

Performance Evaluation of IC Engine with Preheated Fuels - A Review

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Abstract - Diesel engines have proved its utility in transport, agriculture and power sector. Environmental norms and scared fossil fuel have attracted the attention to switch the energy demand to alternative energy source. However, use of straight vegetable oil has encountered problem due to its high viscosity. The viscosity of fuel can be reduced by heating. In the current paper review is about various preheated oils. We have referred research on Jatropha oil, Cotton Seed Oil and Thumba oil. Thus, by using heat exchanger preheated Jatropha oil can be a good substitute fuel for diesel engine in the near future. Optimal fuel inlet temperature was found to be 80 degree Celsius considering the brake thermal efficiency, brake specific energy consumption and gaseous emissions Results shows that a blend containing 60 percentage cottonseed oil with diesel, which is heated to a temperature of 70 degree Celsius, can be used as an alternative fuel without any engine modification. Heating of thumba oil up to 80-100 degree Celsius is sufficient to bring the viscosity nearer to diesel.

Key Words: Alternative energy source, Preheated oils, Jatropha Curcas plant, Cottonseed oil, Thumba oil.

1. INTRODUCTION

Energy is considered as an index of economic growth and social development. Per capita energy consumption is considered as the measure of prosperity of a country. The world is moving towards a sustainable energy era with major emphasis on energy efficiency and use of renewable energy sources. Liquid bio-origin fuels are renewable fuels coming from biological raw material and have been proved to be good substitutes for oil in transportation and agriculture sector. These fuels are gaining worldwide acceptance as a solution for problem of environmental degradation, energy security, restricting import, rural employment and agricultural economy. Most promising biofuels and competitive in current market without subsidy are ethanol, methanol, vegetable oil based fuels. Researchers are also striving to develop second generation biofuels from cellulosic materials using different conversion processes.

Main problems associated with the use of vegetable oil in diesel engine are categorized as operational and durability. Former included the ignition quality characteristics, e.g. poor cold engine start-up, misfire, and ignition delay, and latter includes incomplete combustion, e.g. deposit formation, carbonization of injector tip, ring sticking, lubricating oil

dilution and degradation, polymerization during storage. Carbon deposits around the nozzle orifice, upper piston ring grooves and on piston rings are the main problems during the use of vegetable oil as fuel.

Undoubtedly, transesterification is well accepted method of utilizing vegetable oils in Compression Ignition (CI) engine without significant long-term operational and durability issues. However, transesterification process is not easy and requires reaction vessels, chemicals, electricity and heat inputs. This results into complexity of the process and it becomes very difficult for the rural population or the people located in the remote areas to use transesterification of locally available vegetable oils for fueling their farm machinery or stationary diesel engines and it shall be relevant to develop some alternative to transesterification which would permit the use of neat vegetable oil in diesel engine. Different vegetable oils are used as a replacement of diesel fuel.

Vegetable oil can be used either as an extender or complete replacement to diesel fuel. Many researchers have reported encountering difficulties with use of vegetable oil in diesel engine. These difficulties are mainly attributed to the high viscosity of vegetable oils. Due to high viscosity, two strategies can be employed when using Jatropha oil as fuel for use in diesel engines. The first one is to modify the engine to adapt to the fuel, while the second one is to process the fuel to adapt to the engine. Literature suggests that developing special engines like the Elsbett engine or modifying existing diesel engines to preheat Jatropha oil first to reduce viscosity and filter the fuel could achieve first strategy. Modification of engines to run on raw Jatropha oil requires new injector, glow plugs, filter and heat exchanger to the old diesel engine design. Second option is more practical since developing countries and rural community in particular may not have enough funds to support the engine modification. Adaptation of Jatropha oil to the existing diesel engine can be done by blending Jatropha oil with diesel, producing methyl esters through transesterification process that can be used directly instead of diesel. However, fuel modification techniques such as transesterification process require expertise and equipments and not easily understandable to rural community. Exploring the possibility of using neat Jatropha oil can be done by using an auxiliary heat exchanger unit in the existing engine to heat viscous oil by exhaust gases before entering to the engine.

The high viscosity of Cotton Seed Oil (CSO) drastically falls with the increase in the quantity of diesel in the blend. Even with an addition of 20% diesel, the viscosity of the blend drops from 49.6 cSt to 22.3 cSt, which is 55.04% less than that for CSO. In order to reduce the viscosity, the blends were heated from 20°C to 90°C in steps of 10°C.

Different thumba oil blends is preheated with waste exhaust gases for the measurement of performance and emission characteristics.

2. PROPERTIES AND FEASIBILITY OF VEGETABLE OIL

Characteristics of a variety of vegetable oils fall within a narrow band and are closer to those of diesel oil. The kinematic viscosity of vegetable oils varies in the range of 30-40 cSt at 38°C. High viscosity is due to larger molecular mass and chemical structure. Vegetable oils have high molecular weights of 600-900, which are three or more times higher than diesel fuel. The flash point of vegetable oils is also very high (above 200°C). Their heating value is at the range of 39-40 MJ/kg, comparatively lower than that of diesel fuels (about 45 MJ/kg). This is because the presence of chemically bonded oxygen in vegetable oil lowers heating value by about 10%. Cetane number is in the range of 32-40, while the iodine value ranges from 0 to 200, depending upon unsaturation. The cloud and pour point of vegetable oils are higher than that of diesel fuel.

In the light of above facts, it is clear that straight vegetable oil is not suitable as fuel for diesel engine; hence they have to be modified to bring their combustion properties closer to diesel. Exploring the possibility of using neat Jatropha oil can be done by using an auxiliary heat exchanger unit in the existing engine to heat viscous oil by exhaust gases before entering to the engine.

3. PREHEATING OF FUELS

Oil derived from Jatropha curcas plant has been considered as a sustainable substitute to diesel fuel. The aim of present work is to reduce the viscosity of oil by heating before fed to the engine. Jatropha oil is heated from 40-100°C. The viscosity of cottonseed oil (CSO), which is considered a potential alternate fuel, is reduced by blending it in different proportions with diesel, and its viscosity at various temperatures was analyzed and used as a fuel in a compression ignition (CI) engine. In order to reduce the viscosity, the CSO blends were heated from 20°C to 90°C in steps of 10°C. The viscosity of 20%, 40% and 60% diesel blends at 70°C are close to that for diesel. Therefore, blends containing 20%, 40% and 60% diesel were tried as a fuel for the CI engine and results for 20% and 40% are presented keeping in mind the maximum reduction of diesel usage. Viscosity of thumba oil is reduced by blending with diesel fuel along with preheating through waste heat of engine's exhaust gases instead of transesterification, that requires chemicals and process heat, which is not available in rural area due to

logistic problem. Thumba oil is heated upto 80-100 °C, also various blends of thumba oil with diesel is used for testing. Jatropha oil, CSO and thumba oil is heated to reduce the viscosity and then fed to engine.

Performance parameters and emission characteristics are plotted in the form of graphs.

3.1 Performance and Emission Study of Preheated Jatropha Oil on Medium Capacity Diesel Engine

The variation of the brake thermal efficiency (BTE) of the engine vs brake mean effective pressure with preheated Jatropha oil at different temperature is shown in Chart 1 and compared with baseline data of diesel and unheated Jatropha oil. It was observed that initially with increasing brake power; brake thermal efficiencies of all the fuels were increased and then tend to decrease with further increase in brake power. Brake thermal efficiencies of Jatropha oil (unheated and preheated) were found to be lower than diesel fuel throughout the entire operating range. As the degree of temperature of preheating of Jatropha oil increases brake thermal efficiency also increases and at highest temperature it is close to diesel fuel. The possible reason for this reduction is lower calorific values due to presence of oxygen in unsaturated hydrocarbon and high viscosity of Jatropha oil as compared to diesel fuel. However, thermal efficiency of preheated Jatropha oil was higher than unheated Jatropha oil. This is due to the fact that preheated Jatropha oil has lower viscosity which results in increase of brake thermal efficiency. In case of preheated Jatropha oil highest brake thermal efficiency was found at 100°C. Peak thermal efficiency for PJO 40 (preheated Jatropha oil at 40°C), PJO 60 (preheated Jatropha oil at 60°C), PJO 80 (preheated Jatropha oil at 80°C) and PJO 100 (preheated Jatropha oil at 100°C) was 26.17%, 26.44%, 27.4% and 27.69% respectively whereas peak thermal efficiency of diesel was 28.51%.

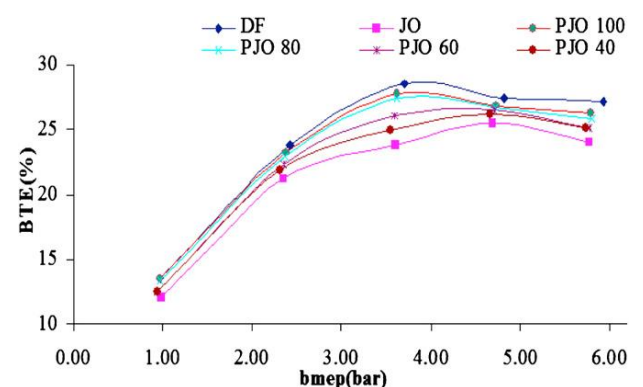


Chart -1: Variation of brake thermal efficiency with brake mean effective pressure

Brake specific energy is a parameter to compare the energy requirement for producing unit power in case of each test fuel. Variation of BSEC (brake specific energy consumption) vs. BMEP (brake mean effective pressure) for all the test fuels is shown in Chart 2. It is clear that brake specific energy consumption of Jatropha oil (either unheated

or preheated) is higher than diesel which is due to high density and low calorific value of fuel. It was observed that with increase in degree of preheating, brake specific energy consumption was found to be lower. This was due to the fact that higher fuel inlet temperature results in lower viscosity which causes better atomization and subsequently better combustion and results in lower brake specific energy consumption.

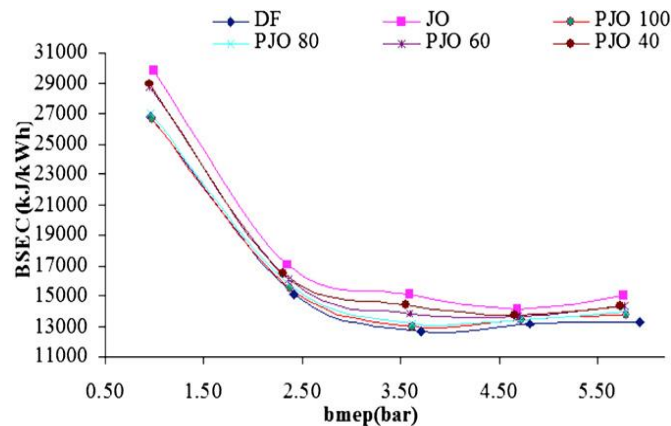


Chart -2: Variation of brake specific energy consumption with brake mean effective pressure.

Chart 3 shows the comparison of CO emissions for all the test fuels at different engine load. Within the experimental range, CO emission of unheated Jatropa oil is higher than diesel fuel and preheated Jatropa oil. This is possible because of high viscosity of vegetable oil. Higher the viscosity, more difficult is to atomize inside the combustion chamber and hence incomplete combustion occurs in case of vegetable oil as fuel.

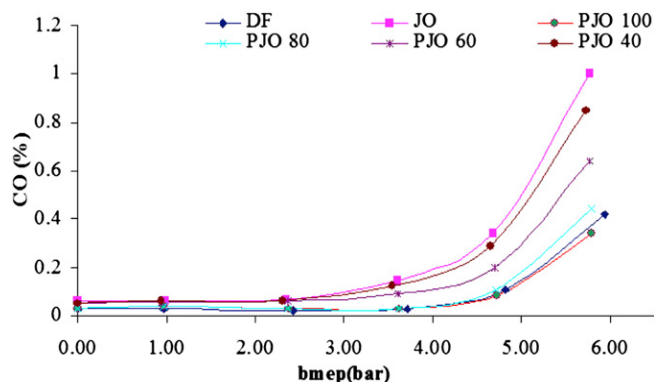


Chart -3: Variation of carbon monoxide with brake mean effective pressure.

3.2 Performance of Pre-Heated Cottonseed Oil and Diesel Fuel Blends In a Compression Ignition Engine

The brake thermal efficiency plots in Chart 4 shows an increase of brake thermal efficiency with increase in the engine load, as the fuels are preheated. The brake thermal efficiency of CSO increased from 28% to 28.8%. The values are 30% and 30.5% as against 32.3% for diesel at 100% load. This is due to the reduction in viscosity, density and

improved atomization, fuel-air mixture formation and increase in the heating value as the proportion of diesel in the blend increases.

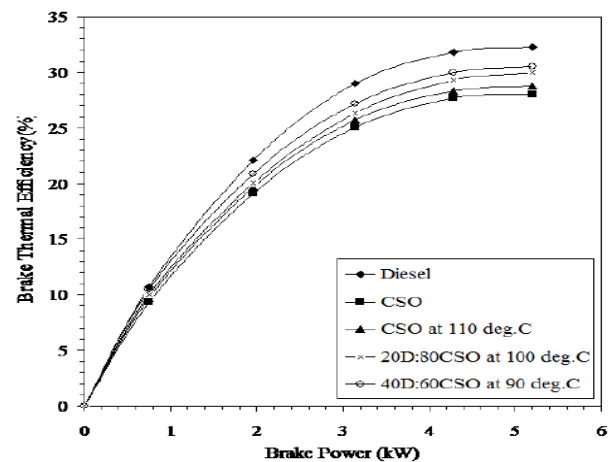


Chart -4: Variation of Volumetric efficiency with brake power.

Chart 5 shows the variation of volumetric efficiency with brake power. There is an improvement of volumetric efficiency with preheat when compared to CSO at room temperature. The volumetric efficiency of preheated oil increased from 82.3% to 83% at the peak load. The trend is the same for the blends also. Volumetric efficiency is 84.6% for diesel and 84.12% for 40% preheated diesel blend.

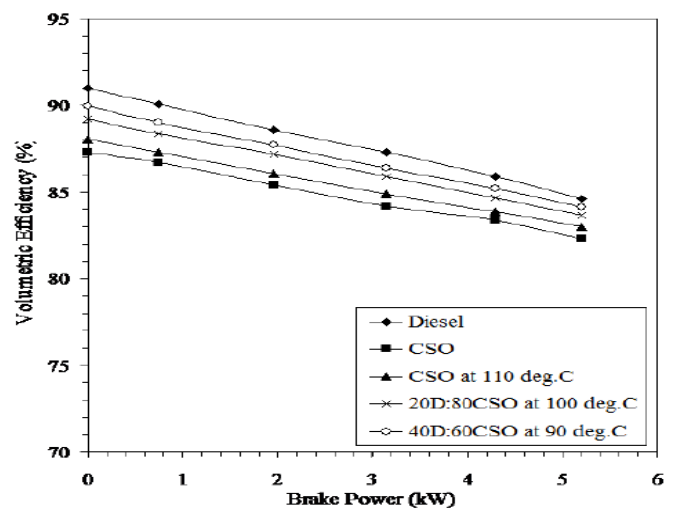


Chart -5: Variation of Volumetric efficiency with brake power.

Chart 6 is about Variation of Carbon Monoxide Emission with brake power. Continuous exhaust gas sampling shows a significant reduction in the hydrocarbon and carbon monoxide emissions with the preheated CSO and the blends as compared to neat CSO. Nevertheless, through out the load range, the HC and CO emissions for CSO, preheated CSO and blends were higher than that for diesel. However, the HC and CO levels are less for preheated CSO when compared to neat CSO.

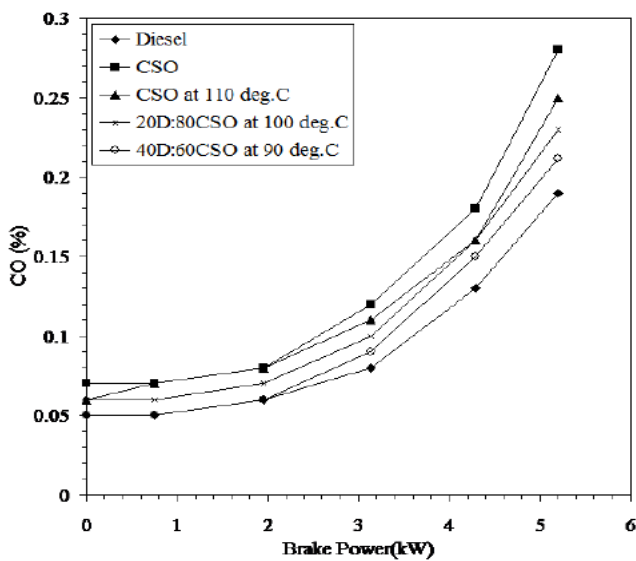


Chart -6: Variation of Carbon Monoxide Emission with brake power.

3.3 Performance and Emission Characteristics of Preheated and Blended Thumba Vegetable Oil in a Compression Ignition Engine

Break thermal efficiency (BTE) increases with rise in load and same trend is found for all the blends of thumba oil. It is observed from Chart 7 that BTE decreases as the blend percentage of thumba oil increases. BTE of B20 (20% Thumba oil with 80% Diesel fuel) thumba oil blend is higher than other blend of thumba oil. Results of B10 and B30 are closer to B20. BTE for B10, B20, and B30 blends at 100 % load are 24.2%, 25.93 %, and 25.23% respectively.

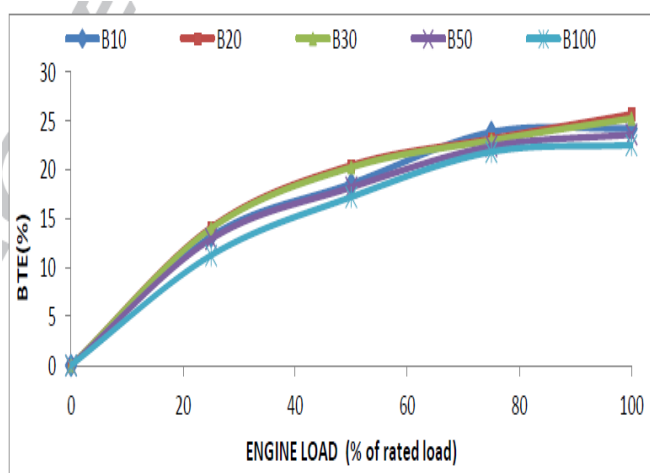


Chart -7: Break thermal efficiency of various preheated thumba blend v/s load

Chart 8 is about Comparison of BTE of diesel, preheated and unheated thumba B20 blend v/s load. It is observed that BTE for diesel is higher than both unheated and preheated

all thumba blends for all the load conditions. Possibly it is due to higher viscosity of both pre heated and unheated thumba B20 blend than the diesel and higher fuel viscosity results in poor atomization and followed by inadequate mixing of fuel and air.

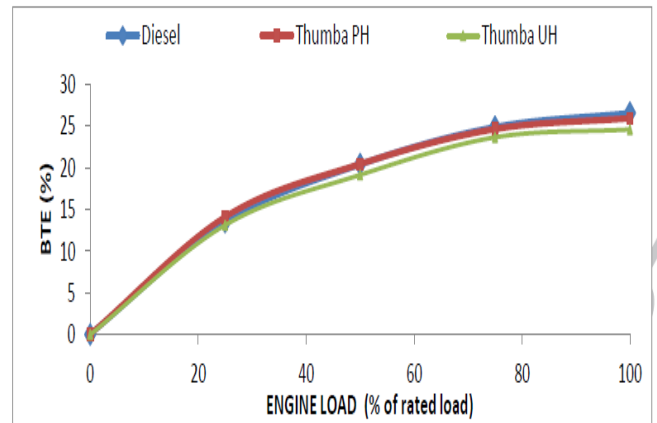


Chart -8: Comparison of BTE of diesel, preheated and unheated thumba B20 blend v/s load

Break specific fuel consumption (BSFC) for various preheated thumba blends from B10-B100 has been shown in Chart 9. BSFC is decreases as the load is increases and it is increases as the blend percentage of preheated thumba oil increases.

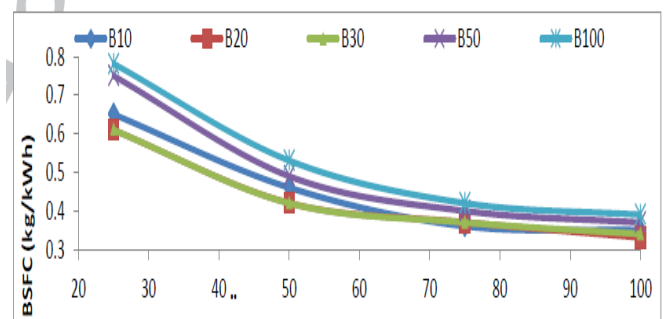


Chart -9: BSFC for various thumba oil blends at different load

Comparison of BSFC for diesel, preheated B20 thumba blend, and unheated same thumba blend has been shown in Chart 10. BSFC decreases as the load increases and it is lowest at 100% load. BSFC for diesel fuel and preheated thumba B20 blend (0.33 kg/kWh) is same and lower to unheated B20 thumba blend (0.35). Preheating improves atomization and mixing of fuel so that BSFC is reduced.

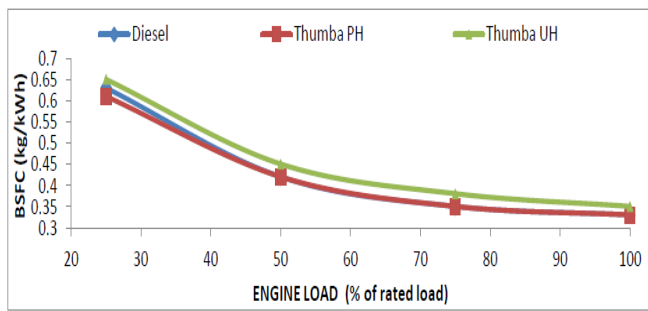


Chart -10: Comparison of BSFC for preheated and unheated thumba oil B20 blend and diesel

Carbon monoxide (CO) emitted due to incomplete combustion of fuel and CO emission with various preheated thumba blends has been shown in Chart 11. CO emission decreases on initial loading and increases on further loading for all the thumba blends except B20 preheated thumba blend, in which emission remain constant after 50% rated loading. It is lowest for B20 preheated thumba blend as compared to all other blends at full load condition.

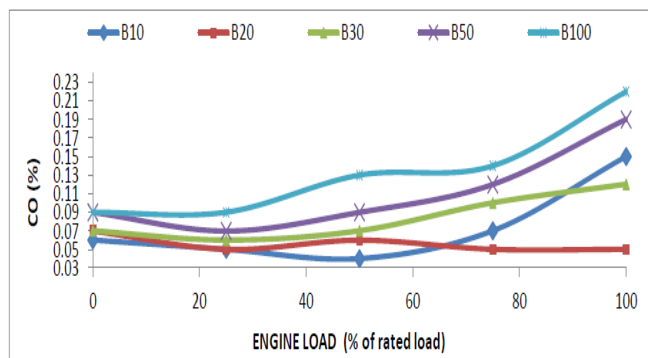


Chart -11: CO emissions for various preheated thumba oil blends at different load

Comparison of CO emission for diesel preheated and unheated B20 blend has been shown in Chart 12. CO emission for preheated B20 (0.05%) blend is lower than both diesel (0.06%) and unheated B20 blend (0.07%). It shows better combustion for preheated B20 blend than diesel and unheated same blend.

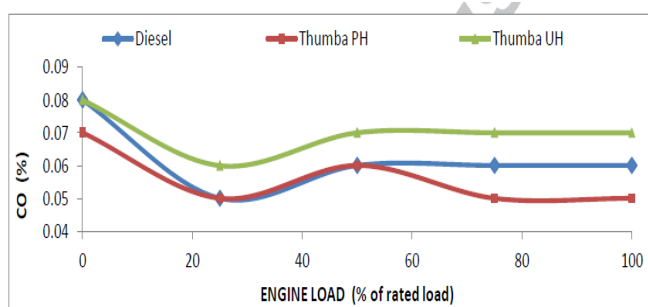


Chart -12: Comparison of CO emissions for diesel, preheated and unheated thumba oil B20 blend

3.4 Conclusions

As fuel inlet temperature of Jatropha oil increased, viscosity decreased, the engine performance improved. Thermal efficiency of the engine was lower and brake specific energy consumption of the engine was higher when engine was fueled with unheated Jatropha oil compared to diesel fuel. However, in case of preheated Jatropha oil, these parameters were superior to unheated Jatropha oil.

The blend containing 20% and 40% diesel, preheated to 70°C shows an increase in brake thermal efficiency, which is very close to diesel. Volumetric efficiency increases for preheated CSO.

Highest thermal efficiency and lowest break specific fuel consumption are found for preheated B20 thumba blend among all the preheated thumba blends. Preheated optimized thumba B20 blend gives 1.27% (25.93%) higher thermal efficiency and 0.02 kg/kWh (0.33 kg/kWh) lesser break specific fuel consumption than the unheated same blend (24.66%) (0.35kg/kWh).

Preheating of fuels such as Jatropha oil, CSO, thumba oil blend improve engine performance and emission.

4. RESULT AND CONCLUSION

Results show that BTE (brake thermal efficiency) of engine was lower and BSEC (brake specific energy consumption) was higher when the engine was fueled with Jatropha oil as compared to diesel fuel. Increase in fuel inlet temperature resulted in increase of BTE and reduction in BSEC.

Lower thermal efficiency (28%) is found in neat CSO compared to diesel (32.3%). However, preheating the mixture increases the thermal efficiency.

Preheating of optimized thumba blend results an improvement in break thermal efficiency by 1.27%. It also gives reduced smoke opacity, CO, HC emissions by 2.6%, 0.2%, and 5 PPM respectively.

Preheating of Jatropha oil, CSO, thumba blend oil increases break thermal efficiency of the engine. CO emission is reduced for preheated Jatropha oil, CSO, B20 thumba oil blend.

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