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Comparative Performance Evaluation of IDI Engine Fueled with Mahua Biodiesel blended with Additive

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***Abstract*:- The mahua oils is available in larger quantity without being utilized in accordance to its potential. Mahua Bio-diesel is a renewable, inexhaustible and a clean burning fuel. The research has been carried out to ascertain the feasibility of utilization of mahua biodiesel in CI engines. The viscosity index of mahua biodiesel is found to be high which imposes the limitation of its utilization for better engine performance. The additives have been used to reduce the viscosity. The testing of engine with modified fuel was carried out with changes in injector pressure and time of fuel injection. Performance and emission parameters were recorded while changing the engine operating parameters. The result analysis was carried out to find fuel injection pressure and injection timing to achieve optimum engine performance. The engine performance at manufacturer's designed operating parameter and the new set of operating parameters were compared. The specific fuel consumption was minimum when 0.75% Ethyl Acetone was added, the injection pressure was 185 bar and the fuel was injected at 24^0 crank angle before TDC. The brake thermal efficiency (BTE) was obtained 31.68% with Mahua biodiesel mixed with additive and engine run at suggested operating parameter against 32% with diesel fuel. The recommended new operating parameters also improved engine emission characteristics to great extent.**

Keywords: Mahua oil, Additives, BTE, BSFC, BTDC

1. INTRODUCTION

Preparation of biodiesel from mahua oil by process of trans-esterification was carried out. The viscosity of mahua biodiesel was still higher than the commercial diesel. The reduction of viscosity to greater extent was further achieved by adding additive. The fuel injection system of diesel engine is modified to achieve efficient combustion sand thereby higher BTE. The suggested engine modification can be implemented to existing engine without much of the cost involved in it. This research work was aimed to modify the engine which can run efficiently with blend of mahua biodiesel blend with additive. The modified fuel injection system and addition of additive in biodiesel not only enhance the engine performance but also improve the emission characteristics of engine.

The use of non-edible oil as fuel in diesel engine has potential to provide a low cost sustainable energy solution. High viscosity of fuel results in injector choking, gum formation and piston sticking on long term (Haldar et al, 2009). Herchel (Herchel T.C. et al, 2009) states that one hundred percent vegetable oil can be used safely in an indirect injection engine but not in direct engine due to high degree of atomization required for this type. Mustafa Canakci (Mustafa Canakci et al, 2009) has tested the SVO for combustion analysis in IDI diesel engine and reported that high viscosity and density of vegetable oil led to problem in the injection system and combustion chamber of the engine for a long term usage. Therefore it is warranted that the viscosity should further be reduced in order to attain viscosity close to the value of viscosity of commercial diesel. The desired result can be achieved by different methods but in this research work the additive have been added to the mahua biodiesel.

Deepak Agrawal (Agarwal Deepak et al, 2008) stated that the vegetable oils have comparable heat content, cetane number, heat of vaporization, stoichiometric air / fuel ratio with mineral diesel. He also commented that, the use of SVO in diesel engine present problems primarily due to their high viscosity and low volatility. Michael (Michael S. et al, 1998) investigated that besides the viscosity effect the surface tension also affects the spray particle size. Higher the surface tension, higher the droplet size. The droplet size of fuel in combustion chamber directly influences the fuel atomization efficiency. Habbal (Hebbal O.D et al, 2010) also reported that the viscosity of Deccan Hemp oil (non edible SVO) on heating to 95^0 C became almost equal to the viscosity of petro diesel at 30^0 C. The high viscosity leads to poor atomization of fuel spray and less accurate operation of the fuel injectors (Michael S. et al, 1998). Abolle Abolle, Loukou Kouakou, Henri Planche (Henri Planche et al, 2009) reported that the sauter mean diameter (SMD) which is the ratio the mean volume to the mean surface area of the fuel droplet has important role in defining fuel atomization characteristics.

2. CHARACTERIZATION OF MAHUA BIODIESEL:

The biodiesel obtained from Mahua feed stock was purchased from market. The physio- chemical properties of mahua biodiesel were determined in lab. Following results obtained is listed in table 1. The calorific value was found to be 39 MJ/kg against 42MJ/kg of commercial diesel. This indicates that the calorific value of mahua Biodiesel is comparable to the calorific value of commercial diesel. The viscosity of mahua biodiesel is 4.98cSt, which is much higher than the viscosity of diesel.

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Table1: Physio-Chemical properties of Diesel, Mahua Oil and Mahua Biodiesel

Fuel properties	Commercial diesel	Mahua oil	Mahua Bio diesel
Calorific value (MJ /kg)	42	37	39
Flash point (^{0}C)	68	226	197
Specific Gravity	850	956	882
Auto ignition temperature (^{0}C)	-	-	317
Viscosity (cSt @ 25^{0}C)	2.98	23.68	4.93
Carbon Residue	0.73	3.2	0.22

3. EXPERIMENTAL TEST SET UP

3.1 Engine

Adequate arrangements were made in the diesel engine so that operating parameters can be varied as per the requirement. The IDI diesel engine used for experimentation was designed and made by Field Marshal Diesel Engines Pvt. Ltd. India. The engine is low speed engine which was connected with alternator having capacity of 7.5kVA when operated by mineral diesel fuel. The design parameters of engine and generator are listed in Table 2.

Table2: Design parameters of Experimental test set up

Sl No	Parameters	
1	No of Cylinders in engine	One
2	Type of engine	4 stroke , vertical cylinder
3	Engine cooling	Water Cooled
4	Bore	120mm
5	Stroke	139.7mm
6	Sped of engine	Constant speed of 1000 rpm
7	Type of engine governor	centrifugal speed governor
8	Power output	7.35kW
9	Type of generator	230 V single phase AC generator
10	Generator capacity	7.5kVA

3.2 Engine Data Acquisition Systems

Resistive engine loading system was fabricated. The output of engine alternator was supplied to the load bank having heating coils of1000Watts each and filament bulb of 200W each. The engine was tested at variable engine loads. Standards burette arrangement was used for measuring the fuel consumption. The time taken for consumption of 50 cc fuel was recorded using stop watch. The gravity feed supply of fuel to the injector was ensured by placing the fuel tank at appropriate level. The temperatures were measured by thermocouples made of Chromel / alumel. Sensors were installed at inlet and outlet ducts of exhaust gas, lubricating oil as well as cylinder wall. The temperatures were recorded through digital temperature indicators connected with these sensors.

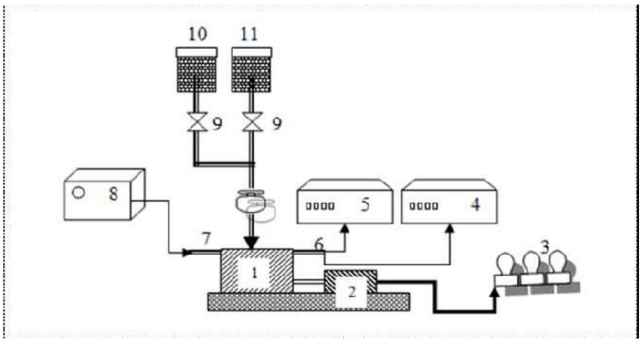

Figure1: experimental test set up

3.3 Measurement of emission parameters of exhaust gas:

The exhaust gas was analyzed using gas analyzer (AVL DIGAS – 4000 model). The measurements of CO, CO_2, NO_x, O_2 and HC contained in exhaust gas were done using gas analyzer. NDIR (Non-diffractive infrared radiation) technology was utilized for measuring the emission parameters. The technical specification of gas analyzer is shown in Table3. Smoke opacity was measured by using smoke meter (AVL Austria, 437).

Table3: Exhaust gas analyzer specifications

Exhaust gas	Resolution	Measurement range
NO_x	1vol ppm	0-4000 vol. ppm
CO	0.01 vol. %	0-10 vol. %
CO_2	0.1 vol %	0-20 vol. %
HC	1ppm	0-20000ppm
O_2	0.01 vol. %	0-22 vol. %

4. SELECTION OF ADDITIVES:

The additives used for reducing the viscosity are ethyl acetate, methyl isobutyl ketone and methanol, acetone, methanol, acetone and methanol, and ethanol. In this research work the ethylene acetone has been taken as additive. The different quantities (0.00%, 0.25%, 0.50%, 0.75% and 1.00%) of additive were mixed with biodiesel and the mixture was kept for 3hours. The viscosity of mixture was determined after 3 hours; it was found that the optimum quantity of additive was 0.75% which reduces the viscosity by 39%.

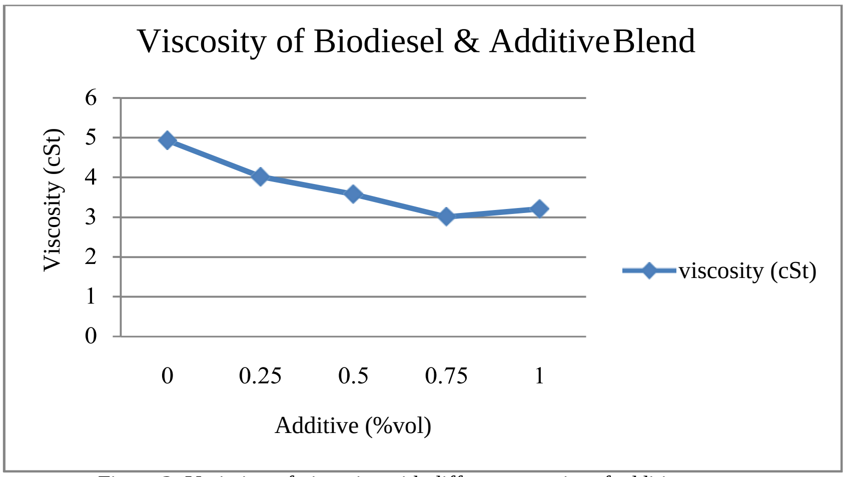

Figure 2: Variation of viscosity with different quantity of additives

5. ENGINE PERFORMANCE:

5.1 Effect of fuel injection pressure on engine performance:

The engine test was carried out at different engine operating parameters. The designed operating parameters for optimum performance as prescribed by engine manufacturer are 165 bar fuel injection pressure and 22 degree BTDC fuel injection time. The fuel injection pressure was varied from 145 bar to 205 bar at an interval of 10bar while keeping the fuel injection time constant at 22 degree BTDC. The engine was tested with diesel fuel and the blend of additive and Mahua biodiesel. It wasobtained that the diesel engine efficiency deteriorated when the injection pressure was reduced from 165 bar and also when the pressure was increased more than 165 bar. The optimum BTE for diesel fuel was 32% at 165 bar fuel inject pressure. When the engine was tested with blend of additive and Mahua biodiesel, the engine performance was obtained minimum at 145bar. The engine efficiency increased when the injection pressure was increased. The maximum efficiency was obtained at fuel injection pressure 185bar. The efficiency was reduced when the injection pressure was increased beyond 185 bar.

The efficiency increases at increased fuel injection pressure because the fuel particle size injected in combustion chamber reduces at higher injection pressure. The smaller fuel particle size results more efficient fuel atomization process leading to more efficient combustion process. At very high injection pressure the fuel particle size injected in combustion chamber gets reduced to such an extent that the momentum of fuel particle gets reduced to great extent, hence fuel particle can not traverse in combustion chamber to large distance. This phenomena reduces the scavenging efficiency and the hence suffocation inside the combustion chamber takes place, Due to non efficient scavenging process the combustion efficiency also gets deteriorated and hence engine outputreduces.

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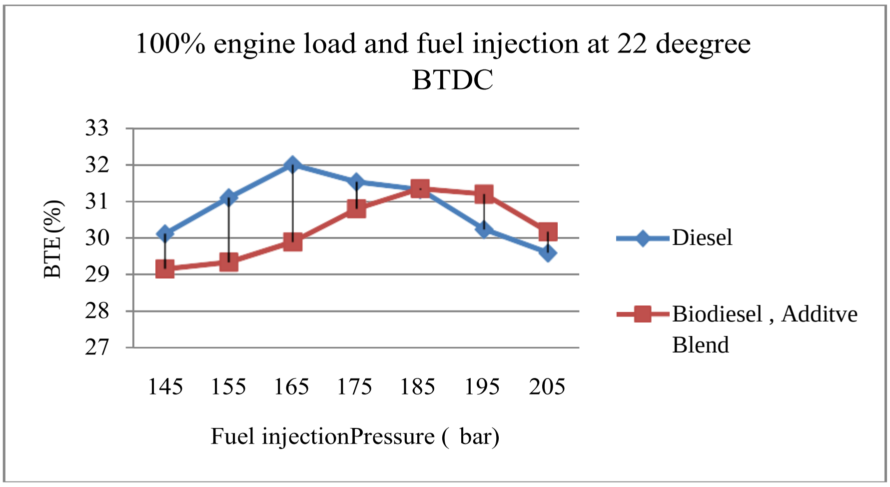

Figure 3: Effect of fuel injection pressure on BTE

5.2 Effect of fuel injection time on engine performance:

The engine was tested at variable fuel injection advance angle from 20^{0}BTDC to 26^{0}BTDC while keeping the fuel injection pressure 165 bar. The engine efficiency with diesel as test fuel was obtained 31.40% against the engine efficiency 32% at 22^0 BTDC fuel injection time. As the fuel injection advance angle was further reduced the engine efficiency started reducing. The engine efficiency with blend of additive and Mahua biodiesel was obtained 29.89% at 20^{0}BTDC. The engine efficiency increased as the advance angle of fuel injection was reduced to 22^{0}BTD and 24^{0}BTDC, where as the efficiency started reducing as the advance angle o f fuel injection was further reduced to 26^{0}BTDC . The optimum engine performance was obtained at 24^{0}BTD fuel injection pressure.

The increases in efficiency at retarded fuel injection time could have taken place because time available for air fuel mixture to complete pre combustion process gets increased. The increased time availability results to efficient fuel atomization and thereby efficient combustion phenomenon. The engine efficiency reduced as the fuel injection was further advanced beyond 24^{0}BTD because the maximum pressure in combustion chamber could have occurred much before TDC hence some of the work output might have been used to take the piston to TDC against higher combustion chamber pressure. The optimum efficiency of engine with biodiesel-additive blend at 24^0 BTDC was obtained to be 31.02% .

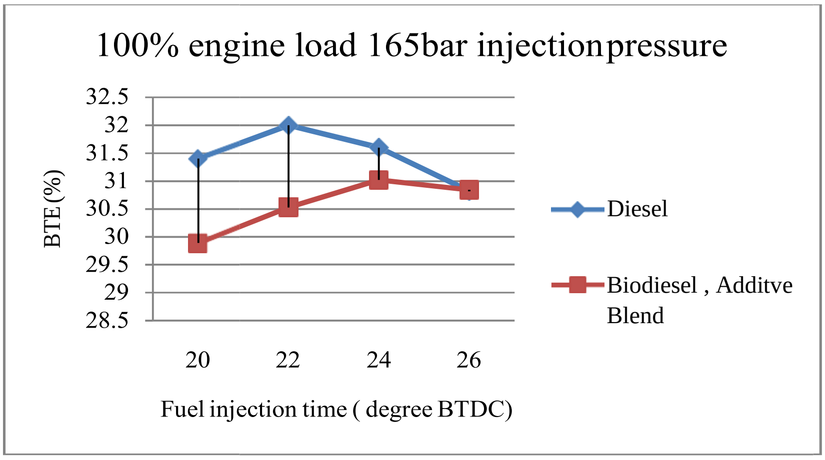

Figure4: Effect of fuel injection time on BTE

5.4 Cumulative effect of Fuel injection pressure and Fuel injection time on Efficiency

As we could observe that the fuel injection pressure and advance angle of fuel injection time increases the engine efficiency individually. The cumulative effect of these operating parameters on engine efficiency was studied. The engine was operated at variable load (0%, 25%, 50%, 75% and 100%) with fuel injection pressure 185bar and fuel injection time 24^{0}BTDC.

The engine efficiency with diesel fuel as well as with blend of additive and Mahua biodiesel increased as the engine load was increased. The optimum efficiency in both the cases had been obtained at 100% engine load. The cumulative effect of both the operating parameters, 185bar fuel injection pressure and 24^{0}BTDC fuel injection time on engine efficiency was recorded while operating the engine at 100% load. The efficiency was attained to be 31.68% against the engine efficiency with diesel fuel 32%.

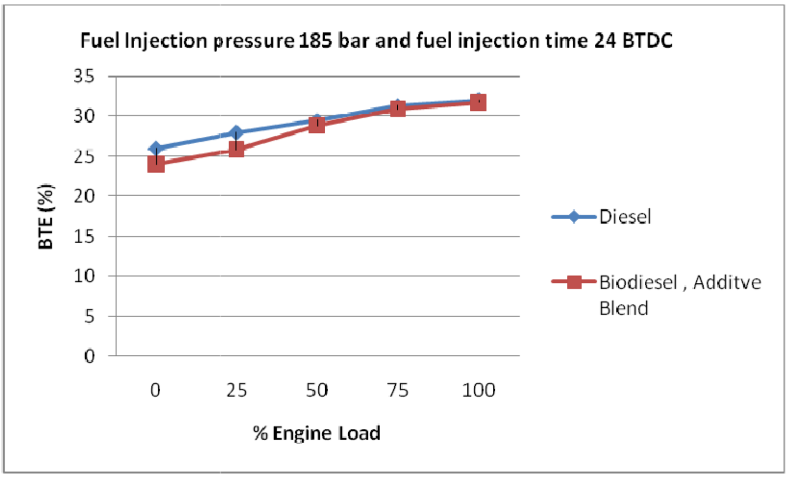

Figure 5: Comparison of BTE of Diesel fuel ant recommended test fuel

6. ENGINE EMISSIONS:

6.1 CO emission of test fuel at recommended operating parameter in comparison to commercial diesel

The CO emission has been recorded using AVL gas analyzer. The engine was run with diesel fuel at variable engine loads (0%, 25%, 50%, 75% and 100%) and CO emission was recorded. Again the engine was run at same load conditions with fuel as blend of mahua biodiesel and additive and emission was recorded.

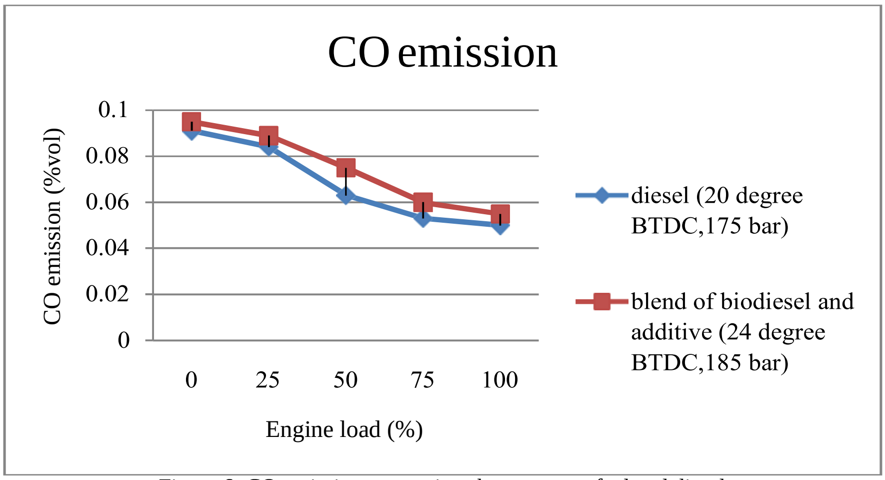

Figure 6: CO emission comparison between test fuel and diesel

It was observed that CO emission gap between both the fuels was very less at 0% engine load condition, which increased till the engine load was reached to 50% and thereafter gap was decreased as the load was increased to 100%. The CO emission with test fuel at 100% engine load was found to be 0.055% vol against CO emission 0.050 % volume with diesel fuel. Though the emission was higher but it was very close to value of CO emission with reference fuel.

6.2 CO_2 emission of test fuel at recommended operating parameter in comparison to commercial diesel

The CO_2 emission has been recorded using AVL gas analyzer. The engine was run with diesel fuel at variable engine loads (0%, 25%, 50%, 75% and 100%) and CO emission was recorded. Again the engine was run at same load conditions with fuel as blend of mahua biodiesel and additive and emission was recorded. It was observed that CO_2 emission gap between both the fuels was 0.15% vol at 0% engine load condition, which decreased to 0.05 % vol at 100% load condition. Though the CO_2 emission was 4.1% higher with blend of mahua biodiesel and additive yet it was very close to value of CO_2 emission with reference fuel.

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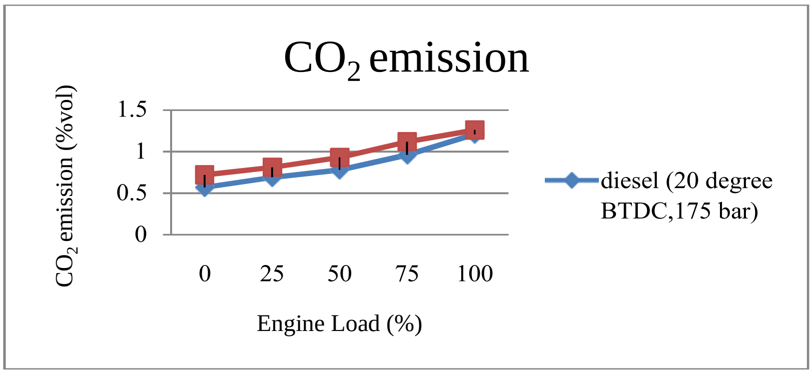

Figure 7: CO_2 emission comparison between test fuel and diesel

6.3 HC emission of test fuel at recommended operating parameter in comparison to commercial diesel

The HC emission has been recorded using AVL gas analyzer. The engine was run with diesel fuel at variable engine loads (0%, 25%, 50%, 75% and 100%) and HC emission was recorded. Again the engine was run at same load conditions with fuel as blend of mahua biodiesel and additive and emission was recorded. It was observed that HC emission gap between both the fuels was very less at 0% engine load condition, which increased till the engine load was reached to 50% and thereafter gap was decreased as the load was increased to 100%. The HC emission with test fuel at 100% engine load was found to be 5.1 ppm against CO emission 4.5ppm with diesel fuel. The HC emission was higher with fuel mahua biodiesel and additive blend in comparison to reference fuel by about 13%.

6.4 NOx emission of test fuel at recommended operating parameter in comparison to commercial diesel

The NOx emission has been recorded using AVL gas analyzer. The engine was run with diesel fuel at variable engine loads (0%, 25%, 50%, 75% and 100%) and NOx emission was recorded. Again the engine was run at same load conditions with fuel as blend of mahua biodiesel and additive and emission was recorded. It was observed that NOx emission gap between both the fuels was large at 0% engine load condition, which decreased at 100% engine load. The NOx emission with test fuel at 100% engine load was found to be 361ppm against NOx emission 350 ppm with diesel fuel. Though the emission was 3.1% higher but it was very close to value of NOx emission with reference fuel.

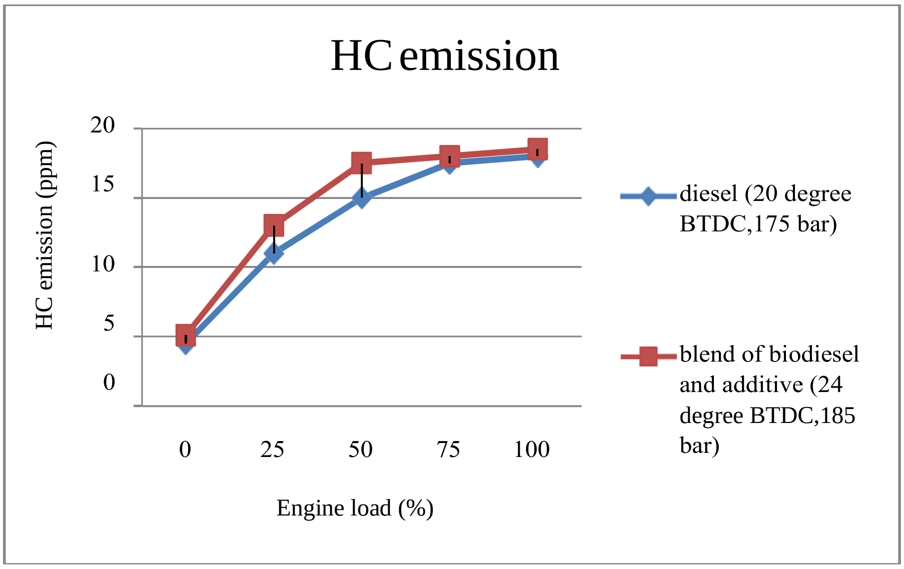

Figure 8 : HC emission comparison between test fuel and diesel

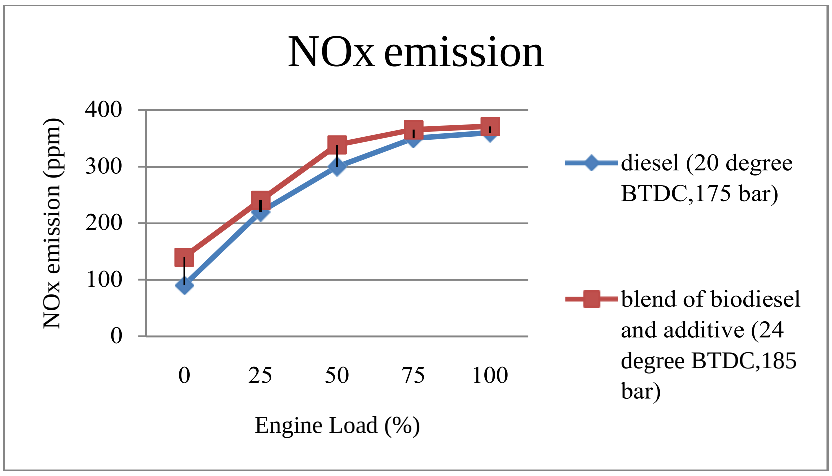

Figure 9: NOx emission comparison between test fuel and diesel

7. CONCLUSION AND SCOPE OF FUTURE WORK

The research was carried out with an objective to search for such alternate fuel whose efficiency can be almost the same as the efficiency of engine with commercial diesel as reference fuel. The viscosity of mahua biodiesel was reduced to great extent by adding additive, reduced viscosity enhanced the fuel atomization characteristics of test fuel which ultimately improved the combustion efficiency.

In the literatures available in this direction it has been reported that the engine efficiency with mahua biodiesel is much lower than the engine efficiency using diesel. It is also reported that the major reason for low efficiency is higher viscosity of mahua biodiesel. Many researchers enhanced the efficiency by using method of pre-heating the biodiesel but it needs heat source and also heat exchanger for transfer of heat. Therefore, major modification in engine design is required in this process. The higher viscosity of mahua biodiesel presents less efficient fuel atomization characteristics and hence less efficient combustion efficiency giving low BTE. In present research work the viscosity was reduced by use of additive which does not need any change of engine hardware. The engine efficiency by use of recommended fuel operating at recommended operating parameter gives BTE of engine 31.68% in comparison to 32% engine efficiency with diesel fuel. The emission parameters were also tested, it was found that emission with mahua biodiesel was higher than the emission using reference fuel but the difference was very less. Hence, the recommended fuel can be accepted as a potential alternate fuel of diesel engine while giving good Brake Thermal efficiency.

The scope of search for some other additive which can improve the viscosity further more can explored as future work. Also, the test can be carried out to test the DI diesel engine with recommended fuel as scope for future work.

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