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PERFORMANCE AND EMISSION CHARACTERISTICS OF A CI ENGINE FUELED WITH BIODIESEL EXTRACTED FROM WCO-MUSTARD OIL

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ABSTRACT

Substitute for conventional diesel fuel by biodiesel is widely considered to have more societal benefits, such as reducing greenhouse gas emissions and supporting rural agriculture economies. Biodiesel is a natural fuel extracted from various feedstock or vegetable oils or from animal fats. This is defined as a biodegradable matter formed from fatty acid methyl and ethyl esters. Nowadays, most of the biodiesel fuels are extracted from edible oils such as palm oil, soya bean oil, sunflower oil etc., due to their eco-friendly characteristics.

The present work includes the production of Biodiesel from Waste cooking oil and Mustard oil by transesterification process and mixed in 1:1 ratio followed by performance and emission characteristics of 3.675 kW C.I engine with extracted biodiesel as fuel. This experimental investigation includes blending of said biodiesel with diesel at three different proportions as B10, B20, B30 and 2% of ethanol to enhance the ignition quality of fuel and cold starting of the Engine. The performance parameters such as brake power (BP), brake specific fuel consumption (BSFC), and emission characteristics about NOx, HC, $CO_2$and CO of above specified engine at three injection pressures as 180bar, 200bar, and 220 bar respectively, are studied and compared with convention Diesel as a fuel at an injection pressure of 180 bar.TheBiofuel sample title as B10 is found optimum from efficiency and economy point of view compared to rest two B20 and B30 samples.

KEYWORDS: *Biodiesel Blends, Mustered Oil, Pressure Injectors, Transesterification and Waste Cooking Oil*

Article History

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INTRODUCTION

The concept of the utilization of vegetable oil as a fuel dates back to 1895 when Dr. Rudolf Diesel invented the first diesel engine which runs on vegetable oil. He stated that the use of vegetable oil for engine fuels may be insignificant today, but such oil may become a source in time as important as petroleum and coal tar products of the present time.

Biodiesel is natural and biodegradable fuel isdefines as a mixture of fatty acid methyl and ethyl esters derived from vegetable or animal fat and it is used in diesel engines and heating system. This mineral diesel has an advantage of the reduction of greenhouse gases because it is a renewable resource. As it is well known that most of the biodiesel are extracted from oils like soya bean, sunflower, palm seed, rapeseed etc., throughout the world. Depending on the weather and soil conditions, various nations are looking into different feedstock or vegetable oils for diesel fuel substitute.

Among such research works, some of the research works on vegetable oils as an alternative to diesel fuel are discussed. Goering C E et al. (1981)[1] conducted research on 11 different bio-oils to study the characteristic properties. It was done to know which of these oils were be best suited for use as an alternative fuel. Of all the bio-oils it was found that sesame, corn, rapeseed, soybean, and cottonseed oils had the better and favorable fuel properties. Auld D L et al. (1982) [2] conducted research on diesel engine filled with rapeseed oil and studied the effect on the performance of the engine. Use of rapeseed oil gave similar performance as that of diesel fuel used the engine.

The results were conducted for short-term.The long-term test was needed for further investigations. Royan D et al. [3] studies the enzymatic production of biodiesel by methanol analysis of cotton oil by using immobilized candidaAntarctica lipase catalyst in an at-butanol solvent. He concluded that the concentration of t-butanol for optimum conversion is not high and consequently energy expense needed for its recovery can be taken and it is needed in all cases to take off the excess amount of methanol during the process. Sebos I et al. [4] Conducted a study on the catalytic hydroprocessing of cotton oil in petroleum and diesel using a conventional Como/al2o3 hydrotreatment catalyst.

The studies reveal that hydroprocessing of vegetable oil not only contributes to the production of fuel from renewable feedstock, but also results in the production of diesel like hydrocarbons of superior quality. Abolle Abolle et al. [5] Conducted experiments on diesel oil blends with the other oil to change several physical properties, mainly focused on viscosity. The report shows that the viscosity can be varied to a great extent using the straight vegetable oil blends with diesel and all the blends behave Newtonian. Umer Rashid et al. [6] carried out an evaluation of transmethylated jatropha oil obtained from jatropha seeds under optimized set of reaction conditions like 6:1 methanol/oil molar ratio with the use of 1% sodium methoxide catalyst concentration at a temperature of 650C and mixing intensity of 600 rpm resulting in 94% yield of biodiesel.

The gas chromatographic analysis showed JOME comprises 49.75% linoleic, 16.8% stearic, 13% oleic, 5.01% arachidic, 12.15% palmitic and 2% gadoleic acids. H-NMR and thermogravimetric analysis are also checked and came to a conclusion that the fuel properties of biodiesel produced are as per the standard specification of ASTM D 6751 and EN 14214. Xiaohu Fan et al. [7] Studied parameters affecting transesterification process of cottonseed oil by response surface methodology with SAS and PSI plot programs. The experimental results based on Ride Max analysis and RSM showed the optimal conditions are methanol/oil molar ratio of 7.9, time of 45 min, the temperature of 53^{0}C, the catalyst concentration of 1% and rate of mixing is 268 rpm. This optimized condition was validated with actual biodiesel yield of 97%. For methanol/oil molar ratio of 6, the parameters affecting transesterification were maintained at the optimal values results with the biodiesel yield of 95%. Since there was no significant increase in biodiesel yield, a suggestion has been given to use methanol/oil molar ratio of 6 for biodiesel production from crude cottonseed oil. Arjun.s et al [8] – have studied the Extraction of Biodiesel from the waste cooking oil. By using a method called Transesterification processes. Which depends on the amount of free fatty acid and water content in the sample. Bruwer J J et al. (1980) [9] conducted the research on the use of sunflower seed oil as an alternative source of energy. He operated tractor for 1000 hours using sunflower seed oil and it was noted that there was a drop of 8% power loss compared to diesel. This power loss is recovered by introducing a fuel injector and injector pump. With this change when operated for 1300 hours' equivalent amount of carbon deposition as that of diesel except for the injector tips was found. Sergio C. Capareda et al. [10] Conducted engine power tests using a 14.2 kW diesel engine fueled with petroleum diesel DF500 and cottonseed oil biodiesel blends B5, B20, B40, B60, B80, and B100.

This usage of cottonseed biodiesel blends showed CO, total HC, NOx and SO_2 emissions decreased compared to petroleum diesel. For B_5 and B_{100}, CO emission decreased by an average of 12% and 19%, HC emission decreased by 14% and 26% and NOx emission decreased by 4% and 14% and also for B100 SO_2 emission decreased by 86%. For B_5 peak power of 13.6 kW was obtained at a load of 43.9 Nm and for B20 peak power of 13.4 kW was obtained at a load of 43.7 Nm. The BSFC at peak power for B_5, B_{20}, and B_{100} are 1276, 1155 and 1238 g/kWh is observed. GVNSR Ratnakara Rao et al. [11] carried out engine tests on four-stroke diesel engine at injection pressures of 160, 200 and 250 bar and also for injection timing of 11 and 14^0 bTDC. From the test they concluded that BTE will be better for IP of 200 bars and IT of 11^0 bTDC and BSFC is lesser at IP of 200 bar and IT of 11^0 bTDC. However, there is a slight increase in frictional power at 200 bar pressure. Anganathan L et al. [12] studied the different parameters affecting transesterification process for biodiesel production from cottonseed oil and then experimented to analyze combustion, as well emission characteristics of a four Stroke, single cylinder, direct injection, naturally aspirated diesel engine and the results showed 75% biodiesel production was achieved at 20% methanol and 0.5% NaOH at 55^0C reaction temperature. It is found that the heat release rate, burning rate, peak rate of pressure rise, ignition delay, brake thermal efficiency, CO emission, HC emission and soot concentration for CSOME and its blends are lower compared to diesel oil whereas NOx and CO_2 emissions are found to be higher for CSOME and its blends. Thus he concluded that the cottonseed oil and its blends are a potential substitute for diesel oil with satisfactory combustion and emission characteristics.

Thangavelu Elango et al. [13] compared combustion, performance and emission characteristics of a single cylinder diesel engine with blends of jatropha and diesel at different loads. It resulted in peak pressure of all blends at full load are slightly lower than the diesel. Increase in ignition delay and lower brake thermal efficiency were found for biodiesel compared to diesel. Maximum brake thermal efficiency and minimum specific fuel consumption were found for blend B20 among the blends. Jinlin Xue et al. [14] investigated the effect of biodiesel on engine power, economy, durability and emissions, including regulated and non-regulated emission corresponding effect factors are surveyed and made an analysis in detail with the help of reports about biodiesel engine performances and emissions published by highly rated journals in scientific indexes for the year 2000. The use of biodiesel results in the reduction of PM, CO and HC emissions accompanied with imperceptible power loss, increase in fuel consumption and NOx emission due to low heating value in a diesel engine. The suggestion has been made about optimization and modification of the engine so that petroleum diesel is completely substituted by biodiesel. Later K.Ashok et al. [15] studied the Combustion Characteristics and Performance of a direct injection diesel engine fueled with Rice-Bran oil derived biodiesel/diesel blends. They concluded that increasing trend BTE decreased with an increase in the proportion of biodiesel in the blends. The amount of CO and HC in exhaust emission reduced, whereas NOx increased with an increased % of the blend. Further, The above study leads to concentrate on the extraction of biodiesel from the resources as a waste cooking oil, which is available at low cost and also encouraged to study its utilization on 4stoke single cylinder diesel engine.

BIODIESEL EXTRACTION

Preparation of Biodiesel

Though there are different methods for the extraction of biodiesel from vegetable oils, namely Dilution method, Micro emulsification, Pyrolysis (Thermal cracking), yet Transesterification process is found easier and less expensive compared to others. Hence it is chosen for the extraction process.

This process enables the conversion of different vegetable oils into usable biofuels (ethyl or methyl-ester) in the presence of a catalyst. This converts vegetable oil to methyl esters, ethyl esters, 2propyl esters, and butyl esters in the presence of KOH or NaOH as catalysts, by reducing the viscosity of the vegetable oil.Biodiesel esters have the notable fuel properties which include density, viscosity, acid value, iodine value, pour point, cloud point, the gross heat of combustion, and volatility. Biodiesel fuels consume more fuel per power and torque outputs compared to diesel fuel.When compared to diesel, biodiesel has few good properties such as flash point, sulfur content, aromatic content, and biodegradability. Hence, without any alterations to the existing engines, biodiesel can be used as fuel.

Since Viscosities of the vegetable oils are usually higher than that of the conventional diesel fuel. Fuel atomization reduces and penetration increases with the increase in the viscosity. Due to this there forms deposits in the engine, injector coking, piston ring sticking and the oil thickening. Hence selecting of suitable method plays a vital role in an extraction process.

Transesterification Process

When Mustard oil and WCO are compared with conventional diesel, pumping and atomization are difficult due to high viscosity. The conversion of methyl or ethyl esters by the transesterification process of oils requires 3 moles of alcohol psychometrically. Even though it is an equilibrium reaction, additional alcohol is required to obtain the reaction close to the formation. The edible and non- edible oils are chemically reacted with the methanol or ethanol (alcohol) in the presence of NaOH/KOH (catalysts) to produce methyl or ethyl esters. The mixture was stirred continuously at the temperature range of 60^0-65^0C and then allowed to settle in a separating funnel. Two clear layers are found due to density variation, the top layer is of methyl/ethyl esters and the bottom layer is of glycerol. The bottom layer was separated out after the separation of esters is mixed with distilled warm water to remove the catalyst presented in the esters and allowed to settle under gravity. When the water reacts with catalyst, soap formation is observed and gets separated from the esters. When the distilled water is added to the esters for the removal of the catalyst, there is a chance of water molecules retained in the methyl esters. To remove the water molecules trapped, the esters are further heated above the 100^0C till the water molecules get evaporated. The process is referred to the drying process. Finally, at the end of process glycerin is produced as a byproduct.

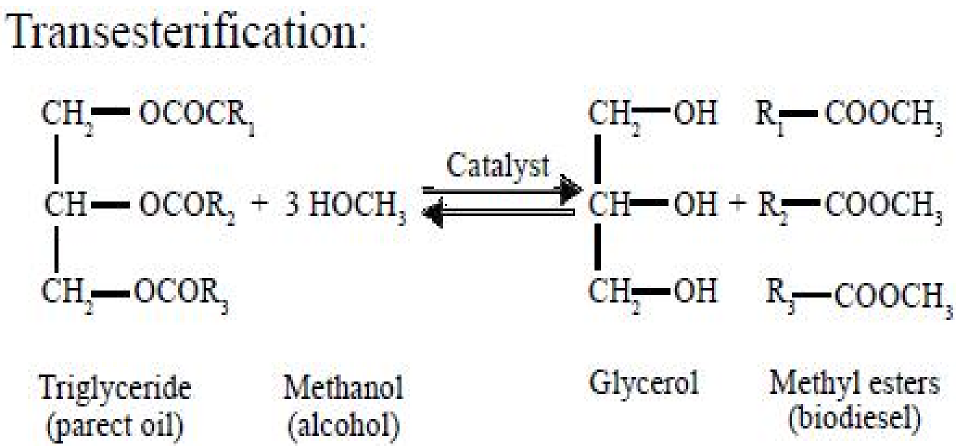

Figure 1: Transesterification Reaction

FIGURES AND TABLES

Drying Process	Biodiesel	Test Rig

Figure 2

Engine Specifications

Table 1

1.Engine	4 Stroke Single Cylinder Diesel Engine	**6.Stroke**	110mm
2.Fuel	Diesel	**7.Dia. Of brake drum**	300mm
3.Rated power	3.675kW	**8.Rope diameter**	15mm
4.Rated speed	1500 RPM	**9.Cooling**	Water cooled
5.Bore	80mm	**10.Temperature measurement**	Digital Thermocouple

Properties of Diesel, Bio-Oils and Ethanol

Table 2

Properties	Diesel	WCO	Mustard	Ethanol
Density at 15^0C (Kg/m^3)	830	890	940	790
Kinematic viscosity At 40^0C (cst)	1.81	3.65	10.3	1.4
Flash point (^{0}C)	53	160	145	14
Fire point(^{0}C)	58	164	150	20
Calorific value (MJ/Kg)	42.34	39.76	32.43	29.7

Properties of WCO-MUSTARD Biodiesel with 2% Ethanol

Table 3

Properties	B10D88E2	B20D78E2	B30D68E2
Density at 15^0C (Kg/m^3)	837.8	846.4	855
Kinematic viscosity At 40^0C (cst)	2.3	2.82	3.34
Flash point (^{0}C)	62	72	82
Fire point(^{0}C)	67	77	87
Calorific value (MJ/Kg)	41.46	40.83	40.21

RESULTS AND DISCUSSIONS

Engine Testing Performance Results

Brake Specific Fuel Consumption (BSFC)

Brake specific fuel consumption is one the important performance characteristics to be studied to understand the performance of an IC engine. Brake specific fuel consumption is defined as the amount of fuel consumed per unit power output. In this work BSFC values for WCO –Mustard Biodiesel samples, B10, B20, B30 were noted at three different injection pressures of 180bar, 200 bar, and 220bar respectively at 25%, 50%, 75%and 100% loading on Engine test rig. From the test data, it is found, that BSFC values decreased with the increase in brake power. And these values for WCO-Mustard Biodiesel were found comparatively more than the conventional diesel fuel. This is due to the lower calorific value and high viscosity of the biodiesel. For the extracted Biodiesel sample (WCO-Mustard) compared to conventional diesel, BSFC found optimum at an injection pressure of 200bar. Because at optimum pressure, fuel-air mixing and spray atomization is improved and intern BSFC decrease. Hence out of three injection pressure for the WCO-Mustard, 200bar found suitable. This is found optimum at 200bar injection pressure for sample B10, with BSFC value as 0.20kg/kW-hr. Where minimum BSFC was found for B10 at 200bar compared to B20 and B30. For Mustard-WCO B10 biodiesel at full load, when injection pressure was increased from 180 bar to 200bar BSCF decreased by 15%. For 220 bar BSFC increased by 28% compared to 200bar.

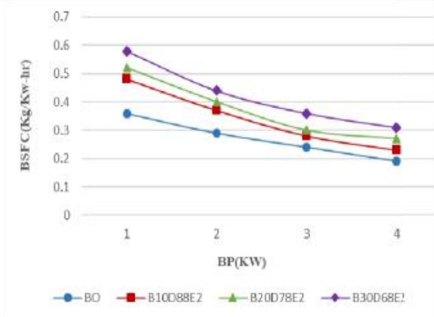

Figure 3: Variation of Brake Specific Fuel Consumption for WCO-Mustard Biodiesel at 180bar Injection Pressure

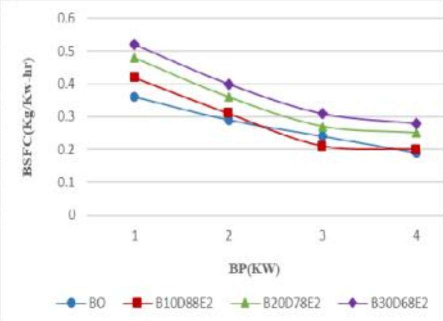

Figure 4: Variation of Brake Specific Fuel Consumption for WCO-Mustard Biodiesel at 200bar Injection Pressure

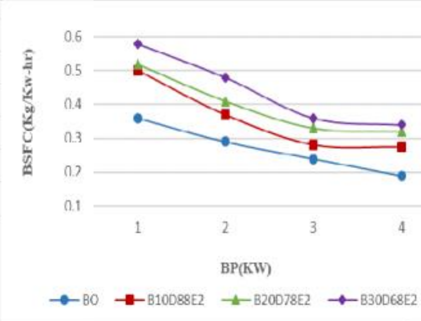

Figure 5: Variation of Brake Specific Fuel Consumption for WCO-Mustard Biodiesel at 220bar Injection Pressure

Brake Thermal Efficiency (BTE)

Brake thermal efficiency is defined as the ratio of the heat equivalent of the brake output to the heat supplied to the engine. BTE of WCO-Mustard biodiesel B10, B20, and B30 were taken at three different injection pressures of 180bar, 200bar and 220bar. Variations in BTE were noted at 25%, 50%, 75% and 100% loads. BTE increases with the increase in brake power. At all the different injection pressures BTE of WCO-Mustard biodiesel were comparatively less than pure diesel. This is because of the lower calorific value of biodiesel. For Mustard-WCO biodiesel in comparison to Diesel, maximum BTE is observed at an injection pressure of 200bar. 200bar is found to be optimum pressure. In optimum pressure, fuel-air mixing and spray atomization will be improved thereby increases BTE. So in this case the injection pressure of 200bar is optimum compared to 180bar and 220bar. Hence, forWCO-Mustard biodiesel maximum, BTE of 25.3% was found for B10 blend at 200bar. The following graphs show variations of BTE at different injection pressures.

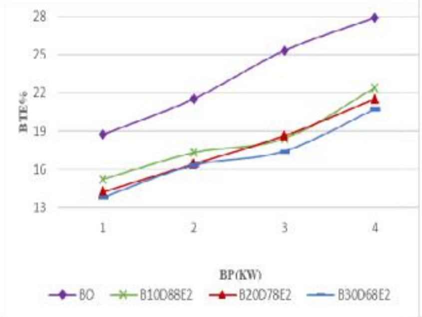

Figure 6: Variation of Brake Thermal Efficiency with Brake Power for WCO-Mustard Biodiesel at 180bars Injection Pressure

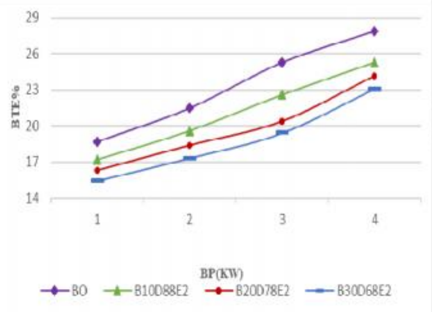

Figure 7: Variation of Brake Thermal Efficiency with Brake Power for WCO-Mustard Biodiesel at 200bars Injection Pressure

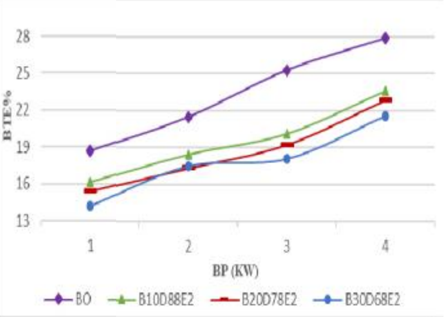

Figure 8: Variation of Brake Thermal Efficiency with Brake Power for WCO-Mustard Biodiesel at 220bars Injection Pressure

Engine Testing Emission Results

Unburnt Hydrocarbons (UBHC)

Unburnt hydrocarbons are the result of incomplete combustion of the carbon components. The variation of UBHC emission for different injection pressures. The amount of Hydrocarbon in the emission decreases with the increase of biodiesel proportion if the fuel blends. When compared to diesel emissions, HC emission for biodiesel blends are lower. This may be due to the reason that the biodiesel has a high cetane number, the more oxygen content and have more gas temperature compared to conventional diesel. As the cetane number increases, ignition delay reduces and hence reduced hydrocarbon emission. Condensation of higher HC is prevented as the temperature is high in a case of biodiesel.

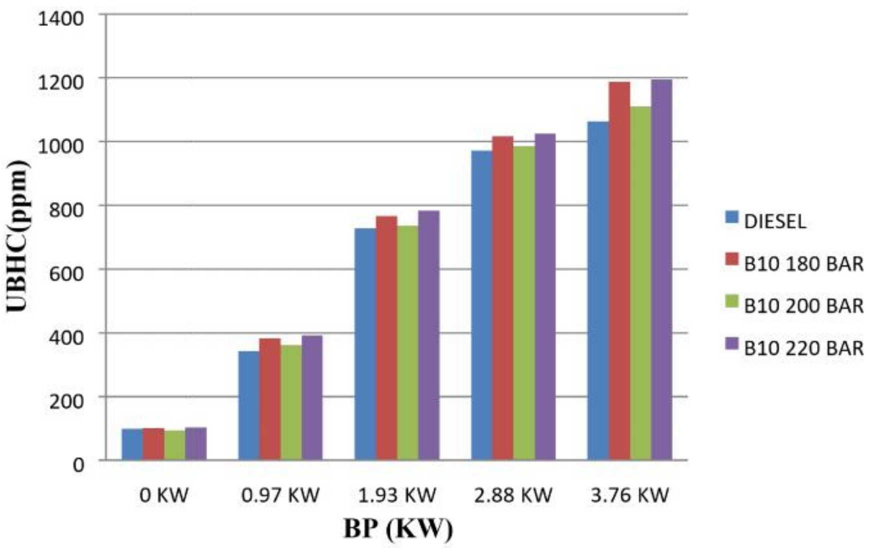

Figure 9: Variation of UnburntHydrocarbon with Brake Powerfor WCO-Mustard Biodiesel

Carbon Monoxide (CO)

Carbon monoxide is an odorless, colorless and toxic gas and it is emitted due to combustion of fuel. With the increase in the proportion of biodiesel in the blend CO emission decreases. CO emission for biodiesel is less compared to diesel. This may be due to the reason that biodiesel has a high cetane number to that of diesel. It is found that with the increase in the BP, CO emission increases. The highest cetane number will reduce the "%CO" content in emissions.

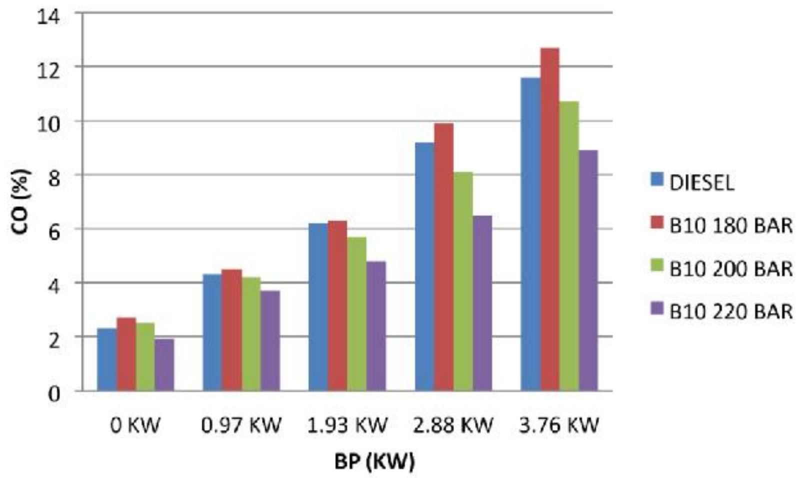

Figure 10: Variation of Carbon Monoxide with Brake Power for WCO-Mustard Biodiesel

Carbon Dioxide (CO_2)

Carbon dioxide is a colorless, odorless, incombustible gas formed during respiration, combustion, and organic decomposition. Carbon dioxide emissions are less as compared to diesel emission. It was found that with an increase in injection pressure CO_2 emission reduces. This is due to the fact that, at low injection pressure the combustion rate will be low, resulting in high carbon dioxide emission whereas, at high injection pressure the combustion rate will be higher resulting in low carbon dioxide emission.

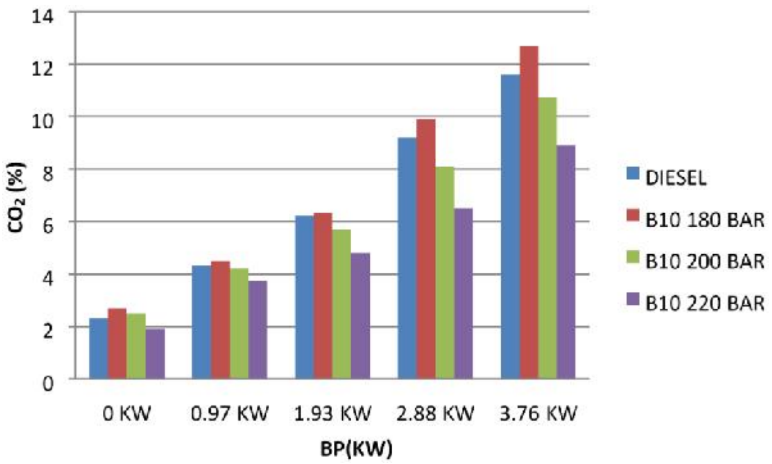

Figure 11: Variation of Carbon Dioxide withBrake Power forWCO- Mustard Biodiesel

Nitrogen Oxides (NO_X)

Nitrogen oxides are the direct result of combustion in the presence of atmospheric nitrogen and oxygen. Nitrogen oxides emission increases with increase in injection pressure and an increase in the proportion of biodiesel in fuel blends. Higher injection pressure results in high temperature and thereby NO_X emission increases. Biodiesel show slows burning nature, due to which there is a delay in energy released, due to this high amount of energy present at the end of the power stroke, a temperature is high, hence increase NO_X emission.

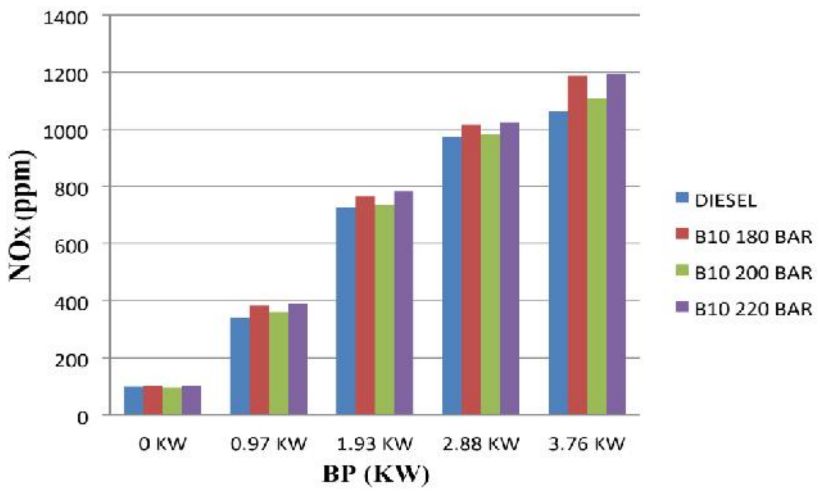

Figure 12: Variation of Nitrogen Oxide withBrake Power for WCO-Mustard Biodiesel

CONCLUSIONS

Biodiesel, a renewable source of energy, which is a very promising alternative to fossil Fuel and to fulfill the energy requirement of the future. Since Biodiesel has the properties closer to the conventional Diesel fuel, many researchers are working on this area to produce the best alternative Biofuel. The overall studies based on the production, engine performance and exhaust emission of WCO-Mustard biodiesel. Precisely, it includes the production of biodiesel sample from WCO and Mustard oilin 1:1 ratio and blended with 2% of ethanol, further some samples are obtained as B10, B20 and B30 by blending the above said Biodiesel with conventional Diesel fuel, to enhance the performance characteristics. The present work demonstrates 1) `extraction of Biodiesel from transesterification process, 2) Performance characteristics of a 4Stroke singe cylinder Diesel engine, with 3.675kW @1500 rpm with B10, B20 and B30 samples as fuels at 0%, 25%, 50%, 75% and 100% loading at injection pressures of 180bar, 200bar and 220bar respectively. From the above investigations, it is found that Biodiesel sample with "B10" designation found optimum at an injection pressure of 200bar, in performance as well as in emission characteristics, compared to the rest two designations. From the investigation,WCO-Mustard sample B10 shown BSFC as 0.20kg/kW-hr and BTE as 25.3% at 200bar of injection pressure, that is almost near to the conventional diesel fuel at its regular injection pressure of 180bar.

The emissions characteristics revealed, that the biodiesel samples of WCO-Mustard, produces reduced % of UBHC, CO and CO_2 compared to conventional Diesel fuel, whereas NOx% in emission found to be increased compared to Diesel fuel. It is clearly observed that the average NOx emission in case of conditioned biofuel 1110PPM, which is slightly higher than the conventional Diesel fuel (1063). Further scope of this work could be, the study of reduction of NOx% in emission by introducing EGR (exhaust gases recirculation) technique.

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