Analysis on Tribological Characteristics of Waste Ayurvedic Oil Biodiesel Blends using Four Ball Tribometer

R. Balakumar, G. Sriram, S. Arumugam, A. Shree Navin

IOP Conference Series: Materials Science and Engineering

PAPER • **OPEN ACCESS**

Analysis on Tribological Characteristics of Waste Ayurvedic Oil Biodiesel Blends using Four Ball Tribometer

Analysis on Tribological Characteristics of Waste Ayurvedic Oil Biodiesel Blends using Four Ball Tribometer

R. Balakumar [a],*, G. Sriram [b], S. Arumugam [c], A. Shree Navin [d]

[a, b, c] Department of Mechanical Engineering, [d] Master in AeroMat-Innovation,

[a, b, c] Sri Chandrasekharendra Saraswathi Viswa Mahavidyalaya,

Enathur, Kanchipuram – 631 561. Tamilnadu, India.

[d] Institute Mines Telecom Mines Albi, France.

[a,] *balavhd@gmail.com, [b]drg.sriram@gmail.com, [c]aru_amace@yahoo.co.in, [d]shreenavin.a92@gmail.com

Abstract. Tribology related problems in an engine give challenges to the automobile sector. To minimize the issues raised by diesel fuel, the biodiesel gains a vertical attention by the researchers. Especially, the waste oils will lead a high pollutant material to the environment and it needs a proper procedure to disposal. In this present study it is aimed to investigate the friction and wear characteristics of Waste Ayurvedic Oil (WAO) biodiesel blends by varying the applied load in a four ball wear test Tribotester. The investigations of fuels were WAO biodiesel blends (B10, B15 and B20) and diesel fuel was analysed with test conditions viz: load 40Kg and 80Kg, constant temperature 75°C, duration: 300 sec, sliding speed: 1200rpm for all the tested fuels. For the given experimental conditions more wear scar diameter were observed for diesel than WAO biodiesel blends for both the loads. The coefficient of friction and frictional torque were absorbed less with WAO15 for both the loads than other blended fuels and diesel fuels. The worn surfaces of the steel balls were examined by a Scanning Electron Microscope (SEM). The morphology image results showed that minimal friction, wear and smoother surface were absorbed for all the biodiesel concentrations than the diesel fuel.
Keywords: WAO Biodiesel, Wear, Friction, load variation, Four Ball Tribometer.

1. Introduction

The ever growing environmental issues and fastest depletion of petroleum based fossil fuels leads the researchers to work out in the way of alternate fuels [1, 2]. In this scenario the energy supply by fuel to the vehicles is not only the important point as well as it should lead less emission and give good lubricity without changing the atmospheric condition [3]. Many researchers investigated the biodiesel in terms of conversation and Tribology from neat vegetable oils, waste cooking oil, waste transformer oil and animal fats [4-8]. Mostly the biodiesels are made from edible vegetable oil sources in all over the world. There is equal weightage and importance given for edible oils for human nutrition's purpose. The vegetable oils used in engines will be good for present research but this may lead more important than petroleum products in near coming years. So, it is necessary to replace the input oil source with low cost or price less oil sources viz waste oils like cooking oil and animal fats etc [4, 5].

There are many studies were undertaken to investigate the production of biodiesel from waste oils and animal fats [6]. In the engines the temperature inside the cylinder will be more and it will affect the lubricity of the fuel. This may lead more friction in the mating parts inside the engine [7]. In-fact the commercially available petroleum based fossil fuel supplies poor lubricity. So, from the above issues it leads to search an alternate fuel for diesel engines called biodiesel. The biodiesel is a renewable and it can be generated from many vegetable oil sources, animal facts and waste oils [8, 9]. Nabi et al. [10] investigated the waste transformer oil (WTO) as a biodiesel blends (B10, B15 B20) in a single cylinder diesel engine. From the test results the WTO biodiesel blend (B20) produce high brake thermal efficiency, less fuel consumption and reduced exhaust emission than other biodiesel blends and diesel fuel. Biodiesel supplies some good advantages than diesel fuel like reduction in emission, biodegradability, higher flash point, good cetane number etc [11].

From all the above, the impact of friction and wear by the diesel or the biodiesel will affect the engine component life cycle. The wear and friction properties of the alternate fuel as well as the diesel were studied by many researchers using four ball wear test tribometer, High Frequency Reciprocating Rig and pin on disc tribometer. Fazal et al. [12] investigated the friction and wear characteristics of palm oil biodiesel using four ball wear tester for the different biodiesel blends viz. B10, B20, B50, B100 with a input parameters like speed: 600, 900, 1200,1500 rpm, load: 40Kg, temperature: 75°C. From the investigation results the increase of biodiesel blends and speed will decrease the wear and friction characteristics. If the temperature increases then the wear and friction will increase but at the same time the biodiesel blends will reduce the wear and friction. Kumar N and Chauhan S [13] analyzed the jatropha oil methyl ester (B20, B40 and B100) in a four ball wear tester with a speed: 1500 rpm, duration: 1 hour, temperature: 45, 60, 75°C and load: 40, 50, 60 Kg. There was a positive impact were observed by reduction in load, temperature and increase in biodiesel blends. Basically the biodiesels have high viscosity this will form a stable film between the mating parts and it will reduce the wear and friction between the liner and ring in the engine [14].

My previous study investigates the tribological characteristics of Waste Ayurvedic Oil (WAO) biodiesel blends (B10, B15, and B20) along with diesel as a lubricity enhancer using Four Ball Wear Tribometer. The co-efficient of friction and wear scar diameter were observed less for the blend WAO (B15) than other blended fuel and diesel fuel. From the SEM results the abrasive and adhesive were absorbed less for B15 than other fuels [15]. From the many number of researches conducted on the lubricity of various biodiesel and its blends none of them touched in the area of Waste Ayurvedic oil biodiesel blends by varying the loads (40kg and 80kg) in a four ball wear tester.

2. Materials and methods

2.1 Synthesis of Waste Ayurvedic Oil Biodiesel production and blend preparation

After one use of ayurvedic oil becomes waste and it is highly difficult to dispose. The waste ayurvedic oil (after the treatment) was procured from Sri Jayendra Saraswathi Ayurveda College and Hospital, Chennai, India. The chemical used for transesterification process viz. methanol, sodium hydroxide, hydrochloric acid and anhydrous sodium sulphate was purchased from M/S Ganapathy Trading Company, Chennai. The oil contains more number of unwanted impurities and it need to be filtered. The figure 1shows the WAO filtration process.

Figure 1 WAO filtration setup

The waste ayurvedic oil was converted as waste ayurvedic oil methyl ester via transesterification process. The 400ml of methoxide (methanol and NaOH) and 1400ml of WAO both were mixed with constant rotation and heated in the mantle for one hour at a temperature of 60°C. Then the mixture was poured in a separating funnel to separate the glycerol and methyl ester. Then the methyl ester was separated and heated above 60°C to remove excess methanol. Finally the bubble was wash was carried out to remove the left out catalyst and glycerol. At final the blends were prepared by mixing with the diesel fuel i.e. 90% of diesel fuel with 10% WAO Methyl ester referred as WAO10, 85% of diesel fuel with 15% WAO Methyl ester referred as WAO15 and 80% of diesel fuel with 20% WAO Methyl ester referred as WAO20. The properties of biodiesel and diesel were considered from balakumar et al. [15].

IOP Conf. Series: Materials Science and Engineering **390** (2018) 012080 doi:10.1088/1757-899X/390/1/012080

2.2 Tribological test on four ball wear Tribotester

To analyse the wear and frictional characteristics of WAO biodiesel blends the four ball wear tester was used. The stainless steel balls were used for this analysis. Before testing the four balls need to be cleaned thoroughly by using toluene and wiped with wet tissues. Three balls were tightly fixed in the steel cup at the bottom and fourth ball is kept at the top of rotating spindle using chuck. The test was conducted as per the standard ASTM D4172 for wear and ASTM D5183 for frictional characteristics.

The lower three balls were filled with test fuel. The analysis was carried under a test conditions viz. load: 40kg and 80kg, constant temperature: 75°C, duration: 300 seconds, sliding speed: 1200 rpm (constant speed). The computer was interconnected with the four ball machine to analyse the wear and friction. After the test the wear scar image and wear scar diameter was measured using the optical microscope for the lower three balls. The upper ball will not be subject to wear scar image analysis. The change in the wear scar diameter depends on the applied load and the friction.

3. Results and discussion

3.1 Wear scar diameter analysis

The figure 2 (a - h) shows wear scar diameter (WSD) of different WAO biodiesel blended fuel and diesel fuel for both applied loads. The oxidation rate during the experiment will be effect on the wear scar diameter. The WSD was observed less for all WAO biodiesel blends than the diesel fuel for both the loads.

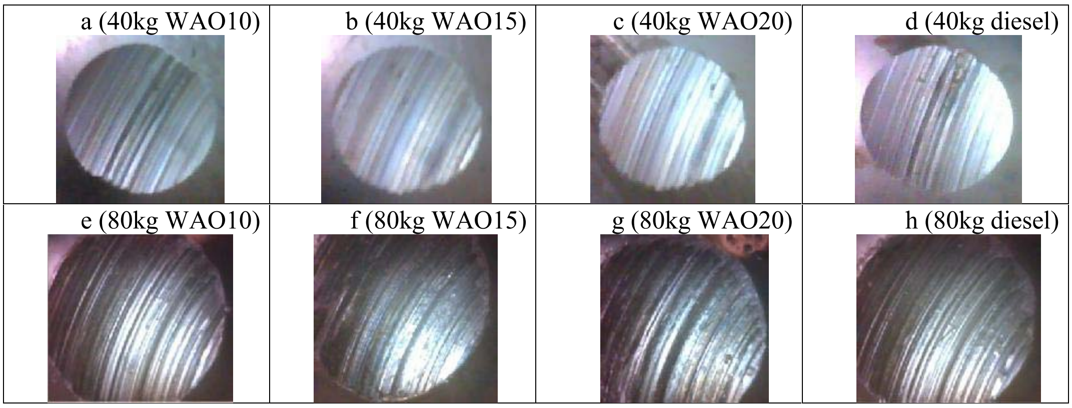

Figure 2 Optical microscope image of the tested steel ball

The WSD were noted less for WAO15 for both loads than other WAO blended fuel and diesel fuel. In general, if the applied load increases then the pressure applied on the balls will tends to increase the WSD. For the 40kg applied load the WSD value for WAO15 is 0.392mm for other bended biodiesel fuel and diesel WSD varies between 0.439 to 0.491mm. Similarly, for higher load the least WSD was absorbed for WAO15 as 2.458mm which is better than other blended fuels and diesel fuel. Similarly largest WSD was observed for 80kg applied load which is higher than the 40kg load. For the applied load WAO15shows less wear scar diameter than the other blended fuel and diesel fuel. Marginally the scar diameter was measured for WAO15 is 2.458 mm. At the same time the WSD value for WAO20, WAO10 and diesel were measured as 2.490, 2.564 and 2.682 mm which is higher than WAO15. The test results were consistent with the results by Syahrullail et al. [16].

3.2 Wear and friction characteristics

The figure 3 (a & b) shows the time and frictional torque characteristics for WAO biodiesel blends and diesel fuel for 40kg and 80kg. After few minutes the frictional torque reached the stable condition for all the tested fuel and at all the test conditions. The frictional torque was observed less for all the WAO biodiesel blends than the diesel fuel.

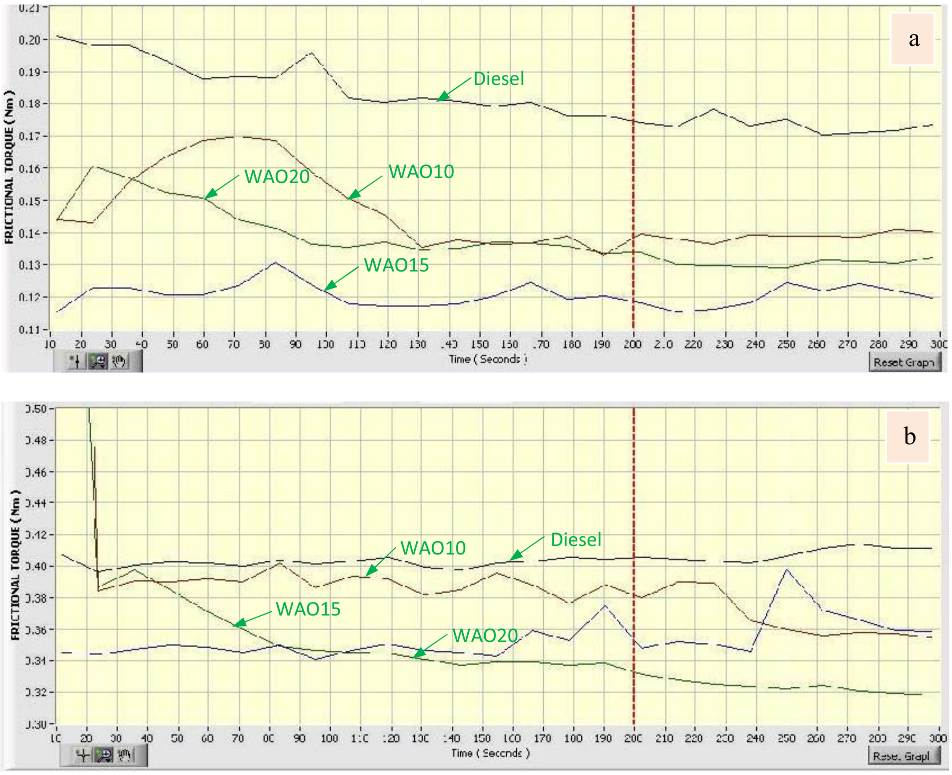

Figure 3 Frictional torque versus time for (a) 40kg, (b) 80kg.

The figure depicts that the frictional coefficient was decreasing with the increase in time for all the tested fuels. For 40kg applied load the WAO15 marginal reduction in frictional torque was observed i.e. 0.117Nm to 0.13Nm. However the frictional torque for WAO20 and WAO15 shows slightly higher than the WAO15 and lower than diesel fuel the frictional torque value varies between 0.13Nm to 0.17Nm. At the same time the diesel fuel shows higher value of frictional torque than the biodiesel blends which falls between 0.17Nm to 0.2Nm.

Similarly for higher load i.e. 80kg applied load also the WAO biodiesel blends shows reduction in frictional torque than the diesel fuel. Generally, for higher load the frictional torque will be high because the more pressure over the ball will be high. More fluctuations were observed at the beginning for all the fuels used. After 30 seconds all the blends the WAO biodiesel blends and diesel fuel become stable conditions. For the WAO15 the frictional torque fluctuates between 0.32 to 0.34Nm. At the same time higher level of frictional torque were observed for diesel fuel which lies between 0.40 to 0.42Nm. The other WAO biodiesel blends shows less frictional torque than diesel fuel and higher than WAO15. The test results consistent with the results from Habibullah et al. [17].

3.3 Coefficient of Friction

The figure 4 shows the graph between the different fuels and coefficient of friction (COF) value for 40kg and 80kg applied load. From the figure it is found that high coefficient of friction was observed at higher load.

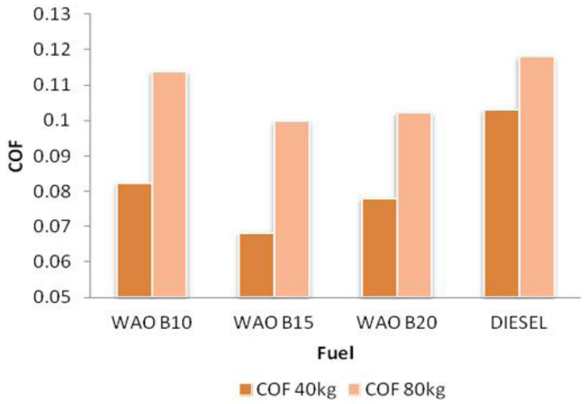

Figure 4 Co-efficient of friction with respect to fuel for 40kg and 80kg.

The variation frictional coefficient was minimal for all the fuels. From the graph it is found that for 40kg load the coefficient of friction were fluctuates between 0.06817 to 0.08244 for WAO biodiesel blends and for the diesel 0.10312 was absorbed which is higher than biodiesel blends. Similarly for 80kg the WAO biodiesel blended fuels the coefficient of friction varies between 0.09995 to 0.11386 and for the diesel fuel it is found higher than biodiesel fuel. The results were consistent with the results from wain et al [18].

3.4 SEM analysis of steel ball worn surfaces

Figure 5 (a-h) shows the SEM micrographs of worn surfaces of the steel balls via WAO10, B15, B20 and diesel fuel for the loads of 40kg and 80kg. From the analysis of worn surfaces of tested steel balls it shows that the sizes of the particles removed from cavities of the tested worn balls are much lesser for WAO15 followed by WAO10, B20 and diesel fuel.

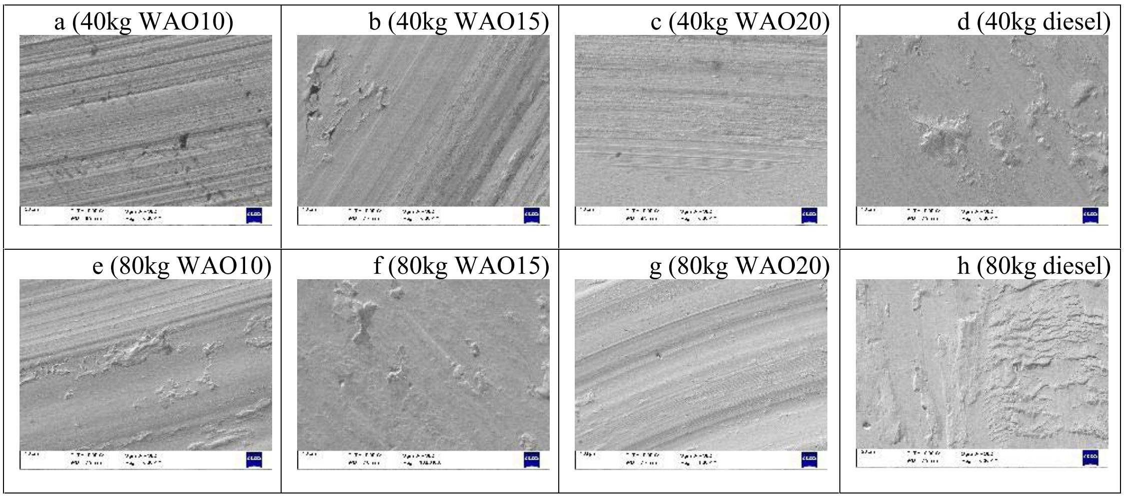

Figure 5 SEM image of tested steel ball

The deformation of the wear surface of steel balls was severe for diesel fuel. Further the wear scar was less for all the biodiesel blends than the diesel fuel. The surface morphology demonstrates that the edge of the surface at the diesel fuel is plastically elongated which gives cracks and wear debris. From the definition removal of wear debris more than 20µm is called as adhesive wear and less than 20µm is called as abrasive wear. From the image morphology the diesel fuel falls in the category of adhesive wear and the WAO biodiesel blends were falls in the abrasive wear. From the image the layer of metals from the worn surfaces was excluded out in the direction of sliding of the test balls. Although the extrusion of metal is less for WAO15 than other blended fuels and diesel fuel. The wear debris and the deformation were less for WAO15 followed by WAO10, B20 and diesel fuel. Especially in diesel fuel very micro level cracks were occurred than blended biodiesel. No severe wear and damages can be seen in WAO15 than other blended fuel and diesel fuel. Some regular, thin and radial scratches were observed on the tested surface which results abrasive wear. Finally the morphology shows that less wear was observed with all the biodiesel concentrations than the diesel fuel. The test results consistent with the results from Habibullah et al. [17].

Conclusion

From the investigation results the following were concluded

- The lubricity of the WAO biodiesel blends gives good lubricity which leads for reduction in wear and friction for both the applied loads.
- The WSD increases with increase of load which leads increase of wear. The WSD for WAO15 biodiesel blend at 40kg and 80kg load was 9.82% and 22.4% better than the diesel fuel. The WSD was considerable better for WAO15 than other blended biodiesel and diesel fuel.
- The lubricity in terms of wear and friction were decreased for WAO15 than other blended fuel and diesel fuel. The frictional torque value fluctuates between 0.117Nm to 0.13Nm for WAO15 which is marginally lesser than other blended fuels and diesel fuels.
- The coefficient of friction for WAO15 at 40kg and 80kg applied load was 3.5% and 1.8% better than diesel fuel. The increase in applied load will act more pressure on the balls which leads the increase in friction.
- The surface morphology of the tested steel balls revealed that more wear debris was found for diesel fuel which falls in adhesive wear. But for all the concentrations of biodiesel less wear were absorbed and falls in abrasive wear.
- From the investigation results it is suggested that WAO15 exhibits better lubricating performance in terms of friction and wear for both the applied loads and hence it can be used as a engine fuel which leads the engine life.

Reference

[1] Restrepo-Flórez, J.-M., Bassi, A., Rehmann, L., Thompson, M.R., (2014). Investigation of bio film formation on polyethylene in a diesel/biodiesel fuel storage environment. *Fuel* 128,240–247.

[2] Silitonga, A.S., Masjuki, H.H., Mahlia, T.M.I., Ong, H.C., Chong, W.T., Boosroh, M.H., (2013). Overview properties of biodiesel diesel blends from edible and non-edible feedstock. *Renewable Sustain. Energy Rev*. 22 (0), 346–360

[3] Tung SC, McMillan ML. (2004) Automotive tribology overview of current advances and challenges for the future. *Tribol Int*;37:517–36.

[4] Girotto, F., Alibardi, L., Cossu, R., (2015). Food waste generation and industrial uses: a review. *Waste Manage*. 45, 32–41.

[5] R. Balakumar, G. Sriram, and S. Arumugam Waste Ayurvedic Oil as an Engine Fuel—A Review. (2018) *Adv. Sci. Eng. Med.* 10, 249–254

[6] Bhatti, H.N., Hanif, M.A., Qasim, M., Rehman, A., (2008). Biodiesel production from waste tallow. *Fuel* 87, 2961–2966.

[7] Sarvi A, Fogelholm CJ, Zevenhoven R. (2008) Emissions from large-scale medium speed diesel engines: 2 – Influence of fuel type and operating mode. *Fuel Process Technol*; 89:520–7.

[8] Demirbas A. (2009) Biodiesel from waste cooking oil via base-catalytic and supercritical methanol transesterification. *Energy Convers Manage*;50: 923–7.

[9] Ushakov S, Valland H, Aesoy V. (2013) Combustion and emissions characteristics of fish oil fuel in a heavy-duty diesel engine. *Energy Convers Manage*; 65: 228–38.

[10] Md uran abi, Md shamin akhter, Md atiqur rahman, (2013) aste transformer oil as an alternative fuel for diesel engine. *Procedia Engineering*: 56: 401-406.

[11] Ozsezen AN, Canakci M (2011). Determination of performance and combustion characteristics of a diesel engine fueled with canola and waste palm oil methyl esters. *Energy Convers Manage*; 52:108–16.

IOP Conf. Series: Materials Science and Engineering **390** (2018) 012080 doi:10.1088/1757-899X/390/1/012080

[12] Fazal, M.A., Haseeb, A.S.M.A., Masjuki, H.H., (2013). Investigation of friction and wear characteristics of palm biodiesel. *Energy Convers. Manage*. 67 (0), 251–256.
[13] Kumar, N., Chauhan, S., (2014). Analysis of tribological performance of biodiesel. *Proc. Inst. Mech. Eng., Part J: J. Eng. Tribol*., http://dx.doi.org/10.1177/ 1350650114532452.
[14] Syahrullail, S., Zubil, B.M., Azwadi, C.S.N., Ridzuan, M.J.M., (2011). Experimental Evaluation of Palm Oil as Lubricant in Cold Forward Extrusion Process, *International Journal of Mechanical Sciences*, 53, pp.549-555.
[15] R. Balakumar, G. Sriram, S. Arumugam, (2018) Investigation of Friction and Wear Characteristics of Waste Ayurvedic Oil Biodiesel Blends, *Advanced Science, Engineering and Medicine* Vol. 10, 1–4.
[16] Syahrullail, S., Wira, J.Y., Wan Nik, W., Fawwaz, W., (2013). Friction characteristics of RBD. Palm olein using four-ball tribotester. *Appl, Mech. Mater*. 315, 936–940.
[17] M. Habibullah, H.H. Masjuki, M.A. Kalam, N.W.M. Zulkifli, B.M. Masum, A. Arslan, M. Gulzar (2015). Friction and wear characteristics of Calophyllum inophyllum biodiesel. *Ind. Crops and Products* 76: 188–197
[18] Wain KS, Perez JM, Chapman E, Boehman AL (2005). Alternative and low sulfer fuel options: boundary lubrication performance and potential problems. *Tribol Int*; 38:313–9.