Performance and Emission Analysis on Diesel Engine using Blended Cotton Seed Oil with Natural Additives

Karthikeyan R*, Balaji A, Arun D, Amaresh A
Department of Mechanical Engineering, Kongu Engineering College, Perundurai – 638 060
Corresponding author: E-Mail:karthi150392@gmail.com

ABSTRACT

Natural additives increase the engine performance on its addition into the diesel. This work deals with the performance and emission test that have been carried out in diesel engine using various combinations which includes Diesel, Biodiesel (B) and Biodiesel with additives. The cotton seed oil methyl ester based biodiesel has been prepared by two step Trans esterification process. In the first step, the cottonseed oil is treated with Ortho-phosphoric acid and Sulphuric acid to remove the gums and fatty acids. In the second step, methanol and potassium hydroxide are added to the cottonseed oil to segregate biodiesel and glycerol. The high surface volume ratio of additives in biodiesel leads to increase in efficiency and also reduce the emissions as it acts as a catalyst. The following combinations are considered for the performance analysis of the engine namely B100 (100% of Cottonseed oil methyl ester), B50 (50% of Cottonseed oil methyl ester and 50% of Diesel), B100A (B100+0.5% of Additives) and B50A (B50 +0.5% of additives). The experimental evidence shows the fuel properties like calorific value, flash point, fire point and viscosity has been enhanced for B50, B100A and B50A. The Brake Thermal Efficiency (BTE) has been enhanced to 1.65%, 2.76% and 8.16% for B50, B100A and B50A respectively compared to B100. Emission characteristics were also analyzed for the above said combinations. Carbon Monoxide (CO) emission is reduced for B100A and B50A about 9% and 5.9% respectively compared to B100 and B50. When compared to B100, the Nitrogen Oxide (NO) emission is reduced about 5.8% and 6.9% for B100A and B50A respectively.

KEY WORDS: Biodiesel, Additives, Brake thermal efficiency, Emission.

1. INTRODUCTION

The energy demand is increasing every day in the global market. Fuel price and pollution factor of petrol and diesel are also becoming a challenge factor day by day, as these are non-renewable form of energy. So there is a need for an alternative source of energy. The possible alternative sources are biodiesel, bio alcohol, fuel cells, batteries, hydrogen and LPG. Among these, biodiesel is a good alternative to diesel because it is extracted from vegetable oil and animal fats. There are many vegetable oils like olive oil, coconut oil, linseed oil, olive oil, soya bean oil and sunflower oil which are used for biodiesel conversion process. Among this cottonseed oil have high oil content which can be used for biodiesel production. Many research works have been investigated by using vegetable oil methyl ester in diesel engine and reported that while increasing the percentage of biodiesel in the diesel blend, CO and HC emissions were decreased but NOx emission has been increased (Ashraful, 2014). The higher percentage of diesel in biodiesel has been substitute for diesel without modification of engine. The fuel properties were enhanced and CO, smoke opacity has been reduced when using mixture of metal additives in diesel (Ali Keskin, 2011). The Brake Specific Fuel Consumption (BSFC) has been increased which led to the decrease of Brake thermal efficiency (BTE), while the engine has been operated with 100% biodiesel fuel. This may due to lower heating value of biodiesel fuel. Further, the ignition delay has been increased in the case of 100% biodiesel and it can be reduced by blending the biodiesel with the diesel (Murat, 2008).The biodiesel conversion has been increased when increasing the molar ratio of oil to alcohol (Umer Rashid, 2014). The mixture of additives in biodiesel has been increasing the fuel properties, fuel efficiency and reduces the percentage of emission level. The effect of Alumina, Ceria, Copper oxide, Cobalt, Led, Cadmium, Nickel, Chromium, Manganese and Iron Nano particles have been studied and reported that the catalytic activity of biodiesel has been improved by high surface to volume ratio of nanoparticles. The more amount of oxygen has been reacting with fuel which enhances the engine performance and reduces the percentage of emission level due to enhancement of oxygen stability. Especially, NO_X emission has been reduced. The minimum ignition delay and reduction of reaction time are another reason for reduction of oxides of nitrogen (Karthikeyan, 2014).

In this research work cottonseed oil is selected to blend with diesel while biodiesel conversion process. Further, natural based muffin fiber nano-particle has been mixed with biodiesel as an additive to overcome the draw backs.

2. MATERIALS AND METHODS

Production of Biodiesel: The biodiesel production has been carried out in a laboratory by a two-step Trans-esterification process. The setup contains the following components and materials: Pure Cottonseed oil, Methanol, KOH, Ortho phosphoric acid, Sulphuric acid, Magnetic stirrer and separating vessel with stand.

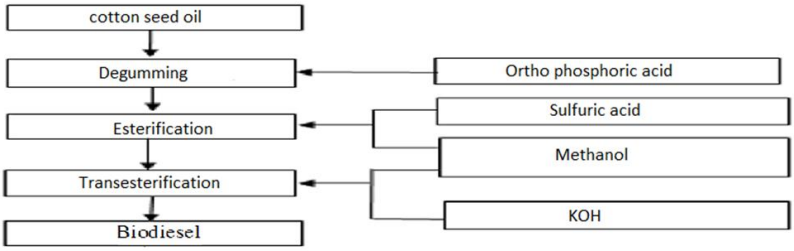

Figure.1. Stages of biodiesel production

The two step trans-esterification process has been carried out by acid and alkaline is explained in fig 1. The amount of adding optimized variables like sulfuric acid (1%), Ortho-phosphoric acid (1%), KOH (7.5 grams) and Methanol (6o ml).In first step, the cottonseed oil is treated with Ortho-phosphoric acid to remove the gums. In next step Sulphuric acid and Methanol are added to remove the fatty acids. This process is known as esterification. The Methanol and KOH are added to esterified oil to separate the glycerol and fatty acids. After this, wash the Bio-diesel by ionized water in-order to remove any dust present in it and then made to dry before using. Before entering the process heating of oil should not more than 65°C when adding of Methanol in oil**.** The experimental results are shown in fig 2 in a step by step manner.

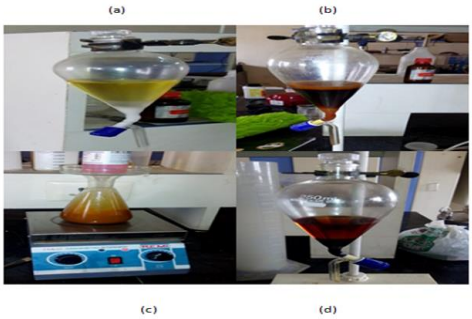

Figure.2. (a) Degumming (b) Esterification (c) Trans esterification (d) Separation

Figure.3. Experimental Arrangement of diesel engine in which tests to be carried over using various combinations

The performance and emission test of B100 and B50 mixed with additives were carried out in computerized single cylinder, four strokes, vertical air cooled, 4.4 kW power diesel engines which has been shown in fig 3. The experiments were carried out with B100, B50, B100A and B50A. The performance of engine like BTE, BSFC and emissions like HC, CO_2 and NO emissions are measured. The AVL DIGAS-444 gas analyzer has been used for measuring the emissions from the engine and AVL combustion analyzer has been used for finding the combustion characteristics cylinder pressure and crank angle. The specification of engine has been specified in Table 1.

Table.1. Engine specification

Type	Particulars
Number of stroke	4
Number of cylinder	1
Method of cooling	Air cooling
Bore diameter (D)	87.5 mm
Stroke (L)	110 mm
Compression ratio	17.5:1
CC	661 cm^3
Rated power	4.4 kW
Injection pressure	200 bar

Fuel properties: The physical properties of diesel, cottonseed oil methyl ester, and mixture of cottonseed oil methyl ester with natural based additive are described in Table.2.

Table.2. Properties of Fuels

Fuel Properties	Diesel	B100	B50	B100A	B50A
Density (kg/m3)	860	905	887	889	884
Calorific value (kJ/kg)	44500	41500	42600	41900	42885
Kinematic viscosity (Cst)	3.92	5.35	5.12	5.93	5.66
Flash point (°C)	48	158	110	149	102
Fire point (°C)	65	182	140	168	128

The density and kinematic viscosity are 4.97% and 26% high for B100 when compared to diesel. The flash point and fire point are high for B100 and it is reduced to 30%, 5.6% and 35% for B50, B100A and B50A. The calorific value of B100 is 6.7 % lower than that of diesel and it is enhanced to 2%, 0.9% and 3% for B50, B100A and B50A when compared to pure biodiesel due to addition of Nano additives in biodiesel.

3. RESULTS

Combustion characteristics: The combustion characteristics are the graphical representation of cylinder pressure with crank angle with aid of computer. The variation of cylinder pressure with respect to crank angle for diesel, B100, B50, B100A and B50A with brake power is shown in fig 4. The cylinder pressure is maximum for B100 (72.43 bar) and B50 (71.84 bar) when compared to diesel (70 bar) as a result of heat release rate is maximum. This is due to enhancement of pre-mixed combustion of fuel as a result of prolonged ignition delay. The reduced cylinder pressure for B100A and B50A is 1.4% and 3.9% low when compared to diesel. This could be attributed by improved ignition properties and shorten ignition delay of fuel because of fuel mixed with additives. The additives act as a catalyst to initiate the early combustion when compared to diesel.

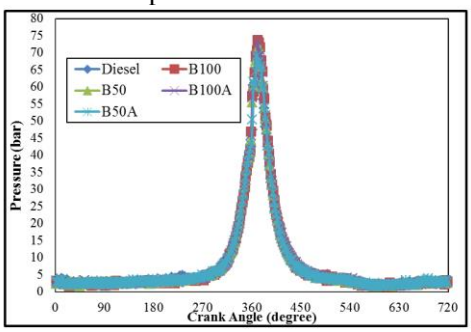

Figure.4. Comparison of Cylinder Pressure with respect to Crank Angle

Brake Thermal Efficiency: Brake Thermal Efficiency is defined as break power of a heat engine as a function of the thermal input from the fuel. It is used to evaluate how well an engine converts the heat from a fuel to mechanical energy. The variation of brake thermal efficiency for various brake power are described in fig 5. The brake thermal efficiency of B100 is lower than that of diesel for all loads. The BTE of B100 is 12.76% lower than that of diesel because of high viscosity and lower heating value of biodiesel.

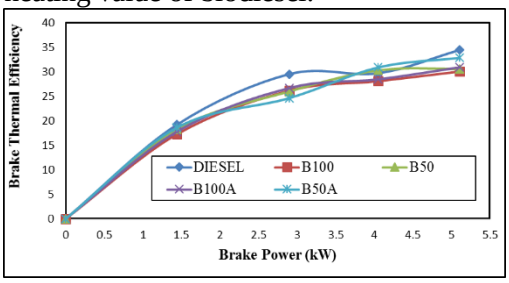

Figure.5. Comparison of Brake Thermal Efficiency

The BTE of B50 is 11.11 % lower than that of diesel and it is 1.65% high when compared to B100, because viscosity is reduced to 4% and calorific value is increased to 2.5%. The BTE of B100Ais 10% and B50A is 4.6% which is lower than diesel. The BTE of B100A is 2.76%and B50A is 8.16% higher when compared to B100 because of increase in calorific value of fuel.

Brake Specific Fuel Consumption: Brake specific fuel consumption (BSFC) is a measure of the fuel efficiency of any prime mover that burns fuel and produces rotational, or shaft, power. It is the rate of fuel consumption divided by the power produced. The brake specific fuel consumption with various brake power are described in fig 6. The BSFC is increased for zero loads and decreased for other loads. The BSFC for B100 is 19% higher than that of diesel because of high viscosity and high specific gravity. The viscosity is reduced to 10%, 3% and 7%, as a result decrease in BSFC is 2.15%, 1.39%, 9.35% for B50, B100A and B50A. It's due to increase in calorific value as a result of complete combustion in combustion chamber.

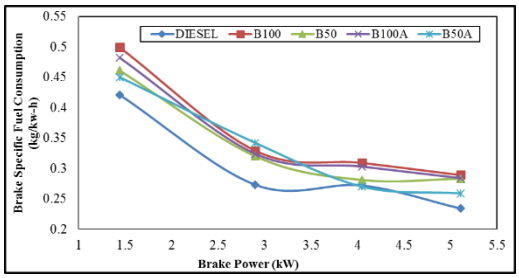

Figure.6. Comparison of Brake Specific Fuel Consumption

Engine Emission Performances:

Hydrocarbon (HC): The variation of unburned hydrocarbon emission for diesel, B100, B50, B100A and B50A and mixtures of additives in biodiesel are shown in fig.7.

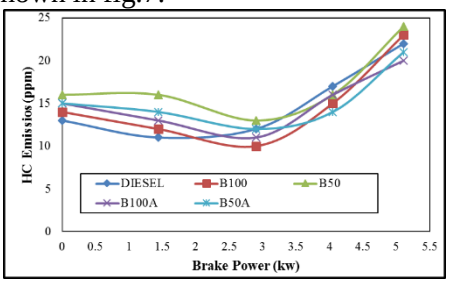

Figure.7. Variation of HC with respect to Brake Power

The HC emission for B100A and B50Ais 9.09% and 4.54% lower than diesel, due to secondary atomization; shorten ignition delay and catalytic activity of Nano particles in fuel leading to increase the reaction. The HC emission is 4.53% and 8.3% higher for B100 and B50 when compared to diesel because of reduced gas temperature and incomplete combustion.

Carbon monoxide (CO): The variations of CO emission for diesel, B100, B50, B100A and B50A with brake power are shown in fig.8.

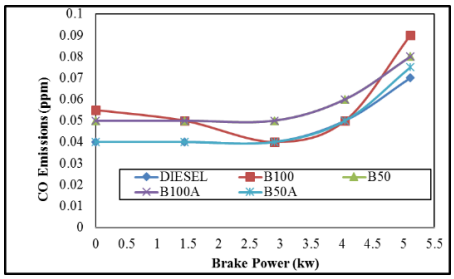

Figure.8. Variation of CO with respect to Brake Power

The CO emission for B100 and B50 is22% and 12.5% higher than that of diesel, due to poor fuel-air mixing in the engine cylinder led to incomplete combustion. The CO emission for B100A and B50A is12.5% and 6.6% high compared to diesel but 9% and 5.9% low when compared to B100 and B50. It is due to the high oxygen content in the fuel to enhance the combined effect of better fuel- air mixing and uniform burning.

Carbon di oxide (CO_2): The variations of CO_2 emission for diesel, B100, B50, B100A and B50A with brake power are shown in fig.9.

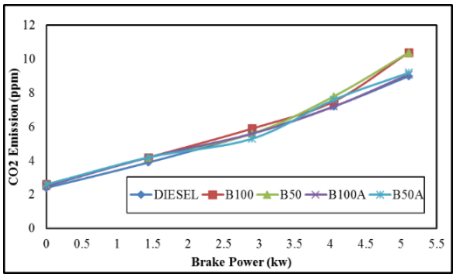

Figure.9. Variation of CO_2 Emission with respect to Brake Power

The CO_2 emission for B100 and B50 is 13.46% higher than that of diesel, due to high Carbon content in the fuel. The value of B100A and B50A is1.07 and 2.17 high compared to diesel but 0.96% and 1.45% low when compared to B100. The secondary atomization and micro explosion of fuel are contributes more oxygen to react with fuel and to reduce the CO_2 emission.

Nitrous Oxide (NO): The variations of NO emission for diesel, B100, B50, B100A and B50A with brake power are shown in fig.10.

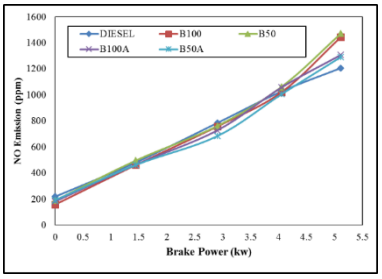

Figure.10. Variation of NO Emission with respect to Brake Power

The percentage of NO emission for B100 andB50 are 16.47% and 18% higher than that of diesel, due to improved fuel spray characteristics, extra oxygen in biodiesel and high combustion temperature. The NO emission is reduced to 5.8% and 6.9% for B100A and B50A when compared to B100. This is due to increase of the cetane number to minimize the fuel-air mixing in the combustion chamber.

4. CONCLUSION

The vegetable oil is a good alternative fuel to diesel because of easily available and renewable. The cottonseed oil is user for biodiesel production because of viable properties and high oil content in fuel. The problems in cottonseed oil like high viscosity, high flash point and high fatty acids are remedied by two step trans esterification process**.** The optimized variables for biodiesel production are 9:1 molar ratio, 65°C reaction temperature and 7.5 grams of KOH. The purpose of adding Nano additives in biodiesel is to enhance the fuel properties. The flash point and fire point of biodiesel has been reduced to 30%, 5.6% and 35% for B50, B100+0.5A and B50+0.5A compared to B100. The calorific value enhanced to 2%, 0.9% and 3% for B50, B100+0.5A and B50+0.5A when compared to pure B100.The reduced cylinder pressure for B100A and B50A has been 1.4% and 3.9% low when compared diesel. The BTE of B100A has been 2.76%and B50A has been 8.16% higher when compared to diesel. The BTE of B50 has been 1.65% high when compared to B100.The BSFC has been reduced to 10%, 3% and 7% for B50, B100A and B50A.The HC emission for B100 and B50 has been 4.53% and 8.3%higher than diesel and it has been reduced to 3.91% and 4.06 for B100A and B50A.The CO emission for B100 and B50 has been 22% and 12.5%higher than that of diesel. The reduction of CO emission for B100A and B50+0.5A has been 9% and 5.9% compared to B100 and B50.The CO_2 emission for B100 and B50 has been 13.46% higher than that of diesel. The value of B100A and B50A has been reduced to 0.96% and 1.45% when compared to B100.The percentage of NO emission for B100 has been 16.47% higher than that of diesel. The reduction of NO emission has been 5.8% and 6.9% for B100A and B50A when compared to B100.

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