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Influence of Aluminum Oxide Al_2O_3 Nano Particles Blended With Waste Cooking Oil in the Performance, Emission and Combustion Characteristics on a DI Diesel Engine

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ABSTRACT

An experimental investigation is carried out to establish the performance and emission characteristics using Aluminum oxide (Al_2O_3) as nano additive in WCO blended with various proportions of nano additives 25ppm, 50ppm and 75ppm respectively. The biodiesel is produced from the WCO by standard transesterification process and subsequently, the nano particles are blended by means of an ultrasonicator to achieve stable suspension. It is observed that the blends are stable which are suitable for the performance test on the compression ignition engine. The characterization study of the nano particles such as SEM is carried out to analyze their morphology. The whole investigation is carried out in a single cylinder DI diesel engine using different proportions of nano additive blended biodiesel. The result shows a considerable enhancement in brake thermal efficiency and specific fuel consumption due to the influence of aluminium oxide nanoparticles addition in biodiesel blend.

Keywords - Aluminium oxide Nanoparticles (Al_2O_3), WCO, Ultrasonicator, Diesel engine.

1. INTRODUCTION

The increase in energy consumption in past several decades has increased the awareness of exhausting natural resources. Rapid industrialization and massive growth of population have increased the dependence and use of natural fuels. Approximately 90% [1] of our energy requirements are met by fossil fuel. A study shows that if exploited at the same rate, the coal depletes in next 200-300 years and petroleum will deplete in the next few decades [2-5]. So researchers show more interest in the development of alternative fuels for the future.

Biodiesel fuels are considered as best alternative for diesel fuel as it is renewable, eco – friendly, non-toxic and basically free of sulphur [4]. In recent year several kind of vegetable oil are employed as fuel in engine. Various edible oil such as peanut oil, corn oil, palm oil where used as alternative fuel for diesel engines edible oil increases the cost of food products they are not recommended to use directly. The oil after use are being wasted which can be used as alternative fuel. The burning of fossil fuel is connected with emission such as CO_2, CO, NOx, SOx and particulate matter, which are currently the foremost global sources of emission [3].

Use of WCO after transesterification has been widely used by various researchers. Research has been conducted by using nano particles which in turn act as a liquid fuel catalyst, which turns enhance the ignition, and combustion process of the engine [4]. Addition of nano particles have more reactive surface allowing them to act as more efficient chemical catalyst, thereby increasing the combustion. Moreover the presence of the nano particles increases fuel-air mixing in the combustion chamber, which leads to more complete burning [5]. In this work, the performance and emission characteristics of the diesel engine using WCO biodiesel as a fuel and Al_2O_3 is used as an additive are studied [6-8].

2. MATERIALS AND METHODS

2.1 Preparation of biodiesel

The WCO is collected from a nearby hotel in Melmaruvathur, Tamilnadu, India. The collected oil is filtered to remove the impurities present in it. The viscosity of the oil is higher than that of the biodiesel standards. Use of high viscous oil leads to improper combustion. Hence, transesterification is done to reduce the viscosity.

Transesterification process of exchanging the organic group "R" of an ester with the organic group "R" of an alcohol. These reactions are often catalyzed by the addition of an acid and base and an alcohol in the presence of a catalyst [6]. Fig. 1 shows the transesterification process of biodiesel. Transesterification is basically a chronological reaction. Triglycerides are first reduced to diglycerides. The diglycerides are subsequently reduced to monoglycerides. The monoglycerides are finally reduced to fatty acid ester [8].

A 500 ml of the filtered WCO is taken in a flask .A mixture containing 125 ml of methanol and 3g of KOH is mixed with WCO and stirred in a magnetic stirrer for 60 min at a reaction temperature of 60^0c. The entire mixture is allowed to settle in a separating flask for 24 hrs. Glycerine, the heavier liquid, settled at the bottom is separated. After separation, the fatty acid methyl ester is washed with water. The process is repeated until the ester layer becomes clear [11].

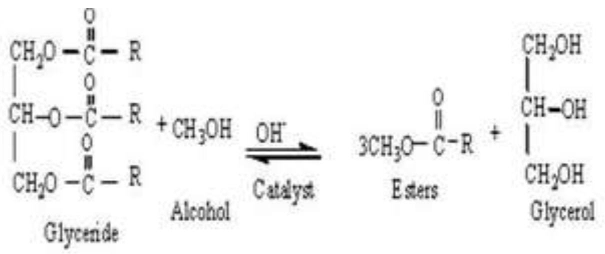

Fig. 1 Transesterification process of Biodiesel

The properties of the Fatty acid methyl ester is found out and presented in Table 1. The values are in line with the biodiesel standards.

Table 1 Properties of biodiesel blends

Properties	Diesel	B20 Al_2O_3 25ppm	B20 Al_2O_3 50ppm	B20 Al_2O_3 75ppm
Kinematic Viscosity @40°C	2.54	5.57	5.37	5.10
Flash Point °C	50	183	185	188
Calorific Value KJ/kg	42500	36815	36841	36869
Specific Gravity @27°C	0.845	0.8588	0.8643	0.885

Based on several studies B20 (20% biodiesel + 80% Diesel) is found to be the optimum blend for the use in DI diesel engine, hence in this work B20 is taken for further studies.

2.2 Preparation of nano blend

Fig 2 shows the Ultrasonicator for blending process of Nanoparticles. Aluminium oxide Al_2O_3 alpha, 30-50 nm, purity 99.5% was purchased from Nano Lab Jamshedpur, India. The ultrasonicaton is a best method for Nano blend for uniform suspension [14 &18]. One liter of l B20 biodiesel and 25ppm of Al_2O_3 nanoparticles are mixed in a ultrasonicator for 30min. Same procedure is followed to prepare the sample of with 50 ppm, 75 ppm respectively. These fuel blends are used to conduct test on diesel engine after preparation.

Fig. 2 Ultrasonicator

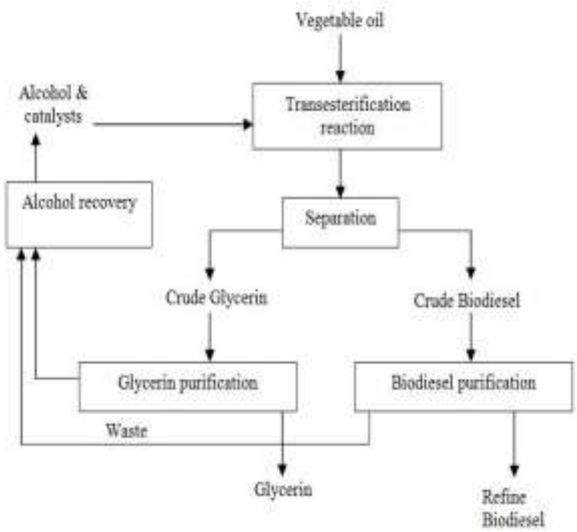

Fig. 3 Transesterification of Biodiesel [10]

2.2.1 SEM of aluminium oxide Al_2O_3

The morphological characterization of Al_2O_3 was carried out using Scanning electron microscopy (SEM).

Spherical shaped Al_2O_3 obtained were confirmed. SEM image of aluminum oxide is shown in Fig 4.

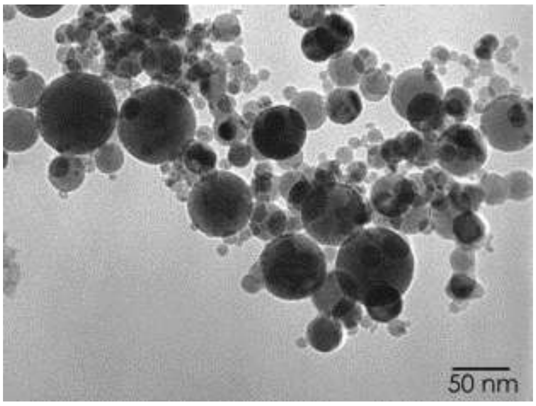

Fig. 4 SEM image of $Al_2O_3$50nm

2.2.2 XRD analysis of aluminium oxide Al_2O_3

X-rays are electromagnetic radiation of wavelength about1 Å (10^{-10} m), which is about the same size as an atom. X-ray diffraction provides most definitive structural information. To provide information about structures we need to probe atomic distances - this requires a probe wavelength of 1 x $10^{-10\ m}$. XRD (X-Ray) diffraction used to look at single crystal or polycrystalline materials. Fig. 5 shows the XRD analysis of Al_2O_3 nanoparticles.

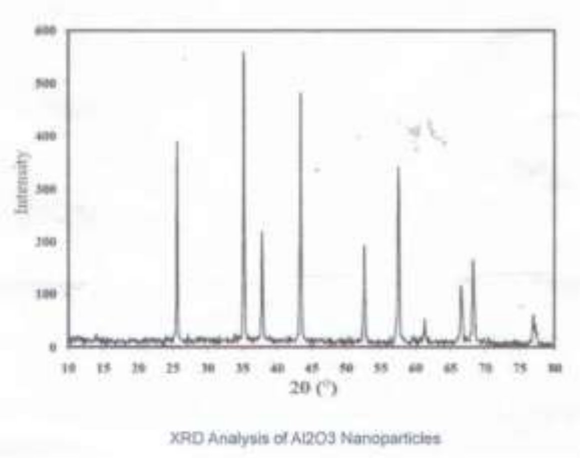

Fig. 5 XRD Analysis of Aluminium Oxide

3. EXPERIMENTAL SETUP

The experimental setup consists of single cylinder, four strokes, water cooled, naturally aspirated direct injection diesel engine connected to a eddy current type dynamometer for loading. The schematic representation is shown in the Fig. 6. The engine setup is provided with necessary instruments for measuring the combustion pressure, fuel line pressure and crank-angle measurements. These signals are interfaced with computer for pressure crank-angle diagrams. Instruments are provided with interface to measure airflow, fuel flow, temperatures and load measurements. The set up has stand-alone panel box consisting of air box, manometer, fuel measuring unit, transmitters for air and fuel flow measurements, process indicator and hardware interface. Lab view based Engine Performance Analysis software package "Engine soft" is provided for on line performance evaluation of the engine. A standard burette and a digital stop watch are also provided to measure fuel flow manually.

The exhaust emissions such as carbon mono oxide CO, carbon di oxide CO_2, nitric oxides NO_x , hydro carbon HC are measured through using AVLDigas 444 five gas analyzer.

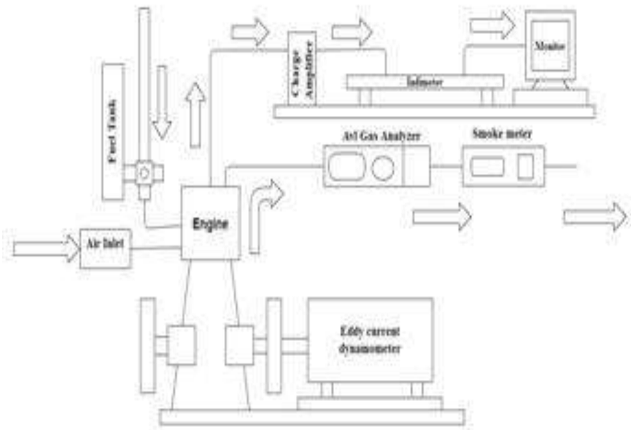

Fig. 6 Engine Setup

Table 2 Engine Specification

Make	Kirloskar AVL model
Type	Single Acting High speed 4S, vertical DI engine
Number of cylinder	One
Speed	1500 rpm
Power output	3.7 kw
Bore	80mm
Stroke Length	110mm
Compression ration	16:5:1

4. RESULT AND DISCUSSION

It has been observed that the operation of the engine was very smooth throughout the rated load, without operational problem. The performance and emission characteristics of the engine fuelled with Aluminium oxide nano particles blended fuel blends were discussed and compared with the neat diesel fuel.

4.1 Engine performance parameters

4.1.1Brake thermal efficiency

Fig. 7 shows the Brake Power Vs brake thermal efficiency. The result shows that all the blends of Al_2O_3show higher value of BTE than diesel, even though the higher percentage of Al_2O_3 shows improvement in BTE. The reason may be the aluminium oxide nanoparticles present in the blend promote longer and more complete combustion and also act an oxygen buffer, thus increasing the efficiency [12]. The maximum brake thermal efficiency obtained for B20 with the addition of 75ppm of aluminumoxide nanoparticles as 24.95% at full load.

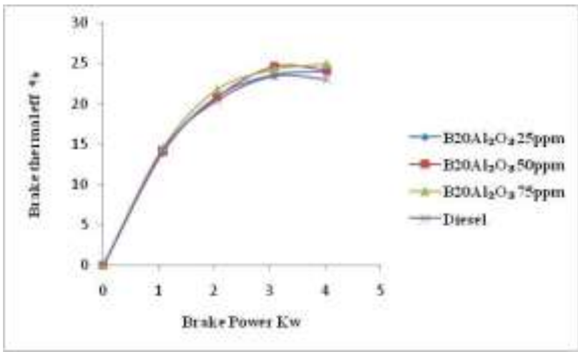

Fig. 7 Brake power Vs Brake thermal efficiency

4.1.2 Brake specific fuel consumption

Fig. 8 shows the brake specific fuel consumption with brake power with different dosing level of biodiesel with blended Al_2O_3 nanoparticles. The brake specific fuel consumption of nanoparticles is lower in $B20Al_2O_3$75ppm when compared with the different dosing level. The lowest brake specific fuel consumption is obtained as 0.392619376 kg/kw-hr for 75ppm nanoparticles added with B20. The addition of aluminium oxide nanoparticles which improves the combustion process.

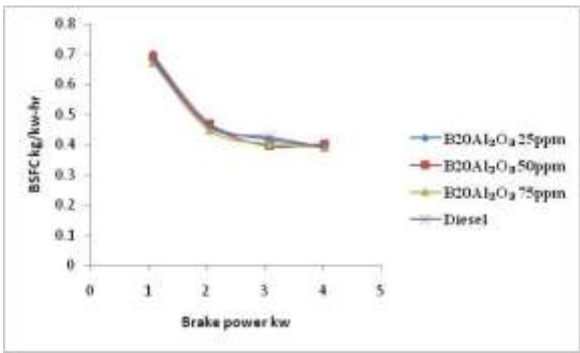

Fig. 8 Brake power Vs BSFC

4.2 Emission parameters

4.2.1 Oxides of nitrogen

Fig. 9 shows the emission of NOx Vs BP. The all values of nano blended biodiesel show a higher value than that of diesel. As the nanoparticles plays a major role in combustion which in turns increases in cylinder temperature the formation of NOx [20]. The NOx emissions for B20 Al_2O_3 25ppm, $B20Al_2O_3$ 50ppm, $B20Al_2O_3$ 75ppm were 6.78, 6.98 and 7.5 respectively.

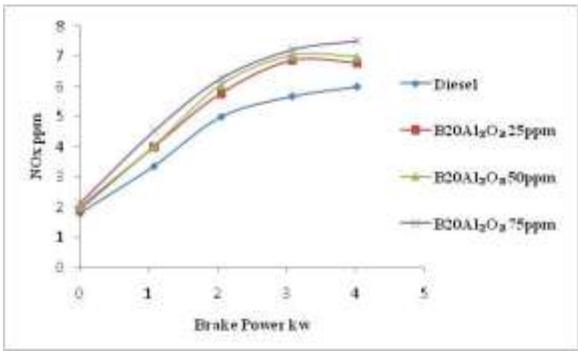

Fig. 9 Brake power Vs NOx

4.2.2 Carbon monoxide

The Fig. 10 shows the emission of CO Vs BP. The presence of oxygen in nanoparticles leads to better combustion there by reduction in carbon monoxide is recorded. Carbon monoxide emission for $B20Al_2O_3$ 25ppm, B20 Al_2O_3 50ppm, B20 Al_2O_3 75ppm were 5.5, 5 and 4.565 respectively.

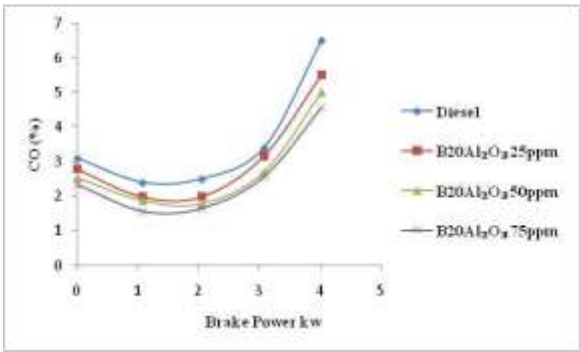

Fig. 10 Brake power Vs CO

4.2.3 Hydrocarbon

Fig. 11 shows the emission of HC Vs BP. By adding of nanoparticles the oxygen level in the biodiesel tends to increases. Better combustion leads to less formation of HC [17]. HC emission for B20 Al_2O_3 25ppm, B20 Al_2O_3 50ppm, B20 Al_2O_3 75ppm were 0.17, 0.14 and 0.126 respectively.

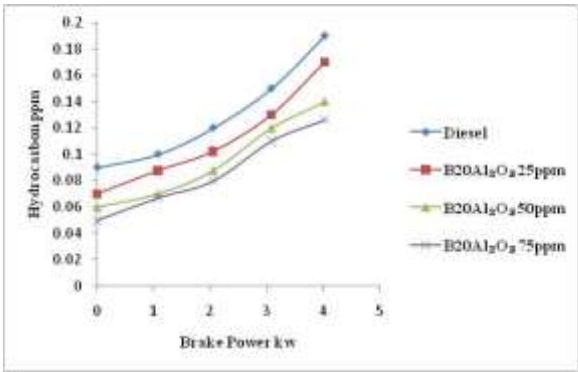

Fig. 11 Brake power Vs Hydrocarbon

4.3 Combustion characteristics

4.3.1 Cylinder pressure

Fig. 12 shows the Crank angle Vs Cylinder pressure. The increase in addition of nanoparticles leads higher cylinder pressure. This may be due to reduction in ignition delay and improves the combustion [16]. The cylinder pressure for B20 Al_2O_3 25ppm, B20 Al_2O_3 50ppm, B20 Al_2O_3 75ppm was 66.76, 73.45 and 75.34 respectively. The increase of nanoparticles tends to increase of cylinder pressure. The crank angle Vs cylinder pressure bar were 73.80642 bar, 75.16402 bar and 76.55651 bar.

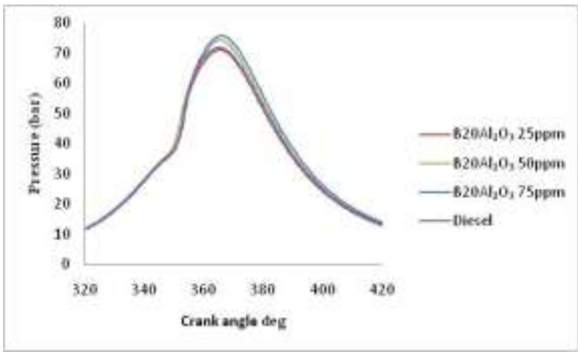

Fig. 12 Crank angle Vs Pressure

4.3.2 Heat release rate

Fig. 13 shows the Crank angle Vs Heat release rate. The increases of higher carbon combustion activation and hence promotes the complete combustion by addition of nanoparticles [15, 19 & 20]. The addition of nanoparticles increased the combustion process. Due to higher calorific value of nanoparticles blended biodiesel trends to the behavior. The heat release rate for B20Al_2O_3 25ppm, B20Al_2O_3 50ppm, B20Al_2O_3 75ppm was 26.03557 kJ/deg, 27.35283 kJ/deg and 29.5592 kJ/deg.

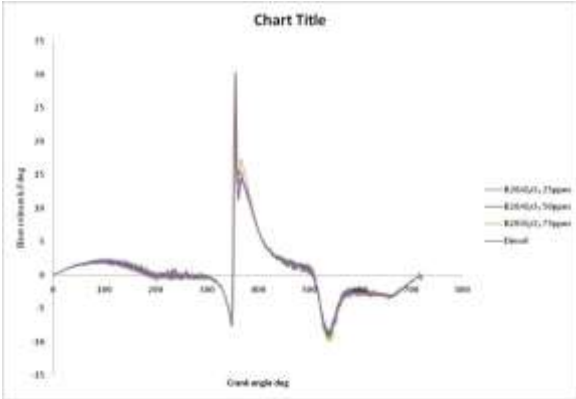

Fig. 13 Crank angle Vs Heat release

5. CONCLUSIONS

The performance and emission characteristics of DI diesel engine with diesel-blended biodiesel with the addition of aluminium oxide nanoparticles were investigated. The following conclusion were drawn the experimental result.

- The brake thermal efficiency was increased in B20$Al_2O_3$75ppm at all loads than neat diesel.
- The specific fuel consumption is higher for the B20$Al_2O_3$75ppm than neat diesel at the entire load comparing with the different dosing level of blends.
- The CO emission decreases by addition of B20Al_2O_3 75ppm.
- The HC emission level was decreased at B20Al_2O_3 75ppm.
- The NOx emission is lower for the diesel than the addition of B20Al_2O_3. By addition of Al_2O_3 slightly increased compared with diesel.

The overall performance and emission characteristics were clearly obtained that the addition of aluminium oxide nanoparticles (Al_2O_3) is efficient in improving the properties of biodiesel blend.

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