INFLUENCE OF Al_2O_3 NANO MATERIAL ADDITIVES BASED BIODIESEL BLENDS ON THE PERFORMANCE OF DIESEL ENGINE

Syed Sameer Hussain[1], Syed Abbasali[2], Altaf Hussain Bagwan[3], Dilip Sutraway[4], Mahammadrafeeq Manvi[5], Abbasali L Bagwan[6]

[1,2,3,4,5,6]Professor, Dept. of Mechanical Engineering, SECAB Institute of Engineering and Technology, Vijayapur, Karnataka.

Abstract - *A Energy is one of the important resources for mankind and its sustainable development. Fuels are of most import because they can be burned to produce significant amounts of energy. An alternative fuels have been received much attention due to the depletion of world petroleum reserves and increased environmental concerns The main objective of this paper is to produce the biodiesel from WCO (Waste Cooking Oil) an to evaluate the properties of biodiesel from WCO dispersed with nanoparticles (Al_2O_3) as well as to investigate the performance parameters of a single stage IC engine using Waste cooking oil biodiesel dispersed with nanoparticles and their blends in varying Proportions. A single cylinder diesel engine is used to conduct experiments at a constant speed of 1500rpm under variable load conditions. The experimental results of performance characteristics like brake thermal efficiency, brake specific fuel consumption are recorded and compared with that of diesel. It is noticed that, the brake thermal efficiency of diesel was obtained as 25.61% and that of biodiesel blends + Al2O3 was obtained as 25.08%, 25.49%, 25.97%, and 28.63% at full load condition.*

Key Words: Waste cooking oil, Diesel Engine, Brake thermal efficiency, Nano additives

1. INTRODUCTION

Increasing concerns regarding environmental impacts, the soaring price of petroleum products together with the depletion of fossil fuels have prompted considerable research to identify alternative fuel sources. Biofuel has recently attracted huge attention in different countries all over the world because of its renewability, better gas emissions and its biodegradability. Biodiesel is superior to conventional diesel in terms of its sulphur content, aromatic content and flash point. It is essentially sulphur free and non-aromatic while conventional diesel can contain up to 500 ppm SO2 and 20–40 wt% aromatic compounds. These advantages could be a key solution to reduce the problem of urban pollution since transport sector is an important contributor of the total gas emissions. Amongst vehicle fuels, diesel is dominant for black smoke particulate together with SO2 emissions and contributes to a one third of the total transport generated greenhouse gas emissions [1]. According to Utlu and Kocak [2], there was on average of a decrease of 14% for CO2, 17.1% for CO and 22.5% for smoke density when using biodiesel.

Biodiesel production from vegetable oils has been extensively studied in recent literature reviews. There were more than 50 papers cited relating to biodiesel production from vegetable oils in the Fukuda et al.'s work [3]. Many researchers have reported the biodiesel production in several ways: (a) the effect of operating parameters [4,5,7,8,9]; (b) the effect of the type of catalysts such as enzyme catalysts [3,10,11,12,13], heterogeneous catalysts [14,15] and acidic catalysts [16,17]. However, the raw material costs and limited availability of vegetable oil feedstocks are always critical issues for the biodiesel production. The high cost of vegetable oils, which could be up to 75% of the total manufacturing cost, has led to the production costs of biodiesel becoming approximately 1.5 times higher than that for diesel [18, 19]. Nevertheless, the price of waste cooking oils (WCO) is 2–3 times cheaper than virgin vegetable oils. Consequently, the total manufacturing cost of biodiesel can be significantly reduced [19]. In addition, a similarity in the quality of biodiesel derived from WCO and from vegetable oils could be achieved at an optimum operating condition [20]. Increasing food consumption has increased the production of a large amount of waste cooking oils/fats. It was, for example, 4.5–11.3 million litres a year in USA or 4 105 –6 105 ton/year in Japan [21]. The conversion of this amount of WCO into fuel also eliminates the environmental impacts caused by the harmful disposal of these waste oils, such as into drains [22]. Biodiesel from WCO (or used frying oils) has been recently investigated [20, 22, 23].

2. EXPERIMENTS

2.1 Materials

WCO samples were collected from restaurants and shops within Vijaypur City, Karnata India with 5–10 litters each and filtered to remove inorganic residues. The WCO samples were obtained from different ways: (a) collecting after being used several times for frying purposes at small shops; (b) taking after being used once for big restaurants. The properties of the blends of WCO with nano additives samples are illustrated in Table 1.1.

Table -1: Properties of the blends of WCO with nano additives samples

Property	Diesel (B0)	WCO + Nano additives			
		B10	**B20**	**B30**	**B40**
Density (kg/m3)	832	837.5	843	848	854
Calorific value (kJ/kg)	44000	43152	42304	41456	40608
Flash point (°C)	69	64.7	69.2	96.8	104.9
Fire point (°C)	53.4	78.9	84	110.9	121.9

2.2 Transesterification

Transesterification is the process in which by using an alcohol (e.g. methanol, ethanol or butanol), in the presence of a catalyst, such as sodium hydroxide or potassium hydroxide, to break the molecule of the raw renewable oil chemically into methyl or ethyl esters of the renewable oil, with glycerol as a by-product. Transesterified, renewable oils have proven to be a viable alternative a reaction scheme for transesterification is as follows

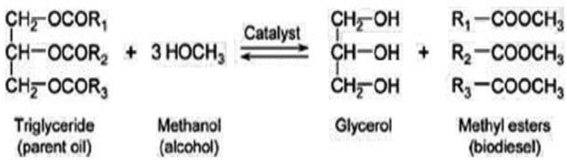

Fig.1: Chemical reaction scheme for transesterification

In fig. 1, R1, R2, and R3 in this diagram represent long carbon chains that are too lengthy to include in the diagram. Waste oil is collected and blended for various proportions and are treated with adequate amount of CH_3OH (methanol)and required amount of NaOH (sodium hydroxide) as a catalyst which are available in chemical laboratories. Since these oils are of high viscosity and low volatility, then direct use of feedstock in diesel engines can cause problems including: high carbon deposits, scuffing of engine liner, injection nozzle failure, and gum formation, lubricating oil thickening and high cloud and pour points. In order to avoid these problems, the feedstock is chemically modified to its derivatives which have properties more similar to petro-diesel. The free fatty acids (FFA) and triglycerides contained in the oil are reduced to Fatty Acid Alkyl Esters (FAAEs). This process is known as Transesterification. Here, we are conducting transesterification process in single stages for the production of biodiesel.

Transesterification process is affected by parameters like amount of methanol, concentration of sodium hydroxide (NaOH), reaction temperature and reaction time. One of the most important variables affecting the yield of biodiesel is the molar ratio of alcohol to vegetable oil used. In the present work we have optimized all these variables.

2.3 Experimental procedure

The Transesterification process is conducted in single stages for the production of biodiesel from the waste cooking oil.

2.4 Esterfication procedure

- NaOH is weighed and dissolved in 30% of methanol using a stirrer.
- 250 ml of WCO is added to the methanol and NaOH mixture.
- The mixture is stirred continuously at 1500 rpm for 90 minutes at a constant temperature of 60°C.
- The mixture then is transferred to the separation flask and kept there for 6 hours.
- Glycerol is then separated and biodiesel is obtained.

Fig.2: Esterification process setup

2.5 Water wash

Once the biodiesel is separated from the glycerin, the biodiesel is washed gently with warm water to remove residual catalyst, acidic or soapy contents. And then collect it in a storage tank. In some processes this water wash is not necessary. This is normally the end of the production process resulting in a clear amber-yellow liquid with a viscosity similar to petro diesel. In some systems the biodiesel is distilled in an additional step to remove small amounts of color bodies to produce a colorless biodiesel. After normalizing the pure bio-diesel obtained which removes the acid content presence in the crude bio diesel. Then the crude bio-diesel is heated up to boiling temperature of water, which helps to evaporate moisture content.

Fig.3: Pure biodiesel after water wash

2.6 Blending bio-diesel with diesel

The pure biodiesel are blended with the diesel in the ratio of B10, B20, B30, and B40. And keep it for minimum of 24 hours to get a homogenous mixture.

Fig.4: Various blends of biodiesel

2.7 Fuel properties measurement

The physical and chemical properties of Waste cooking oil were measured. The calorific value was measured by Bomb Calorimeter, The viscosity was measured by Redwood Viscometer, The flash point and fire point were determined by Pensky-Martens apparatus by closed-cup method. The conversion of waste cooking oil into its methyl ester can be accomplished by Transesterification process. Before Transesterification the properties of waste cooking oil is as shown in the table 2.

Table -2: Properties of waste cooking oil

Properties	Value
Flash point	1800C
Fire point	2000C
Pour point	50C
Cloud point	140C
Viscosity	46 CST
Calorific value	35000 KJ/KG

2.8 Preparation of Nano-Particles (Al_2O_3)

Nano additives are the nano particles, which have capable of increasing biodiesel properties to compete with diesel. The heterogeneous reaction occurs on the surface. Nanoparticles have a large surface area than the bulk one. It enhances the number of reaction sites for the reaction to occur. Surface atom is more unstable and reactive. This unstability is related to their position on the lattice that forces them to unbound their neighbor atoms or molecules. In nano particle case, as the surface/bulk atoms ratio increases, the unstability and reactivity also increase. Therefore, nano particles are having high surface to volume ratio. Main advantage of nano particles is its nano size and because of its size it can easily mixed with biodiesel. It improves the efficiency and also reduces the emission in biodiesel and it also makes biodiesel to completely burn.

Alumina (Al2O3) nanoparticles prepared by simple sol-gel method, Al2O3nanoparticles were synthesized by ethanol solution of aluminum nitrate Firstly, 10g of Al (NO3)39.H2O (Aluminum Nitrate Nona hydrate) was completely dissolved in 150 mL pure water with stirring at room temperature. 14 mL of ethanol solution was then added drop by drop to the solution and synthesis temperature was increased to 80°C. The color of solution changed from orange color to dark brown color. The pH was maintained between 2 and 3 during the synthesis. The white product was evaporated for 3 hours, cooled to room temperature and finally calcined at 500°C for 5 hours. All analyses were done for samples without any washing and more purification. The specification of the size, structure and optical properties of the as-synthesis and annealed Al2O3 nanoparticles were carried out. X-ray diffractometer (XRD) was used to identify the crystalline phase and to estimate the crystalline size. The morphology was characterized by field emission scanning electron microscopy (SEM).

2.9 Dispersion of Nano-Particles (Al_2O_3)

Dispersion of Nano particles in Biodiesel and its blends are done by using Ultrasonicator machine High shear forces created by ultrasonic cavitation have the ability to break up particle agglomerates and result in smaller and more uniform particles sizes. The stable and homogenous suspensions produced by ultrasonic are widely used in many industries today. Probe sonication is highly effective for processing nanomaterials (carbon nanotubes, graphene, inks, metal oxides, etc.

3. EXPERIMENTATION

3.1 Engine Setup

The Test-Rig consists of four stroke Diesel Engine, which is connected to the electrical swinging field dynamometer with the resistive loading. The DC machine is used as motor for starting the engine. Once the engine is started with the changeover of the switch to the generator mode; it will act as a DC generator which is connected to the resistive load Air heaters. The engine and the dynamometers are coupled by a coupling. The exhaust of the engine is connected to the exhaust gal calorimeter. Temperature sensors are fitted at the inlet and outlet of the calorimeter for temperature measurement. The complete set up is mounted on Anti Vibration Mounts. The layout of experimental test rig and its instrumentation is shown in Fig 5,6 &7. It is a water cooled engine with a rated power of 3.7 kW at 1500 rpm having bore 80mm and stroke 110mm,compression ratio of 16:1 to 25:1. A fuel tank is fitted inside control panel along with fuel measuring unit. An air box is powered for damping pulsation in air flow line. An orifice meter with manometer is fitted at the inlet of air box for flow measurement. Thermocouple type temperature sensors measure cooling water inlet, outlet and exhaust temperatures. These temperatures are digitally indicated on indicator suited on control panel.

Fig.5: Compression Ignition Engine

Fig.6: Computerized Engine testing setup

Fig.7: Emission analyzer machine

4. RESULT AND DISCUSSIONS

4.1 Performance graphs for different loading conditions

Table -3: Results of Brake Power

LOAD (Kg)	2.5	5	7.5	10
DIESEL	0.66	1.39	2.09	2.74
B10WCO+Al2O3 30 ppm	0.73	1.42	2.07	2.71
B20WCO + Al2O3 30 ppm	0.70	1.38	2.05	2.73
B30WCO +Al2O3 30 ppm	0.75	1.42	2.09	2.74
B40WCO +Al2O3 30 ppm	0.75	1.44	2.1	2.73

From table 3 it can been seen that the variation of brake power for different loading condition.

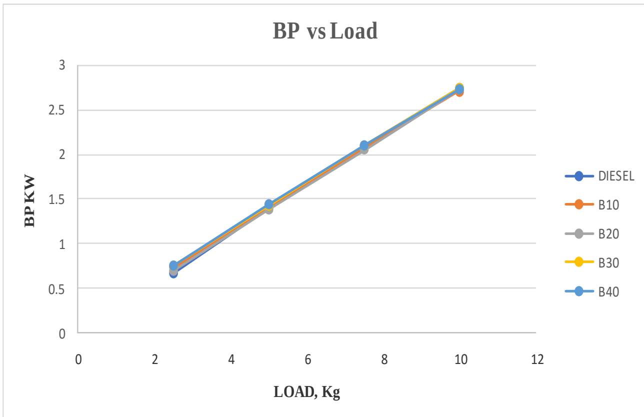

Chart -1: Variation of Brake Power with Respective Load

The above graph shows the Variation of Brake Power with Respective Loading conditions. From this graph it can be seen that brake power for diesel and for B30 WCO + A_2O_3 is same.

Table -4: Results of Brake Thermal Efficiency

LOAD (Kg)	2.5	5	7.5	10
DIESEL	16.22	28.96	37.72	44.35
B10WCO+Al2O3 30 ppm	17.02	29.16	37.15	43.68
B20WCO + Al2O3 30 ppm	18	28.28	37.40	43.87
B30WCO +Al2O3 30 ppm	17.17	27.67	35.44	40.95
B40WCO +Al2O3 30 ppm	17.17	25.90	32.18	39.92

The table 4 shows results of Brake thermal efficiencies for different load conditions. Brake thermal efficiency for B40WCO + Al_2O_3 as compare to diesel is more.

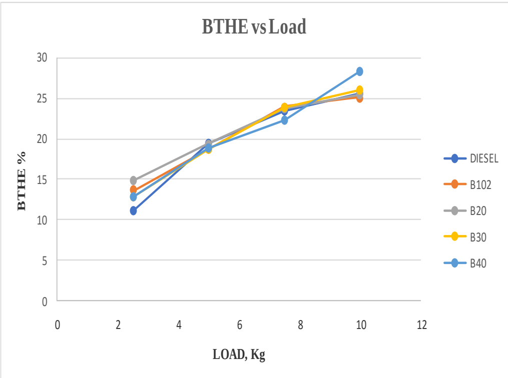

Chart -2: Variation of Brake Thermal Efficiency with Respective Load

The above graph shows variation of Brake Thermal Efficiency with Respective Loads. Brake thermal efficiency for B40WCO + Al_2O_3 is more as compare to diesel.

Table -5: Results of Mechanical Efficiency

LOAD (Kg)	2.5	5	7.5	10
DIESEL	11.09	19.42	23.47	25.61
B10WCO+Al2O3 30 ppm	13.61	18.73	23.99	25.08
B20WCO + Al2O3 30 ppm	14.82	19.39	24.23	25.49
B30WCO +Al2O3 30 ppm	12.85	18.64	23.82	25.97
B40WCO +Al2O3 30 ppm	12.85	18.87	22.30	28.63

The table 5 shows results of Mechanical efficiencies for different load conditions. Mechanical efficiency of B20WCO + Al_2O_3 as slightly less as compare to diesel.

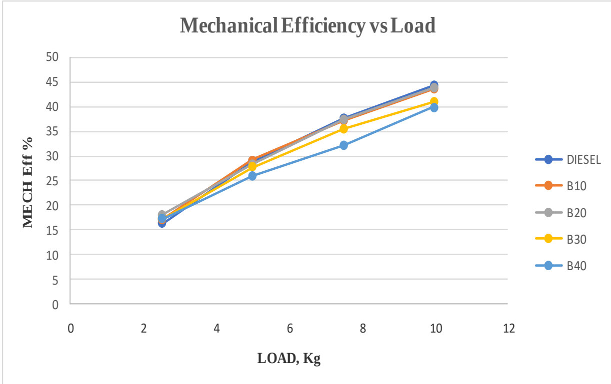

Chart -3: Variation of Mechanical Efficiency with Respective Load

The Chart 3 shows the variation of mechanical efficiency v/s Load for different biodiesel blends dispersed with nano additives from the above graph, it is noticed that, the mechanical efficiency of diesel was obtained as 44.35% and that of biodiesel blends was obtained as 43.68%, 43.87%, 40.95% and 39.92% at full load condition. It is observed that the mechanical efficiency of biodiesel B20WCO + Al_2O_3 (43.87%) at full load is minimum compared to diesel, this is because uniform distribution of fuel droplets inside the combustion chamber. Hence uniform combustion has been taken place.

5. CONCLUSIONS

The present study is carried out in order to compare the performance of a diesel engine fueled with mineral diesel and waste cooking oil biodiesel dispersed with nanoparticle blends. Alternative fuel production from renewable resources poses many challenges. Depletion of fossil-fuel resources, unstable price of crude oil and other fossil-fuels and environmental concerns are the main reasons for finding a new fuel which should be environmentally friendly, cheap, widely available and technically acceptable. Biodiesel is one of the best fuel alternatives that researchers are focused. These are the main conclusions of this study:

- Small scale biodiesel production unit is developed.
- In this study, biodiesel is produced successfully from waste Cooking oil dispersed with nanoparticles.
- The properties of biodiesel dispersed with nanoparticles are found very similar to that of mineral diesel. It can be used directly at the place of diesel fuel without any significant alterations in diesel engines.
- Performance characteristics of biodiesel dispersed with nanoparticles of blends are found to be close comparison to diesel fuel.

The above conclusions prove biodiesel, which is a green product, can replace the mineral diesel in coming years. The shortcomings with biodiesel for now are slightly more price and insufficient feedstock which can be removed selecting an optimized process for production. The engine performance is improved with biodiesel and it adds in greenery and economic strength of a country as well. This is why it is also termed as “biodiesel: the future fuel”.

REFERENCES

[1] Nas B, Berktay A. Energy potential of biodiesel generated from waste cooking oil: an environmental approach. Energy Sources 2007;2:63–71.

[2] Utlu Z, Kocak MS. The effect of biodiesel fuel obtained from waste cooking oil on direct injection diesel engine performance and exhaust emissions. Renew Energy 2008;33:1936–41.

[3] Fukuda H, Kondo A, Noda H. Biodiesel fuel production by transesterification of oils. J Biosci Bioeng 2001;92:405–16.

[4] Antonlin G, Tinaut FV, Brceno Y, Castano V, Perez C, Ramirez AI. Optimisation of biodiesel production by sunflower oil transesterification. Bioresour Technol 2002;83:111–4.

[5] Freedman B, Butterfield RO, Pryde EH. Transesterification kinetics of soybean oil. JAOCS, J Am Oil Chem Soc 1986;63:1375–80.

[6] Gurusala NK, Selvan VAM. Effects of alumina nanoparticles in waste chicken fat biodiesel on the operating characteristics of a compression ignition engine. Clean Technol Environ Policy. 2014; 3:72-76.

[7] Freedman B, Pryde EH, Mounts TL. Variables affecting the yields of fatty esters from transesterified vegetable oils. J Am Oil Chem Soc 1984;61:1638–43.

[8] Ma F, Clements LD, Hana MA. The effects of catalyst, free fatty acids and water on transesterification of beef tallow. Trans Am Soc Agric Eng 1998;41:1261–4.

[9] Rashid U, Anwar F. Production of biodiesel through optimized alkalinecatalysed transesterification of rapeseed oil. Fuel 2008;87:265–73.

[10] Iso M, Chen B, Eguchi M, Kudo T, Shrestha S. Production of biodiesel fuel from triglycerides and alcohol using immobilized lipase. J Mol Catal – B Enzym 2001;16:53–8.

[11] Nelson LA, Foglia TA, Marmer WN. Lipase-catalysed production of biodiesel. JAOCS, J Am Oil Chem Soc 1996;73:1191–5.

[12] Nie K, Xie F, Wang F, Tan T. Lipase catalysed methanolysis to produce biodiesel: optimization of the biodiesel production. J Mol Catal – B Enzym 2006;43:142–7.

[13] Shimada Y, Watanabe Y, Sugihara A, Tominaga Y. Enzymatic alcoholysis for biodiesel fuel production and application of the reaction to oil processing. J Mol Catal – B Enzym 2002;17:133–42.

[14] Kim H-J, Kang B-S, Kim M-J, Park YM, Kim D-K, Lee J-S, et al. Transesterification of vegetable oil to biodiesel using heterogeneous base catalyst. Catal Today 2004;93–95:315–20.

[15] Suppes GJ, Dasari MA, Doskocil EJ, Mankidy PJ, Goff MJ. Transesterification of soybean oil with zeolite and metal catalysts. Appl Catal A: Gen 2004;257:213–23.

[16] Canakci M, Van Gerpen J. Biodiesel production via acid catalysis.Trans Am Soc Agric Eng 1999;5:1203–10.

[17] Lotero E, Liu Y, Lopez DE, Suwannakarn K, Bruce DA, Goodwin JG Jr. Synthesis of biodiesel via acid catalysis. Ind Eng Chem Res 2005;44(14):5353–63.

[18] Ma F, Hanna MA. Biodiesel production: a review. Bioresour Technol 1999; 70:1–15.

[19] Zhang Y, Dube MA, McLean DD, Kates M. Biodiesel production from waste cooking oil: 2. Economic assessment and sensitivity analysis. Bioresour Technol 2003; 90:229–40.

[20] Cetinkaya M, Karaosmanoglu F. Optimisation of base-catalysed transesterification reaction of used cooking oil. Energy Fuels 2004;18: 1888–95.

[21] Pugazhvadivu M, Jeyachandran K. Investigations on the performance and exhaust emissions of a diesel engine using preheated waste cooking oil as a fuel. Renew Energy 2005;30:2189–202.

[22] Utlu Z. Evaluation of biodiesel obtained from waste cooking oil. Energy Sources, Part A 2007; 29:1295–304.

[23] Zheng Y, Kates MM, Dube A, McLean DD. Acid-catalyzed production of biodiesel from waste cooking oil. Biomass Bioenergy 2006; 30:267–72.

BIOGRAPHIES

Syed Sameer Hussain is an assistant professor in the Mechanical Department from SIET Vijaypur, Karnataka, India. Currently pursuing his PhD from Visvesvaraya Technological University.

Dr. Syed Abbasali is an associate professor in the Mechanical Department from SIET Vijaypur, Karnataka, India.

Altaf Hussain Bagwan is an assistant professor in the Mechanical Department from SIET Vijaypur, Karnataka, India. Currently pursuing his PhD from Visvesvaraya Technological University.

Dilip Sutraway is an assistant professor in the Mechanical Department from SIET Vijaypur, Karnataka, India.

Mahammadrafeeq Manvi is an assistant professor in the Mechanical Department from SIET Vijaypur, Karnataka, India. Currently pursuing his PhD from Visvesvaraya Technological University.