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Experimental Investigation on Diesel Engine Using By-Products from the Vegetable Oil Industry

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Abstract: ***The world is presently confronted with the twin crises of fossil fuel depletion and environmental degradation. It is widely recognized that alternative diesel fuel produced from vegetable oil and animal fat can reduced the exhaust emission from CI engine without engine modification. In this present work biodiesel is converted from ground nut acid oil, it is by product of vegetable oil refinery waste. Experimental tests have been carried out to evaluate the performance, emission and combustion characteristics of a diesel engine when fuelled with different blends of Thermal cracked ground nut acid oil biodiesel (TCGAO) and ordinary diesel fuel separately. Tests on ordinary diesel fuel have also been carried out for comparison purposes. The experimental results show that the engine brake thermal efficiency and fuel consumption are comparable to diesel when fueled with B20TCGAO blends. The emission is lower for B20TCGAO blends compare to diesel and all other bio diesel blends.***

Keywords: Biodiesel; Fatty acid; Thermal cracking; Vegetable oil;

1. Introduction

Current energy policies are greatly reliant on fossil energy. Fossil fuels are the greatest energy source among all energy resources. The major part of energy requirements in the world is provided thorough fossil fuels such as petroleum, natural gas, oil and coal. Due to resource limitations, it is expected that the rising demand and diminishing supply will affect global fuel prices dramatically [1]. The declining reserve of fossil fuels, and more importantly, the high fuel prices have strongly motivated the search for alternative engine fuels. For diesel engines, a great deal of research effort has been oriented toward using biodiesel as an alternative fuel for land, transport and power generation.

Biodiesel has become a popular alternate of mineral diesel fuel in recent past as it has several advantages over latter, viz., environment friendly, biodegradable, non-toxic, has low emission profile of particulate matter, aromatic hydrocarbon, SO , CO, green house gases, and renewable [3,4]. Chemically, biodiesel is fatty acid alkyl ester, and prepared by the acid, base or enzyme catalyzed transesterification reactions of triglycerides (vegetable oils and animal fats) with short chain alcohols such as methanol and ethanol. The main disadvantages of vegetable oils, as diesel fuels, are associated with the highly increased viscosity, 10–20 times greater than the normal diesel fuel. Thus, although short-term tests using neat vegetable oils showed promising results, problems appeared after the engine had been operated for longer periods. To solve the problem of the very high viscosity of neat vegetable oils, the following usual methods are adopted: blending in small blend ratios with diesel fuel, micro-emulsification with methanol or ethanol, thermal cracking, and conversion into bio-diesels mainly through the transesterification process [5,6]. The advantages of bio-diesels as diesel fuel are the minimal sulfur and aromatic content, and higher flash point, lubricity, cetane number, biodegradability and non-toxicity.

Biofuel production from vegetable oil is potentially a good alternative to conventional fossil derived fuels. Moreover, liquid biofuel offers many environmental benefits since it is free from nitrogen and sulfur compounds. Biofuel can be obtained from biomass (e.g. pyrolysis, gasification) and agricultural sources such as vegetable oil, vegetable oil sludge, rubber seed oil, and soybean oil [7]. One of the most promising sources of biofuel is vegetable oil sludge. This waste is a major byproduct of vegetable oil factories. It consists of triglycerides (61%), free fatty acid (37%) and impurities (2%). The hydrocarbon chains of triglycerides and free fatty acid are mainly made up of C_{16} (30%) and C_{18} (36%) hydrocarbons. The others consist of C_{12}–C_{17} hydrocarbon chains. Transesterification can help in converting vegetable oil sludge into biofuel. The disadvantage of this method is that a large amount of methanol is required [8]. The alternative method for this conversion is catalytic cracking.

Currently, the amount available of vegetable sludge is not much in India (approximately 0.6 million tons/year), because vegetable oil plants almost import purified vegetable oil and they only continue to purify more by the request of customer. The price of import purified vegetable oil is expensive [9]. The price of crude vegetable oil is much cheaper than purified one. But the treatment of vegetable oil sludge is complicate. So, by the obtained result of this research, Vietnam now may import cheap crude vegetable oil to produce purified type. The vegetable oil sludge could be more available and applied for the field of biofuel production.

2. Materials and Method

2.1 Activated Carbon

Activated Charcoal, technically known as Activated Carbon, is one of the most exploited agents in the 21st century. Activated carbon is a black solid substance resembling granular or powdered charcoal. It is extremely porous with a large surface area, and typically produced from organic precursors such as bamboo, coconut shells, palm-kernel shells, wood chips, sawdust, corncob and seeds. High-grade activated carbon can be obtained from woody material like bamboo with inherent mechanical strength, high carbon (40%) and low ash content [10,11]. Bamboo based carbon can serve as a good adsorbent and can be regenerated and reused many times. Oil may be contaminated with unwanted natural and anthropogenic compounds, such as polycyclic aromatic hydrocarbons (PAH), dioxins and polychlorinated biphenyls (PCB), which may in turn be removed with activated carbon. The desulfurization of oil by adsorption process using activated carbon showed a reduction in the amount of sulfur by more than half of the original amount of sulfur. The charcoal has lots of internal spaces or "pores. These pores help activated charcoal "trap" chemicals.

2.2 Preparation of biodiesel

The preparation of biodiesel was in two phases. In the first phase biodiesel is prepared in thermal cracking. The second phase of the work to improve the cetane number, calorific value of the thermal cracked biodiesel by carbon filtered method. The thermal cracking setup was shown in figure 2. The thermal cracking reactions of fatty acid oil were carried out at temperatures 550°C, under atmospheric pressure. The thermal cracking reaction of fatty acid was carried out using 2000g. The reactor was heated to the desired reaction temperature using external electronic resistance. The temperature was measured at two sites with calibrated thermocouples. The product mixture leaving the reactor was condensed in a condenser to separate the gaseous and liquid products. The liquid product was collected in a vessel positioned behind the condenser. Thermal cracked biodiesel feed into carbon fitter. The carbons filter arrangement as shown in fig 2. Initially cotton was filled some space in glass tube. Then the charcoal powder was half of the portion in the glass tube and thermal cracked ground nut acid oil was filled in reaming portion. The TCGAO oil was collected bottom of the glass tube with natural drained. Improved properties such as lower viscosity, lower specific gravity, increased in calorific value and removed in all contaminate were obtained in the filtered oil.

3. Experimental Setup

Single cylinder water cooled, four stroke direct injection compression ignition engine with a compression ratio of 17.5:1, developing 5.2 kW at 1500 rpm (Kirloskar TV-1) is used for this study. The overall view of the experimental setup is shown in figure 1. The engine was run at a constant speed of 1500 rpm at different loads, the loads were applied to the engine through an eddy current dynamometer. The engine was run at various loads of the eddy current dynamometer (20%, 40%, 60%, 80% and 100%). The governor of the engine was used to control the engine speed. The dynamometer was interfaced to a control panel. The emissions like HC, CO, NOx were measured in the AVL Di gas analyzer and smoke density was measured by smoke meter. AVL combustion analyzer was used to analyze the combustion characteristics. The exhaust gas temperature was measured using K-type thermo couple. Experimental tests have been carried out to evaluate the performance, emission and combustion characteristics of a diesel engine when fueled with thermal cracked carbon filtered groundnut acid oil (TCGAO) biodiesel lends of 20%, 40%, 60%, 80% and 100% with ordinary diesel fuel separately.

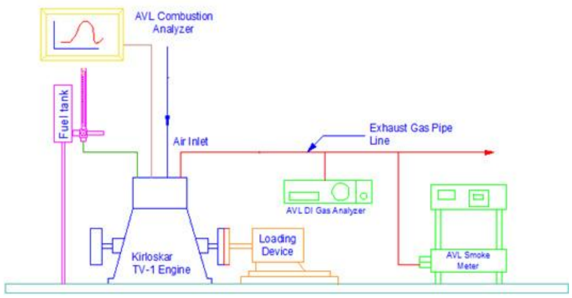

Figure 1: Experimental setup

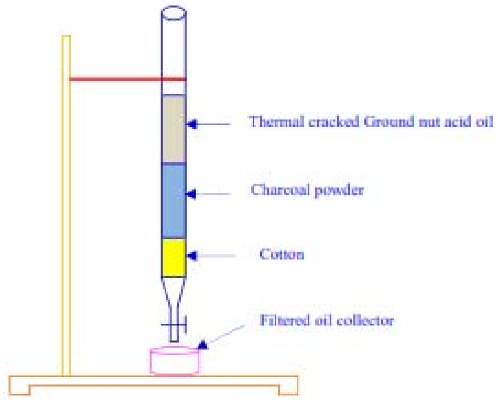

Figure 2: Thermal cracked oil filtration method

Table 1: Engine Specifications

Type	:	Single cylinder, vertical, water cooled, 4 stroke Diesel Engine
Bore	:	87.5 mm
Stroke	:	110 mm
Cylinder diameter	:	0.0875 m
Stroke length	:	0.1m
Compression ratio	:	17.5 : 1
Power	:	5.2 kW (7HP)
Speed	:	1500 rpm
Loading device	:	Eddy current dynamometer

4. Result and Discussion

Figure 3 shows the variation of specific fuel consumption with Brake Power. It can be concluded that the fuel consumption of B20 blend of TCGAO is slightly higher than diesel fuel, over the entire output range though lower than that for other blends of TCGAO. The fuel consumption for diesel is 0.252 kg/kW-hr at maximum load while the corresponding figures for various blends B20, B40, B60, B80, and B100 of TCGAO are 0.269, 0.283, 0.295,0.306 and 0.313 Kg/kW-hr respectively.This was reason for B20TCGAO blend having higher calorific value compare to other blends.

Figure 4 shows the variation of brake thermal efficiency with brake power for TCGAO and its blends. For all the blends the brake thermal efficiency increases with increase in brake power. Among B20, B40, B60, B80 and B100 blend ratios, biodiesel blend of B20 has maximum brake thermal efficiency of 29.42% at full load. It is almost close to that of diesel fuel.

The efficiency of B20 has increased by 1.95% when compared to that of B100TCGAO Biodiesel operation. This may be due to better spray characteristics of B20TCGAO blend fuel in the combustion chamber, which leads to effective utilization of air resulting in complete combustion of fuel [12].

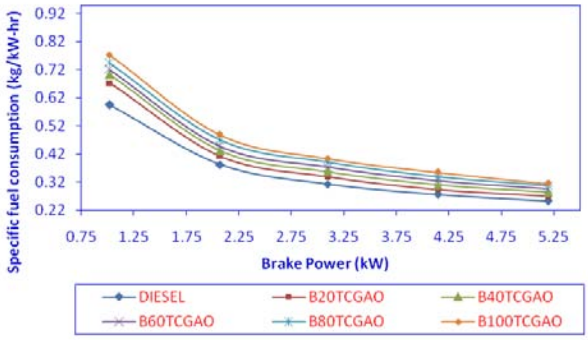

Figure 3: Specific fuel consumption against Brake power

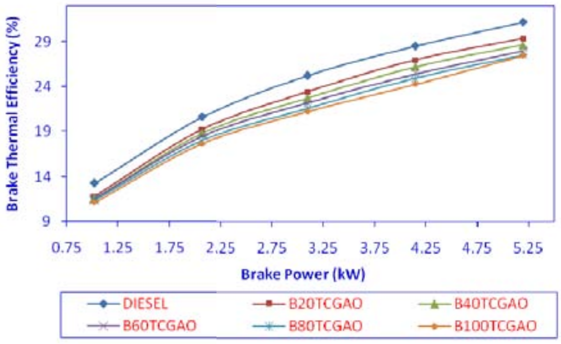

Figure 4: Brake thermal efficiency against Brake power

Figure 4 shows variations of smoke density for diesel, B20, B40, B60, B80 and B100 blends of TCGAO at various brake power of the engine. From the graph it is observed that smoke density increases with increase in load. The smoke density was about 43 HSU with diesel, 41.1 HSU for B20TCGAO blend, 50.1 HSU for B40TCGAO blend, 53.9 HSU for B60TCGAO blend, 61.2 HSU for B80TCGAO blend and 63.5 for B100TCGAO blend. The B20TCGAO blend was lower smoke density compare to all other TCGAO blend and diesel. This is due to excess oxygen and lower viscosity which improves the combustion [13]. The B20TCGAO contains oxygen and lower viscosity is the factors for improved combustion and decreased smoke emission compared to other TCGAO blend.

Figure 5 indicates that B20 blend of TCGAO always results in low NOx emission compared to other blends of TCGAO. The trend indicates that as brake power increases NOx emission also increases and attains maximum at maximum load. This is due to high combustion temperature and the excess availability of oxygen and nitrogen. The reduction of NOx emission from diesel fuel value is due to reduced premixed burning rate. This may be due to the oxygen content in the fuel and longer ignition delay with TCGAO blends compared to diesel [14].

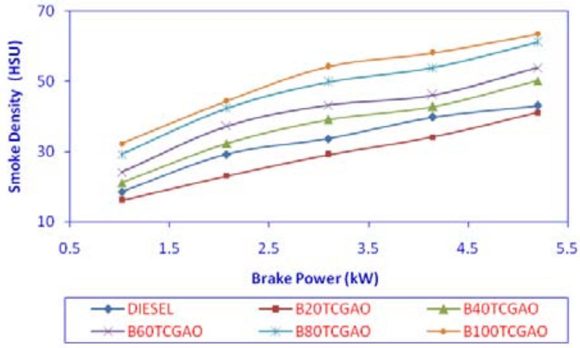

Figure 5: Smoke density against Brake power

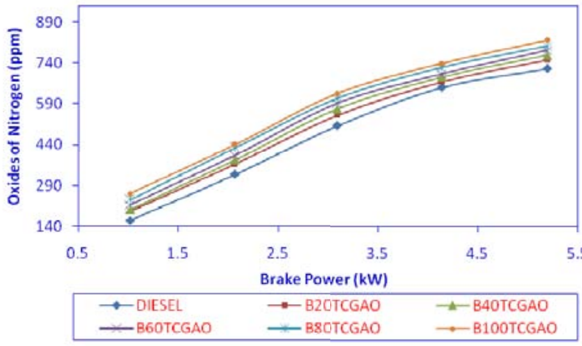

Figure 6: Oxides of nitrogen against Brake Power

Figure 7 shows the comparison of HC emission using Diesel and TCGAO blends. The HC level varies from 25 ppm at 20 % load to 67 ppm at full load and from 29 ppm to 69 ppm with TCGAO blends and diesel respectively. For (B40 to B100) TCGAO blends HC emission were higher when compared to Diesel. Incomplete combustion of fuel in the combustion chamber leads to higher emission of hydrocarbon. High viscosity leads to bigger fuel droplets hence a non uniform distribution with air [15]. Non uniform distribution will lead to too rich pockets that can result in HC. The Figure 8 shows the comparison of carbon monoxide using diesel and TCGAO blends. The CO emission with B20TCGAO and diesel is 0.08% by volume and 0.09% by volume respectively at full load. The increase in CO in the case of higher TCGAO blends may be due to poor spray characteristics and hence improper mixing, resulting in poor combustion. CO emission reduces with increase in the concentration of diesel in the blend. This may be because of the oxygen content in the added TCGAO. Too high TCGAO blends deteriorate performance due to poor mixture formation.

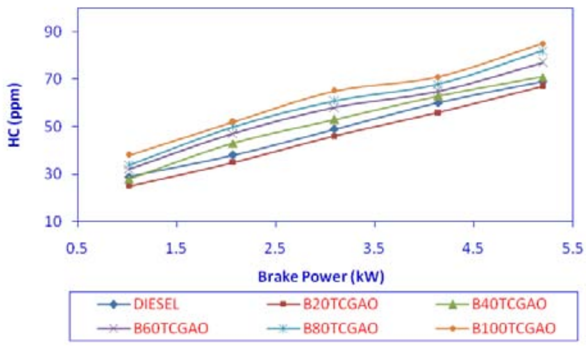

Figure 7: Hydrocarbon against Brake power

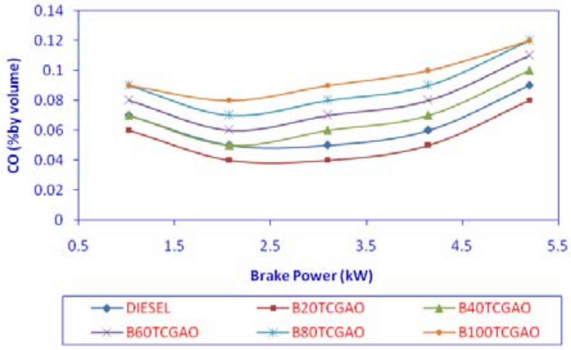

Figure 8: Carbon monoxide against Brake power

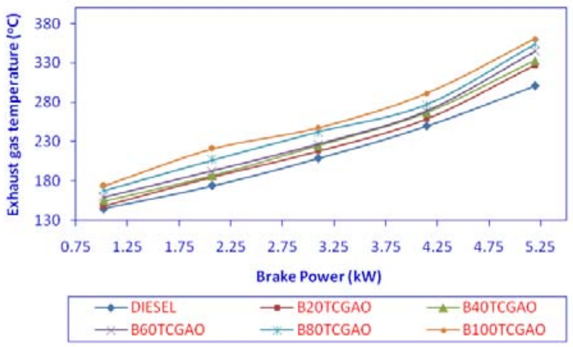

Figure 9: Exhaust gas temperature against Brake power

Figure 9 shows the comparison of engine exhaust gas temperature using diesel and TCGAO blends. This also results in higher exhaust gas temperature. The longer heat release will lead to lesser thermal efficiency with TCGAO blends. The exhaust gas temperature with TCGAO blends at all the loading condition is higher than that of diesel. It is due to late start of combustion of TCGAO blends due to increased ignition delay as well as increased combustion duration. Another reason may be due to the inherent oxygen content in RSOME that enhances the oxidation of soot before it leaves the combustion chamber.

Figure 10 shows variation of heat release rate with crank angle for diesel and TCGAO blends. It can be observed that the high heat release rate of diesel is a consequence of premixed combustion phase. It is clear that premixed combustion phase of TCGAO blends is significantly lower in comparison with diesel. This is due to the high viscosity of fuel leading to a reduction in air entrainment and fuel air mixing rates. This results in lesser fuel being prepared for rapid combustion with TCGAO during ignition delay. The diffusion burning, indicated by the second peak is also higher with B20TCGAO due to the burning of more quantity of fuel [16]. Higher peak values of diesel and B20TCGAO indicate better atomization and mixing.

Figure 11 shows variation of cylinder pressure with crank angle for diesel and TCGAO blends. From figure 11 results in lower peak pressure in TCGAO blends compared to diesel on account of lower combustion rates. The peak pressure in the case of B20TCGAO is about 65.49 bar at maximum power where as in diesel it is 68.21 bar. In compression ignition engines, the peak pressure depends strongly on the initial combustion rate, which in turn depends on the amount of fuel taking part in the premixed combustion phase. Even though the ignition delay of B20TCGAO is less, the premixed combustion rate is quite high. This indicates that most of the fuel injected during the delay period is prepared for ignition.

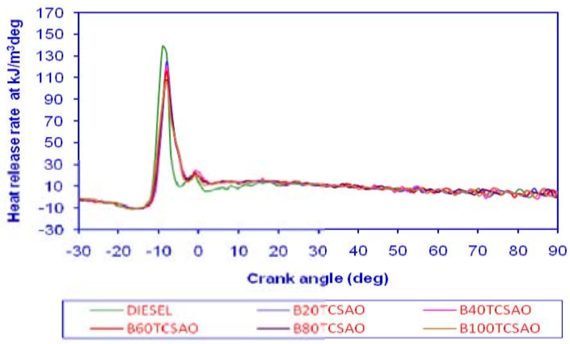

Figure 10: Heat release rate against Crank angle

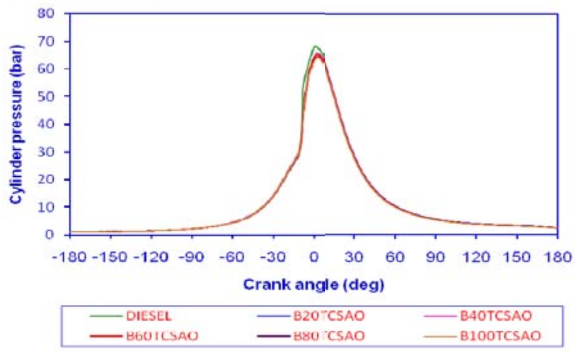

Figure 11: Cylinder pressure against Crank angle

5. Conclusion

Based on the results, the comparisons are made and conclusions are derived as follows:

The selection of fuel on biodiesel alternative is B20TCGAO. B20TCGAO exhibits the lowest (0.269 kg/kW-hr) specific fuel consumption at full load compared to other TCGAO blends. B20TCGAO has the maximum brake thermal efficiency of 29.42% compared with other TCGAO blends. Lower smoke density of 41.1 HSU is recorded for B20TCGAO at full load. The NOx emission of B20TCGAO is 753 ppm which is lower compared to other TCGAO blends. The result of this comparison shows that the optimized biodiesel blend is B20TCGAO and it is considered as fuel for biodiesel alternative.

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