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Research Article

Production and Performance Testing of Waste Frying Oil Biodiesel

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Abstract

Due to rapidly diminishing petroleum resources and the escalating environmental pollution from the use of the fossil fuels, there is a gigantic search for alternative sources of fossil fuels. Biodiesel demonstrates to be the best appropriate substitute for the diesel fuel because it can be used in any existing diesel engine without incorporating any adaptation. Waste Frying Oil (WFO), which is not suitable for human utilization, and whose safe disposal is a challenge, may be suitably used for biodiesel production. The present paper deals with the details of conversion of WFO into biodiesel through cavitation techniques followed by its performance testing on a diesel engine.

Keywords: *Waste Frying Oil, Cavitation, Transesterification, Biodiesel, Smoke Opacity*

1. Introduction

The worldwide dependence of transport systems on fossil fuels is continuously increasing as well as price of crude oil is also rising day by day. The economical growth of any developing country is based on agriculture and industrial sector. The basic power source of industrial sector as well as agriculture sector is diesel fuel. Also the emissions produced by these fuels are creating a threat to our existence. (Ramesh, and Sampatraja, 2008). Majority of the world's energy needs are abounding through petrochemical sources, coal and natural gases, the exception of hydroelectricity and nuclear energy. It is understood that within four decades, the present reserves of petroleum fuel including diesel will be exhausted fully (Nabi, *et al*, 2009). Also, petroleum fuels are at present the principal global source of CO_2 and posing a stronger threat to clean environment. Depleting reserves of crude petroleum, uncertainty in availability, environmental degradation and speedy hike in petroleum prices has necessited search of alternate fuels (Lin, *et al*, 2011). The prerequisite for an alternative fuel is that it should be easily available, renewable, environment friendly and techno-economically competitive. India is a developing country and its energy requirement is growing day by day. Most of the country's oil demands are met by import from the foreign countries. Bio-diesel is an alternative to petroleum-based fuels derived from vegetable oils or animal fats which can substitute them locally (Murugesan, *et al*, 2008).Lower cost feed stocks, such as waste Frying oil, grease, soap stocks are preferred because of their economic viability, since feedstock costs are about more than 85% of the total cost of biodiesel production (Pal, and Kachhwaha, 2013). The biodiesel produced from vegetable oil or animal fat is usually more expensive than petroleum based diesel fuel from 10 to 50 %. Many vegetable oils like Soybean, Groundnut, Rapeseed, Palm, Olive etc. are wildly used for a number of food items. But once they are heated above a critical temperature for deep, they become unfit for eating, as their further use may lead to cholesterol formation. Thus they need to be disposed in an environment friendly manner. In developing countries like India, the significant amount of WCOs may be collected from catering industry. Their use for biodiesel production offers solution to a growing problem of the increased WFO generation from household and industrial sources all around the world. Biodiesel can be produced by various conventional methods such as: alkali catalysis, acid catalysis, lipase catalysis etc. Acid catalyzed process is helpful when a high amount of free fatty acids are present in the vegetable oil, but the reaction time is very long (48–96 h), even at the boiling point of the alcohol, and a high molar ratio of alcohol is needed (20:1 wt/wt to the oil). In the base catalyzed procedure, some soap is formed and it acts as phase transfer catalyst, thus helping the mixing of the reactants. Presently, mechanical stirring is the commonly adopted process in worldwide industrial applications. Considering these limitations, there is a strong quest to develop an efficient, time-saving, economically functional and environmental friendly biodiesel production process at industrial scale having superiority over the classical procedure.

Recently developed biodiesel production technologies such as hydrodynamic cavitation and power ultrasound may prove very good for biodiesel production at industrial scale due to their easy scale-up property. (Pal, *et al*, 2013).presented the details of thumba biodiesel production test rig based on hydrodynamic cavitation followed by

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results of experimental investigation carried out on a CI engine. The transesterification reaction of vegetable oils using base catalyst and short-chain alcohols was studied by Gogate, and Pandit, 2005),by the method of hydrodynamic cavitation. This is a rapid technique for preparing alkyl esters from triglycerides at pilot plant scale operation. The transesterification reaction of vegetable oils using base catalyst and short-chain alcohols using the method of hydrodynamic cavitation was studied by (Gogate*et al*, 2006) Cavitation results in the generation of local turbulence and liquid micro- circulation (acoustic streaming) in the reactor, enhancing the rates of transport processes. The generation, subsequent growth and collapse of cavities results in very high energy densities of the order of 1x 10^{18} kW/m^3.

Hydrodynamic Cavitation

In hydrodynamic cavitation method mixing of two phases of reaction is carried out by cavitation conditions, produced by pressure variation, which in turn obtained by using the geometry of system to create velocity variation. Cavitation is generated by the flow of liquid under controlled conditions through simple geometries such as venturi tubes & orifice plates. When the pressure at the throat falls below the vapour pressure of liquid, the liquid flashes, generating a large number of cavities which subsequently oscillate and then give rise to pressure & temperature pulses. (Pal, *et al*, 2013). It is reported that hydrodynamic cavitation can be successfully applied to transesterification reaction for more than 90% yield of the product according to stoichiometry in as low as 15 minute of the reaction time.

2. Biodiesel Production: Material and Methods

Biodiesel production through cavitation technology

In this work the WFO is collected from Hotel Paris Hilton of Delhi. The filtered WFO (3kg) is taken in a beaker and then it is heated up to 110^0C in order to remove any water content in the oil. This oil is then brought down to 55^0C temperature so that after mixing the reactants the mixture temperature is limited to 50^0C. Simultaneously methyl alcohol (CH_3OH) is taken in molar ratio of (1:4.5 & 1:6) and Catalyst (KOH) is taken as (0.5%, 0.75% and 1% by weight of the oil).The mixer of methyl alcohol and KOH is stirred until KOH dissolves in methyl alcohol. Experiments have been conducted with the main objectives of converting the WFO in to biodiesel by both types of cavitation technique and to compare both the methods in terms of biodiesel production time and yield (%). Table1 presents the details of ingredients used for biodiesel production. Experiments were carried out for molar ratio of 4.5:1 and 6:1. Results for biodiesel production yield and time are shown in Fig 1 to Fig. 3 respectively. It is observed that the Hydrodynamic cavitation can be successfully applied to transesterification reactions, more than 90% yield of the product for molar ratio 4.5:1 and minimum catalyst percentage of 0.5%. Changing molar ratio to 6:1 does not give any appreciable increase in yield %.

Table 1: Oil, alcohol and catalyst used for mechanical stirring

Molar ratio (alcohol/oil)	WFO(g)	methanol (g)	Catalyst (KOH)		
			0.5%	0.75%	1.0%
6:1	3000 g	660 g	15 g	22.5 g	30 g
4.5:1	3000 g	492 g	15 g	22.5 g	30 g

Experimental results

As shown in figures 1 and 2, biodiesel yield increases as reaction time increases and eventually it becomes constant after 75 min of reaction time. The yield is more for molar ratio 6:1 and 1 % catalyst as compared to molar ratio 4.5:1 and 0.75% catalyst.

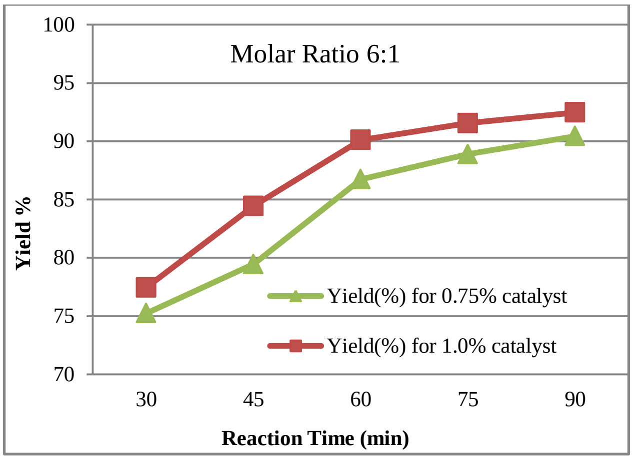

Figure 1 Time v/s Yield (%) for molar ratio 6:1 and different catalyst percentage

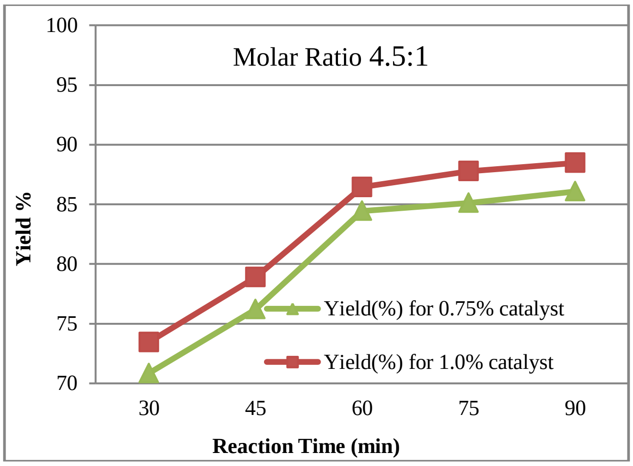

Figure 2 Time v/s Yield (%) for molar ratio 4.5:1 and different catalyst percentage

Hydrodynamic cavitation

The schematic diagram of the hydrodynamic cavitation test rig developed is shown in Figure 4. Like cavitation in turbines and pumps, hydrodynamic cavitation can be generated by the passage of the liquid through a constriction such as throttling valve, orifice plate etc. As the liquid passes through the orifice plates, the velocities at the orifice increase due to the abrupt reduction in the flow area, resulting in a decrease in the pressure. If the local pressure goes below the medium vapour pressure under operating conditions (at constant temperature), vapour bubbles are formed. At the downstream of the orifice, however, due to an increase in the area of cross-section, the velocities decrease giving rise to increasing pressures and pressure fluctuations, because of which bubbles collapse and local cavities are formed at a number of locations. This process generates conditions of very high temperatures and pressures locally. The collapse of the cavitation bubbles disrupts the phase boundary and impinging of the liquids create micro jets, leading to intensive emulsification of the system, which result in increase of reaction rate at much faster rate. This process is carried again and again until all the mixture is converted into biodiesel.

Experimental results

As shown in figures 3 and 4, the yield is more for molar ratio 6:1 and 1 % catalyst (max value is 98.12%) as compared to molar ratio 4.5:1 and 0.75% catalyst (max value is 95.14%).

3. Experimental Work on Performance and Emission in CI Engine

The setup consists of four cylinders, four stroke, Tata Indica diesel engine connected to eddy current type dynamometer for loading. It is provided with necessary instruments for combustion pressure and crank-angle measurements. The signals are interfaced to computer through engine indicator for p-θ diagrams. Provision is also made for interfacing airflow, fuel flow, temperatures and load measurement.

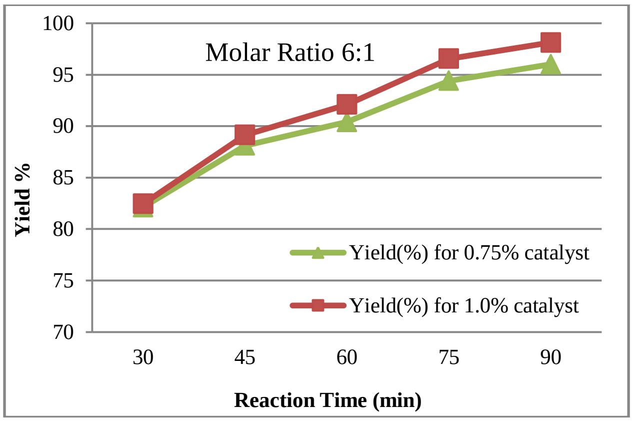

Figure 3 Time v/s Yield (%) for molar ratio 6:1 and different catalyst percentage

The set up has stand-alone panel box consisting of air box, fuel tank, manometer, fuel measuring unit and transmitters for air and fuel flow measurements. Experiment has been performed by taking WFO biodiesel blends diesel in proportion of volume 20%, 40% and 60% respectively and following parameters has been obtained. The main aim of this experiment is to investigate the suitability and effect on performance of blending of biodiesel in comparison to the petroleum diesel fuel.

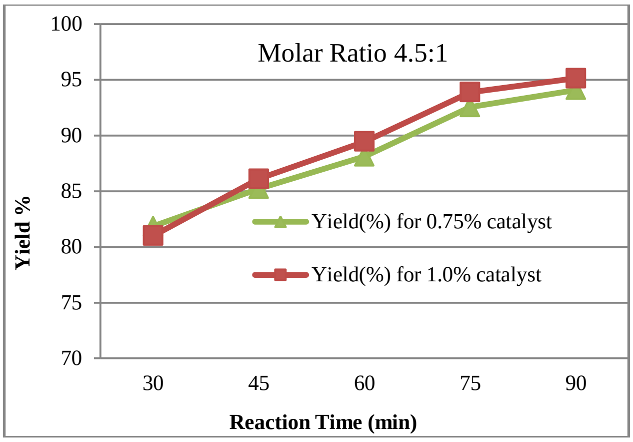

Figure 4 Time v/s Yield (%) for molar ratio 4.5:1 and different catalyst percentage

Brake thermal efficiency v/s brake power

Figure 5 shows comparison of Brake thermal efficiency v/s brake power for different blends in comparison to diesel. For WFO-B20 AND WFO-B40 blend brake thermal efficiency values are higher as compared to diesel at higher load. This is due to better combustion efficiency of blends caused by presence of extra amount of oxygen. The maximum thermal efficiency achieved by WFO-B40 is around 40.33 % at 4.0 kW.

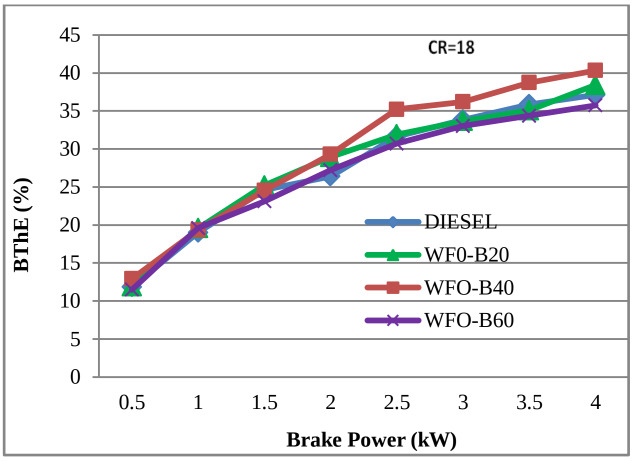

Figure 5 Comparison of brake thermal efficiency v/s brake power

Brake specific fuel consumption v/s brake power

The variation of specific fuel consumption vs. brake power is shown in figure 6 for blends and diesel. For all cases the bsfc initially decreases sharply with increase in brake power and afterward remains stable. In case of blends bsfc values are higher at the beginning because of higher viscosity. Once the required temperature is attained inside the engine cylinder the values are comparable with diesel but little bit higher specifically for WFO-B20 and WFO-B40 as compared to diesel.

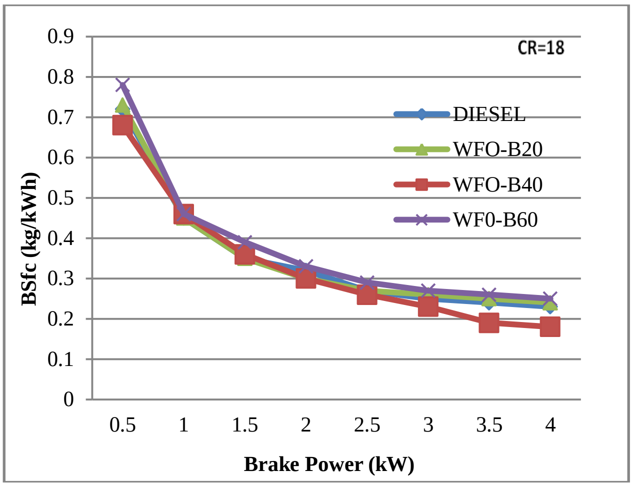

Figure 6 Comparison of specific fuel consumption v/s brake power

Exhaust gas temperature v/s brake power

Exhaust Temperature of the blends such as WFO-B20, WFO-B40 and WFO-B60 at various brake powers compared to diesel are shown in the Figure 7. The Ex. Temperature values are higher for blends because of better combustion efficiency. This high temperature is also indication of more NOx emission in case of blends.

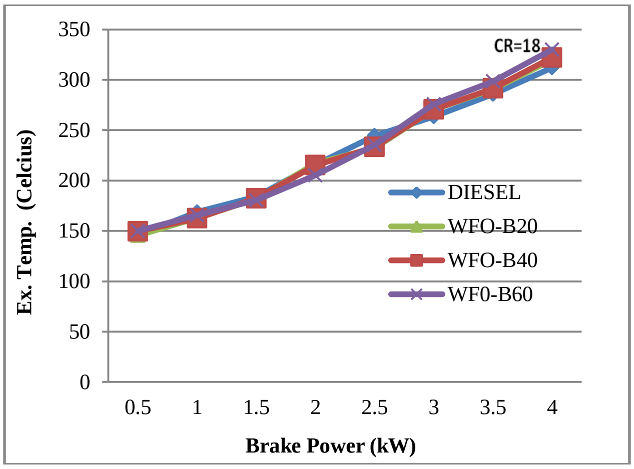

Figure 7 Comparison of exhaust gas temperature v/s brake power

Smoke opacity v/s brake power

To understand the pollution aspect of WFO and diesel blends the variation of opacity v/s brake power are shown in Figure 8 for blends in comparison to pure diesel. The opacity value for pure diesel is higher as compared to all type of blends for wide range of Brake power. At all brake power condition the opacity of all blends has less value than diesel oil. Maximum value of opacity has obtained at 59.21 at 4.0 kW brake power for pure diesel and for blends 45.7 at 4.0 kW for B-20.

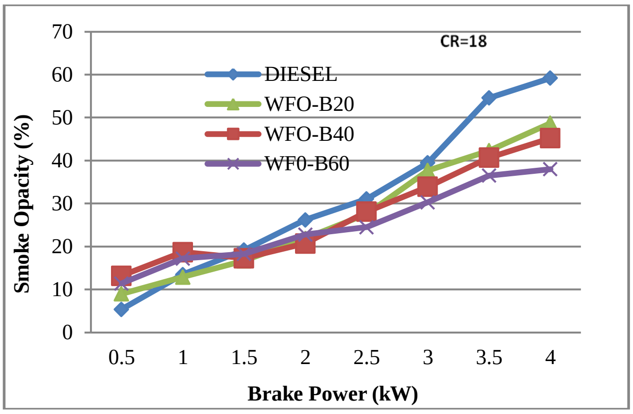

Figure 8 Comparison of smoke opacity v/s brake power

Conclusions

The production and performance testing of biodiesel from low-cost waste Frying oil have been investigated. The experimental study performed in this work has demonstrated that the hydrodynamic cavitation method is more efficient than the conventional mechanical stirring method with better yield in less reaction time**.** Waste Frying oil can be a good source of biodiesel production especially in Indian condition where large amount of waste oil is produced and then dumped either into land or river causing environmental pollution. As per performance testing performed in this work it can be seen that waste Frying oil biodiesel blends give better thermal efficiency and have got safer impact on environment as compared to diesel fuel. Thus present Experimental study on performance and emissions prove that WFO biodiesel can be easily used through blending it with diesel in existing diesel engines for better combustion and greener exhaust emissions.

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