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Effects of Al_2O_3 Nano Particle Addition in Karanja Biodiesel on Performance, Emission and Combustion Characteristics of Diesel Engine

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ABSTRACT: Experimental investigations are carried out to study the engine performance, emission and combustion characteristics of diesel engine using nano fuel additives in Karanja biodiesel emulsion fuels. The performance characteristics are studied for pure diesel, Karanja biodiesel (KBD) and KBD emulsions blended with 50, 100 ppm alumina nano particles. The biodiesel emulsion fuels are prepared using emulsification technique consisting of 88% Karanja biodiesel, 10% water, surfactants Span 80 and Tween 80 each 1% were added for homozinisation of water and KBD. Mechanical agitator and ultrasonicator was used for blending the biodiesel, water, surfactants and nanoparticles. The investigations are carried out in a computerised diesel engine with data acquisition system and piezo electric pressure sensor to measure the combustion pressure. The emissions are also measured using five gas anlyser and smoke meter. The experimental results revealed that biodiesel emulsion fuels can consider as alternate for diesel as it is observed that alumina nano particles incorporated biodiesel emulsions gave good performance than diesel and significant decline in harmful emissions. It has been observed that the brake specific fuel consumption is slightly decreased, NO_X emissions are found 12% less and 16% decrement in smoke opacity for the 100 ppm alumina nano particles incorporated KBD emulsion fuel at peak load. Owing to micro explosion and secondary automisation associated with alumina nano particles combustion characteristics were improved.

Keywords: Alumina nano additives, diesel engine performance, emission characteristics, emulsion fuels Karanja biodiesel.

Abbreviations: KBD, Karanja biodiesel; ppm, parts per million; CO, Carbon monoxide; HC, hydro carbon; NO_X, Nitrogen Oxides; C.I, compression ignition; Al_2O_3, Alumina; BTE, brake thermal efficiency; BSFC, brake specific fuel consumption; UHC, unburnt hydro carbon; SP, smoke opacity.

I. INTRODUCTION

The first diesel engine invented by Rudolf Diesel was demonstrated with peanut oil by way of fuel. Due to plentiful supply of petrol-diesel much development of vegetable oils were not taken place. It received much interest recently when it is found fossil fuels were exhausting fast renewable fuels must be recognized [1] and also India imports 70% petroleum fuels it will be burden on Indian economy, practice of alternate fuels from oil seeds which are non edible to ease the problem on Indian budget [20]. There is a need to reduce the petroleum based fuels and stringent engine exhaust norms should implement, the chief policy decision from the Indian Govt. to use the bio diesel derived from oil seeds which are not fit to eat [21]. Sunflower, Peanut, Winter rape, Canola, Soya bean, Cotton, Safflower are the major oil producing crops alternate for fuel.Various agencies in India cultivating these crops as India has vast dry lands, Karankja, Neem, Mahua and Jatropha are the most important uneatable oil species [22]. Raheman and Phadatare (2004) led performance tests on KBD and its amalgams with fossil diesel and found that performance and exhaust prameters are at par with fossil diesel, hence KBD is a good replacement for fossil diesel [2]. Sahoo and Das (2009) investigated the various biodiesels and their blends combustion characteristics [3]. Dhar and Agarwal (2014) conducted tests on KBD by using transportation engine and admit that CO, HC and smoke of KBD blends were lower than diesel and NO_X slightly higher [4]. Chauhan *et al.*, (2013) carried out the investigations on unmodified diesel engine by using KBD and compared the emissions, performance and combustion parameters with pure diesel and also evaluated the properties of KBD, all the properties were within the acceptable limits with standard values [5]. Unburnt hydrocarbons, CO and smoke were lower for KBD. NO_X were slightly increases for KBD and its amalgams than diesel. Various techniques were used to lessen the NO_X emissions such as exhaust gas recirculation, changing the fuel injection pressure, fuel injection timing etc however these methods leads to rise smoke and particulate matter. Selim and Elfeky (2001) carried out an experimental investigation to observe the water/diesel emulsion fuel in C.I engine and noticed NO_X were controlled upon the addition of water [6]. In emulsion technique H_2O is suspend in the blend with help of appropriate emulsifier [7]. The difference between volatility of diesel and water causes micro explosion of emulsion fuel which disintigrate the fuel droplets into tinier which helps in forceful vaporisation and improved mingling of air which increases the combustion response during the burning of fuel. It has been also observed rough engine operation during the combustion of emulsion fuel owing to prolonged delay in ignition, more heat release rate and great peak pressure [8].

Due to advancement in nano technology aids further research on emulsion fuels, some recent studies shows that imparting nano particles to the fuel shorten the delay in ignition. Adding aluminium and alumina nano particles to diesel improves the ignition properties of diesel and reduces the ignition delay [9]. Kao *et al.*, (2008) done experiments on Al_2O_3 nanoparticles unified in water diesel emulsion fuel and accomplish a notable development in bsfc and reduced emissions. Aluminium nano powder and H_2O react at high temperature and generate H_2 promoting the ignition of the fuel, Al_2O_3 is in nanometer size which has great surface area and higher action to decompose the H_2 from H_2O and it is a good quality fuel that participate in combustion quickly [10]. The existence of nano particles in the fuels improves the surface to volume proportion it permits greater quantiy of fuel to interact with the oxygen to increase output [11]. Emekwuru (2019) has studied the nanofuel droplet evaporation processes by incorporation of nano particles increase the temperature of fuel it enhance evaporation rate of fuel which helps in reduces the ignition delay time and burning more quantity of fuel [12].

Biodiesel performance and exhaust gas emission parameters has not at par with emission norms set by legislative bodies. Addition of nano particles improve the fuel quality helps in achieving the norms. Perumal and Ilangkumaran (2018) has studied the effect of CuO nano particles incorporated to biodiesel derived from pongamia and obtained improved operating conditions of the engine [13]. Shaafi and Velraj (2015) has done investigations on mixtures of diesel, biodiesel derived from Soybean and ethanol blends with Al_2O_3 nano additives and observed performance, emission parameters were improved because of good mixing capabilities of nano particles [14]. Yang *et al.*, (2013) done experiments on fuel emulsions by incorporating nano organic particles and observed that the combustion duration decreases due to micro eruption of tinie water droplets suspended in fuel emulsion which increases the rate of vaporization and enchances air fuel intermingling process [15]. Anbarasu *et al.*, (2016) has investigated by incorporating Al_2O_3 nano sized particles to the emulsions of Canola biodiesel results showed that there was an improvement in the engine operating parameters upon addition of nanopartiles. HC, CO, NO_x and smoke decreases by using nano particles in biodiesel and its emulsions [16]. Annamalai *et al.*, (2016) carried experiments by using Cerium oxide nano particles in lemon grass oil emulsion and found that progress in performance and emission attributes [17]. El-Seesy *et al.,* (2017) has investigated by adding Multi-Walled Carbon nanotubes (MWCNTs) to Jojoba biodiesel and its diesel blends on combustion performance and emission atributes of a C.I. engine. The results revealed significant improvement in all the parameters which were testesd upon addition of carbon nanotubes [18]. Prasad and Gupta (2016) has done the experiments on Karanja biodiesel emulsion fuels and Al_2O_3 blended KBD emulsion fuels with different proportions, they found that the engine performance and as well as emission attributes had enhanced with Al_2O_3 nano particles suspended in KBD emulsion fuel [19]. Khond and Kriplani (2019) done the evaporation atributes of Neem biodiesel and its emulsions blended with CNT at different proportions. There is a betterment in the rate of evaporation of Neem biodiesl and its blends by adding CNT and also enhancement in Cetane number and calorific value [23]. Due to the outstanding nano particle properties the current research study have been conducted to examine the outcome of Al_2O_3 nano particles in the KBD emulsion fuel on the performance, combustion and exhaust emission atributes of a C.I. engine.

II. EXPERIMENTATION

Investigations were carried out on a computerised C.I. engine. To measure the exhaust gas emissions AVL Di Gas analyser and AVL smoke meter were used. Data acquisition system consists of crank angle decoder and piezoelectric pressure sensor was used to measure the performance parameters and cylinder pressures. KBD fuel was tested, the engine is started and allowed for sometime to stabilaize, after that the fuel consumption and emissions were measured. Same procedure has been adopted to test all the fuels. All the investigations has been carried out at 1500 rpm constant speed and loads were increased by 2kg each step.

Table 1: Engine specifications.

Make and Model	Kirloskar TV1
Type	**Computerised single cylinder diesel engine**
Bore x Stroke	87.5 mm x 110 mm
Compression ratio	17.5:1
Swept volume	661.45 cc
Rated output	5.2 kW
Rated speed	1500 rpm

Fig. 1. Engine Test Rig.

Fig. 2. Gas Analyser & Smoke meter.

KBD emulsion fuels preparation: Firstly surfactants Span 80 and Tween 80 each 1% by volume added to 88% of KBD by volume. These are mixed in a vessel with the help of mechanical agitator at a speed of 2000 rpm for about 15 minutes. Distilled water 10% by volume added to this mixture and agitated for another 30 minutes KBD emulsion is prepared. In the next phase Al_2O_3 nano particles 50 ppm added to KBD emulsion and blended with ultrasonicator for 30 minutes. The same procedure has been used for 100 ppm also.

Fig. 3. Mechanical Agitator.

Fig. 4. Ultrasonicator.

III. RESULTS AND DISCUSSIONS

The test results presented below. The variation of brake thermal efficiency (BTE), brake specific fuel consumption (BSFC) and the exhaust gas emissions like HC, CO, NOx and smoke opacity are plotted against the load for various fuels. The BTE has been increased for all the fuels with increase in load. The BTE of Al_2O_3 nanoparticle unified emulsion fuels is greater than that of for KBD2SW and KBD fuels. The increase in efficiency due to tinyeruption and secondary automisation at the presence of alumina nanoparticles. The volatility differences in water and biofuel give rise to micro explosion in the biodiesel emulsion fuel. It is exposed to great pressure and temperature in the cylinder when the alumina nanoparticles surround it, the water droplets captivate the heat rapidly (water has lesser boiling point compared to biodiesel).

Table 2: Tested fuels properties.

Specification of the Fuel	Calorific value kj/kg	Density kg/m^3
D100 (100 % Diesel)	49,140	831
KBD (100 % Karanja biodiesel)	41,280	871
KBD2SW (80% KBD+2% Surfactants+10% Water)	35880	879
KBD2SW50A (80% KBD+2% Surfactants+10% Water+ 50 ppm Al_2O_3)	36162	890
KBD2SW100A (80% KBD+2% Surfactants+10% Water+ 100 ppm Al_2O_3)	36414	891

Table 3: Details of alumina nano particles.

Manufacturer	Souvenier Chemicals
Chemical name	Alumina/Aliminum Oxide (Al_2O_3)
Average particle size	50-80 nm
Specific surface area	130 – 140 m^2/g
Colour	White

This causes the explosion of water droplet called as micro explosion. Consequently droplets of fuel very small dimension are generated which evaporates swiftly promote efficient automisation of the fuel. Eventually the micro explosion leads to the development of tiny droplets in the engine combustion chamber emphasising the mixture in existence of nanoparticles. Moreover they posses improved surface to volume ratio. It results in increased chemical reactions and plays the role of a catalyst. In direction to these BTE of nano particle emulsion fuels is emphasied under the influence of the alumina nano particle's catalytic action. Contrarily BTE of KBD2SW emulsion fuel is less, as water addition, low temperature and prolonged delay in ignition of the engine play a major role. The highest BTE at the peak load is 27.66% for the KBD2SW100A it is 26.7%, 24.81%, 25.14%, 27.66% for KBD2SW50A, KBD2SW , KBD and Diesel respectively.

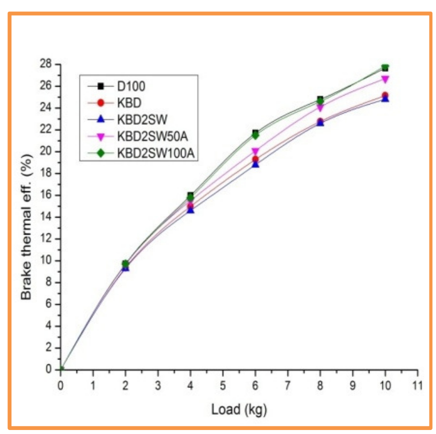

Fig. 5. Variation of BTE with load.

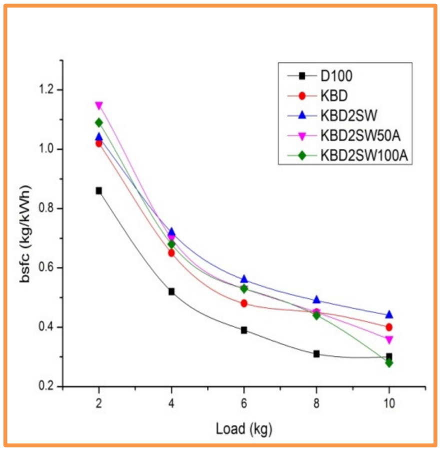

Fig. 6. Variation of BSFC.

The BSFC has been decreased for all the fuels. Further it is observed that the BSFC is improved for nano blended emulsions than that of KBD2SW. The existing alumina nao particles trapped in water droplets present in the emulsion fuel might lead to this. Due to outstanding surface to volume ratio and lessen delay in ignition attribiutes of the aluminium oxide nanoparticles, enough fuel is available in the combustion chamber to experience potential catalytic effect of the fuel through combustion. Due to this phenomenon there is an improvement in the BSFC of the nano additive KBD emulsion fuel. Excess fuel burning in case of KBD2SW due to existence of water drops in the fuel delay autoignition because of extended delay in ignition, which causes higher BSFC than that of alumina nanoparticles mixed Karanja biodiesel emulsion fuels. The BSFC is 0.28 kg/kWh for KBD2SW100A where as it is 0.36 kg/kWh, 0.44 kg/kWh and 0.4 kg/kWh for KBD2SW50A, KBD2SW and KBD fuel at peak load respectively.

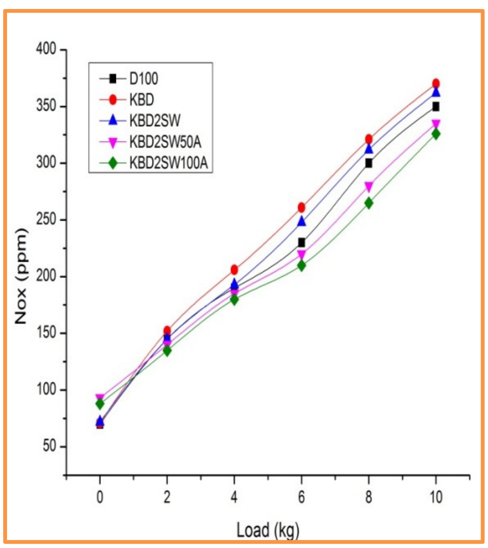

Fig. 7. NO_X emissions Vs load.

The formation of NO_X in the diesel engines is because of high temperature and surplus O_2 in the combustion chamber during combustion. From the Fig. 7 NO_X emissions are high for KBD than other emulsion fuels due to more O_2 content and high gas temperature. A very fine water droplets are present in the KBD2SW emulsion fuel due to tinie explosion,hence the existence of water droplets in the combustion chamber reduces the exhaust gas temperature, because of these effects the magnitude of NO_X emissions for KBD2SW fuel is less than that of KBD fuel. Further there is a decrement in emissions of NO_X for the aluminium oxide nanoparticle mixed KBD emulsion due to shorten ignition delay and early combustion of the fuel. The amount of NO_X emissions are 326ppm for KBD2SW100A, while it is 335ppm, 362ppm, 370ppm and 350ppm for KBD2SW50A, KBD2SW, KBD and Diesel at peak load respectively.

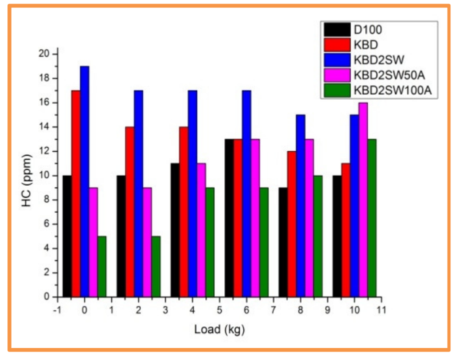

Fig. 8. Load Vs HC.

Fig. 8 depicts the emissions of unburnt hydrocarbon (UHC) for the fuels tested. The UHC emissions are high for the KBD emulsion fuels due to more accumulation of fuel during combustion phase as an effect of extended ignition delay. The magnitude of UHC emissions are less in nano particle mixed emulsion fuels due to oxidation of hydrocarbons and secondary automisation. Also the degree of air fuel mixing could have improved due to secondary automisation and catalytic effect of the nano particle mixed biodiesel emulsion fuel.

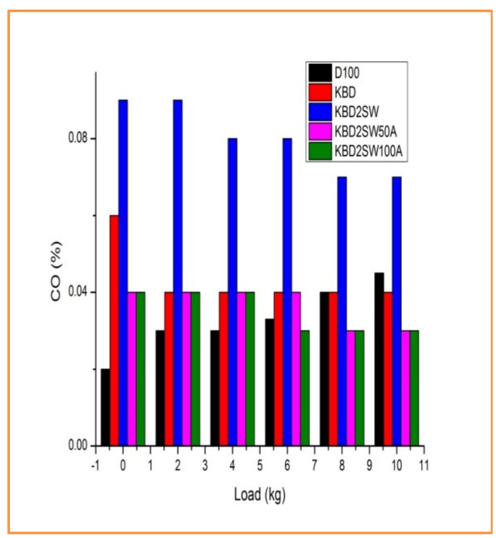

Fig. 9. Variation of CO.

From the above figure CO emisions are high for the KBD2SW fuel, because of prolonged ignition delay owing to existence of water. The CO emissios are slightly decreased for the fuels which are blended with Al_2O_3 nano particles. Al_2O_3 nano particles have high surface area/ volume ratio hence it has high catalytic effect which reduces the ignition delay. Because of this there is an increase in air fuel mixing in the cylinder of the engine lead to complete combustion.

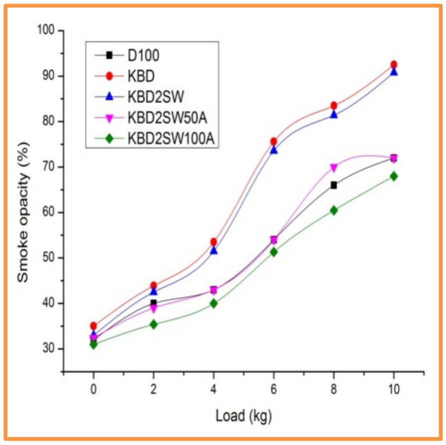

Fig. 10. Variation of smoke opacity.

The change in smoke opacity (SP) for the KBD, KBD2SW, KBD2SW50A, KBD2SW100A and Diesel fuels provided in Fig. 9. It is understood that SP is less for the emulsion fuel than pure KBD fuel. At peak load the SP for the KBD fuel was 92.5% & it is 90.5 % for the KND2SW fuels correspondingly. There is a declining in the smoke emissions due to water content in KBD emulsion this occurs because of quick evaporation of water vapour in the fuel-rich areas and increase in OH radicals which helps in preventing the soot formation. At the same time adding Al_2O_3 nano particles to the KBD emulsion helps in more reduction of smoke emissions related to KBD2SW fuel.At peak load the SP has been observed for the KBD2SW100A fuel was 68%, whereas it is 72%, 90.8%, 92.5% and 72% for KBD2SW50A, KBD2SW and KBD and diesel respectively.

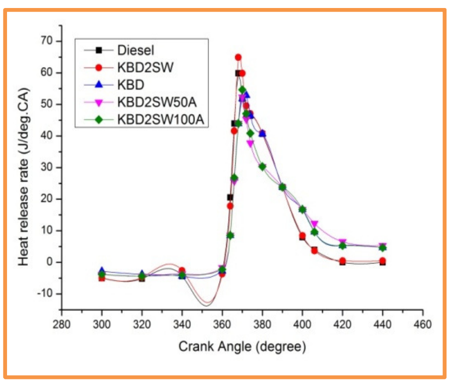

Fig. 11. Heat release rate vs crank angle at peak load.

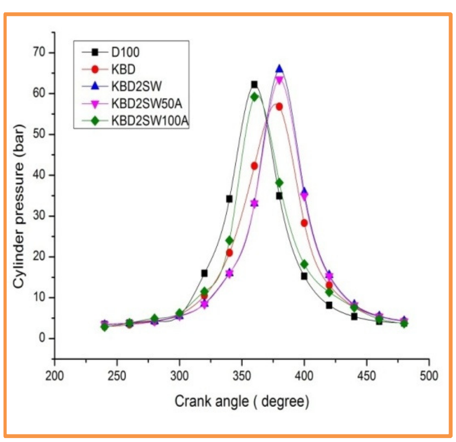

Fig. 12. Cylinder pressure vs crank angle at peak load.

Fig. 11 and 12 illustrates the difference in heat release rate and cylinder pressure with respect to crank angle. It is observed that the magnitude of the heat release rate and peak pressure is high for the KBD emulsion due to the prolonged delay in ignition compared to other tested fuels. On the other hand due to presence of Al_2O_3 nano particles in KBD emulsion fuels ignition characteristics has been improved and shortened their ignition delay which leads to early combustion, reduced the heat release rate and peak pressure. The peak pressure for the KBD2SW at the peak load is 65.92 bar where as it is 63.49 bar, 59.2 bar, 56.8 bar and 62.2 bar for KBD2SW50A, KBD2SW100A, KBD and Diesel respectively.

IV. CONCLUSIONS

The BTE increases with increase in load. It is higher for KBD2SW100A fuel. The BTE is 8 % higher than KBD fuel at peak load.

The BSFC is marginally higher for KBD2SW50A fuel than KBD fuel, it is slightly decreased and it is almost same as KBD fuel at peak load for KBD2SW100A fuel BSFC improved upon addition of 100ppm nano particles. The CO and HC emissions are less for the emulsion fuels than neat KBD fuel.

The NO_X gasses are declined for the KBD2SW100A and KBD2SW50A fuels than that of neat KBD and diesel. At peak load NO_X gasses are 326 ppm for KBD2SW100A, 335 ppm for KBD2SW50A and 370 ppm for KBD. The NO_X emissions are 12 % les for the KBD2SW100A fuel at peak load when compare to KBD fuel.

The SP is more for the KBD fuel when compared to emulsion fuels. It decreases significantly after adding the alumina nano particles. The smoke is 16% less for the KBD2SW100A fuel at peak load when compared KBD fuel.

Significant drop in the peak cylinder pressure and heat release rate for KBD emulsions mixed with Al_2O_3 than that of KBD emulsions without Al_2O_3 due to reduced ignition delay effect.

As a whole the alumina nano particle blends has great advantages on enhancing the performance and dropping the emission characteristics of diesel engine.

V. FUTURE SCOPE

Further researchers can do the experiments by adding 15% water to the fuel. Ethanol or Methanol can also add and can try different blends

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Conflict of Interest. No conflict of interest

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