was chosen as fuel.

Safflower, Carthamustinctorius, L. is an oilseed crop that belongs to the family Asteraceae, a diverse group of flowering plants that grow in many parts of the world. It is originated in the eastern Mediterranean, and spread to Egypt, Ethiopia, southern Europe, south Asia and the Far East early in its evolution. India pas the primary centers of origin of safflower. Currently India as the largest producer of safflower. Safflower is mainly cultivated for its seed, which is used primarily for edible oil. In the past, the crop is grown for its flowers used for coloring and flavoring foods, making dyes and medicine.

Safflower is a dicotyledonous, herbaceous, winter annual, thistle-like plant that is highly self-fertilizing, with out-crossing rates of less than 10%. Its most prominent features are colorful flower heads, a deep taproot, and the production of white, oil-bearing fruits. Safflower is suited to grow in hot, dry climates, where soils are moist in early spring but generally well-drained and can be cultivated in regions where seasonal rainfall is around 375 mm and 1400m altitude. Depending on environmental conditions, the typical generation length of safflower varies from about 17-20 weeks and the growth cycle is divided into the following stages: emergence, rosette, stem elongation, branching, flowering and maturity. [12]

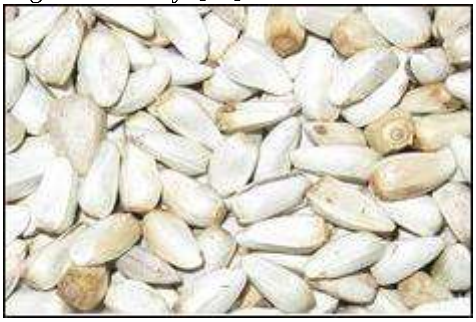

Fig 1.1: Safflower seeds

Milk scum is collected from the scum removing area of the effluent treatment plant in a fresh condition and processed immediately to avoid increase in free fatty acid further by biological action. Scum is turbid white in color and semi solid in texture. Annual production of milk in India is 150 million tons per year. Thousands of large dairies are engaged in handling this milk across the country. Raw chilled milk of cows and buffalos are standardized into market milk and milk products such as Butter, Ghee, Cream, Peda, Panner, Cheese, Yoghurt, Ice cream and other products. Large dairies are handling number of equipments for processing, handling, storage, packing and transportation of milk and milk products. Enormous quantities of water are used for housekeeping, sterilizing and washing equipments, during this process residual butter and related fat which are washed and get collected in effluent treatment plant as a scum. Scum is a less dense floating solid mass usually formed by a mixture fat, lipids, proteins, packing materials etc. A large dairy, which processes 5 lakh liters of milk per day, will produce approximately 200–350 kgs of effluent scum per day, which makes it difficult to dispose. By doing so, it is economically wasteful and generates pollutants. Further, scum causes direct as well as indirect operational difficulties for effluent treatment [14].

Fig 1.2: Diary waste scum and Scum oil.

Vedat Beyyavas et al. [12] determined the yield and yield components of 26 safflower cultivars, lines and populations in semi-arid conditions during the 2001-2002 and 2002-2003 growing seasons. The experimental plots were arranged in a randomized complete block design with three replications. In this study, seed yield (kg ha-1), plant height (cm), number of branch per plant, number of head per plant, 1000 seed weight (g), oil content (%) and oil yield(kg ha-1) properties were investigated. According to the average of two years study, the highest seed yields were obtained from cultivars Syria Hama (1585 kg ha-1), Hartinan (1543 kg ha-1) and S-541-2 (1582 kg ha-1) lines, while the lines 250540 (34.8%) and S-541-2 (34.2%) had the highest oil contents. The highest oil yields were obtained from Syria Hama (530 kg ha-1) cultivar and S-541-2 (541 kg ha-1) line.

Benson Varghese Babu et al. [13]: showed the diary waste scum were used as the raw material to produce biodiesel. Scum oil methyl ester (SOME) is produced in laboratory by Transesterification process. An experiment has been carried out to estimate the performance, emission and combustion characteristics of a single cylinder; four stroke diesel engine fuelled with scum biodiesel and its blends with standard diesel. Tests has been conducted using the fuel blends of 10%, 20%, 30% and 100% biodiesel with standard diesel, with an engine speed of 1500 rpm, fixed compression ratio 17.5 and at different loading conditions. The performance parameters elucidated includes brake thermal efficiency, brake specific fuel consumption, and exhaust gas temperature.

P. Sivakumar [14] et al: studied the potential of using dairy waste scum as a feed stock for bio-diesel production. Present study optimized the parameters involved in Transesterification process of Dairy Waste Scum Oil. Gas chromatography was used to determine the fatty acid composition of Dairy Waste Scum Oil. Results revealed that the low free fatty acid content was a notorious parameter to determine the viability of alkaline Transesterification. The yield of bio-diesel reached 96.7% when 1.2 wt.% of Potassium Hydroxide, reaction temperature of 75C, 30 min of time and 6:1 Methanol oil ratio at 350 rpm. Thermo gravimetric analysis followed the evaluation of Transesterification process. The present analysis confirms that bio-diesel from dairy waste scum is quit suitable as an alternative to petroleum diesel with recommended fuel properties as per ASTM standards. This new way for using dairy waste scum reduces the cost of production of bio-diesel and the problem related to the disposal of Dairy scum.

II. EXPERIMENTAL INVESTIGATION

The detailed explanation of experimental set up and measurement systems and procedure carried out in this research work has discussed below. The experiment aims at determining appropriate proportions of biodiesel & diesel for which higher efficiency is obtainable. Hence experiments are carried out at constant speed, comparing the performance of a compression ignition engine operated at different blends [15-18].

A. Material for Biodiesel Production

Safflower seeds were collected locally and then it is converted into oil by seed crushing machine then oil is filtered to remove impurities and filtered raw milk scum is purchased from the "KMF", Yelahanka, Bangalore. Methanol, Isopropyl, NaOH, Phenolphthalein indicator are purchased from "Vasa Scientific Supply", Bangalore.

B. Production of biodiesel

The esterified oil was poured into the reactor and heated at 60°C to optimize the temperature of reaction for maximum yield. A mixture of NaOH in methanol was heated at the same temperature for 5 min and added slowly to the heated oil. There action mixture was heated, re-circulated for about 3 hours. After 3 hours, two distinct layers were formed and the mixture was allowed to settle for 2 hours or overnight. The heavier glycerol layer was separated from the lighter Methyl ester layer by separating tank. The obtained Biodiesel is transferred into the washing tank where it is washed by spraying the 40°C warm water without any agitation to remove the NaOH content and it was allowed to settle for 15 minutes. A bottom layer of soap is formed. Bottom layer of soap was carefully drained out, this procedure was repeated 3 times and the pH value of the 3rd time drained water is checked using the pH paper. Washing is continued to till the pH of the soap water reaches 7. After final wash the biodiesel is heated to the 100°C to remove the water. After removing the moisture content it is allowed cool gradually, and then they obtained biodiesel is transferred to the clean and dry container [19-20].

C. Engine Setup

Schematic diagram of the engine test rig is shown in Fig 2.1. The engine test was conducted on four-stroke single cylinder direct injection water cooled compression ignition engine connected to electric type loading. The engine was always operated at a rated speed of 1500 rpm. The engine was having a conventional fuel injection system. The injection nozzle had three holes of 0.3 mm diameter with a spray angle of 120º. It is also provided with temperature sensors for the measurement of jacket water, calorimeter water, and calorimeter exhaust gas inlet and outlet temperatures

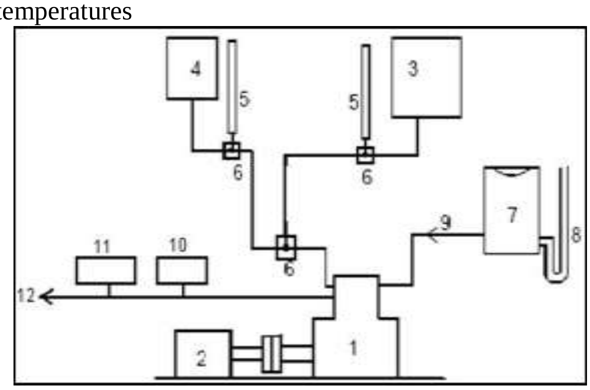

Fig 2.1: Experimental setup

1) Engine , 2)Alternator , 3) Fuel Tank(Bio-diesel) , 4) Diesel Tank , 5) Burettes 6) Three way valve , 7) Air box , 8) Manometer , 9) Air flow direction 10) Exhaust Analyzer (CO & HC) , 11) Smoke meter , 12) Exhaust flow

III. RESUTS AND DISCUSSIONS

A. Properties of Biodiesel

Mixture of safflower and milk scum methyl ester were mixed with diesel at various proportions and kept untouched for 24 hours. It was observed that they did not separate. It showed that these oils are completely miscible with diesel in all proportions.

Flash Point: Petroleum based diesel fuels have flash points of $50^{o}C$ to $80^{o}C$ so they are considered to be intrinsically safe. Biodiesel has a flash point that is considerably higher than petroleum-based diesel fuel. This means that the fire hazard associated with transportation, storage, and utilization of Biodiesel is much less than with other commonly used fuels. The flash Point of oils is determined by using open cup test method. **Fig 3.1** shows flash point for conventional diesel to biodiesel.

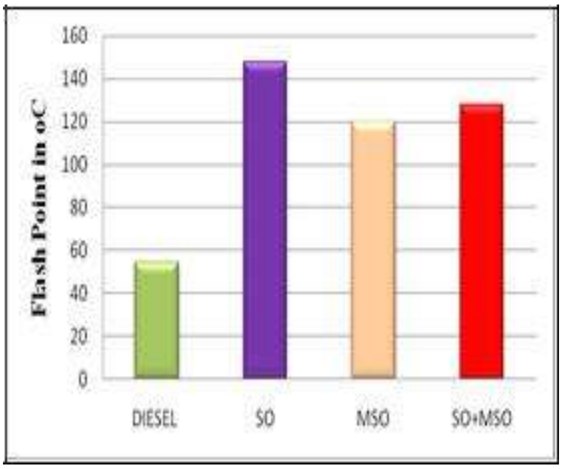

Fig 3.1: Flash Point

Fire Point: Petroleum based diesel fuels have fire points of $3^{o}C$ to $5^{o}C$ temperature after the flash point so they are considered to be intrinsically safe. Biodiesel has a flash point that is considerably higher than petroleum-based diesel fuel. This means that the fire hazard associated with transportation, storage, and utilization of Biodiesel is much less than with other commonly used fuels. The flash Point of oils is determined by using closed cup test method. **Fig 3.2** shows fire point for conventional diesel to biodiesel.

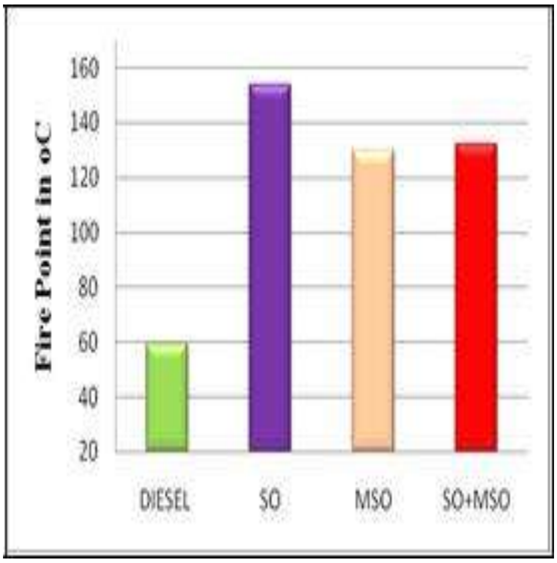

Fig 3.2: Fire Point

Specific Gravity: Specific Gravity of the SO and MSO methyl ester was determined using Hydrometer. The specific gravity of the SO biodiesel is 0.879 & the specific gravity of MSO biodiesel is 0.873 and the specific gravity of mixture of safflower and milk scum biodiesel is 0.876 which is higher than the diesel 0.845. **Fig 3.3** shows Specific Gravity for conventional diesel to biodiesel.

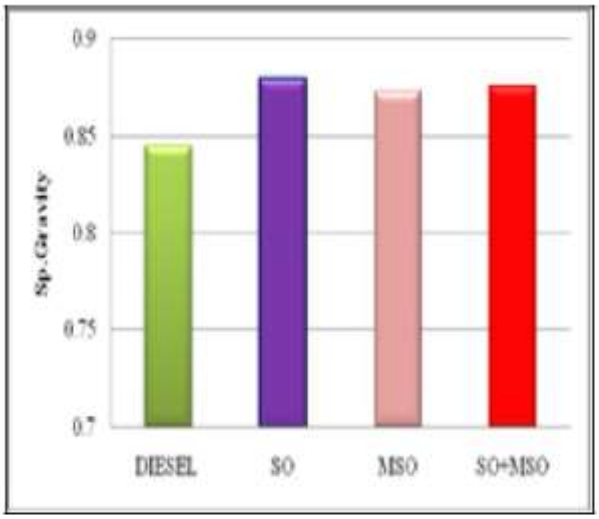

Fig 3.3: Specific Gravity

Kinematic Viscosity: The kinematic viscosity of vegetable oils is in the range of 30-60 mm^2/s and Biodiesel is in the range of 4-9 mm^2/s which is closer to diesel fuel (3-4 mm^2/s). The viscosity of these oils was found at various temperatures. **Fig 3.4** shows Kinematic Viscosity for conventional diesel to biodiesel.

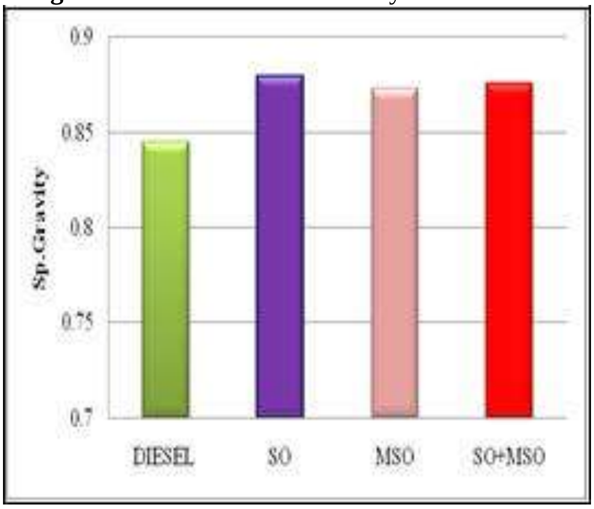

Fig 3.4: Kinematic Viscosity

Calorific Value: The calorific value of the mixture of SO & MSO methyl ester is 3.740 MJ/Kg and its blends is determined by using a Bomb Calorimeter. **Fig 3.5** shows Calorific Values for conventional diesel to biodiesel.

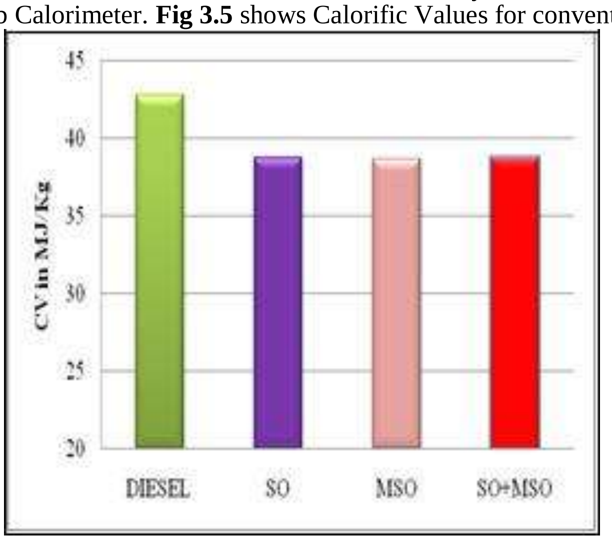

Fig 3.5: Calorific Value

B. Performance characteristics

Fig 3.6 Shows the variation of brake thermal efficiency (BTE) with load for different blends at compression ratio of 17.5:1 and injection pressure of 200 bar for various fuel blend. It has been observed that the brake thermal efficiency of the blends is increasing with increase in applied load because of reduction in heat loss and increase in power developed with increase in load.

The maximum brake thermal efficiency at full load is 34.51 % for petro diesel. BTE goes on decreasing by increasing the percentage of blend forB20 it is 33.03 % which is 4.28 % lower than the diesel. The brake thermal efficiency of B40, B60, B80 and B100 are 30.43 %, 28.05%, 27.68 % and 26.06 % respectively. By increasing the load of the engine, the brake thermal efficiency also increases for all the fuel types tested.

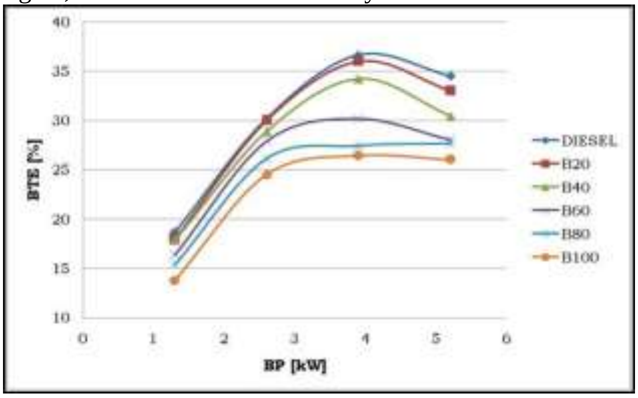

Fig 3.6: Variation of BTE with BP

Fig 3.7 Shows the variation of specific fuel consumption with respect to load for various biodiesel blends and diesel at compression ratio of 17.5:1 and injection pressure of 200 bars. As the load increases, BSFC decreases for all fuel blends. At full load, petro diesel shows the lowest fuel consumption and is 0.2438 kg/kWh. Out of all blends B20 having BSFC value closer to Petro diesel which is 0.2596 kg/kWh. The remaining blends B40, B60, B80 and B100 are show the BSFC in the increasing order. Lesser values of BSFC are apparently desirable.

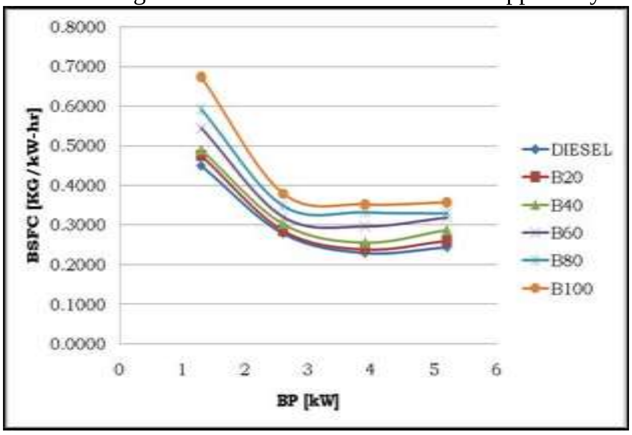

Fig 3.7: Variation of BSFC with BP

Fig 3.8 Shows the variation of exhaust gas temperature with applied load for different blends is shown in the result indicates that the exhaust gas temperature decreases for different blends when compared to that of diesel at compression ratio of 17.5:1 and injection pressure of 200 bar. The highest temperature obtained is 310 °C for a B100 for a full load. It is decreases to 265 ° for the blend B20.

As an increasing blend percentage EGT goes on increasing, B80, B60 and B40 the exhaust temperature values are300°, 289° and 278° respectively and for standard petro diesel is 255° C.

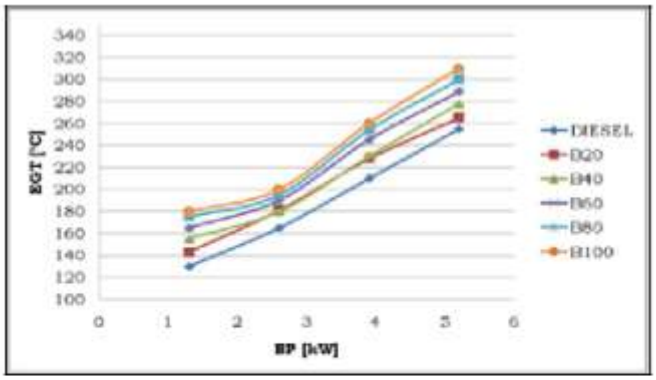

Fig 3.8: Variation of Exhaust Gas Temperature with BP

C. Emission characteristics

Fig 3.9 Shows the variation of NOx emissions with BP for different diesel–biodiesel blends & neat diesel at compression ratio of 17.5:1 and injection pressure of 200 bar. The NOx emission for biodiesel and its blends is higher than that of standard diesel. From Figure it is shows that B20 having higher NOx 755 ppm which is higher than the Petro diesel NOx value 730 ppm. The NOx emission for diesel and blend B40, B60, B80 and B100 at full load are 780 ppm, 805 ppm, 825 ppm and 850ppm respectively.

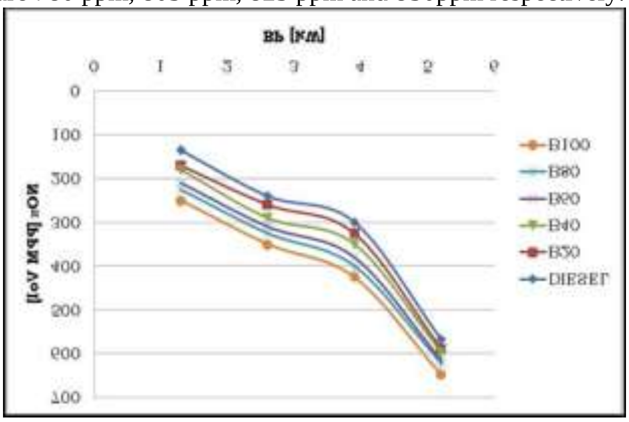

Fig 3.9: Variation of NOx emissions with BP

Fig 3.10 Shows the variation of carbon monoxide emission of the blends and diesel for various loads at compression ratio of 17.5:1 and injection pressure of 200 bars. CO is a byproduct of combustion. The proportion of CO increases is due to rising temperature in the combustion chamber, physical and chemical properties of the fuel, air–fuel ratio, lack of oxygen at high speed, and smaller amount of time available for complete combustion. At full load, B20 shows the lower CO emission and neat diesel shows sudden increase in CO emissions.

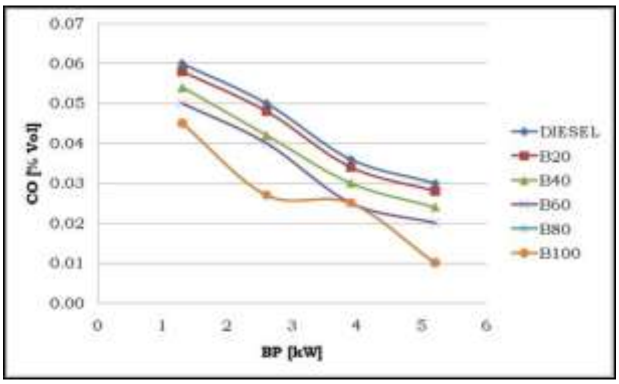

Fig 3.10: Variation of CO with BP

Fig 6.11 Shows the variation of CO2 emission of the blends and diesel for various loads at compression ratio of 17.5:1 and injection pressure of 200 bars. Carbon monoxide is one of the compounds formed during the intermediate combustion stages of hydrocarbon fuels due to lack of oxidants or due low gas temperature.

The CO2 emission for all the blends and neat diesel goes on increases as load increases for both injection pressures. B20 shows the lower CO2 emission compared to neat diesel at all loads. As blend percentage increases than CO2 emission goes on decrease. A reason for the reduction of CO2 emissions with biodiesel is the oxygen content in the fuel, which enhances a complete combustion of fuel, thus reducing CO2 emissions.

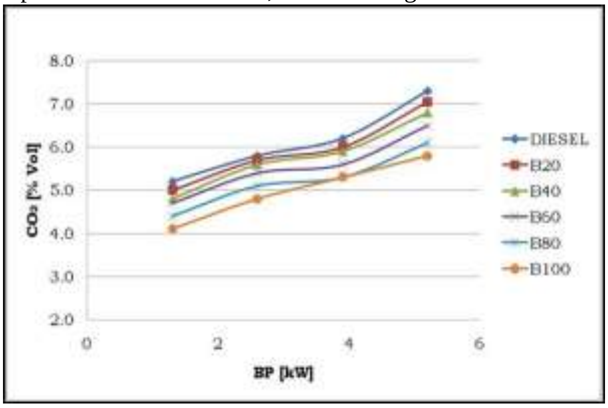

Fig 6.11: Variation of CO2 with BP

Fig 6.12 Shows the variation of Variation of HC emission of the blends and diesel for various loads at compression ratio of 17.5:1 and injection pressure of 200 bars

Biodiesel and its blends results in less HC emission as compared to that of neat diesel fuel at full load condition. This could be due to complete combustion of biodiesel and its blend.

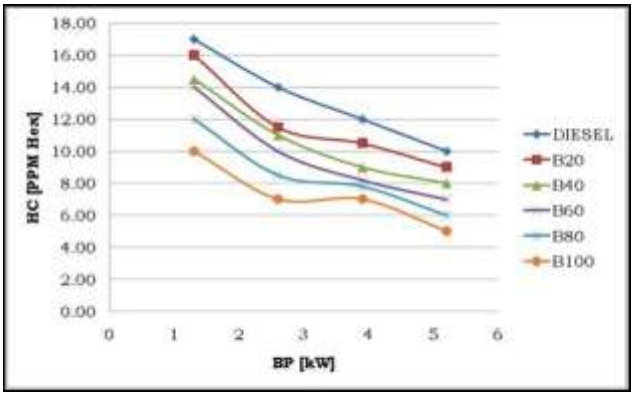

Fig 6.12: Variation of HC with BP

IV. CONCLUSION

The following conclusions can be drawn from the present work. Brake thermal efficiency blends are slightly less than that of diesel. Compared to Petro diesel at higher load, the BSFC of B20 is decreased by 4.25% at full load. Brake specific fuel consumption of biodiesel blends is slightly more than that of diesel. Compared to Petro diesel at full load, the BSFC of B20 is increased by 6.08% at full Load. Exhaust gas temperature of B20 is closed to that of Petro diesel. NOx emission for B20 is slightly higher than that of petro diesel. Emission of CO and CO2 was considerably reduced as the load increased for biodiesels compared to Petro diesel. Hydro carbon emission for B20 is 10% less than that of Petro diesel.

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