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Full Length Article

Influences of thermal stability, and lubrication performance of biodegradable oil as an engine oil for improving the efficiency of heavy duty diesel engine

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HIGHLIGHTS

- Biodegradable olive oil contains 68.7% of oleic acid in FAC.
- Olive oil has a better thermally stable up to 390 °C.
- Olive oil produces 63% of lower COF compared to SAE15W40.
- The lower worn scar surface found with biodegradable oil.

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ABSTRACT

Nowadays, the development of biodegradable products is important in improving energy efficiency and green environment, particularly in energy conservation and rotation of machinery systems. In the case of sliding components, lubrication system and lubricant quality plays an important role for energy efficiency as it is directly involved with frictional force and components wear characteristics. The conventional mineral oil-based lubricant is used for machinery lubrications; however, it is nonbiodegradable and is an environmental pollutant. This investigation attempts to develop biolubricant acquired from various vegetable oils to replace mineral oil-based lubricants. This study evaluates the physicochemical properties, thermal stability, and lubricating and tribological characteristics of olive oil and its comparative analysis with commercial lube oil. A four-ball tribotester was used to measure the friction and wear properties of the sample according to the ASTM 4172 method. Olive oil has an excellent oxidation stability due to the presence of high percentages of oleic acid in fatty acid composition. Olive oil showed higher viscosity index and kinematic viscosity than other vegetable oils; hence, it is better for boundary lubrication. Thermogravimetric analysis showed that olive oil persists thermally steady up to 390 °C. Olive oil showed a lower coefficient of friction, wear scar diameter, and worn scar surface area than commercial lube oil. Therefore, due to the better lubricating performance, olive oil has high potential for use as an engine lubricating oil for improving efficiency of heavy-duty engines in the automotive applications.

1. Introduction

Globally, different kinds of lubricants, such as refined, synthetic, mineral, and vegetable oils, are used as lube oil. The mineral oil-based lubricant is mostly used as engine and motor oil. Mineral oils obtained from petroleum crude oil are available in the world market; however, these are harmful to the environment due to their nonbiodegradability and toxicity [1–3]. The diminution of the oil reserves that resulted in increasing oil prices and the pressing concern for environmental protection led to the development of biolubricants, which can substitute the use of mineral oil. Vegetable oils are renewable, less toxic, biodegradable, and thermally stable compared with mineral and commercial oils [4,5,1]. Biolubricants have better lubrication performance due to their high viscosity,

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viscosity index, and flash and fire point [6,7]. High frictional coefficient, high pour point, and poor oxidation stability are the main disadvantages of vegetable oils [8]. Vegetable oils can be used as a lubricant for boundary and hydrodynamic lubrication because of the long fatty acid chain length and polar groups present in the oil [9,10]. Vegetable oils are obtained from various kinds of oil seeds, and almost 350 oil-bearing crops are available all over the world. Vegetable oils, such as jatropha, karanja, olive, palm, coconut, sunflower, and soybean, can be either edible or nonedible [11,12]. Many researchers used vegetable oils as a replacement for diesel fuel in diesel engines; however few researchers reported about the potential application of vegetable oils as a lubricating oil for engine lubrication purposes.

Lubrication is important to lessen the frictional effects and wears from the various kinds of sliding, moving, and rotating components [13,14]. It can also reduce the temperature from the metal contact zone. Friction is one of the main causes of energy loss. One-third of the world's total energy is lost due to friction between sliding and moving parts. The quality and type of lubricating oil plays an important role in reducing friction between moving and sliding components. An extensive amount of energy is used to reduce the friction, particularly in the power-generation, industrial, and transportation sectors; moreover, large economic losses are caused by wear of mechanical parts, transmission system, and their mechanism and replacement [15]. Fig. 1 shows the total energy losses of heavy-duty diesel engines. In transportation sectors, 33% of energy losses are caused by friction in piston assembly, crankshaft and camshaft mechanism, valve train, pumping, bearing, and transmission system [16,17]. Holmberg et al. [16] reported that

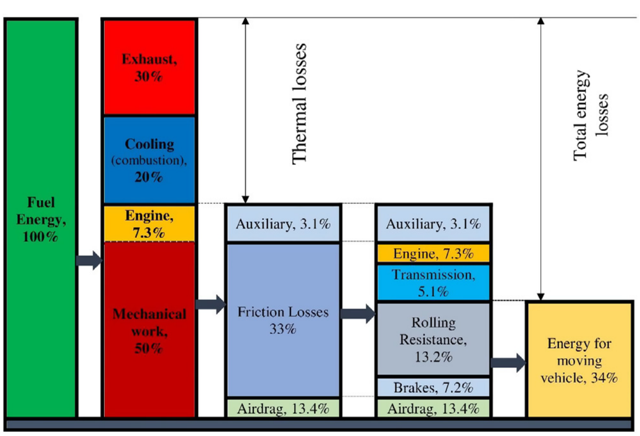

Fig. 1. Energy losses for heavy duty diesel engines.

for heavy-duty engine, 33% of fuel energy losses are due to friction, which is distributed into the engine (7.3%), transmission (5.1%), rolling resistance (13.2%), and brakes (7.2%). These losses can be reduced by substituting the lubricating oil, such as biodegradable or vegetable oils, or improving the lubricant properties by adding antiwear or antifriction additives. Lubricants are mostly used in industries and engine oil applications [18]. Many researchers reported that vegetable oil, such as coconut, olive, sunflower seed, corn, soybean, rice bran, and rubber seed oils, could be used as a lubricant for industrial and engine lubrication purposes. For example, Rani et al. [19] evaluated the lubrication properties of rice bran oil as a biolubricant and found that it had excellent thermal stability and lubrication properties. The kinematic viscosity and oxidation stability of the rice bran oil maybe enhanced by mixing suitable additives. The appropriate additives, such as organozinc compounds, aromatic amine compounds, and phosphorous sulfur compounds, were mostly used for improving the oxidation stability of the oil. Aravind et al. [20] investigated the lubrication property of rubber seed oil and found that it can be used as a lubricant in cold temperature conditions due to its high viscosity index and a low pour point.

1.1. Olive oil

Fig. 2 shows the feedstock of olive oil. Olive is a native crop of the Mediterranean Basin and is one of the members of Oleacase. Wild olives were collected by Neolithic peoples in the 8th millennium BC. The oil is extracted from the olive fruit, which called Olea europaea, by applying pressure. It is commonly used for cosmetics, cooking, soap and pharmaceuticals and as fuel for oil lamps [21,22].

Fig. 3 shows the production and consumption of olive oil around the world. The daily production and consumption of olives is increasing for various applications. Analysis shows that world olive oil production increased by 21% in 2015 from 2014, and decreased by 23% in 2014 from 2013. In 2014, the world consumption of olive oil was higher than the total production [23,24]. The total olive oil production by countries is shown in Fig. 4. EU27 produced higher amounts of olive oil, approximately 2.1 million tons in 2015, and they supplied olive oil all over the world. In EU27, Spain is the largest olive oil producer, producing almost 1.1 million tones, which accounted for 39% of the world's total olive oil production in 2015 [25]. In Spain, 75% of olive oil production originates from Andalucía, predominantly within Jaén province, which produces 70% of the total olive oil in Spain. The world's largest olive oil production mill, which is capable of producing 2500 tons of olive oil daily, is located in Villacarrillo, Jaén [26]. Italy, Turkey, and Spain exported high-quality extra virgin olive

Fig. 2. Olive oil.