International Journal of Applied Engineering Research ISSN 0973-4562 Volume 13, Number 10 (2018) pp. 7317-7322

Effect of Coconut Oil Acid Component on Material Durability and Corrosion in Fuel Supply System of Diesel Engines

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Abstract

Pure vegetable oil are alternative fuel and they are renewable, biodegradable, non-toxic and has the potential to reduce the exhaust emission. Many researches show the big benefits while using pure vegetable oil as fuel in diesel engine. Up to now, there are some methods to improve the disadvantages of pure vegetable oil such as blending with diesel fuel or heating up pure vegetable oil to suitable temperature. Although in an fuel system of diesel engine, mainly steel, ferrous alloys or stainless steel and elastomers come in contact with the fuel, however the influence of pure vegetable oil on the degradation and corrosion behavior of fuel system materials in engine has been rarely investigated. The paper presents the influence of pure coconut oil on fuel system materials durability and corrosion in diesel engine. Pure coconut oil is used to determine the corrosion rate and materials durability and weight loss of steel in fuel system in diesel engine. The paper results orientate to find the most suitable material to fabricate the fuel system while using pure vegetable oil as fuel in diesel engine.

Keywords: Pure coconut oil, acid component, corrosion, durability, fuel supply system, diesel engine

INTRODUCTION

Using pure vegetable oils as fuel was not new and dates back to the end of the 19th century with the inventor of the diesel engine. In 1900, the OTTO Company exhibited a small engine which, at the request of the French government, ran exclusively on peanut oil at the Universal Exhibition in Paris [1]. The engine, which had initially been designed to run on diesel oils, worked with vegetable oil without any modification. During World War II, pure vegetable oils were used as fuel to power diesel engines in isolated areas. For example, palm and coconut oil were used in Southeast Asia, soybean oil was being tested and used in the USA, rapeseed oil and sunflower oil were used in Europe, and cottonseed oil and Jatropha curcas oil were used in West Africa. Pure vegetable oils were similar to fossil diesel fuel. Many studies on pure vegetable oils have revealed lower emission of pollution which was potentially harmful to human beings. Due to these advantages, pure vegetable oils were technically feasible as an alternative fuel in compression ignition engines [2][3]. Besides, some disadvantages of biodiesel included oxidative and hydrolytic degradation, resulted in problems of inferior storage stability along with lower heating value, poor low temperature flow properties and microbial degradation [4][5]. Normally, pure vegetable oils form the deposits accumulated in the vehicular fuel systems. Pure vegetable oils reacted with some elastomers and metals in destructive way and thus leading to engine durability problems like injector cocking, piston ring sticking and severe engine deposits [4].

The materials used in the corrosive environment must not only met the requests of mechanical properties but also had the ability of the very high corrosion-resistant. Metals and alloys were corroded the most because they had both of strong chemical activity, and high electrical conductivity [6][7][8]. The metal corrosion was the spontaneous destruction of the metallic materials by the interaction of the chemical or the electrochemical between them and the environment. The metals and the alloys were considered resistant to the corrosion when they were resistant to corrosive effects of the environment, i.e., the process of corrosion occurred with a very slow speed. There were two types of corrosion were electrochemistry and chemical corrosion. Galvanic corrosion occurred in the electrolyte solution, such as atmospheric and soil moisture, river water and sea water, salt solutions, alkalis and acids. In galvanic corrosion, the electrical current and the metal or alloy dissolve by the electrochemical interaction with the electrolytes appeared [7]. Due to the heterogeneous electrochemical on the metal surface and the corrosive micro battery was formed in the electrolyte solution. On some areas of the surface, called the anode, reaction (1) occurred, in other areas, called the cathode, the reaction (2) or (3) occurred:

$$Me \leftrightarrow Me^{n+} + ne \quad (1)$$

$$O_2 + 2H_2O + 4e \leftrightarrow 4OH^- \quad (2)$$

$$2H^+ + 2e \leftrightarrow H_2 \quad (3)$$

The main components of the diesel fuel system that came in contact with fuel were the diesel fuel tank, fuel filter, lift pump, plunger pump, priming pump, injection pump and the injection nozzles. In diesel engine fuel system, the fuel tank stores and lines delivered the pressurized fuel around the system. The fuel filter removed abrasive, dust and water particles from fuel. The pump lifted the fuel from the tank to the injection pump by creating a pressure difference. The injection pump delivered an exact amount of fuel with high pressure to the injectors through the injector pipes [9][10]. The injector nozzle atomized the fuel and sprayed into the combustion chamber. Leak-off pipes collected and returned the excess fuel from the injecting system to the fuel tank via fuel filter. A detailed study of the various material of

International Journal of Applied Engineering Research ISSN 0973-4562 Volume 13, Number 10 (2018) pp. 7317-7322

construction of different components was an infinite importance to ensure the life of the engine. A large variety of metals and non-metals were used as the material of construction for the various components of the fuel system. The common materials of diesel engine fuel system were given in Table 1.

Table 1. Common materials used in diesel engine fuel system

Parts	**Common material**
Fuel tank	Steel
Fuel filter	Resin impregnated paper
Fuel feed pump	Steel, Copper alloy
Fuel lines	Steel, Synthetic rubber flexible hoses
Fuel pump	Steel
Fuel injectors	Stainless steel
Nozzles	Steel
Cylinder head	Gray cast iron
Cylinder barrel	Gray cast iron, Cast aluminium
Cylinder liner	Gray cast iron
Valves	Steel
Piston	Aluminium alloy, Gray cast iron

Among them, common ferrous metals were steel and cast iron, non-ferrous metals were aluminum and copper alloy and the non-metallic includes elastomers. When fuel flowed through the fuel system and react with above materials under diverse static and dynamic conditions of the temperature, load, pressure and sliding, thus it caused the wear, deterioration and degradation of materials in the diesel engine fuel system [11].

Electrochemical and chemical corrosion was the degradation of a material, usually metal, by the chemical reaction. The above corrosion resulted the deterioration of material properties [12]. Pure vegetable oil was more corrosive than fossil diesel fuel. Pure vegetable oil is higher electrical conductivity and more hygroscopic than that of traditional diesel fuel because of its acid contents so the pH value fell otherwise the microbiological activity degradation increases. The materials, especially metal, where fuel flowed through, could suffer appreciable damage due to electrochemical and chemical corrosion [10]. The electrochemical and chemical corrosion occurring in the relationship between fossil diesel fuel and materials has been fully studied, however the systematic studies of the influence of pure vegetable oil on material corrosion were still very deficient to a large extent [13]. Owing to the difference in the chemical and physical properties, the influence of the corrosion on material dramatically varied for fossil diesel fuels and pure vegetable oil. Corrosion characteristics of pure vegetable oil were momentous for long term compatibility of diesel engine fuel system machine parts.

With the pure vegetable oils, the acidity was small but it also affecte the corrosion resistance of the material, especially for the mechanical parts working in high temperature conditions [8]. At high temperatures, the mechanical parts were destroyed not only by the oxidation temperatures but also by the acid found in pure vegetable oils. Therefore, the study of the effects of pure vegetable oil on the corrosion level of mechanical parts made from of steel was very essential. In terms of time and research conditions, this paper only refered to the ability of corrosion materials by pure vegetable oils.

PROPERTIES OF PURE COCONUT OIL

The analyses of the Fatty acid composition in pure coconut oil (CO100) samples were carried out in triplicate and gotten the medium result. Fatty acid composition of CO100 was given in Table 2.

Table 2. Saturated fatty acid composition of pure coconut oils (% mass)

	Saturated and Unsaturated fatty acid composition				
Pure coconut oil	$C_{8:0}$	$C_{10:0}$	$C_{12:0}$	$C_{14:0}$	$C_{16:0}$
	6.83	5.56	45.16	18.82	10.08
	$C_{17:0}$	$C_{18:0}$	$C_{20:0}$	$C_{22:0}$	$C_{24:0}$
	-	4.31	0.08	-	-
	$C_{16:1}$	$C_{17:1}$	$C_{18:1}$	$C_{18:2}$	$C_{18:3}$
	-	-	7.45	1.8	-
	$C_{20:1}$	$C_{20:2}$	$C_{22:1}$	$C_{22:2}$	$C_{24:1}$
	0.06	-	-	-	-

Where: $C_{8:0}$ is caprilic acid; $C_{10:0}$ is capric acid; $C_{12:0}$ is lauric acid; $C_{14:0}$ is meristic acid; $C_{16:0}$ is palmitic acid; $C_{17:0}$ is margaric acid; $C_{18:0}$ is stearic acid; $C_{20:0}$ is arachidic acid; $C_{22:0}$ is behenic acid; $C_{24:0}$ is lignoceric acid; $C_{16:1}$ is palmitoleic acid; $C_{17:1}$ is miristoleic acid; $C_{18:1}$ is oleic acid; $C_{18:2}$ is linoleic acid; $C_{18:3}$ is linolenic acid; $C_{20:1}$ is gadoleic acid; $C_{20:2}$ is eicosadienoic acid; $C_{22:1}$ is erucic acid; $C_{22:2}$ is docosodienoic acid; $C_{24:1}$ is nervonic acid.

The advantages of CO100 as diesel fuel were liquidity, ready availability, renewability, no sulfur and aromatic content, and biodegradability however the main disadvantages of CO100 were higher viscosity, higher surface tension, higher density otherwise lower volatility. Properties of CO100 were given in Table 3.

Table 3. Properties of pure coconut oil

Properties	Methods	Unit	Result
Higher heating value	ASTM D 240	MJ/kg	38
Water content	ASTM E 203-01	ppm	432
Sunfat ash	ASTM D 874	%wt	0,03
Sulfur content	ASTM D 5453	ppm	170
Phosphoric content	ASTM D 3231	mg/l	25
Cetan number	ASTM D 976	-	41
Cloud point	ASTM D 97	ºC	21
Flash point	ASTM D 93	ºC	200
Ditillation temperature, 90% vl	ASTM D 86	ºC	362
Oxidation stability, 110ºC	EN 14112	h	>24
Acid value	ASTM D 974	mgKOH/g	0,4
Copper plate corrosion	ASTM D 130		1

MATERIALS AND METHODS

Pure coconut oil (CO100) belongs to pure vegetable oils and is chosen in order to analyze the influence of the CO100's acid component to the material corrosion in fuel system of the diesel engine. The CT38 steel sample which the chemical composition is given in the Table 4 and used primarily to fabricate most of the pipes, valves… in the fuel system of diesel engine. Hence, the paper concentrates to evaluate the influence of the CO100's acid component and diesel fuel to the CT38 steel corrosion.

Table 4. Chemical composition of the CT38 steel sample

Standard	Grade	Chemical composition (% mass)				
		C	Si	Mn	P (max)	S (max)
1651-85 (1765-85)	CT38	0.14 – 0.22	0.12 – 0.3	0.4 – 0.65	0.04	0.045

Besides, the sliding between static and dynamic components is always followed by wear, on which produces micro particles of metal. These particles are flushed away by the lubricating oil and are accumulated in the lubricating oil. Adequate information about abrasion rate, resource of element and engine condition can be forecasted by analyzing the concentration of the metallic particle in the lubricant oil after operating. Generally, metallic elements such as Aluminium (Al), Chromium (Cr), Copper (Cu), Iron (Fe) and Lead (Pb) are observed in lubricating oil sump. Wear analysis in engine can be classified into two groups [8][14].

(1) Static engine lab test that the experiments are conducted for a specific periods of time. After the test, oil is collected and analyzed for wear debris.

(2) Engine test installs on the vehicles that are operated for a specific length of time or road distance (km). At the end of the test, oil is collected from oil sump and analyzed for wear debris.

The metal corrosion rate is determined by measuring the curve quickly polarized in the static methods. This method uses electronic devices Potentiostat (Autolab PGSTAT30), AUX electrode (platinum), electrodes compares SCE (AKA calomel electrode saturated) and the working electrode WE (metal samples studied) to measure polarization curves that - current density (Figure 1). Potentiostat is an electronic device that can be a constant voltage to the sample and measuring the current response.

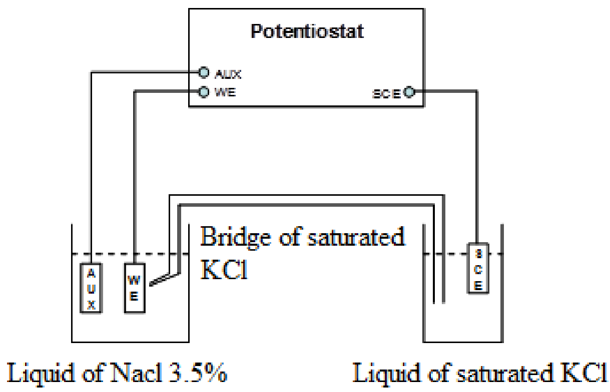

Figure 1. Experimental set-up for detemining the current density corrosion

The sample of research is polarized cathode by applying the potential that is more negative than that of the corrosion. The experiments of the electrochemical were carried out and used a Princeton Applied Research in three electrode cells. Graphite bar was used as a counter electrode, saturated calomel electrode (SCE) was the reference electrode and the CT38 carbon steel with a surface 1.013cm^2 was used as working electrodes. The working electrodes were polished, degreased with acetone and rinsed with distilled water. The working electrode was immersed into diesel fuel and CO100 at 25^{0}C, and then the open circuit potential was measured after 30 minutes.

The polarization curve of the current density cathode corrosion obtained by applying to change with 1mV/s of the scan speed during of more negative potential to get the corrosion one and measure the response electrical current. Similar, polarization curves of the anode is also received from the scanning between the corrosion potential to more positive potential. This paper uses the experiment method with static engine lab test in order to determine the influence of diesel fuel and CO100 component acid on the change of hardness and relative elongation of materials in fuel system in diesel engine. The experiment results between diesel fuel and CO100 are compared in order to carry out and orient the kind of alternative materials.

RESULTS AND DISCUSSION

A. Effect of CO100 on the corrosion rate in the static immersion test

The CT38 steel sample was weighed and immersed in 200 ml of pure coconut oil (CO100), and 3.5%NaCl solution, respectively, for a period of 150h . The CT38 steel sample was removed after the set intervals of time and wiped with trichloroethylene for the removal of the excess CO100, the CT38 steel sample was cleaned and reweighed. The loss in mass was determined, and average result is reported and compared to the diesel fuel. Besides, the corrosion rate of the CT38 steel sample is determined by extrapolating the linear section of the cathode and anode branches.

The sample of CT38 steel immersed in diesel fuel and the CO100 are measured in order to build up the polarization curves, the polarization curves of the CT38 steel sample while is immersed in CO100 and diesel fuel, is shown in the Fig 2.

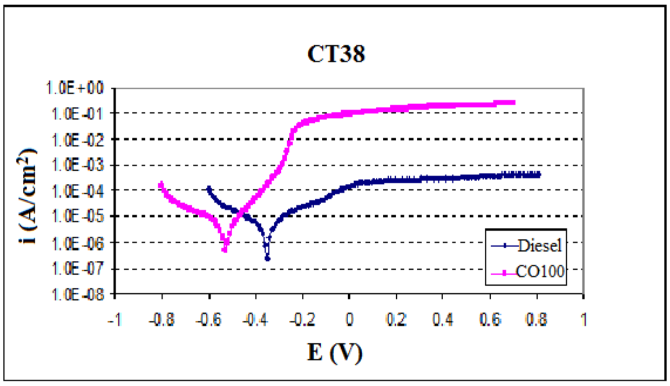

Figure 2. The polarization curves of the CT38 steel sample in the static immersion test

Moreover, the corrosion rate is smaller than that of the machine parts working at high temperatures. The corrosion rate in size depended on time of the CT38 steel sample immersed in diesel fuel and the CO100 is given in the Table 5 by extrapolating the linear section of the cathode and anode branches.

Table 5. The corrosion rate of the CT38 steel sample in diesel fuel and the CO100 at 25^{0}C

CT38 steel sample	Fuel	
	CO100	Diesel fuel
Corrosion rate (mm/year)	0.06046	0.02313

B. Weight loss

Wear measurement of piston rings were carried out on diesel engine fuelled with diesel and CO100. In this experimental work, piston rings include top rings, oil rings and compression rings were weighted after 500 hours of operating the diesel engine and the wear was quantified [9]. The weight loss was measured with an accuracy of ± 0.1 mg. The results on wear of piston rings are shown in Fig 3.

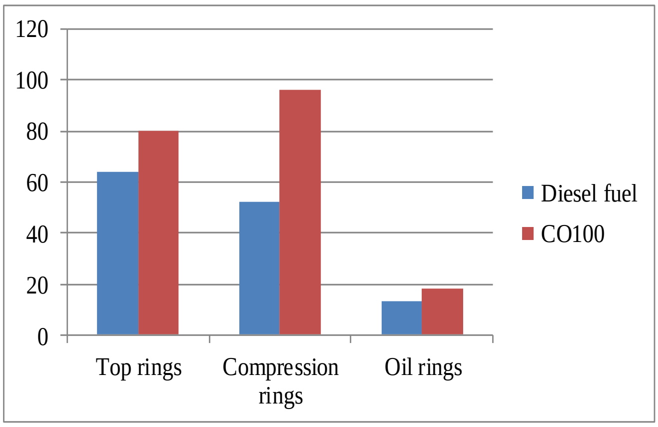

Figure 3. Piston rings weight loss (mg) from diesel fuel and CO100 in diesel engine

The wear of piston rings from diesel fuel and CO100 fuelled diesel engines are compared. After the endurance test, the oil ring wear was observed to be the least. However, the weight loss of piston rings in case of using CO100 as fuel in diesel engine was more as compared to diesel piston rings wear. Fig 3 shows that, while the oil ring, the top ring and the compression ring are immersed in CO100, the oil ring wear is 20% more, the top ring wear is 22.5% more and the compression ring wear is 48% more than that of diesel fuel. The top compression ring faces the combustion gases and it works in the highest temperature zone, therefore top compression ring faces maximum wear. Although, lubricity of CO100 is better than diesel fuel, however, during long term endurance test with CO100, higher crankcase dilutions was observed resulting in decrease in viscosity of lubricating oil and hence higher wear.

C. Hardness and relative elongation change

Experimental studies were carried out to find the degradation of elastomer material such as fuel pipes, valves and oil ring in CO100 by static immersion test for 60 days. Diesel fuel was used as a reference fuel. Change in mass, volume, hardness and relative elongation were measured as per ASTM [14]. The percentage change in hardness of material and percentage elongation change of oil ring out of many experimental results obtained on various concerned durability measurements of tested materials is shown in Fig 4 and Fig 5.

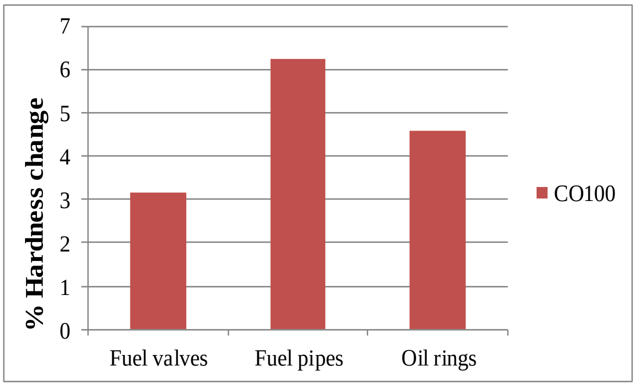

Figure 4. Hardness change of fuel valves, fuel pipes and oil rings in CO100

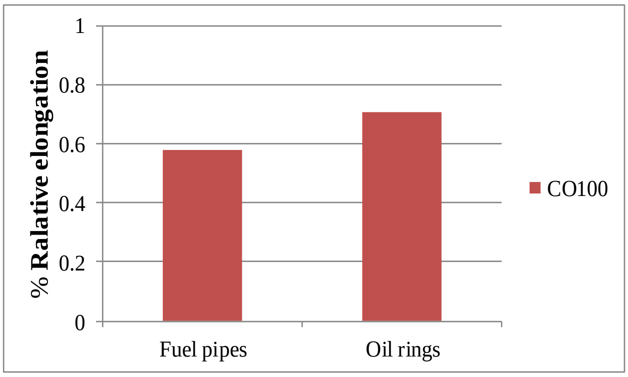

Figure 5. Relative elongation change of fuel pipes and oil rings in CO100

Change in hardness was measured by shore hardness tester (ASTM D2240). Hardness change and percentage elongation for both fuel pipes and oil rings material were increased in CO100 in comparison with diesel fuel. No change in mass, volume, hardness and relative elongation were observed in diesel. Fig 4 and Fig 5 show that the level of hardness and relative elongation change of the oil rings, fuel pipes and fuel valves. Hardness of fuel valves, fuel pipes and oil rings change after immersing in CO100 for 60days are respectively 3.1%; 6.21% and 4.62% more than those in case of diesel fuel. Besides, relative elongation of fuel pipes and oil rings change are respectively 0.59% and 0.71% more than those in case of diesel fuel. The change of hardness and relative elongation of steel sample while immerses in CO100 compared to diesel fuel may be understood that, due to CO100 have much different chemical structures than petro diesel and consequent different effects on elastomeric components. Besides, CO100 is more prone to oxidation upon exposure to air as well as storage conditions and the amount of unsaturation of fatty acids such as palmitoleic acid; miristoleic acid; oleic acid; linoleic acid; eicosadienoic acid; erucic acid; docosodienoic acid; nervonic acid. Degradation of elastomeric components may be attributed to chemical composition of CO100 along with these products.

CONCLUSIONS

Up to now, the designed engines use still traditional fuel such as gasoline or diesel fuel. Alternative fuels such as pure vegetable oils increase the material corrosion in diesel engine that come into contact with the pure vegetable oils. This review shows that the material corrosion in CO100 is higher than that of diesel fuel. The commonly employed metals, alloys and steel were found to be easy to corrosion by CO100. The corrosion voltage E and current density i appearing in the CT38 steel sample while using CO100 and diesel fuel as fuel had analyzed and compare. Hardness and relative elongation of CT38 steel sample increase compared to diesel fuel, thus they will effect destructively on the durability of materials in diesel fuel system. Therefore, it is necessary to completely replace the type of steel that is resistant to the corrosion, change of material hardness and relative elongation. It is able to use the steel alloyed with elements such as Mn, Cr, Ni or the material composite based on rubber such as FKM-GBL-S and FKM-GF-S.

In next research, the influence of other alternative fuels to the hardness, the strength of steel and alloys will be carried out.

REFERENCES

[1] Hoang Anh Tuan, Luong Cong Nho, Le Anh Tuan, Tran Quang Vinh. 2014. Design and Manufacture the Raw Vegetable Oil Heating System Utilizing Heat from Exhaust Gas with Auxiliary Electric Power to Fuel the Diesel Engine. In THE 7th AUN/SEED-Net REGIONAL CONFERENCE IN MECHANICAL AND MANUFACTURING ENGINEERING, Hanoi, 267–72.

[2] Hoang, Anh Tuan, and Van Thu Nguyen. 2017. Emission Characteristics of a Diesel Engine Fuelled with Preheated Vegetable Oil and Biodiesel. Philippine Journal of Science 4(146): 475–82.

[3] Hoang, Tuan Anh, and Vang Van Le. 2017. The Performance of A Diesel Engine Fueled With Diesel Oil, Biodiesel and Preheated Coconut Oil. International Journal of Renewable Energy Development 6(1): 1.

[4] Hoang, Anh Tuan. 2018. A Design and Fabrication of Heat Exchanger for Recovering Exhaust Gas Energy from Small Diesel Engine Fueled with Preheated Bio-Oils. International Journal of Applied Engineering Research 13(7): 5538–45.

[5] Hoang, Anh Tuan. 2017. The Performance of Diesel Engine Fueled Diesel Oil in Comparison with Heated Pure Vegetable Oils Available in Vietnam. Journal of Sustainable Development 10(2): 93.

[6] Hoang, Anh Tuan, Lan Huong Nguyen, and Duong Nam Nguyen. 2018. A Study of Mechanical Properties and Conductivity Capability of CU-9NI-3SN ALLOY.nInternational Journal of Applied Engineering Research 13(7): 5120–26.

[7] Díaz-Ballote, L, J F López-Sansores, L Maldonado-

López, and L F Garfias-Mesias. 2009. Corrosion Behavior of Aluminum Exposed to a Biodiesel. Electrochemistry Communications 11(1): 41–44.

[8] Haseeb, ASMA, H H Masjuki, L J Ann, and M A Fazal. 2010. Corrosion Characteristics of Copper and Leaded Bronze in Palm Biodiesel. Fuel Processing Technology 91(3): 329–34.

[9] Fazal, M A, ASMA Haseeb, and H H Masjuki. 2010. Comparative Corrosive Characteristics of Petroleum Diesel and Palm Biodiesel for Automotive Materials. Fuel Processing Technology 91(10): 1308–15.

[10] Cursaru, Diana, and Sonia Mihai. 2012. Corrosion Behaviour of Automotive Materials in Biodiesel from Sunflower Oil. REV. CHIM.(Bucharest) 63(9).

[11] Sorate, K A, and P V Bhale. 2013. Impact of Biodiesel on Fuel System Materials Durability. Journal of Scientific and Industrial Research 72(1): 48–57.

[12] Shackelford, James F, Young-Hwan Han, Sukyoung Kim, and Se-Hun Kwon. 2016. CRC Materials Science and Engineering Handbook. CRC press.

[13] Bhardwaj, Mayank, Parul Gupta, and Neeraj Kumar. 2014. Compatibility of Metals and Elastomers in Biodiesel-a Review. Int J Res 1: 376–91.

[14] Krishnamurthy, Shyamala R. 2013. A Comparison of Corrosion Behavior of Copper and Its Alloy in Pongamia Pinnata Oil at Different Conditions. Journal of Energy 2013.