Effect of supercharging and combustion improving additives on the performance and combustion characteristics of diesel engine fueled with mahua biodiesel

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Abstract— An experimental study has been conducted to evaluate the effects of supercharging and using diethyl ether as an additive to biodiesel blend on the performance and emission of a direct injection diesel engine. The mahua biodiesel and diesel are blended with diethyl ether (DEE) in the ratio of 0:100:0, 15:80:5, 20:75:5, 25:70:5, 100:0:0 by volume and tested in CI engine. The results obtained were compared with neat diesel, there was slightly lower brake specific fuel consumption for diesel-biodiesel blend. Strong reduction in emissions was observed with diesel – biodiesel-DEE at various engine loads. Methyl ester of mahua biodiesel at 20% and DEE 5% blend with 75% diesel gave best performance in terms of low smoke intensity and emissions characteristics. The optimum blend, M20 (D75M20A5) fuel is used in diesel engine with supercharged condition. In this experimental work M20 blend at 20% supercharging gave best performance in terms of low smoke intensity and emission characteristics.

Keywords— Diesel, biodiesel, diethyl ether, performance, emission.

I. INTRODUCTION

Several alternative fuels have been studied by research scientist as substitute for the diesel fuel partially or completely. Alternative fuels derived from biological sources provide a means for sustainable development, energy conservation, energy efficiency and environmental protection. Some of the alternative fuels explored are biogas, ethanol, vegetable oils etc. the high viscosity of vegetable oils and their low volatility affects the atomization and spray model of fuel, leading to incomplete combustion and severe carbon deposits, injector choking and piston ring sticking. The various methods used to reduce the viscosity are pyrolysis, blending with diesel, trans-esterification and emulsification. In particular, biodiesel has received broad attention as an alternate for diesel fuel because it is recyclable in plant cycle, non-toxic and can significantly reduce exhaust emissions from the engine. Many researches show that using biodiesel in diesel engines can reduce hydrocarbon (HC), carbon monoxide (CO) and opacity emissions, but nitrogen oxide (NOx) emission may increase. Biodiesel can be used in the existing engines without any modifications and the biodiesel obtained from vegetable sources does not contain any metals, aromatic hydrocarbons and Sulphur or crude oil residues. Since biodiesel is an oxy -fuel; emissions of carbon monoxide and soot tend to reduce. The oxygen content of bio diesel is an important factor in the NOx formation, because it causes high local temperatures due to excess hydrocarbon oxidation. The little higher cetane numbers and the absence of aromatics components tend to contribute to less NOx production. On the other hand, biodiesel has some disadvantages such as higher viscosity, pour point and lower volatility compared with neat diesel. The poor cold flow property of biodiesel is a barrier to the use of biodiesel-diesel blends in cold weather. Fuels additives have become essential tool not only improves the performance and combustion of diesel engines but also produce lower emissions that meet the international emission standards. Additional research needs to develop diesel specific additives for better performance, combustion and emissions of diesel engines. DEE possess required characteristics and expected to improve low temperature flow properties.

Earlier studies have recommended that the weight percent of oxygen content in the fuel is the most important factor for opacity reduction. DEE has high cetane number of above 125. The latent heat of vaporization of DEE is higher than diesel. DEE is liquid at room temperature which reduces handling and storage problems. DEE is also has non-corrosive properties compared to alcohols. The flame propagation stages of DEE have been studied by Ohta and Takahashi. DEE has low heat release rates (HRR) during early cool flame generation, but has typical HRR for mid stage blue flame oxidation. The blue flame is followed by a conventional red flame with constant HRR during full stage combustion. By adding DEE to diesel fuel will increase the cetane number of the diesel fuel. Addition of diethyl ether to biodiesel blends can increase the oxygen contents, which may further improve the opacity emissions. Investigations have been carried out on different approaches for improving exhaust emission when biodiesel is used.

In this work the engine is supercharged by a supercharger. The objective of using the supercharger is to increase the power output of the engine without increasing its rotational speed or the dimensions of the cylinder. This is achieved by increasing charge of air, which results more burning of the fuel and a higher mean effective pressure. The supercharging is done at 10%, 20% and 30%. Higher than the normal rate.

The objective of the present work is to investigate the effect of supercharging and DEE as an additive on the performance of DI diesel engine. In the present work different blends of biodiesel, diesel with additive was prepared and their comparative performances were evaluated with neat diesel.

II. MATERIALS AND METHODS

Experimental Fuels

Mahua oil is obtained from the seeds of madhuca indica, a deciduous tree which can grow in semi-arid, tropical and subtropical areas. It grows even rocky, sandy, dry shallow soils and tolerates water logging conditions. Mahua oil is procutared from an oil mill. The oil was filtered to remove the impurities. Flash point and fire point was determined by using pensky martens fire point apparatus. The viscosity was determined at different temperatures by using redwood viscometer to find the effect of temperature on the viscosity of mahua biodiesel. The viscosity of mahua oil was found to be approximately 8 times higher than that of diesel fuel. The flash point of mahua oil was higher diesel and hence it is safer to store. It has seen that the boiling range of mahua oil was different from diesel.

The vegetable oil is trans-esterified before it was blended with diesel. It is because of the presence of glycerol, which will affect the engine performance. The trans-esterification is the most commonly used commercial process to produce clean and environmental friendly bio-fuel. The mahua oil have been successfully tested on C.I. engines and their performance has been studied. Trans-esterification is the process of conversion of triglyceride to glycerol and ester in the presence of alcohol and catalyst. This reaction also known as alcoholics in which the displacement of alcohol from an ester by another alcohol in process similar to hydrolysis except that an alcohol is used instead of water. This reaction has been widely used to reduce the viscosity of the triglycerides. Experimental study shows that the major variables affecting the trans-esterification are: the free fatty acid and the moisture content. Properties of diesel, DEE are given in the table 1. Then with the help of washing the catalyst, soap and excess methanol were removed from biodiesel.

Experimental setup

Test has been conducted on a kirloskar Engine, four stroke, single cylinder, water-cooled direct injection, and naturally aspirated diesel engine with bowl in piston combustion chamber. The specification data of the engine used are given in table and block diagram for the experimental set up is shown in figure. For fuel injection, a high-pressure fuel pump was used, a three-hole injector nozzle. The injector nozzle was located at the center of the combustion chamber and has an operating pressure of 220 bar. The engine was coupled to an eddy current dynamometer set and loaded by electrical resistance to apply different engine loads. The specifications of the dynamometer are demonstrated in the table. Smoke meter model AVL437C made by AVL India Pvt. Ltd. Is used in this experimental study. The measurement is based on the principle of light absorption by particle. Photo electronic smoke detection is based on the principle of optical detection. It is also known as the scattered light principle. Exhaust gas analyzer used for this experiment is Connected at the end of the exhaust outlet. Continuous charging of the analyzer is essential to work in an effective way. The measuring method is based on the principle of light absorption in the infrared region, known as non-dispersive



Schematic diagram of diesel engine for experimental set up

infrared absorption. The broadband infrared radiation produced by the light source passes through a chamber filled with gas, generally methane or carbon dioxide.

Tah	le 1	Engine	Sneci	fications
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Manufacturer	Kirloskar oil engines Ltd, India
Model	TV-SR, naturally aspirated
Engine	Single cylinder, DI

Bore/stroke	87.5mm/110mm	
C.R.	17.5:1	
Speed	1500 rpm, constant	
Rated power	5.2kw	
Working cycle	four stroke	
Injection pressure	180bar/23 deg. before TDC	
Type of sensor	Piezo electric	
Response time	4 micro seconds	
Crank angle sensor	1-degree crank angle	
Resolution of 1 deg	360 deg with a resolution of 1deg	

Experimental procedure

To estimate the performance parameters, operating parameters such as engine speed, power output, and fuel consumption were measured. Significant engine parameters such as Specific fuel consumption (SFC) and Brake thermal efficiency (BTE) for the test fuels were calculated. Emission parameters such as CO, CO₂, HC, NOx and opacity were observed for various fuel blends.

- In the first phase experiments, tests were conducted with neat diesel at 10%, 20% and 30% supercharging
- In the second phase of the work, the engine was operated with diesel-biodiesel blends with DEE in the ratio of 80:15:5, 75:20:5 and 70:25:5 at 10%, 20% and 30% supercharging
- In the third phase of the experiment, tests were conducted with biodiesel at 10%, 20% and 30% supercharging

III. RESULT AND DISCUSSIONS

Experimental investigations have been carried to examine the performance and emission characteristics at different rate of supercharging. The details have been shown below through graphs

PERFORMANCE AND COMBUSTION CHARACTERISTICS OF DIESEL, MAHUA BIODIESEL AND ITS BLENDS ON NORMAL ENGINE

Performance characteristics without supercharging



Fig.1 Variation of BTE with BP

Figure 1 shows the comparison of brake thermal efficiency with brake power with for different fuels. It can be observed that for the certain load the brake thermal efficiency increases with increasing load and then decreases. The brake thermal efficiency of blends of mahua biodiesel are slightly similar to pure diesel. From the graph, it is evident that the blend M20 gives better result than other blends. M20 has around 3-4% lower than the pure diesel fuel.



Fig.2. Variation of Specific Fuel Consumption with Brake Power

Figure 2 shows the comparison of specific fuel consumption with brake power for different fuels. It can be observed that initially the specific fuel consumption of all the fuels is higher because of idle running of the engine, as the load increases specific fuel consumption decreases and it is same at higher loads. The SFC of pure mahua and its blend is slightly higher than that of the diesel fuel it is because of lower heating values, among other blends M20 has lower SFC, and it is about 0.35 kJ/kW-h. which is around 1% lower than that of diesel



EMISSION CHARACTERISTICS

Fig 3. Variation carbon monoxide with Brake power.

Figure 3. shows the variation of carbon monoxide with brake power for different fuels. It can be observed that emission of CO for all blends of mahua biodiesel is less as compared with the pure diesel and emission of CO is more at higher loads as evident from the graph. From the graph it is clear that the emission of CO for blend M20 lies between M15 and M25 as it depends on the proportionate content of biodiesel in the blend. It is due to lower oxidation rate of biodiesels, the moisture content in the biodiesel blends leads to quenching of the engine in turn it leads to lesser CO. the CO of biodiesel blends is reduced by around 50-60% than the pure diesel fuel.



Fig.4 Variation hydrocarbon with Brake power.

Figure 4 shows the comparison of unburnt hydrocarbon with brake power for different fuels. It can be observed that, the emission of unburnt hydrocarbon for all the blends of mahua biodiesel are less as compared to pure diesel. It is evident from the

graph that the emission of unburnt hydrocarbon for the blend M20 is according to its proportion of biodiesel in its blend. It is due to higher oxygen content and longer ignition delay of the biodiesel.



Fig.5. Variation of NOx with Brake power.

The variation of oxides of nitrogen emission with brake power for normal engine for different fuels 5. The oxides of nitrogen emission gradually increase and decreases with increase in load. The oxides of nitrogen for pure biodiesel and its blends are more as compared to the pure diesel as it is evident from the graph. The reason behind increases in NOx is higher ignition temperature and combustion temperature. It may also due to higher oxygen content in the biodiesel and higher oxydation rate

PERFORMANCE AND COMBUSTION ANALYSIS ON SUPERCHARGED ENGINE



Performance characteristics of M20 blend with supercharging.

Fig.7. Variation of Specific Fuel Consumption with Brake Power

Figure 6 shows the comparison of brake thermal efficiency with brake power for M20 blend at different rates of supercharging. It can be observed that up to 80% load, brake thermal efficiency increases with increasing load and decreases at full

load. At 20% supercharging the blend M20 gives better efficiency as compared to other rates of supercharging as it is evident from the graph. Super charging of the engine leads to higher volumetric efficiency, higher intake of air, higher oxygen, which leads to complete combustion and hence more BTE the complete combustion is due to higher swirl rate of air fuel mixture. But as supercharging increases brake thermal efficiency reduces, it is because of leaner mixture and escaping of unburnt fuel due to higher swirl rate. Hence from the graph it can be seen that M20 has better BTE than other supercharging rates.

Figure 7 shows the comparison of specific fuel consumption for M20 blend with brake power at different rates of supercharging. It can be observed that initially at all rates of supercharging, specific fuel consumption is more for M20 blend. As the load increases specific fuel consumption is almost same for all rates of supercharging after the first load as evident from the graph. From the graph, it is also evident that for the blend M20 the specific fuel consumption is lesser at 20% supercharging as compared to other rates of supercharging. Optimum A:F ratio attains at certain level of supercharging, and in this experiment it is 20%. Higher rate of supercharging above the limit leads to higher fuel consumption to compensate the leaner mixture.

EMISSION CHARACTERISTICS.



Fig 8. Variation of carbon monoxide with Brake Power

Figure 8. shows the comparison of carbon monoxide for M20 blend with brake power at different rates of supercharging. The emission of carbon monoxide increases as the load increase. It can be observed that the emission of CO for M20 blend mahua biodiesel at 20% supercharging is less as compared with other rates of supercharging.





Figure 9 shows the comparison of unburnt hydrocarbon for M20 blend with brake power at different rates of supercharging. It can be observed that the emission of unburnt hydrocarbon for M20 blend at 20% supercharging is less as compared to 10%, 30% and without supercharging.





The variation of oxides of nitrogen emission with brake power for supercharged engine for M20 biodiesel diesel blend at different rates of supercharging is shown in figure 10. The oxides of nitrogen emission gradually increase and decreases with increase in load. The oxides of nitrogen for M20 blend at 20% supercharging is more effective and result oriented as the emission of NOx is less as compared to without supercharging and 30% supercharging but it gives slightly more NOx than at 10% supercharging as evident from the graph.







Figure 11 shows the variation of brake thermal efficiency forM20 blend at 20% supercharging and pure diesel. From the graph, it is evident that the BTE for M20 blend at 20% supercharging is slightly lower at initial loads as compared to pure diesel and is higher for 80% and full loads. It is due to complete atomization of fuel due to supercharging.





Figure 12 shows the variation of specific fuel consumption for M20 blend at 20% supercharging and pure diesel. From the graph, it is evident that the specific fuel consumption for M20 blend at 20% supercharging is higher at initial loads as compared to pure diesel and is lower as the load increases.





Figure 13 shows the comparison of exhaust gas temperature with brake power for M20 blend at 20% supercharging and pure diesel. It can be observed that the exhaust gas temperature for all the fuels increases with increase in load. The exhaust gas temperature of pure mahua biodiesel and its blends is slightly higher than the diesel fuel at lower loads and they are lower than diesel fuel at higher loads. This is because of presence of higher oxygen content in the biodiesel, which leads to complete combustion.



Fig.14 Variation of carbon monoxide with brake power.

Figure 14. shows the variation of carbon monoxide with brake power for M20 blend at 20% supercharging and pure diesel. It can be observed that emission of CO for M20 blend of mahua biodiesel is less as compared with the pure diesel. It is due to lower oxidation rate of biodiesels, the moisture content in the biodiesel blends leads to quenching of the engine in turn it leads to lesser CO. the CO of biodiesel blends is reduced by around 50-60% than the pure diesel fuel.





Figure 15. shows the comparison of unburnt hydrocarbon with brake power for M20 blend at 20% supercharging and pure diesel. It can be observed that, the emission of unburnt hydrocarbon for M20 blend of mahua biodiesel are less as compared to pure diesel. It is due to higher oxygen content and longer ignition delay of the biodiesel.



Fig.16 Variation of oxides of nitrogen with brake power

The variation of oxides of nitrogen emission with brake power for M20 blend at 20% supercharging and pure diesel are shown in figure 16 The oxides of nitrogen emission gradually increase and decreases with increase in load. The oxides of nitrogen for pure biodiesel and its blends are more as compared to the pure diesel as it is evident from the graph. The reason behind increases in NOx is higher ignition temperature and combustion temperature. It may also due to higher oxygen content in the biodiesel and higher oxydation rate.

IV CONCLUSION

- The mahua biodiesel satisfies the important properties like density, viscosity. Flash point, fire point and calorific value as per ASTM standards.
- Mahua biodiesel can be directly used in diesel engines without any engine modifications.
- Engine works smoothly on mahua biodiesel with performance comparable to diesel operation.
- > Brake thermal efficiency of 20% blend is nearly equal to diesel compared to other blends.
- Specific fuel consumption is neared to diesel oil at minimum loads and increases at maximum loads. Minimum specific fuel consumption of M15 blend, M20blend, M25 blend and M100 are 0.32kg/kw-h, 0.31kg/kw-h, .33kg/kw-h and 0.33kg/kw-h respectively against 0.34kg/kw-h of diesel.
- > The exhaust gas temperature of all of all blends and diesel increase with increase of operating loads.
- Combustion characteristics of all blends of mahua biodiesel is almost same as that of diesel.
- > The emission characteristics like CO, HC increase and CO₂, NO_X levels decrease against diesel oil.
- From the above conclusions M20 mahua biodiesel blend is suitable for normal engine
- The fuel consumption of all blends is slightly more than the diesel at all varying loads. But D75M20A5 Mahua biodiesel blend have considerable lesser fuel consumption than diesel at 20% at engine supercharging conditions.
- Optimum specific fuel consumption was obtained for D75M20A5 when engine run at 20% supercharged condition compared to diesel, which is nearest to the diesel fuel.
- The brake thermal efficiency of D75M20A5 Mahua biodiesel blend is more is slightly greater than the diesel fuel at 20% super charging condition
- The use of Mahua biodiesel in a conventional diesel engine decreases its torque and brake thermal efficiency, the decrease being more with increase in the biodiesel blends.
- Supercharging of the engine leads to better atomization and profiled spray pattern of the fuel inside the engine cylinder. The better atomization leads to complete combustion which in turn reduces the UBHC. Better spray pattern leads to uniform distribution of the fuel in the engine cylinder, which leads to uniform heat distribution and quenching, which reduces the NOx emission. Higher availability of the oxygen in the supercharging leads to complete combustion and leads to lower CO and CO2 emissions. Uniform distribution of the heat may lead to lower smoke. Too lower (10%) and higher supercharging (30%) leads to richer and leaner fuel mixture, which may reduce the performance and emission characteristics. Hence the optimum supercharging rate is 20% for better performance of the engine.

REFERENCES

[1] A.Rama Krishna, B. Prabakaran, (2015), Performance and emission characteristics of a ci engine fueled with diesel – biodiesel (mahua/mustard) blend with diethyl ether additive

- [2] N. Vadivela, P. Somasundaram, M. Krishnamoorthia (2015), Performance and emission characteristics of a ci engine fueled with diesel –biodiesel (mahua/mustard) blend with diethyl ether additive
- [3] Xiaoyan Shi, Xiaobing Pang, Yujing Mu, Hong He, Shijin Shuai, Jianxin Wang, Hu Emission reduction potential of using ethanol-biodieseldiesel fuel blend on a heavy-duty diesel engine
- [4] Vijayaraj, K. AndA.P. Sathiyagnanam (2014,) Experimental investigation of methyl ester of cotton seed oil blend with diesel on ci engine
- [5] M. Harinathareddy, Dr P. Nageswara Reddy. (2013) Experimental Investigation of Compressed Ignition Engine Using Cotton Seed Oil Methyl Ester as Alternative Fuel
- [6] Xiaohu Fan1, Xi Wang. (2008) Engine Performance Test of Cottonseed Oil Biodiesel
- [7] Leon G. Schumacher. Fueling diesel engines with Blends of methyl ester Soybean oil and diesel fuel
- [8] M. Martin, D. Prithviraja, (2011), Performance of Pre-Heated Cottonseed Oil and Diesel Fuel Blends in a Compression Ignition Engine
- [9] Pani Sharanappa, Dr.M.C. Navindagi, Special Issue, Sep.-2016, A study of fuel properties of ternary blend diesel- mahua methyl ester-ethanol
- [10] Evangelos G. Giakoumis (2013), Exhaust emissions with ethanol or n-butanol diesel fuel blends during transient operation:
- [11] C.V. SubbaReddy1, C. Eswara Reddy2 &K. Hemachandra Reddy3, (October 2012), Effect of fuel injection pressures on the performance and emission characteristics of d. I. Diesel engine with biodiesel blends cotton seed oil methyl ester
- [12] G. Lakshmikanth 1, A.K. Thajudeen 2, S. Santhanakrishnan 3, G. Arunkumar 4
- International Journal of Engineering Research & Technology (IJERT), Vol. 2 Issue 10, October 2013, Performance and emission characteristics of mahua oil biodiesel on a compression ignition engine.
- [13] Dheeraj Joshi, P.V. Viswanath and B. Sandeep, Advance Research and Innovations in Mechanical, material Science, Industrial Engineering and Management - RMMIEM-2014 The Effects of Supercharging on the Performance of C.I Engine Using Blends of Pre-Heated Cotton Seed Oil and Diesel as Alternate Fuel
- [14] Raghuvaran S (2015), Performance and Emission Analysis of Diesel Engine (DI) Using Cotton Seed Oil Methyl Ester

