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Experimental Investigations on Performance And Emission Characteristics of LHR Engine At Different Injection Timings Using Biodiesel Fuels

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ABSTRACT: The reduction of heat loss from the combustion chamber of diesel engines improves fuel efficiency only by 3 or 4 per cent. Some other gains may be possible from a smaller cooling system, recovery of exhaust energy, and improvements in aerodynamics. The use of thermal barrier coatings (TBCs) to increase the combustion temperature in diesel engines has been pursued for over 20 years. Increased combustion temperature can increase the efficiency of the engine, decrease the CO and (possibly) the NOx emission rate. However, TBCs have not yet met with wide success in diesel engine applications because of various problems associated with the thermo mechanical properties of the coating materials. Although, the in-cylinder temperatures that can be achieved by the application of ceramic coatings can be as high as 850-900^{0}C compared to current temperatures of 650-700^{0}C. The increase in the in-cylinder temperatures helped in better release of energy in the case of biodiesel fuels thereby reducing emissions at, almost the same performance as the diesel fuel.The aim of this study is to apply Thermal Barrier Coatings (TBC) onto engine parts for improving engine performance when biodiesel is used as an alternative fuel. For this purpose, a Direct Injection (DI) diesel engine was converted to a LHR engine by applying $MgZrO_2$(TBC) on the Piston Crown and the effects of biodiesel (produced from Pongamia oil) usage in the LHR engine, performance and emission characteristics have been investigated experimentally with injection timings of 21°,23°and 25° BTDC. The results showed that specific fuel consumption and the brake thermal efficiency were improved, and the smoke density of the engine is decreased compared to the base engine when it is run with diesel.

Keywords: LHR engine, Biofuels, Thermal barrier coating, emissions.

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I. INTRODUCTION

Diesel engines are the major source of transportation, power generation marine applications and agriculture etc. Hence diesel is being used extensively, but due to gradual depletion of world petroleum reserves and the impact of environmental pollution of increasing exhaust emissions, there is an urgent need for suitable alternative fuels for use in diesel engines. In view of the vegetable oil like pongamia oil are considered as alternate fuels to diesel which are promising alternative because they have advantages like they are renewable. Eco-friendly and produced easily in rural areas, where there is an acute need for modern forms of energy. If these fuels serve the purpose of diesel to some extent they will be useful to the rural areas in providing employment as well as agriculture energy needs. If these fuels serve the purpose to a larger extent they will be good substitutes in industrial, transportation etc.

A large number of studies on performance, structure and durability of the LHR engine have been carried out since Kamo and Bryzik[1] presented a new concept of the LHR engine combined with the turbo compound system. Although promising the results of the investigations have been somewhat mixed. Most have concluded that insulation reduces heat transfer, improves thermal efficiency, and increases energy availability in the exhaust. However contrary to the above expectations some experimental studies have indicated almost no improvement in thermal efficiency and claim that exhaust emissions deteriorated as compared to those of the conventional water-cooled engines.

Alkidas [2]reported that insulating the combustion chamber walls of the engine, which results in an increase in flame temperature, should significantly decrease combustion generated irreversibility's and, consequently, may improve the second law efficiency. However, Flynn et al. claimed that overall, using in-cylinder insulation would have little impact on the system performance unless secondary heat recovery devices could be used in the exhaust system. The reduction in heat losses also results in increased exhaust enthalpy. For this reason, one of the most important topics that must be addressed in LHR engines seems to be recovering the available energy in the exhaust gas stream using secondary heat recovery devices such as a compounding turbine or a bottoming cycle, thus improving the overall system efficiency.

Sekar and Kamo[3] developed an adiabatic engine for passenger cars and reported an improvement in the performance to the maximum extent of 12%. The experimental results of Morel et al. indicate that the higher temperatures of the insulated engine cause reduction in the in-cylinder heat rejection, which is in accordance with the conventional knowledge of convective heat transfer.Woschni et al.state that 5% of the input fuel energy cannot be accounted for, which is of the order of the expected improvements. Havstad et al.[4] developed a semi-adiabatic diesel engine and reported an improvement ranging from 5 to 9% in ISFC, about 30% reduction in the in-cylinder heat rejection. Prasad et al. [5]used thermally insulating material, namely partially stabilized zirconia (PSZ), on the piston crown face and reported a 19% reduction in heat loss through the piston.Prasad et al. tested a single-cylinder diesel engine with Superni-90 coated piston top and cylinder liner of which had a maximum engine power of 3.68kW and a compression ratio of 16:1. They used raw jatropha and pongamia oils and esterify jatropha oil as fuels. They found that the performance of the LHR engine improved, nitrogen oxide (NOx) levels decreased and exhaust gas temperatures were increased with all three non-edible vegetable oils in comparison with diesel fuel. They also found that the combustion parameters of the non-edible vegetable oils were within reasonable limits and revealed that non-edible vegetable oils can be successfully utilized as substitute fuels in a LHR diesel engine[6-17].

II.FUEL PREPARATION

Biodiesel is produced by combining vegetable oil or animal fat with an alcohol in the presence of a catalyst through a chemical process known as transesterrification. Oil for biodiesel production can be extracted from almost any oilseed crop; globally, the most popular sources are rapeseed in Europe and soybean in Brazil and the United States of America. In tropical and subtropical countries, biodiesel is produced from palm, coconut, jatropha, Pongamia, pinnata and Cotton seed oils. Small amounts of animal fat, from fish-and animal-processing operations, are, such as viscosity and combustibility. Its energy content is 88–95 percent of that of diesel, but also used for biodiesel production. The production process typically yields additional by-products such as crushed bean "cake" (an animal feed) and glycerine. Because biodiesel can be based on a wide range of oils, the resulting fuels can display a greater variety of physical properties it improves the lubricity of diesel and raises the Cetane value, making the fuel economy of both generally comparable.

The higher oxygen content of biodiesel aids in the completion of fuel combustion, reducing emissions of particulate air pollutants, carbon monoxide and hydrocarbons.

The Properties of Diesel and Biodiesel blends
Table:1

S. NO	Properties	Diesel	Biodiesel	B20	B40
1.	Density (Kg/m^3)	832	880	840	850
2.	Kinematic Viscosity@40^{0}C	3.8	5.6	4.16	4.52
	(Cst)				
3.	Calorific value (KJ/Kg)	43,626	36,120	41,464	40,128
4.	Specific gravity @60^{0}C	0.853	0.876	0.857	0.862
5.	Flash point (^{0}C)	60	217	91.4	122.8
6.	Fire point (^{0}C)	63	223	95	127
7.	Cetane number	47	52	48	49

II. EXPERIMENTAL SET-UP

A single cylinder, naturally aspirated, four stroke, constant speed, water cooled, direct injection diesel engine is used for the experiments conducted. The technical specifications of the engine are as below

Table.2 Specifications of kirloskar diesel engine

Make	Kirloskar oil engines Ltd. India
Type	Single cylinder DI,NA CI engine
Stroke	110.0mm
Bore	80.0mm
Injection pressure	200 bar
Rated output	3.68 KW
Compression ratio	16.5:1

Loading device	Water brake dynamometer

The experimental setup used in the present investigation is shown in the figure 5.1

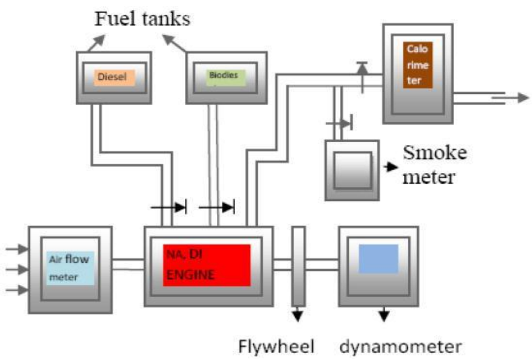


Fig.1 schematic diagram of experimental setup

The experiments are conducted with blends of pongamia oil and diesel; 20P80D at different injection timings. The injection timings considered for the present investigation are 21°, 23°and 25°.The injection timing by increasing changing and decreasing the thickness of shim. Similarly by changing diesel in the fuel tank and taking different fuel oils like 20P80D, 40P60 and diesel. The experiment was conducted by with coating and without coating. In this process surfaces of piston crown, exhaust and inlet valve of a four-stroke, direct injection, single cylinder diesel engine were coated with Magnesium zircon ate ($MgZrO_2$) (see fig.2) by using plasma spray method. After thermal barrier coating the direct injection diesel engine was converted into a LHR engine.

Fig.2 View of Piton crown and valves with coating

III. RESULTS AND DISCUSSIONS

Four sets of experiments were conducted on single cylinder direct injection diesel engine with and without thermal insulated cylinder using diesel and biodiesel blends as fuels. In each set of tests readings of engine power, fuel consumption, exhaust gas temperature, cylinder wall temperatures, and so on, were taken for zero to full load at constant speed.

FUEL CONSUMPTION:

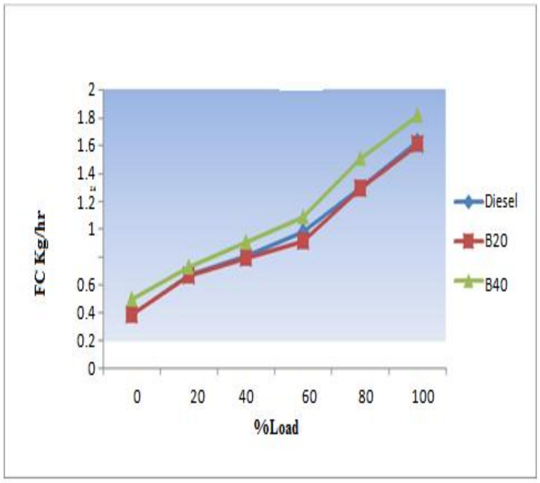


Fig.3. Comparison of fuel consumption of biodiesel blends with diesel at 21^0injection timing without Thermal Barrier Coating.

Fuel consumption for the diesel engine run with diesel and the biodiesel blends at injection timing 21^0 is shown in Fig.3. The Fuel consumption values of the diesel engine run with diesel and B20 were lower than B40. Fuel consumption of diesel and biodiesel blend B20 were equally getting up to 100% load. Fuel consumption is decrease up to 2% in the case of diesel engine run in with biodiesel (blend B20) at maximum load.

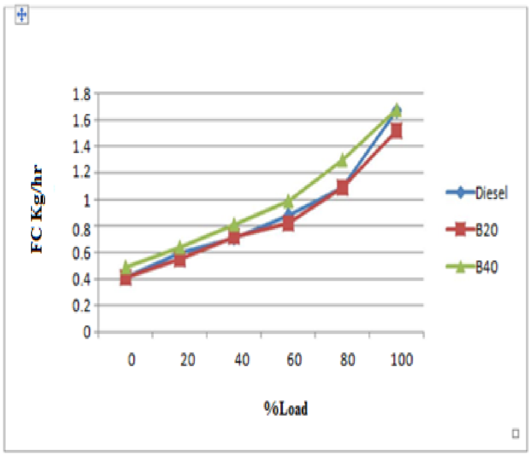


Fig.4. Comparison of fuel consumption of biodiesel blends with diesel at 23^0injection timing without Thermal Barrier Coating.

Comparison of the Fuel consumption for the diesel engine run with diesel and the diesel engine run with biodiesel blends at injection timing

23^0 is shown in Fig.4. fuel consumption of diesel and B20 were lower than the B40. Fuel consumption of B20 was slightly decreases 4% at maximum load.

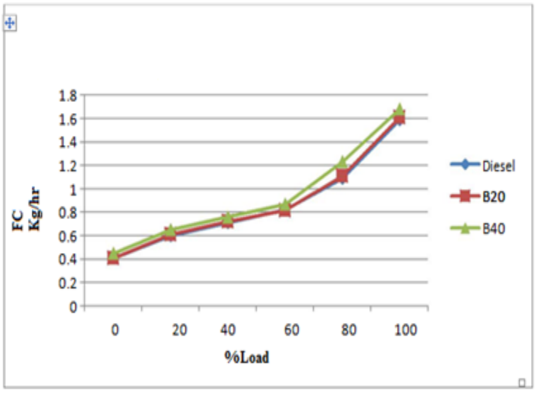


Fig.5 Comparison of fuel consumption of biodiesel blends with diesel at 25^0injection timing without Thermal Barrier Coating**.**

Comparison of the Fuel consumption for the diesel engine run with diesel and the diesel engine run with biodiesel blends is shown in Fig.5. In this test, fuel consumption of diesel biodiesel blend (B20) is comparable up to 40% load and it is increasing when the load is increased.

Specific fuel consumption:

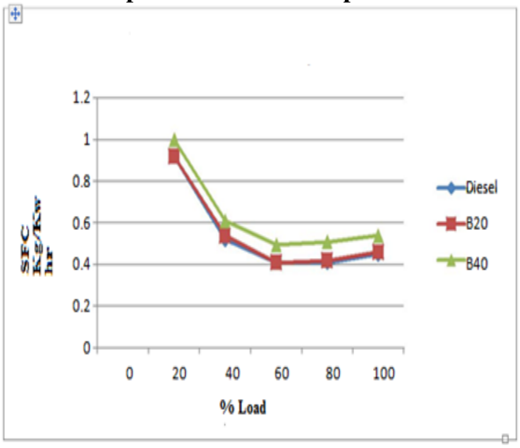


Fig.6. Comparison of specific fuel consumption of biodiesel blends with diesel at 21^0injection timing without Thermal Barrier Coating.

Comparison of the specific Fuel consumption for the diesel engine run with diesel and the biodiesel blends with diesel at 21^0 injection timing is shown in Fig.6. Because of the higher surface temperatures of its combustion chamber, the BSFC values of the biodiesel blends were lower than those of the diesel engine. The relative reduction in the SFC is seen to be within the range of 3–7%. Lower heating value of the biodiesel blends caused an increase in specific fuel consumption of the biodiesel. The specific fuel consumption of the biodiesel blends is still higher than that of diesel fuel.

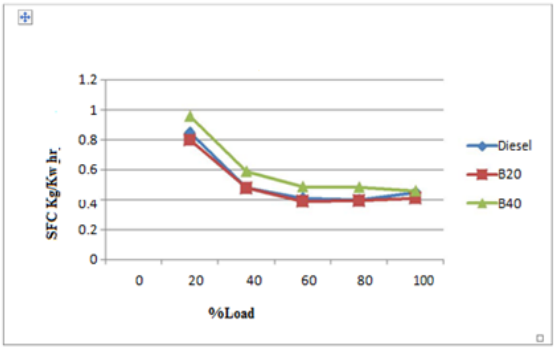


Fig.7. Comparison of specific fuel consumption of biodiesel blends with diesel at 23^0injetion timing without Thermal Barrier Coating.

In the above fig: 7, SFC of biodiesel blends is compared with the SFC of diesel at 23^0 injection timing. It is observed that the SFC of diesel engine with biodiesel fuels was slightly higher than that of diesel. Up to 40% load the specific fuel consumption of diesel and biodiesel blend B20 is same. The improvement in the specific fuel consumption caused an increase of the brake thermal efficiency for both fuels in diesel engine.

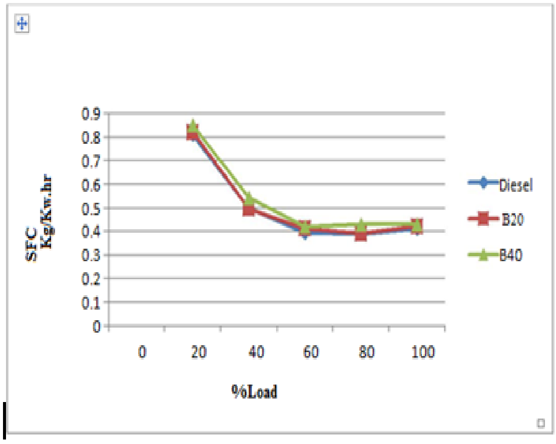


Fig.8. Comparison of specific fuel consumption of biodiesel blends with diesel at 25^0Injection timing.

In the above fig: 8, SFC of biodiesel fuels is compared with SFC of diesel at 25^0 Injection Timing. It is observed that the SFC of diesel engine with biodiesel fuels was slightly higher than that of diesel. Up to 40% load the specific fuel consumption of diesel and biodiesel fuels are same. Above 40%load the specific fuel consumption of biodiesel fuels are more compared to diesel. The specific fuel consumption of the biodiesel blends is still higher than that of diesel fuel. The improvement in the specific fuel consumption caused an increase of the brake thermal efficiency for both fuels in diesel engine.

Brake Thermal Efficiency

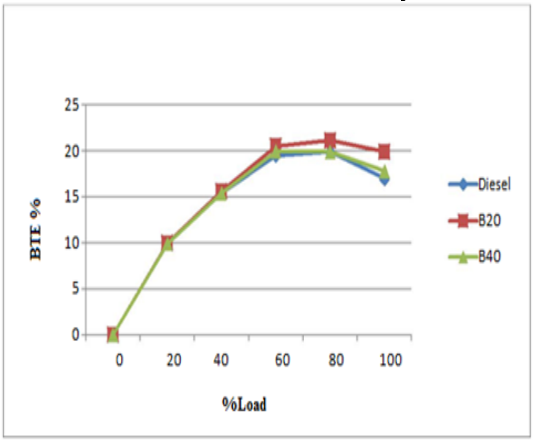


Fig.9. Comparison of Brake thermal efficiency for biodiesel fuels with diesel at 21^0 injection timing without Thermal Barrier Coating

Comparison of the Brake thermal efficiency for the diesel engine operated with diesel and the diesel engine operated with biodiesel fuels at 21^0 injection timing is shown in Fig.9. Above fig up to 40% load brake thermal efficiency of diesel and biodiesel fuels are same. Above 40% load The Brake thermal efficiency values of the diesel were slightly lower than those of the biodiesel blends. This is attributed to the amount of fuel consumed per unit power. Since the fuel consumption is lower, the brake thermal efficiency is improved compared to biodiesel blends.

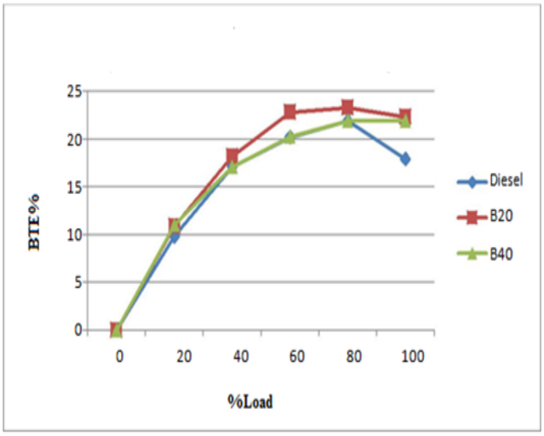


Fig.10. Comparison of Brake thermal efficiency for biodiesel fuels with diesel at 23^0 injection timing without Thermal Barrier Coating.

Brake thermal efficiencies of diesel engine run with diesel and biodiesel blends at 23^0 injection timing is shown in the fig.10. Here, up to 30% load the brake thermal efficiency of diesel is equal to biodiesel fuels, above 30% load the brake thermal efficiency diesel is lower than to biodiesel because of the reduction in heat loss to the coolant water and conversion of heat into useful work due to better atomization of fuel which leads to the complete combustion of fuel. The brake thermal efficiency of the biodiesel blends improved due to the engine power and torque did not deteriorate too much according to diesel fuel.

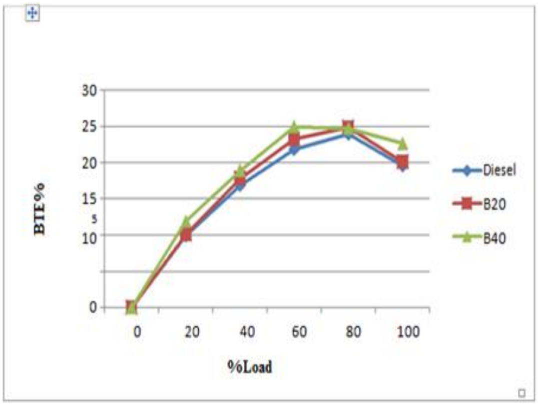


Fig.11. Comparison of Brake thermal efficiency for biodiesel fuels with diesel at 25^0 injection timing without Thermal Barrier Coating.

Comparison of the Brake thermal efficiency for the diesel engine operated with diesel and the diesel engine operated with biodiesel fuels at 25^0 injection timing is shown in Fig.11. Above fig up to 20% load brake thermal efficiency of diesel and biodiesel fuels are same. Above 20% load The Brake thermal efficiency values of the diesel were slightly lower than those of the bio diesel blends. Above 70% load if load increase brake thermal of diesel is decrease and biodiesel efficiency was increase. This is attributed to the amount of fuel consumed per unit power. Since the fuel consumption is lower, the brake thermal efficiency is improved compared to biodiesel blends.

Volumetric Efficiency

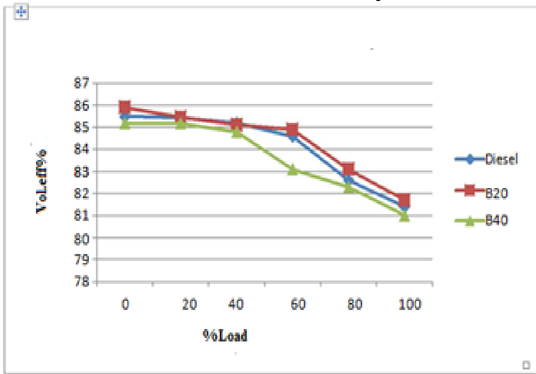


Fig.12. Comparison of Volumetric efficiency of biodiesel fuels with diesel at 21^0injection timing without Thermal Barrier Coating.

Volumetric efficiencies of diesel engine run with diesel and biodiesel blends at 21^0 injection timing Is shown in the fig.12. The volumetric efficiency of the biodiesel blends was observed to be higher than diesel at part loads (40% and 60%) and was decreasing with the increase in the load. This can be attributed to the presence of oxygen in the biodiesel which helps in complete combustion of fuel even at maximum loads thereby releasing more heat which intern causes in the heating up of intake manifold and thereby, in the reduction of volumetric efficiency.

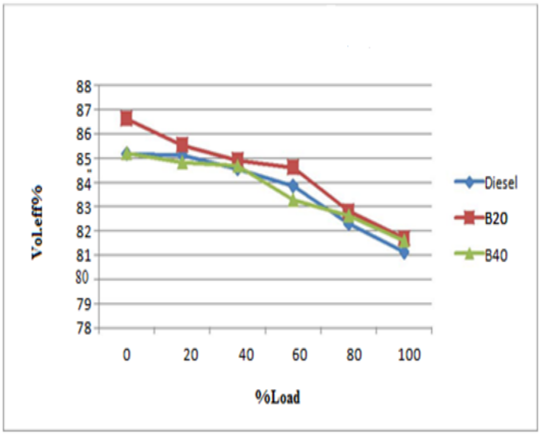


Fig.13. Comparison of Volumetric efficiency of biodiesel fuels with diesel at 23^{0}injection timing without Thermal Barrier Coating.

Figure.13 shows the comparison of volumetric efficiency of biodiesel and diesel at 23^0 Injection Timing. The volumetric efficiency of the biodiesel blend (20) was observed to be higher than diesel and blend (B40) at part loads (40% and 60%) and was decreasing with the increase in the load. This can be attributed to the presence of oxygen in the biodiesel which helps in complete combustion of fuel even at maximum loads thereby releasing more heat which intern causes in the heating up of intake manifold and thereby, in the reduction of volumetric efficiency.

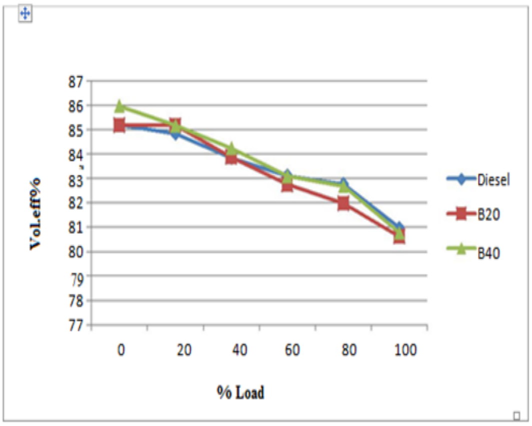
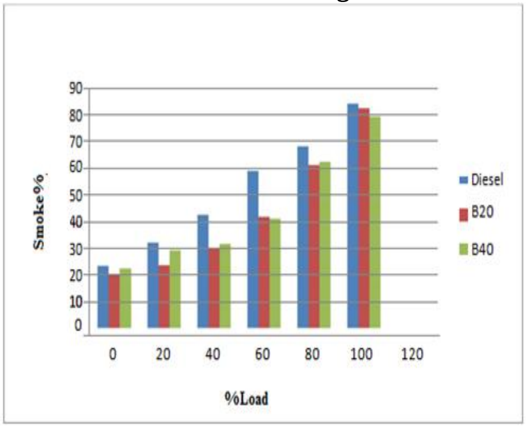


Fig.14. Comparison of Volumetric efficiency of biodiesel fuels with diesel at 25^{0}injection timing.

Volumetric efficiencies of diesel engine run with diesel and biodiesel blends at 25^0 injection timing is shown in the fig.14. The volumetric efficiency of the biodiesel blends was observed to be higher than diesel at part load 40% and was decreasing with the increase in the load. At maximum load diesel and B40 were higher than the B20. This can be attributed to the presence of oxygen in the biodiesel which helps in complete combustion of fuel even at maximum loads thereby releasing more heat which intern causes in the heating up of intake manifold and thereby, in the reduction of volumetric efficiency.

Smoke Percentage



15. Comparison of smoke % of diesel and biodiesel fuels at 21^0 injection timing without Thermal Barrier Coating

Comparison of smoke densities of diesel and biodiesel fuels at 21^{0}injection timings are shown in fig.15. As can be seen from the figures, the smoke density of the biodiesel is significantly less compared to the diesel engine. With diesel engine operation both biodiesel (B40) and biodiesel (B20) results in lower smoke emissions due to better combustion

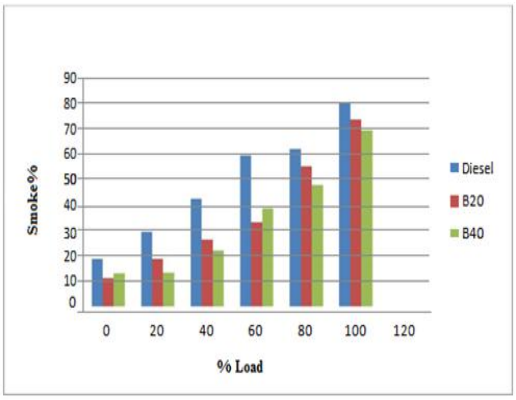


Fig.16. Comparison of smoke % of diesel and biodiesel fuels at 23^0 injection timing without Thermal Barrier Coating

Smoke densities of diesel engine run with diesel and biodiesel blends at 23^0 injection timing is shown in the fig.16. As can be seen from the figures, the smoke density of the biodiesel is significantly less compared to the diesel engine because biodiesel fuel is a carbon neutral it gives less emission. With diesel engine operation biodiesel (B40) results in lower smoke emissions due to better combustion.

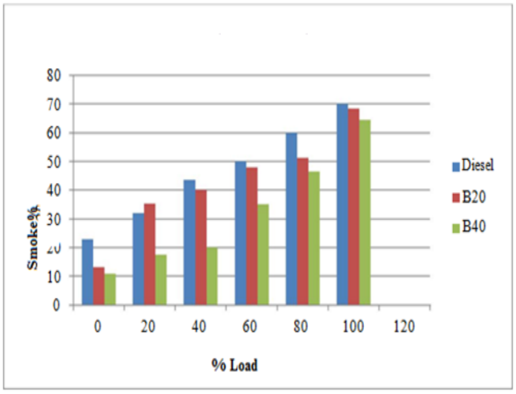


Fig.17 Comparison of smoke % of diesel and biodiesel fuels at 25^0 injection timing without Thermal Barrier Coating.

Comparison of smoke densities of diesel and biodiesel fuels at 25^0injection timings are shown in fig.17. As can be seen from the figures, the smoke density of the biodiesel is significantly less compared to the diesel engine because biodiesel fuel is a carbon neutral it gives less emission. With diesel engine operation biodiesel (B40) results in lower smoke emissions due to better combustion.

Fuel Consumption

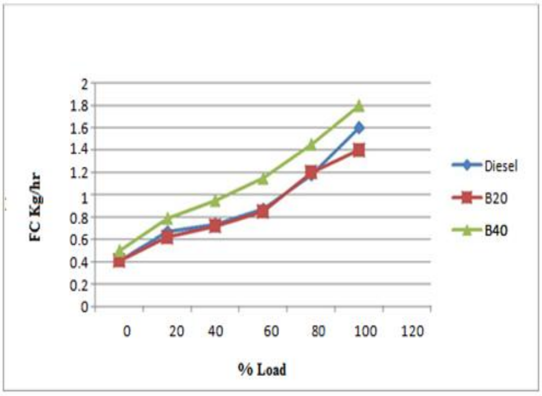


Fig.18 Comparison of fuel consumption of biodiesel fuels with diesel at 21^0injection timing with Thermal Barrier Coating ($MgZrO_2$).

Fuel consumption for the LHR engine run with diesel and the biodiesel fuels at injection timing 21^0 is shown in Fig.18. The Fuel consumption values of the diesel engine run with diesel and B20 were lower than biodiesel fuel. Fuel consumption of diesel and biodiesel blend B20 were equally getting up to 90% load. Fuel consumption is decrease up to 2% in the case of LHR engine run in with biodiesel blends B20, B40 at maximum load.

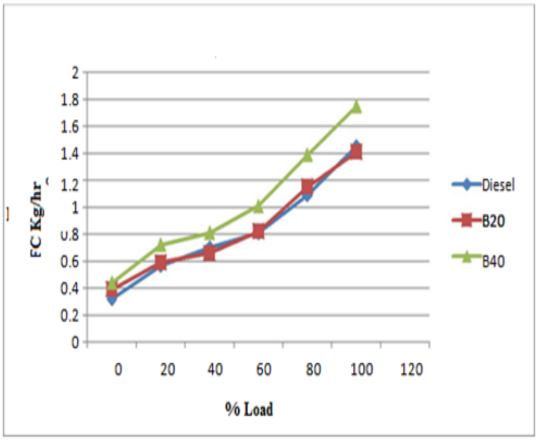


Fig.19 Comparison of fuel consumption of biodiesel fuels with diesel at 23^0injection timing with Thermal Barrier Coating ($MgZrO_2$).

Comparison of the Fuel consumption for the LHR engine run with diesel and the LHR engine run with biodiesel blends at injection timing 23^0 is shown in Fig.19. Fuel consumption of diesel and B20 were lower than the B40 and fuel consumption of diesel and blend B20 were up to 100% load both are equal.

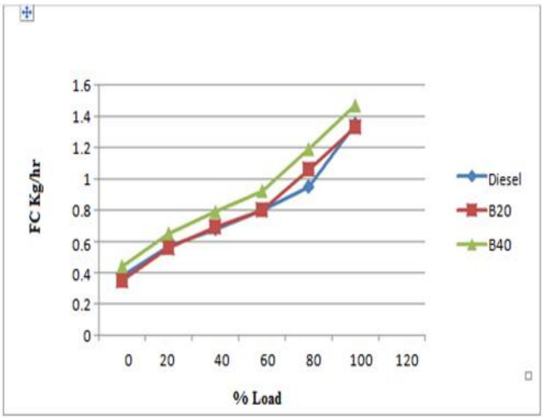


Fig.20 Comparison of fuel consumption of biodiesel fuels with diesel at 25^0injection timing with Thermal Barrier Coating ($MgZrO_2$)

Comparison of the Fuel consumption for the LHR engine run with diesel and the diesel engine run with biodiesel blends is shown in Fig.20. In this test, fuel consumption of diesel biodiesel blend (B20) is comparable up to 40% load and the fuel consumption is increasing when the load is increased. Both diesel and B20 were getting same fuel consumption at maximum load.

Specific Fuel Consumption

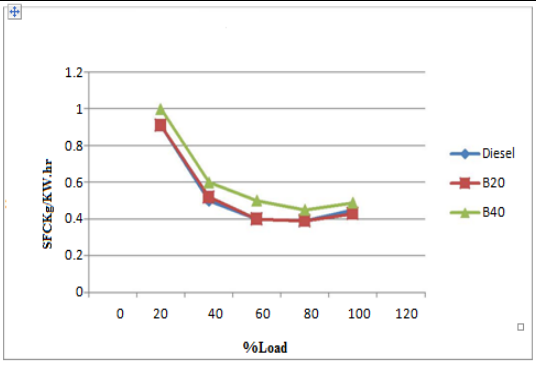


Fig.21. Comparison of specific fuel consumption of biodiesel blends with diesel at 21^0injection timing with Thermal Barrier Coating ($MgZrO_2$).

Comparison of the specific Fuel consumption for the LHR engine run with diesel and the biodiesel blends is shown in Fig.21. Because of the higher surface temperatures of its combustion chamber, the BSFC values of the biodiesel blends were lower than those of the low heat rejection engine. The relative reduction in the SFC is seen to be within the range of 4–6%. Lower heating value of the biodiesel blends caused an increase in specific fuel consumption of the biodiesel blends. The specific fuel consumption of the biodiesel blends is still higher than that of diesel fuel.

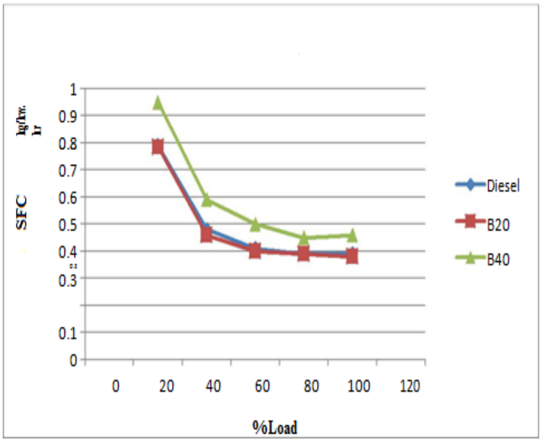


Fig: 22. Comparison of specific fuel consumption of biodiesel blends with diesel at 23^0injection timing with Thermal Barrier Coating ($MgZrO_2$)

In the above fig:22, Specific fuel consumption of biodiesel fuels is compared with the Specific fuel consumption of diesel at 23^0 injection timing. It is observed that the SFC of low heat rejection engine with biodiesel fuels was slightly higher than that of diesel. Up to 40% load the specific fuel consumption of diesel and biodiesel blend B20 is same. The improvement in the specific fuel consumption caused an increase of the brake thermal efficiency for both fuels in low heat rejection engine.

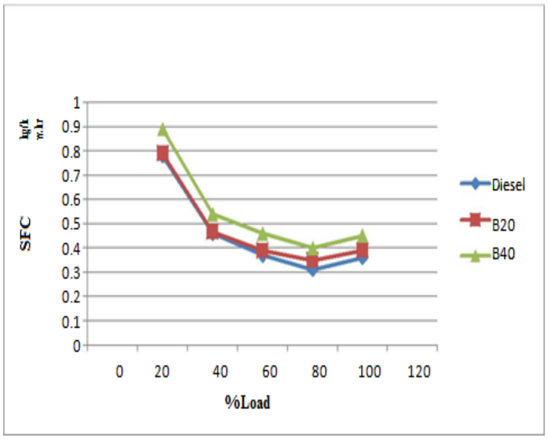


Fig: 23 Comparison of specific fuel consumption of biodiesel blends with diesel at 25^0injection timing with Thermal Barrier Coating ($MgZrO_2$**)**

In the above fig:23, SFC of biodiesel fuels is compared with SFC of diesel at 25^0 Injection Timing. It is observed that the SFC of low heat rejection engine with biodiesel fuels was slightly higher than that of diesel. Up to 40% load the specific fuel consumption of diesel and biodiesel fuels are same. Above 40% load the specific fuel consumption of biodiesel fuels are more compared to diesel. The specific fuel consumption of the biodiesel blends is still higher than that of diesel fuel. The improvement in the specific fuel consumption caused an increase of the brake thermal efficiency for both fuels in low heat rejection engine.

Brake thermal efficiency:

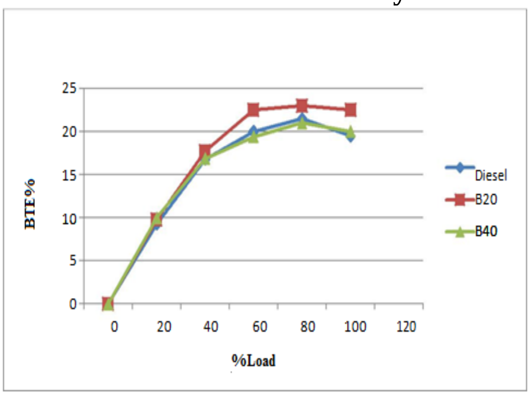


Fig.24 Comparison of Brake thermal efficiency for biodiesel fuels with diesel at 21^0 injection timing with Thermal Barrier Coating ($MgZrO_2$)

Comparison of the Brake thermal efficiency for the low heat rejection engine operated with diesel and the diesel engine operated with biodiesel fuels at 21^0 injection timing is shown in Fig.24. Above fig up to 40% load brake thermal efficiency of diesel and biodiesel fuels are same. Above 40% load The Brake thermal efficiency values of the diesel were slightly lower than those of the bio diesel blends. This is attributed to the amount of fuel consumed per unit power. Since the fuel consumption is lower, the brake thermal efficiency is improved compared to biodiesel blends.

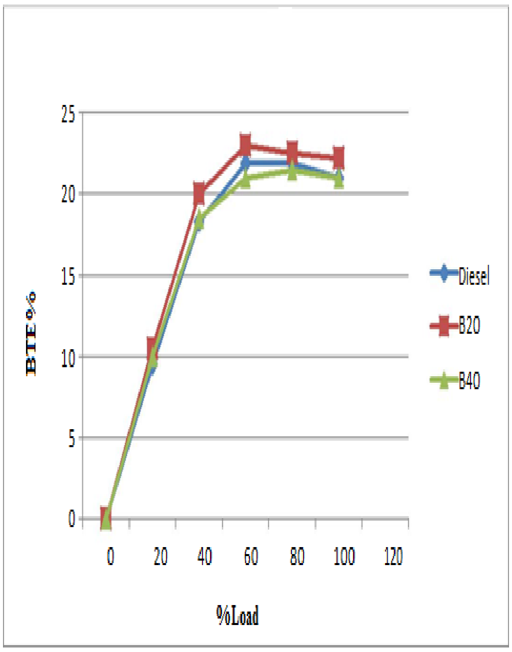


Fig.25 Comparison of Brake thermal efficiency for biodiesel fuels with diesel at 23^0 injection timing with Thermal Barrier Coating ($MgZrO_2$).

Brake thermal efficiencies of low heat rejection engine run with diesel and biodiesel blends at 23^0 injection timing is shown in the fig.25. Here, up to 30% load the brake thermal efficiency of diesel is equal to biodiesel fuels. Above 30% load the brake thermal efficiency diesel is lower than to biodiesel because of the reduction in heat loss to the coolant water and conversion of heat into useful work due to better atomization of fuel which leads to the complete combustion of fuel.

The brake thermal efficiency of the biodiesel improved due to the engine power and torque did not deteriorate too much according to diesel fuel.

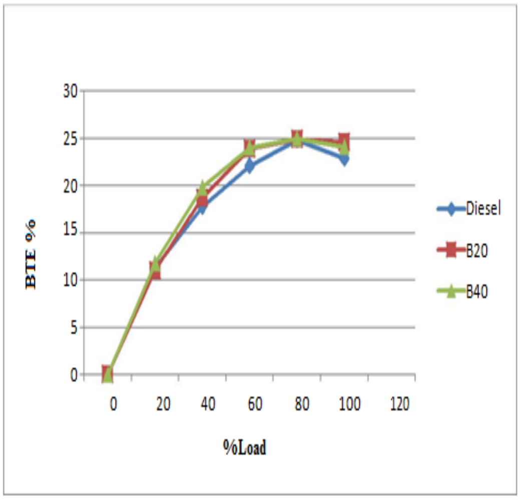


Fig.26 Comparison of Brake thermal efficiency for biodiesel fuels with diesel at 25^0 injection timing with Thermal Barrier Coating ($MgZrO_2$).

Comparison of the Brake thermal efficiency for the low heat rejection engine operated with diesel and the low heat rejection engine operated with biodiesel fuels at 25^0 injection timing is shown in Fig.26. Above fig up to 20% load brake thermal efficiency of diesel and biodiesel fuels are same. Above 20% load The Brake thermal efficiency values of the diesel were slightly lower than those of the bio diesel blends. Above 70% load if load increase brake thermal of diesel is decrease and biodiesel efficiency was increase. This is attributed to the amount of fuel consumed per unit power. Since the fuel consumption is lower, the brake thermal efficiency is improved compared to biodiesel blends.

Volumetric efficiency:

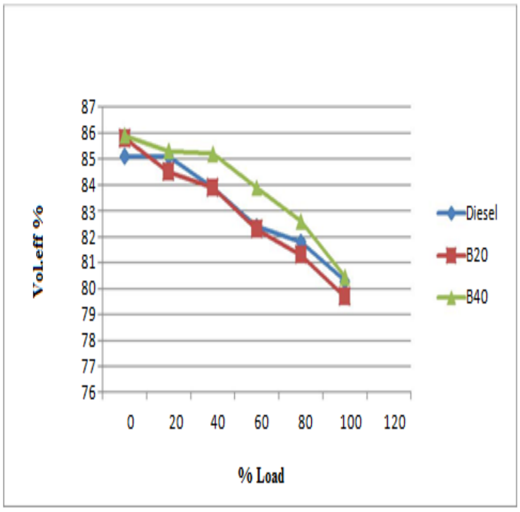


Fig.27. Comparison of Volumetric efficiency of biodiesel fuels with diesel at 21^0injection timing with Thermal Barrier Coating ($MgZrO_2$).

Volumetric efficiencies of low heat rejection engine run with diesel and biodiesel blends at 21^0 injection timing Is shown in the fig.27. The volumetric efficiency of the biodiesel blends was observed to be higher than diesel at part loads (40% and 60%) and was decreasing with the increase in the load. This can be attributed to the presence of oxygen in the biodiesel which helps in complete combustion of fuel even at maximum loads thereby releasing more heat which intern causes in the heating up of intake manifold and thereby, in the reduction of volumetric efficiency.

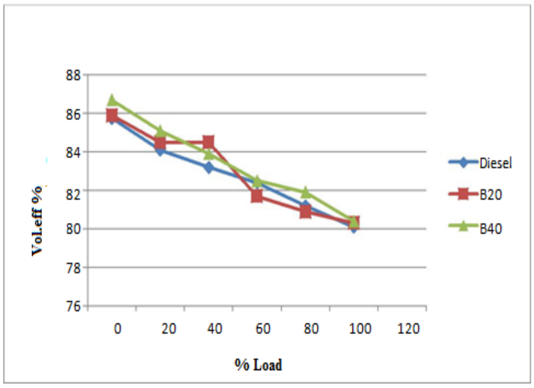


Fig.28. Comparison of Volumetric efficiency of biodiesel fuels with diesel at 23^0injection timing with Thermal Barrier Coating ($MgZrO_2$).

Figure.28 shows the comparison of volumetric efficiency of biodiesel and diesel at 23^0 Injection Timing. The volumetric efficiency of the biodiesel blend (B20) was observed to be higher than diesel and blend (B40) at part loads (40% and 60%) and was decreasing with the increase in the load. This can be attributed to the presence of oxygen in the biodiesel which helps in complete combustion of fuel even at maximum loads thereby releasing more heat which intern causes in the heating up of intake manifold and thereby, in the reduction of volumetric efficiency.

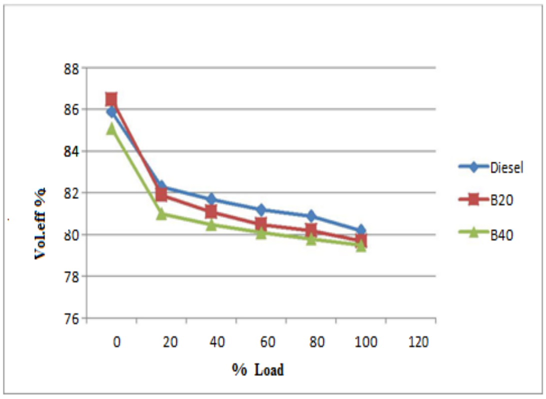


Fig.29. Comparison of Volumetric efficiency of biodiesel fuels with diesel at 25^0injection timing with Thermal Barrier Coating ($MgZrO_2$).

Volumetric efficiencies of low heat rejection engine run with diesel and biodiesel blends at 25^0 injection timing is shown in the fig.29. The volumetric efficiency of the biodiesel blends was observed to be higher than diesel at part load 40% and was decreasing with the increase in the load. At maximum load diesel were higher than the biodiesel blends B40 and B20. This can be attributed to the presence of oxygen in the biodiesel which helps in complete combustion of fuel even at maximum loads thereby releasing more heat which intern causes in the heating up of intake manifold and thereby, in the reduction of volumetric efficiency.

Smoke

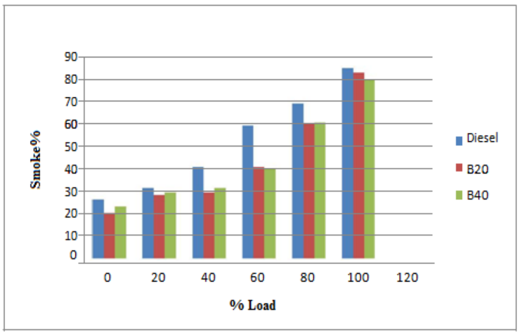


Fig: 30. Comparison of smoke % of diesel and biodiesel fuels at 21^0 injection timing with Thermal Barrier Coating ($MgZrO_2$**)**

Comparison of smoke densities of diesel and biodiesel fuels at 21^0injection timings are shown in fig.30. As can be seen from the figures, the smoke density of the biodiesel blends is significantly less compared to the low heat rejection engine. With diesel engine operation both biodiesel (B40) and biodiesel (B20) results in lower smoke emissions due to better combustion.

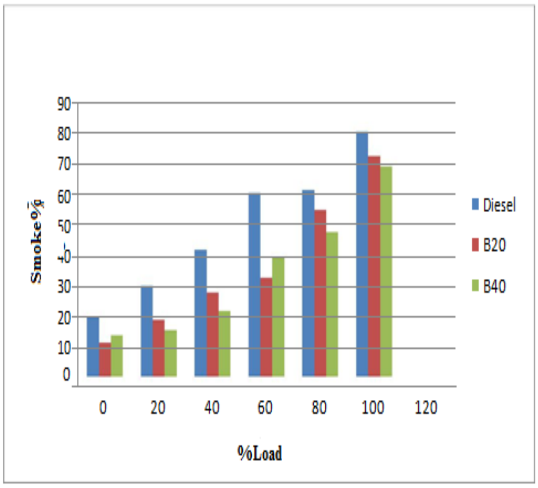


Fig:.31. Comparison of smoke % of diesel and biodiesel fuels at 23^0 injection timing with Thermal Barrier Coating ($MgZrO_2$)

Smoke densities of low heat rejection engine run with diesel and biodiesel blends at 23^0 injection timing is shown in the fig.31. As can be seen from the figures, the smoke density of the biodiesel is significantly less compared to the low heat rejection engine because biodiesel fuel is a carbon neutral it gives less emission. With diesel engine operation biodiesel (B40) results in lower smoke emissions due to better combustion.

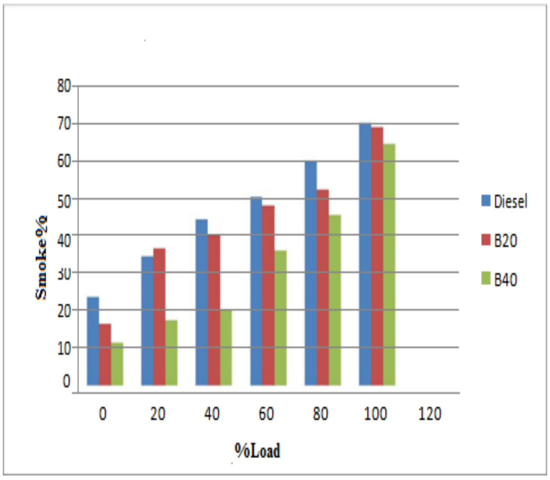


Fig: 32. Comparison of smoke % of diesel and biodiesel fuels at 25^0 injection timing with Thermal Barrier Coating ($MgZrO_2$**)**

Comparison of smoke densities of diesel and biodiesel fuels at 25^0 Injection timings are shown in fig.32. As can be seen from the figures, the smoke density of the biodiesel is significantly less compared to the low heat rejection engine because biodiesel fuel is a carbon neutral it gives less emission. With diesel engine operation biodiesel blend (B40) results in lower smoke Emissions due to better combustion.

V.CONCLUSION

When biodiesel blends were used as fuels, increments in the engine efficiency were mainly caused by the higher mixture heating value of the biodiesel. The deterioration of the engine efficiency for biodiesel fuel was caused by the higher viscosity of the biodiesel. By the application of the thermal barrier coating, the engine efficiency was increased mainly due to better combustion of fuel.

Lower heating value of the biodiesel caused an increase in specific fuel consumption of the biodiesel. As if this reduction would be eliminated particularly in LHR engine, the specific fuel consumption of the biodiesel blends is still higher than that of diesel fuel. Lower heating value of the biodiesel blends also reduced the exhaust gas temperature when biodiesel blends were used in standard diesel engine. With the application of the thermal barrier coating the exhaust gas temperature increases for both fuels in LHR engine.

The brake thermal efficiency of the biodiesel blends improved due to the engine power and torque did not deteriorate too much according to diesel fuel. By the application of the thermal barrier coating, the improvement in the specific fuel consumption caused an increase of the brake thermal efficiency for both fuels in LHR engine.

Scope for the future work:

In the present work piston crown and valves was coated with thermal barrier insulation coating. This is a low degree of insulation. Since there are many levels of degrees of insulations that can be applied for C.I engines, increasing the degree of insulation, heat loss to coolant water can be decreased so that low power consumption cooling systems can be adapted to the engines. As the use of biodiesel doesn't need any modification of the engine, use of other biodiesels derived from renewable feed stocks and their blends can be tested for much better performance and emission characteristics.

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