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Performance and Study of Diesel Engine Using Blends of Sunflower Oil with Diesel

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Abstract- Biodiesel either in neat, clean and sustainable form or as a mixture with diesel fuel is widely investigated to solve the two basic problems of fossil fuels and environmental degradations. The main objective of the present study is to make a comparison of performance, emission and combustion characteristic of biodiesel derived from edible vegetable sunflower oil in a four stroke single cylinder diesel engine with pure diesel fuel. The performance parameters evaluated were brake horse power, fuel consumption rate, brake thermal efficiency, brake specific fuel consumption, temperature of exhaust gas, temperature of cooling water and emission of carbon monoxide as a part of combustion study temperature of cooling water, temperature of exhaust gas was also evaluated. The different properties of sunflower oil after transesterification were within tolerable limits of standards as sets by many countries. The brake thermal efficiency of B-25 fuel is more than B-0 fuel up to 80 % load and then it tends to decreases below B-0 fuel at full load condition and the brake specific fuel consumption of the B-25 fuel at all loads is closely similar to that of the B-0 fuel or it can be said that optimum brake specific fuel consumption is observed at 80 % load by the B-25 amongst all blended fuels. The fuel consumption rate of B-10 and B-20 fuel is very close to that of the B-0 fuel but at full load the fuel consumption rate of B-10 and B-30 fuel increases more than B-0. But the overall the fuel consumption rate of B-25 blends is lower than that of B-0.The results from the experiments suggest that biodiesel derived from edible oil like sunflower oil could be a noble substitute to diesel fuel in diesel engine in the near future as far as decentralized energy production is concerned. In view of analogous engine performance and reduction in most of the engine emissions, it can be decided and biodiesel developed from sunflower and its blends could be used in a conventional diesel engine without any engine modification
Keywords- Internal Combustion Engine, Sunflower Methyl Esters, Transesterification, Performance.

I. INTRODUCTION

In the concern of current energy situation, major research is focused on sustainable energy solution with major prominence on energy efficiency and use of renewable energy sources. The diesel engines lead the field of commercial transportation and agricultural equipment due to its simplicity of operation and higher fuel efficiency. The consumption of diesel fuel is several times higher than that of petrol fuel. Due to the scarcity of petroleum products and its increasing cost, efforts are on to develop alternative fuels specially, to the diesel oil for fully or partial replacement. It has been originate that the vegetable oils are hopeful fuels because their properties are similar to that of diesel and are produced simply and renewably from the crops. Vegetable oils have equivalent energy density, cetane number, heat of vaporization and stoichiometric air–fuel ratio with that of the diesel fuel. None other than Rudolph Diesel, the forefather of diesel engine, validated the first use of vegetable oil in compression ignition engine. He works on the peanut oil as fuel for his experimental engine. During the World War II, efforts were made to use vegetable oils as fuel in diesel engines. Viscosity of vegetable oils is more than a few times higher than that of diesel. Viscosity of liquid fuels disturbs the flow properties of the fuel, such as spray atomization, resultant vaporization, and air–fuel mixing in the combustion chamber. Higher viscosity of oils had an adversative effect on the combustion in the present diesel engines.

In recent years, methodical efforts were under taken by many researchers to conclude the suitability of vegetable oil and its derivatives as fuel or additives to the diesel [1–5]. Blending, emulsification, thermal cracking and trans esterification are the frequently adoptable methods to use the vegetable oil as fuel in diesel engines. Recent years, biodiesel have received substantial consideration both as a possible renewable alternative fuel and as an additive to the prevailing petroleum-based fuels. Biodiesel displays several advantages when compared to that of the existing petroleum fuels. Various researchers have exposed that particulate matter, unburned hydrocarbons, carbon monoxide, and sulphur levels are suggestively less in the exhaust gas while using biodiesel as fuel. However, a rise in the levels of oxides of nitrogen is reported with biodiesel. Presently, considerable research has been undertaken to understand the performance characteristics of biodiesel-fuelled engine as well as the biodiesel production technology [6, 7].

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Biodiesel is a chemically altered alternative fuel for use in diesel engines. It produced from vegetable oils and animal fats. Biodiesel is created commercially by the transesterification of vegetable oils with alcohol. Methanol or ethanol is the frequently used alcohols for this process. These can also be bent from the biomass sources. The direct use of alcohols as fuel causes deterioration and decomposition of various parts in the engine. The transesterification process resolves this problem. The carbon cycle of vegetable oils contains release and absorption of carbon dioxide. Combustion and inhalation process release carbon dioxide and crops for their photosynthesis process engross the carbon dioxide. Thus, the gathering of carbon dioxide in atmosphere reduces. The carbon cycle time for fixation of CO_2 and its relief after combustion of biodiesel is quite small (few years) as likened to the carbon cycle time of petroleum oils (few million years) [8,9].

Swarup Kumar Nayak et al. [11] conducted the experiment on diesel engine at constant speed of engine i.e. at 1500 rpm under varying load conditions with different ratio of blend of Mahua biodiesel. This was a probing investigation to determine the effect of fuel on the engine performance parameters and structure required to use this fuel.

There are following conclusion are made from above experimental investigation.

A. With increase the percentage of Mahua biodiesel in the blend the brake thermal efficiency also increase.
B. But with increase the percentage of Mahua biodiesel in the blend the brake specific fuel consumption decreases.
C. As the increased percentage of Mahua biodiesel in the blend exhaust gas temperature decreases.
D. When engine was run on biodiesel then exhaust emission contains CO, CO_2 and hydrocarbons in comparison to the conventional fuel will less.

Pandey et al. [10] performed production of biodiesel and performance of C.I engine using blend of rice bran oil biodiesel with diesel. His research work mainly focus on the detailed prospect of using crude RBO biodiesel as a substitute fuel without performing any modification in the engine.

There are following conclusion are made from above experimental investigation.

A. With increase the percentage of Rice bran biodiesel in the blend the brake thermal efficiency also increase.
B. Out of all blended fuels the BSFC of the B-20 fuel at all load is closely similar to that of the B-0 fuel or it can be said that optimum brake specific fuel consumption is observed at 80 per cent load by the B-0 and B-20 fuel.
C. It is observed that initially the BTE of B-20 fuel is more than the B-0 fuel up to 60 per cent load and then it because almost equivalent to that of B-0 fuel at 80 per cent, afterwards it decrease below to the B-0 fuel at full load.
D. As the increased percentage of Rice bran biodiesel in the blend exhaust gas temperature decreases.

Saswat Rath et al. [12] for taking measurement under various speed and loading condition and checked various parameters such as brake power, brake thermal efficiency, brake specific fuel consumption and exhaust gas temperature. They uses various ratio of blends like B-0, B-10, B-20, to B-100. B represent Karanja biodiesel and 10, 20 represent the percentage of biodiesel blends. Following conclusion are made from above experimental investigation.

A. The brake thermal efficiency of the engine with karanja methyl ester-diesel blend was marginally better than with neat diesel fuel.
B. Brake specific energy consumption is lower for karanja methyl ester-diesel blends than diesel at all loading.
C. The exhaust gas temperature is found to increase with concentration of karanja methyl ester in the fuel blend due to coarse fuel spray formation and delayed combustion.
D. The mechanical efficiency achieved with KME30 is higher than diesel at lower loading conditions. At higher loads, the mechanical efficiency of certain blends is almost equal to that of diesel.
E. The emission characteristics are higher than pure diesel but the KME30 has relatively better performance with respect to other blends.

The experimental results of several researchers support the use of biodiesel as a feasible alternative to the diesel oil for use in the internal combustion engines. It is also important to reminder that most of the experiments conducted on biodiesel are mainly gotten from refined non edible type oils only. The price of refined oils such as soybean oil and palm oil are high as compared to that of diesel. This increases the whole production cost of the biodiesel as well. But due to limited resources of petroleum product, it is better to use the edible type of oils for biodiesel production. In India, edible type oil yielding trees such as linseed, soybean, palm

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seed, rice bran and cashew are available in large number. The production and consumption of these oils are low at present, because of their limited end usage. Utilization of this oils/biodiesel as fuels in internal combustion engines are not only dropping the petroleum usage, but also improve the rural economy. Efforts are made here to produce biodiesel from typical unrefined oil (sunflower oil) and to use it as the fuel in diesel engines.

II. CHARACTERIZATION OF SUNFLOWER OIL

In the present study, the sunflower seed oil, an edible type vegetable oil is chosen as a potential alternative for producing biodiesel and use as fuel in compression ignition engines. Its technical name is helianthus annuus. The viscosity of crude sunflower oil is much greater, about 15 times larger than that of diesel oil. While it becomes very near to diesel, when it is transesterfied. Fatty acid composition of the oil contains mostly oleic (44.05%), linoleic (10.72%), palmitic (38.60%), and stearic (4.65%) acids.

Sunflower is a high oil content seed and average yields can produce 600 pounds of oil per acre, considerably more than soybeans. There is a great deal of interest from local areas for construction of small processing facilities for sunflower biodiesel production. It is most important that processing equipment be investigated very prudently for small 'press' only facilities. In most cases a major portion of the oil is left in the by-product meal thereby dropping economic efficiency. [13-16]

Table 1 Fatty acid compositions of Sunflower oil in comparison with other oils.

Property	Sunflower oil	Rubber seed oil	Rapeseed oil	Cotton seed oil	Soybean oil
Fatty acid composition (%)					
(i) Palmitic acid $C_{16:0}$	6.8	10.2	3.49	11.67	11.75
(ii) Stearic acid $C_{18:0}$	3.26	8.7	.85	.89	3.15
(iii) Oleic acid $C_{18:1}$	16.93	24.6	64.4	13.27	23.26
(iv) Linoleic acid $C_{18:2}$	73.73	39.6	22.3	57.51	55.53
(v) Linoleic acid $C_{18:3}$	0	16.3	8.23	0	6.31
Flash point (^{0}C)	220	198	280	210	230
Specific gravity	.918	.91	.914	.912	.92
Viscosity (mm^2/s) at 40 ^{0}C	58	66.2	39.5	50	65
Calorific value (MJ/kg)	39.5	37.5	37.6	39.6	39.6
Acid value	.15	34	1.14	.11	.20

III. ESTERIFICATION OF SUNFLOWER OIL

A. Methodology

The main objective of this study is to develop a method for producing biodiesel from a low-cost feedstock like sunflower seed oil.

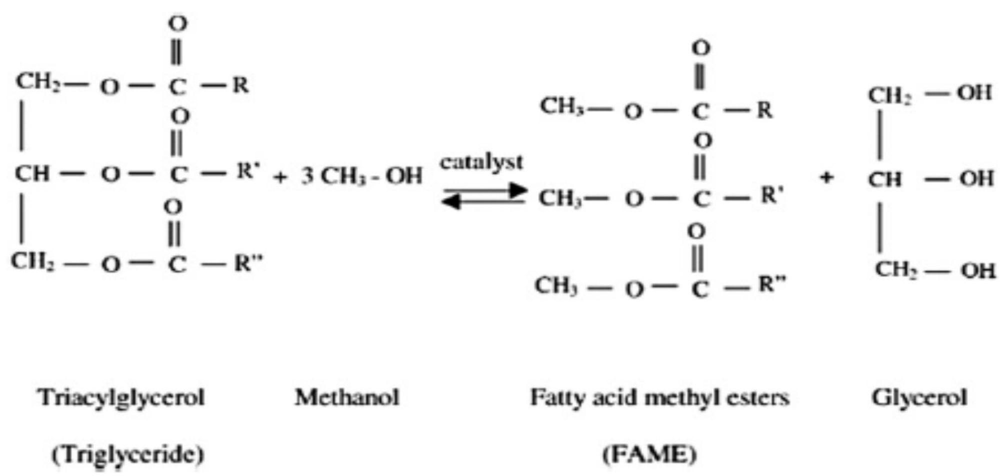
The esterification procedure consists of the following two stages.

1) *Acid-esterification:* The acid-catalysed pre-treatment procedure reduces the high FFA content of the crude oil to about 2% FFA.
2) *Alkaline-esterification:* The products of first step are transesterified using basic catalyst. The essential parameters affecting the esterification process such as alcohol to vegetable oil molar ratio, catalyst quantity, reaction temperature and duration of reaction are analysed

B. Esterification procedure

A round bottom flask of 500 cm^3 is used as laboratory scale reactor for the present analysis. The sunflower oil in the flask was heated on a hot plate having magnetic stirrer arrangement. The mixture was rotated at the same speed for all test runs. The temperature maintained for the whole esterification process is between 40 and 50 ^{0}C. Alcohol to vegetable oil molar ratio is one of the significant factors that affect the alteration efficiency of the process. For the stoichiometric transesterification, 3 moles of alcohol are required for each mole of the oil. However, in exercise, the molar ratio should be greater than this theoretical ratio in order to drive the reaction towards initial completion.

The products of the principal stage are used as the feedback of the alkaline esterification process. A molar ratio of 9:1 and 3.5 gram by weight of sodium hydroxide is found to give the extreme ester yield. After the reaction is accomplished, the products are allowed to discrete into two layers. The lower layer holds impurities and glycerol. This top layer (ester) is separated and purified using distilled water. Hot distilled water (10% by volume) is squirted over the ester and stirred gradually and allowed to settle in the separating funnel. The lower layer is unsolicited and upper layer (purified biodiesel) is separated.



Chemical reaction of transesterification process

IV. BIODIESEL CHARACTERIZATION

The important properties of sunflower methyl esters are establish out and matched with that of other esters and diesel (Table 2 [13–16]). It can be seen that the properties of sunflower methyl esters are relatively comparable to that of other esters. The outcome shows that, transesterification enhanced the important fuel properties of the oil like calorific value, density viscosity, flash point and cetane number. The comparison demonstrates that the methyl ester has relatively closer fuel properties to diesel than that of unique unrefined sunflower oil.

The viscosity was considerably got reduced from a value of 33.9 to 4.6 mm^2/s (approximately one seventh of initial value). The calorific value of methyl ester is lesser than that of diesel because of its oxygen content. The flash point of the ester is greater than that of diesel. A small percentage of biodiesel adding with diesel can definitely improve. Hence, this fuel is safer and harmless to store and transport associated to that of pure diesel.

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Table 2 Properties index of sunflower oil, sunflower methyl ester, soybean methyl ester, rapeseed methyl ester and diesel.

Vegetable oil & Diesel	Kinematic viscosity 38°C (cSt)	Cetane number	Calorific value (MJ/kg)	Flash Point (°C)	Density kg/lit
Sunflower oil(natural)	33.9	37.1	39.6	274	.916
Sunflower oil methyl ester (Biodiesel)	4.6	49	33.5	183	.860
Soybean oil methyl ester	4.08	46	39.76	69	0.885
Rape seed oil methyl ester	4.5	45	37.00	170	0.882
Diesel	3.18	40-55	44.8	68	0.832

V. EXPERIMENTAL SETUP

A Kirloskar make, single cylinder, water cooled, direct injection was selected for the present research work, which is primarily used for agricultural activities and household electricity generations. The detailed technical specifications of the engine are given in Table 3.

Table 3 Test engine specification of sunflower oil

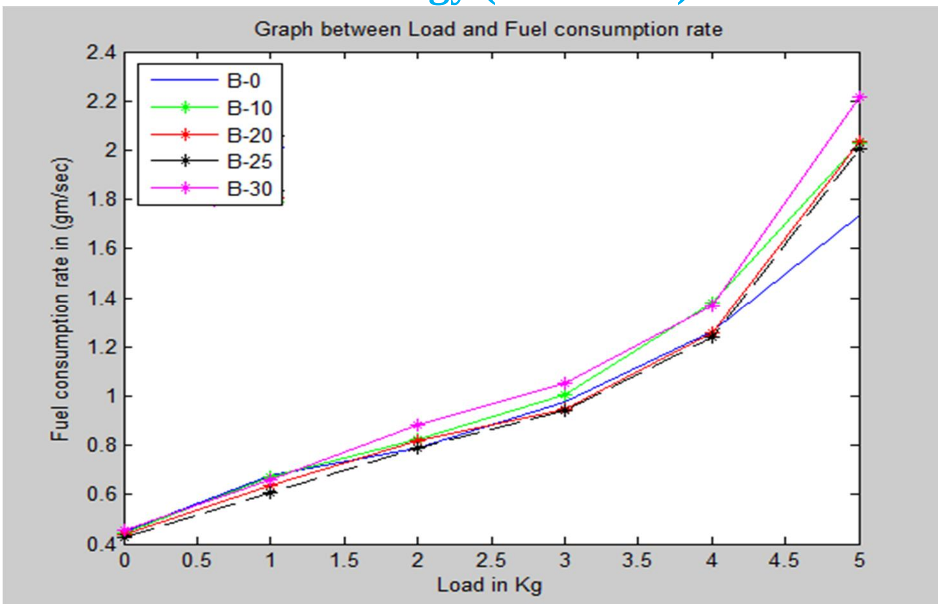
Particulars	Descriptions
Engine type	Four stroke, single cylinder, Water cooled, Diesel engine
Bore Diameter	87.5 mm
Stroke length	110 mm
Compression Ratio	16.7
Rated power	5 horse power
Rated speed	1500 rpm
Dynamometer	Hydraulic dynamometer

Performance and emission tests are conducted on the compression ignition engine, using various blends of biodiesel and diesel as fuels. The tests are accompanied at the rated speed of 1500 rpm at different loads. The experimental data engendered are recognized and presented here using suitable graphs. These tests are intended at enhancing the concentration of ester to be used in the biodiesel–diesel blend for long-term engine operation. In each trial, engine parameters related to thermal performance of the engine such as fuel consumption and applied load are measured. In addition to that, the engine emission parameters such as carbon monoxide (CO), temperature of exhaust gas and temperature of cooling water.

VI. RESULT AND DISCUSSIONS

A. Fuel Consumption Rate v/s Load

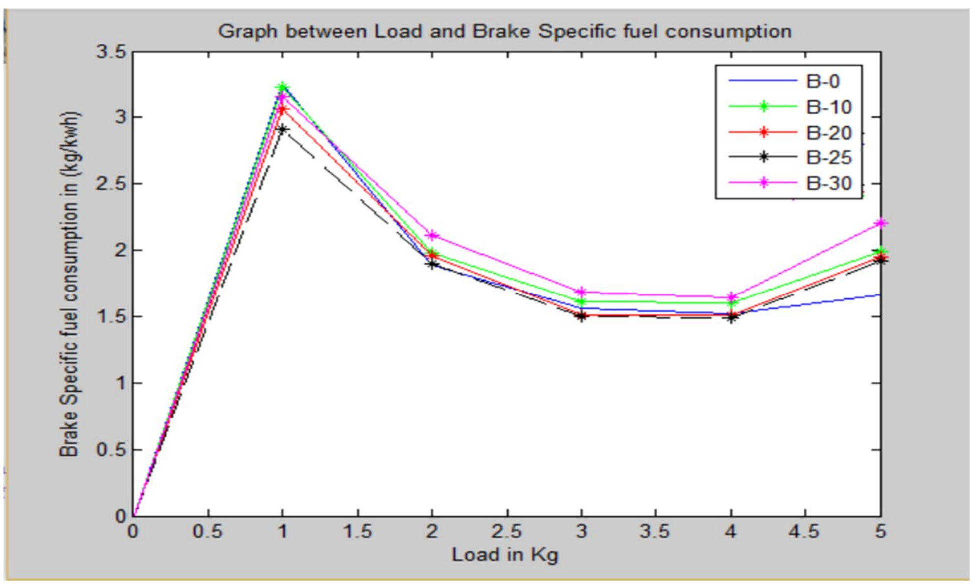
The variation of fuel consumption rate with load for different fuels at different load is presented in graph 1. It is observed from the graph that fuel consumption rate for all blended test fuels increase with increase in the load. The fuel consumption rate of B-25 fuel is minimum in comparison to all blended test fuel at all loads except 5 kg load. Till 80 % loading condition the fuel consumption rate of B-10 and B-20 fuel is very close to that of the B-0 fuel but at full load the fuel consumption rate of B-10 and B-30 fuel increases more than B-0. But the overall the fuel consumption rate of B-25 blends is lower than that of B-0.



Graph 1 Fuel Consumption Rate for blended fuels at various loads

B. Brake Specific Fuel Consumption v/s Load

The variation of brake specific fuel consumption with load for different fuels at different load is presented in graph 2. It is observed from the graph that brake specific fuel consumption for all blended fuel first decreases with increase in load i.e. up to 80 % load and after that they tends to increase with load. But the brake specific fuel consumption of each blended fuel decreases as the percentage of biodiesel i.e. sunflower methyl ester is increased in the blends. But at certain level it will increases with increases in percentage of biodiesel. It is clearly seen that out of all blended fuels the brake specific fuel consumption of the B-25 fuel at all loads is closely similar to that of the B-0 fuel or it can be said that optimum brake specific fuel consumption is observed at 80 % load by the B-25 amongst all blended fuels.



Graph 2 Brake Specific Fuel Consumptions for blended fuels at various loads

C. Brake Thermal Efficiency v/s Load

The variation of brake thermal efficiency with load for different fuels at different load is presented in graph 3. It is observed from the graph that brake thermal efficiency for all blended fuel increases with increase in load i.e. up to 80 % load and after that they tends to decreases with load i.e. it will minimum at full load. In general the brake thermal efficiency of test fuels decreases in

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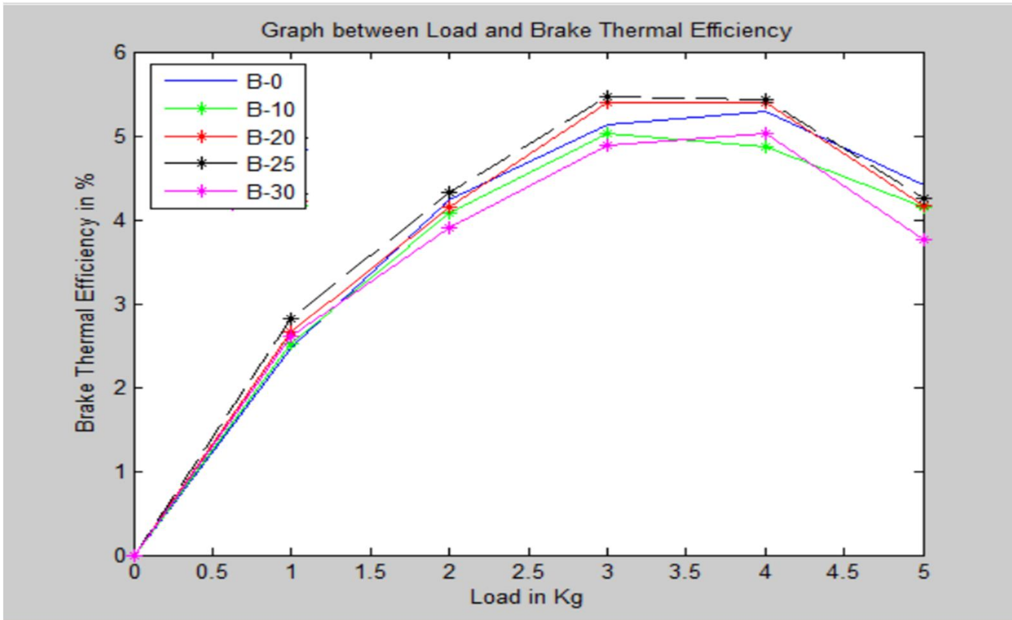
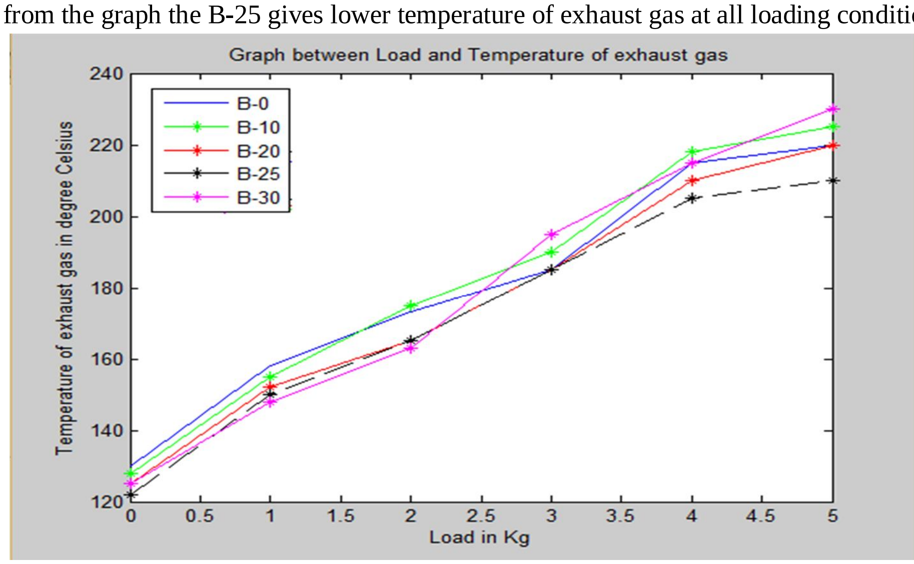
comparison to the B-0 fuel as the percentage of the biodiesel increases in the blended test fuels. But it is observed from the graph that initially the brake thermal efficiency of B-25 fuel is more than B-0 fuel up to 80 % load and then it tends to decreases below B-0 fuel at full load condition.



Graph 3 Brake Thermal Efficiency for blended fuels at various loads

D. *Temperature of Exhaust Gas v/s Load*

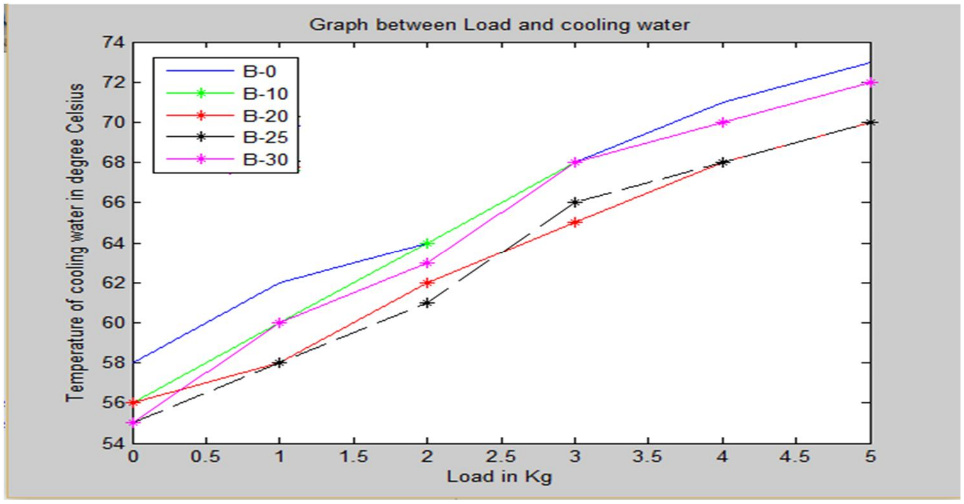
The variation of exhaust gas temperature with respect to applied load for different fuels tested is shown in graph 4. It is observed from the graph that the temperature of exhaust gas increases with increase in load for all tested fuels. The biodiesel also contains some amount of oxygen molecules in the ester form. It is also taking part in the combustion. Up to B-25 blended fuel the exhaust gas temperature is lower but further increases the percentage of biodiesel in the blends the temperature of exhaust gas increases. So we can easily said that from the graph the B-25 gives lower temperature of exhaust gas at all loading condition.



Graph 4 Temperature of Exhaust Gas for blended fuels at various loads

E. *Temperature of Cooling Water v/s Load*

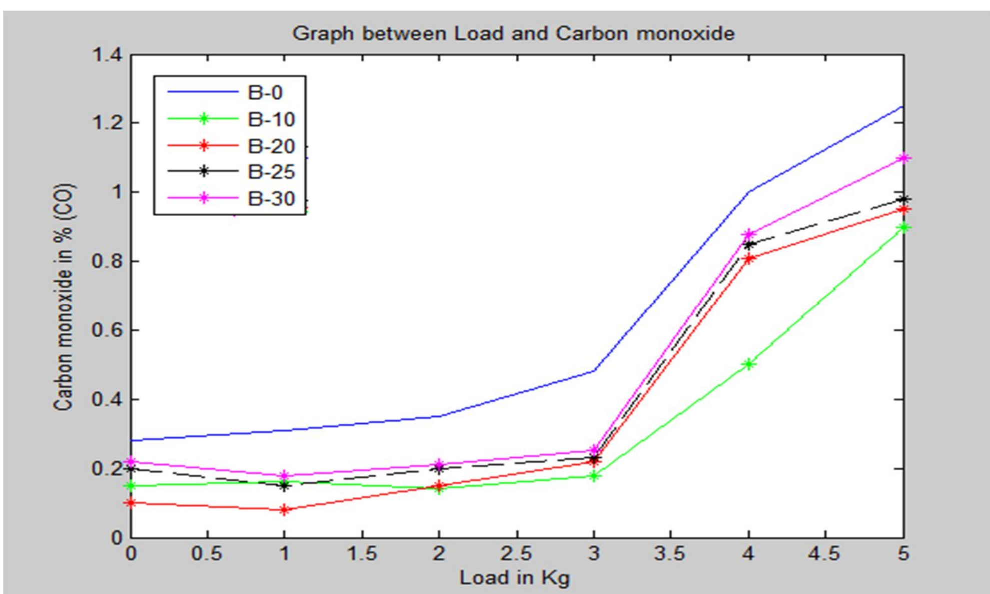
The variation of cooling water temperature with respect to applied load for different fuels tested is shown in graph 5. It is observed from the graph that the temperature of cooling water increases with increase in load for all tested fuels. The biodiesel also contains some amount of oxygen molecules in the ester form. It is also taking part in the combustion. Up to B-25 blended fuel the cooling water temperature is lower but further increases the percentage of biodiesel in the blends the temperature of cooling water increases. The oxides of nitrogen emission are directly associated to the engine combustion chamber temperatures, which in turn specified by the predominant exhaust gas temperature as well as cooling water temperature. With rise in the value of exhaust gas temperature, NO_X emission also increases. So we can easily said that from the graph the B-25 gives lower temperature of cooling water at all loading condition so B-25 produce less amount of NO_X among all blends of fuels.



Graph 5 Temperature of Cooling water for blended fuels at various loads

F. Emission of Carbon Monoxide v/s Load

The emission characteristics of biodiesel take special interest in relation to achieving the environmental norms. Graph 6 demonstrates the plots of carbon monoxide emissions of the sunflower methyl ester and various blends of biodiesel operation at the rated engine speed of 1500 rpm at various load conditions. The fuels are producing less amount of carbon monoxide emission at low loading condition and are giving more emissions at higher loading conditions. With increasing biodiesel percentage in the blends, emission of CO level decreases. Biodiesel itself has about 11% oxygen content in its constituents. This helps for the complete combustion of fuel. Hence, CO emission level decreases with increasing biodiesel percentage in the fuel.



Graph 6 Emission of Carbon Monoxides for blended fuels at various loads

VII. CONCLUSIONS

The main objective of the present thesis work is to produce biodiesel from sunflower oil and after that perform number of test on Four stroke, single cylinder, Water cooled, Diesel engine by using the conventional diesel fuels and various blends of biodiesel fuels. After carrying out series of experiment the following conclusion were made. These conclusions are given below.

A. Out of all blended fuels the brake specific fuel consumption of B-25 fuel at all loading condition is slightly higher than that of B-0 fuel and it can be clearly seen that the optimum brake specific fuel consumption is at 80% loading condition by B-25 and B-0 fuel.

B. It is observed that the brake the brake thermal efficiency of B-25 fuel is more than the B-0 fuels up to 60% loading condition and then it becomes almost equivalent to that of B-0 fuel at 80% loading condition, afterwards it decreases below to the B-0 fuel at full loading condition.

C. Till 75% loading condition the fuel consumption rate of B-20 and B-25 blended fuel is very close to that of the B-0 fuels but at full load the fuel consumption rate of B-20, B-25 and B-30 fuel increases more than B-0 fuel.

D. we can easily said that from the graph the B-25 gives lower temperature of exhaust gas at all loading condition.

E. it is clearly seen that from the graph the B-25 gives lower temperature of cooling water at all loading condition so B-25 produce less amount of NO_X among all blends of fuels.

F. It is observed that due to presence of oxygen content in the biodiesel helps in the complete combustion of fuel. Hence, CO emission level decreases with increasing biodiesel percentage in the fuel.

VIII. RECOMMENDATION

B-25 fuel is found suitable to use as a sustainable, green, clean substitutes in the C.I engine and its fuel consumption rate, brake specific fuel consumption, brake thermal efficiency are very close to that of the conventional diesel fuel.

IX. SCOPE FOR FUTURE WORK

Due to unavailability of apparatus and equipment I was not able to measure various parameters of exhaust gas which are emitted from the engine by using pure diesel and various blends of fuels at the time of experiment. It is observed from various research papers that by using biodiesel and blends of biodiesel with diesel as a fuel in the C.I engine reduce the emission of carbon dioxide, oxides of nitrogen and hydrocarbons.

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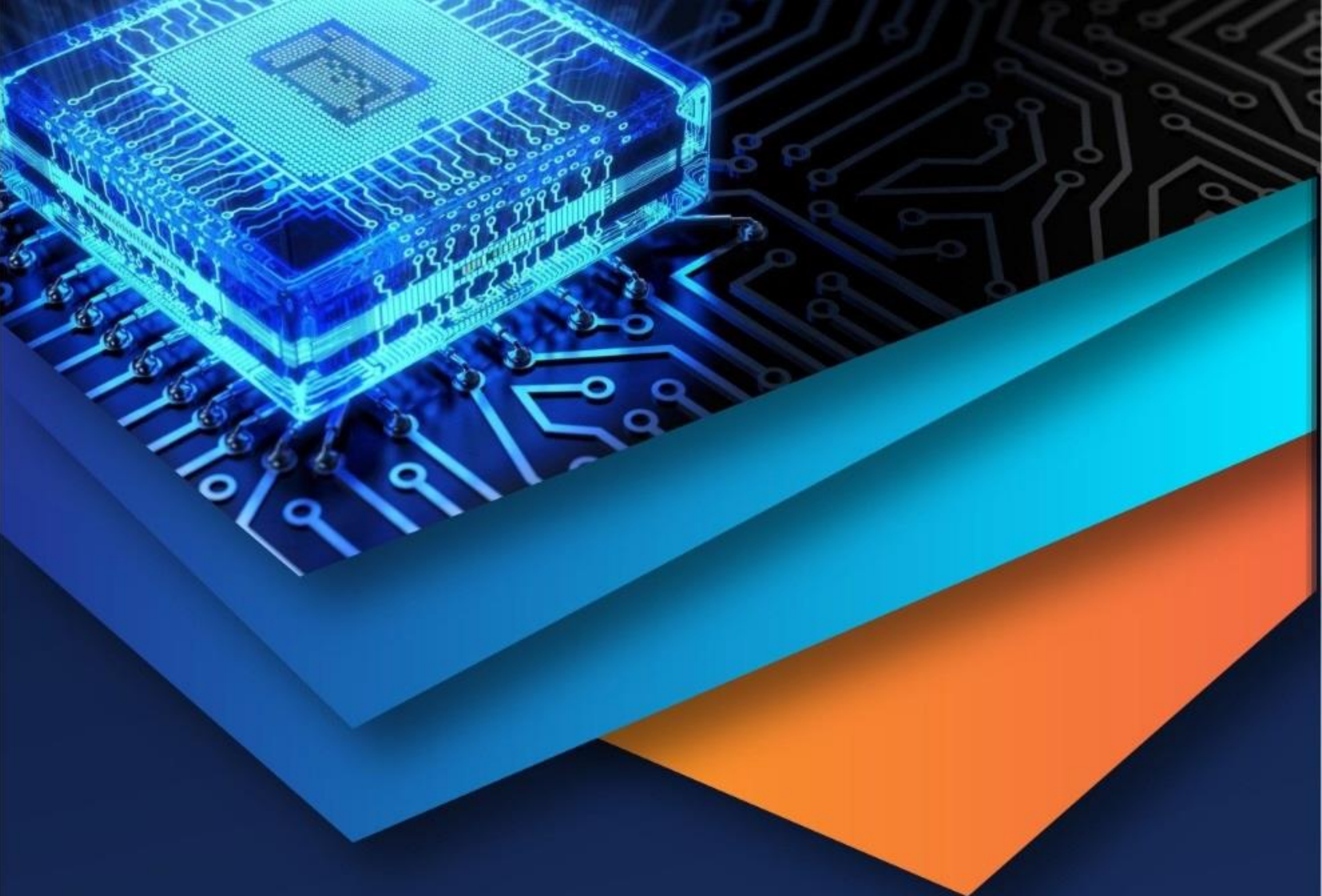

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