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The investigation of the effects of washing process on biodiesel production to fuel properties and engine performance

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Abstract

The major part of all energy consumed worldwide comes from fossil sources (petroleum, coal and natural gas). The search for alternative fuels, which promise a harmonious correlation with sustainable development, energy conservation, efficiency and environmental preservation, has become highly pronounced in the present context. One of the more promising approaches is the conversion of vegetable oils (VOs) and other feed stocks, which primarily contain triglycerides (TGs) and free fatty acids (FFAs), into biodiesel. Injection, atomization and combustion characteristics of vegetable oils are very different from those of diesel fuel. Experiments were made on single-cylinder, four-stroke, water-cooled, direct injection diesel engine. Crude biodiesel was produced utilizing refined cottonseed oil through the transesterification method. Crude biodiesel was subjected to wash with pure water (distilled water DW) and deionized water (DEW). At the end of this process biodiesel is obtained. The effect of the specifications of diesel fuel with these produced-biodiesels on engine performance has been observed. Result of the experiments prove that COME (DEW)fuel obtained by being washed with deionized water gives better performances than COME (DW) fuel obtained by being washed with distilled water on engine torque, effective power and specific fuel consumption respectively at the values as following %0.8, %0.75 and %0.81.

***Keywords*:** Washing process; Cottonseed oil; Biodiesel; Engine performance

1. Introduction

Energy as an indispensable part of human life, has always been on the top list of the World agenda as one of the hotly debated issues. Energy remains to be an indispensible factor in economic and social development, and thus in increasing the wealth of societies [1]. The major part of all energy consumed worldwide comes from fossil sources (petroleum, coal and natural gas). However, these sources are limited, and will be exhausted by the near future. Thus, looking for alternative sources of new and renewable energy such as hydro, biomass, wind, solar, geothermal, hydrogen and nuclear is of vital importance [2]. While energy efficiency is an important issue, the development and encouragement of technologies that will use renewable energy sources and extending the use of such technologies constitutes another important step in national energy studies [3].

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The search for alternative fuels, which promise a harmonious correlation with sustainable development, energy conservation, efficiency and environmental preservation, has become highly pronounced in the present context [4]. All nations have been confronted with the energy crisis due to depletion of finite fossil fuels reserves, which results an increasing global demand of biofuels for energy security, economic stability and reduction in climate change effects, and generate the opportunity to explore new biomass sources [5].

Fossil fuels has the largest share among the world's energy sources. In spite of very serious studies and searches for alternative energy sources, the share of fossil fuels in meeting world energy demand is still as high as 85 to 90 % [1]. The world is presently confronted with the twin crises of fossil fuel depletion and environmental degradation. Indiscriminate extraction and lavish consumption of fossil fuels have led to reduction in underground-based carbon resources [4].

Since traditional fossil energy resources are limited and greenhouse gas emissions are becoming a greater concern, research is now being directed towards the use of alternative renewable fuels that are capable of fulfilling an increasing energy demand. One of the more promising approaches is the conversion of vegetable oils (VOs) and other feed stocks, which primarily contain triglycerides (TGs) and free fatty acids (FFAs), into biodiesel [6]. In recent years, interest of the studies on biodiesel production is increasing rapidly as the biodiesel is an eco-friendly product and also a good alternative to the gasoline due to the rapid increases in gasoline prices and as the gasoline will run out soon. Also, as the oil reserves are in certain areas and the countries not having these reserves wanting to reduce dependence on foreign countries for energy, revealed the inevitability of alternative energy sources [7].

Vegetable oil has too high a viscosity for use in most existing diesel engines as a straight replacement fuel oil. There are a number of ways to reduce the viscosity of the vegetable oil. Dilution, micro-emulsification, pyrolysis and transesterification are the four techniques applied to solve the problems encountered with the high fuel viscosity. One of the most common methods used to reduce oil viscosity in the biodiesel industry is called transesterification [8]. Vegetable oils and animal fats can be converted to their alkyl esters (biodiesels) by transesterification reaction [9]. After oil transforming to methyl ester, some features of methyl ester and oil are changing [10]. After the reaction in order to purify biodiesel from wastes different techniques are applied [11]. During the reaction the emergent soap can be annihilated by washing with water process can be used to separate catalysts, soap, salt, methanol from biodiesel during transesterification reaction. Therefore alcohol level in biodiesel will be lower. But when the transesterification reaction completed and biodiesel is washed with water a little soap will be left. 0.2% alcohol rate is acceptable for Europa Biodiesel Standards but it doesn't contain ASTM standards. The importance of washing process is any longer the separation of catalyst from ester [12]. The resulting biodiesel is quite similar to petroleum based diesel fuel in its fuel properties, and this fuel is biodegradable and non-toxic and has low emission profiles as compared to petroleum based diesel fuel [13]. However due to high free fatty acid (FFA), in direct use of engines causes problems because of negative effects such as blockage of the fuel pump and injectors, bad odour during combustion, the amount of sediment left on the cylinders and injectors, high viscosity and density value [14]. Injection, atomization and combustion characteristics of vegetable oils are very different from those of diesel fuel [4].

As biodiesel is different from diesel fuel with approximately 11% of oxygen it includes, its burning characteristics, engine performance and exhaust emissions are different as well. As a result of its oxygen content, good burning properties increase thermal efficiency. As a result of good burning due to the oxygen content CO emission decreases and NOx emissions increase. Increase in NOx emission with biodiesel is a result of abundant oxygen in the ambient. As they hardly have sulfur, SO_2 emission does not occur, which is a positive step to deal with acid rain problem. With biodiesel fuels, decreases in HC, PM and is emissions are observed [1]. Commonly accepted biodiesel raw materials include the oils from rapeseed, soybean, corn, and palm. New plant oils that are under consideration include safflower,mustard seed, peanut, sunflower and cottonseed [15].

2. Experimental

This study is made on the following engines. Single-cylinder, four-stroke, water-cooled, direct injection diesel engine (Fig. 1). The technical specifications of the test-engine are given on Table 1. Biodiesel has been produced from refined cottonseed oil through the method of transesterification at the following conditions. 3.5 g/l NaOH catalyst ratio, 20% (v/v) alcohol/fat, 65 °C reaction temperature and 1 h reaction time.

The obtained crude biodiesel was washed by pure water (distilled water DW) and deionized water (DEW). At the end of this process biodiesel has been obtained. Having determined the physical and chemical properties of diesel fuel and biodiesel fuel, the effect of washing process on fuel characteristics and engine performance has been observed. The evaluation of fuel characteristics is based on TS EN 14214 and ASTM standards.

As a result of the experiments, methyl esters of cottonseed oil and the characteristics of diesel fuel obtained by being washed with distilled water (DW) and deionized water (DEW) are given at Table 2.

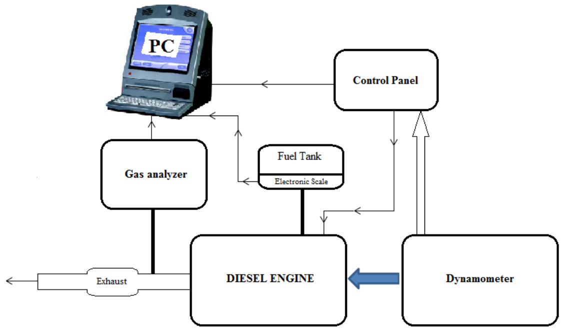

Fig 1. Schematic diagram of engine test rig.

Table 1. Technical specifications of the experimental engine

Items	Specification
Numbers of cylinder	1
Volume (cm^3)	686
Bore/stroke (mm)	75/77,6
Compression ratio	22,8:1
Cooling system	Water cooled
Maximum engine torque (Nm/rpm)	40,5/2000

Table 2. The chemical, physical and fuel properties of reference fuels and COME.

Property	Unit	EN590 EURO	COME (DW)	COME (DEW)
Cetane Number	---	52.1	---	---
Kinematic Viscosity	mm^2/s (40 ºC)	2.4	4.63	4.56
Density	kg/m^3 (15 ºC)	0.838	0.885	0.883
Calorific Value	MJ/kg	---	38.87	39.16
Cloud Point	ºC	-6	5.1	6.4
Pour Point	ºC	---	2.8	1.6
Flash Point	ºC	64	172	172
Copper Strip Corrosion	(3h, 50 ºC)	No 1	No 1	No 1

3. Result and discussions

3. 1. Engine performance

The torque changes of diesel fuel and biodiesel fuels are given in Figure 2. The maximum torque values are obtained at 2000 rpm. At 2000 rpm engine speed, diesel fuel gives higher torque values than biodiesel at all engine cycles. Observed respectively diesel 38.578 Nm, COME (DEW) 38.075 Nm and COME (DW) 37.772 Nm. Despite the fact that engine torque value of COME (DEW) fuel is 0.8% higher than COME (DW) fuel, the fuel consumption is 1.28% lower than diesel fuel. The reason for this situation is that viscosity of COME (DEW) is less than that of COME (DW). Viscosity of biodiesel is higher than that of diesel fuel and this affect the injection characteristics [4].

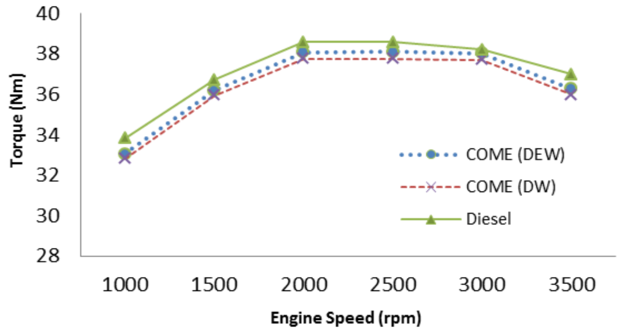

Fig. 2. Engine torque changes in diesel fuel and biodiesel fuel according to engine speed.

The changes of effective power of diesel and biodiesel fuels are given at Figure 3. The effective power values at 2000 rpm were observed respectively as following 8.34 kW diesel, COME (DEW) 7.97 kW and COME (DW) 7.91 kW. The effective power was decreased in avarege 2.64% in COME (DEW), and 3.41% in COME (DW).

The engine power of COME (DEW) fuel is %0.75 higher than COME (DW) fuel. A few authors thought that the higher viscosity results in the power losses, because the higher viscosity decreases combustion efficiency due to bad fuel injection atomization [16]. This decrease is less than the heating value difference and this can be explained by biodiesels providing better combustion in especially rich mixture regions as a consequence of oxygen content and high cetane number of biodiesel fuels, the fact that same volume pump is injecting more fuel as a consequence of higher density, and lower pump and injector leakage realized as a consequence of high viscosity [4].

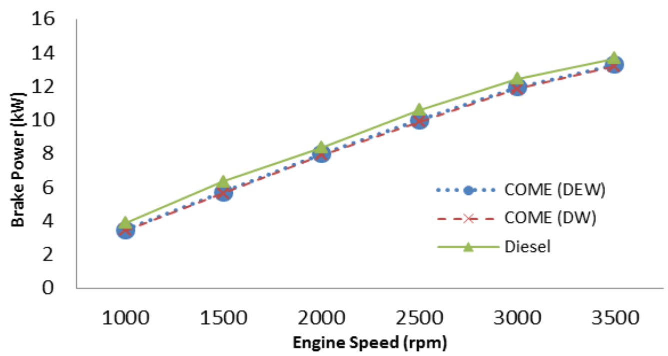

Fig. 3. Changes in engine power of diesel fuel and biodiesel fuel according to engine speed.

3. 2. Specific fuel consumption

The specific fuel consumption on 2000 rpm was observed respectively as following. 242.45 g/kWh of diesel 264.31 g/kWh of COME (DEW) and 266.46 g/kWh of COME (DW). While diesel fuel enables minimum specific fuel consumption, 9.01% increase was observed in COME (DEW) and 9.9% increase in COME (DW).

The vast majority of authors agreed that fuel consumption increase when using biodiesel. The increase in biodiesel fuel consumption is mainly due to its low heating value, as well as its high density and high viscosity. The different feedstock of biodiesel with different heating value and carbon chain length, or different production processes and quality, also have an impact on engine economy [16].

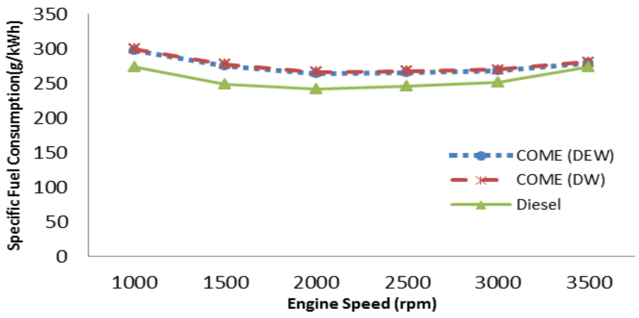

Fig. 4. Changes in specific fuel consumption in diesel fuel and biodiesel fuel according to engine speed.

3. 3. Exhaust emissions

Biodiesel offers cleaner combustion over conventional diesel fuel including reduced particulate matter, carbon monoxide and unburned hydrocarbon emissions. However, several studies point to slight increase in NOx emissions (about 10%) for biodiesel fuel compared with conventional diesel fuel. Low flame temperature and too rich fuel air ratio are the major causes of CO emissions from engine. Higher CO emissions results in loss of power in engine. Different factors can be at the origin of its formation, insufficient residence time, too low or too high equivalence ratios are part of those reasons [17]. The CO emission of biodiesel was lower than that of diesel. This is due to higher oxygen content and higher cetane number of the biodiesel [18]. Biodiesel with a higher cetane number had comparable NOx emissions with the diesel [19]. Higher cetane number of biodiesel shortens ignition delay and thus combustion advances. Higher cetane number will not only lead to burn early, but also lead to lower premixed combustion, which will lead to softer changes in pressure and temperature, thus it causes lower NO formation [16]. The fuel properties such as fuel bound oxygen, degree of saturation, cetane number, viscosity, density, surface tension, thermal conductivity, heat capacity, vapor diffusion coefficient all have significant impact on the emissions [19].

The NOx emissions according to engine speed are provided in Figure 5. The NOx emissions of diesel fuel are significantly lower than biodiesel fuels. The results are similar to the literature.

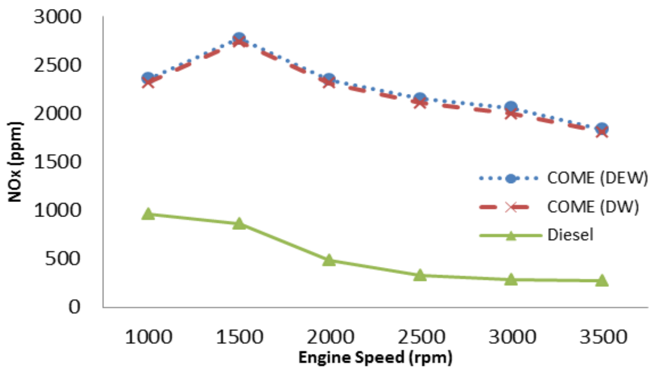

Fig. 5. Changes in NOx emissions according to engine speed.

4. Conclusions

As a result of the study, the engine torque and engine power of COME (DW) and COME (DEW) fuels are lower than diesel fuel according to engine speed. An increase in specific fuel consumption and NOx emissions have been observed. Regarding to washing process in two different fuels, in COME (DEW) approximately 0.8% better values were observed at fuel torque, power, specific fuel consumption and NOx emissions comparing to COME (DW). These values were obtained since the viscosity, density and heat value of the fuel had improved at the end of washing process. Using pure water during the biodiesel production, production of the pure water and its cost generates a difficult situation. Deionized water can be produced by a simple filtering mechanism. It's determined in this study that deionized water can be used successfully in washing process in terms of both economically and its beneficial effects on fuel properties. In the next productions, deionized water can be used in biodiesel production at the stage of washing due to the fact that it reduces the cost of biodiesel production and improves fuel properties.

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