USING VEGETABLE OIL ADDITIVES TO ENHANCE THE PERFORMANCE OF PETROLEUM PRODUCTS

Vegetable oil is a biodegradable, and environmentally friendly alternative to other additives like petroleum [1]. However, solid lubricants can only have approximately 7% of biodegradable additives like vegetable oil in the base oil [2]. Vegetable oil is used in industries like the port industry, waterways, and agriculture where environmental contamination may occur. There has been a 16.3% increase in the use of biobased lubricants like vegetable oil in 2006 [3]. Vegetable oil has a triacylglycerol structure which allows improvements on thermo-oxidative properties, stability properties, and lubricity when compared to other lubricant structures. The triacylglycerol structure also allows the formation of tribofilm which is claimed to prevent metal contact surfaces from interacting. To be an effective lubricant additive, the vegetable oil must be able to work under extreme temperatures [1].

The two types of vegetable oil are drying oil, which includes unsaturated fatty acids, and non-drying oil, which includes saturated fatty acids. Some examples of drying oil include linseed oil, canola oil, and sunflower oil. The best vegetable drying oil is said to be soybean oil because of its performance as a lubricant additive without modification. Some examples of non-drying oil include palm oil, peanut oil, and olive oil [1]. Drying oils contain approximately 66-74% of fatty acids while non-drying oils contain around 7-11% of fatty acids [4].

Structure and Modification of Vegetable Oil

The most common vegetable oil used for lubrication is soybean oil. Soybean oil has a triacylglycerol structure with approximately 14 to 22 carbons and up to 3 double bonds. As shown in figure 1, the triacylglycerol structure of soybean oil contains up to 3 double bonds [2]. Additionally, the addition of an ether, a functional group, allows for soybean oil to improve its properties. Along with the triacylglycerol structure in olive oil, oleic acid also plays a major role in olive oil [5]. Oleic acid is an omega-9 fatty acid which means that there is only one double bond located at the end of the carbon chain that is found in olive oil. The oleic acids form a triacylglycerol structure which allows the olive oil to have its tribological properties [6]. This structure allows for high lubricity, high viscosity, and low volatility [7].

However, the main drawbacks of using vegetable oil-based additives are their low oxidative stability and low-temperature properties. It was determined that to improve the oxidative stability property, functional groups are attached to the vegetable oils through a process called epoxidation. The epoxidation of the soybean oil allows for a lower coefficient of friction because the addition of functional groups improves the oxidation stability properties [3].

As time passes, there is a gradual increase in exposure to low temperatures which can cause poor flow properties. It was discovered that the vegetable oils that contain more saturated fatty acids perform the worst at low temperatures while the vegetable oils that contain the least saturated fatty acids and the most unsaturated fatty acids perform the best at low temperatures [7]. This trend indicates that vegetable oil-based additives with the least amount of saturated fatty acids should be added to the base oil to have better thermal properties. Another way to improve thermal properties is to add pour point depressants. Pour point depressant can improve the thermal properties because it delays the crystallization of wax in vegetable oils-based additives [7]. Although the addition of pour point depressants may only delay the problem instead of preventing it, depressants serve as a promising solution to the poor thermal properties of vegetable oil-based additives. Future research could be done on preventing the crystallization of wax so vegetable oil-based additives can be used on a wider scale which can help the environment.

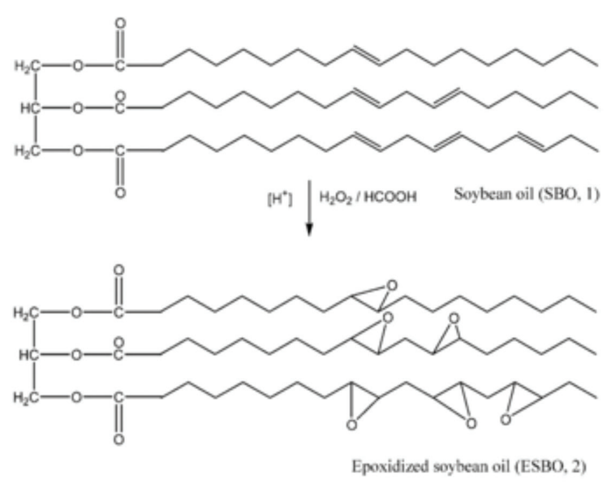

Figure 1. The triacylglycerol structure of soybean oil [2].

Tests Performed on Vegetable Oil Additives

Vegetable oil has poor oxidation stability. The oxidation stability test was performed on the soybean oil with a functional group and without a functional group at 150°C, 175°C, 200°C, and 225°C with a pressure of 1379 kPa for 2 hours. It was determined that the vegetable oil attached to a functional group has higher oxidative stability than the vegetable oil before epoxidation [3]. This means that to improve the oxidation stability of vegetable oil-based additives, a function group can be added.

The tribological properties of the base oil hexadecane oil were measured along with the hexadecane oil that contains hydroxy ester derivatives by implementing the ball on disk test. The ball on disk test was performed at 5 rpm for half an hour with a load of 1779N at 25°C. The results of this test showed that the hexadecane oil with hydroxy ester derivatives had a lower coefficient of friction when compared to the original base oil hexadecane [3].

The reaction between soybean oil and organic thiols created hydroxy thioether. This hydroxy thioether derivative was measured for its tribological properties by performing the ball on disk test. The ball on disk test was performed at 5 rpm for 15 minutes with a load of 1780 N at room temperature. It was found that as the concentration of hydroxy thioether additives increases the coefficient of friction decreases [2].

Rapeseed oil containing 2-mercaptobenzothiazole derivatives, known as di-n-dodecyl-[2-(2-benzothiazolyl)thio]ethylborane and di-n-dodecylthio-[2-(2-benzothiazolyl)thio]ethylborane, underwent several tests including the corrosion tests, wear scar test, and the four-ball test. The copper strip corrosion test was performed accordingly to the ASTM D-130 standards which are at 100°C for 3 hours. It was determined that both vegetable oil additives had anti-corrosion properties. Another test performed on these derivatives is to determine the wear scar. The scanning electron microscope was used, and it was found that the wear scar diameter of the surface with rapeseed oil containing the two vegetable oil additives was lower when compared to the wear scar of the surface with rapeseed oil. The four-ball test was conducted accordingly to the ASTM D2783 standards. The top ball rotates at 1450 revolutions per minute for half an hour at room temperature. This test determined that the additives produced a low shear tribofilm which helps reduce friction and wear [8]. Adsorbed layers cause metal-to-metal contact which produces shear-induced tribofilm [9].

Tribofilm

The addition of an ester group to a vegetable oil allows for the formation of a monolayer tribofilm which prevents direct contact between the two metal surfaces [3]. The triacylglycerol structure of the vegetable oil reacts with the polar end of a contact surface which creates a multimolecular layer that results in tribofilm [2].

The hydroxy thioether derivatives release sulfur which reacts with the surface and forms a thin tribofilm layer. It was also determined that as the number of polar groups increases causes the sulfide tribofilm is more stable which reduces friction and increases antiwear properties. Additionally, at high temperatures, the triacylglycerol structure of the hydroxy thioether derivative forms acrolein film. With the addition of the acrolein tribofilm and sulfide tribofilm, there is an increase in antiwear, antifriction, and EP properties [2].

Conclusion

Vegetable oils when modified can be effective lubricants, and in addition, as discussed in this paper, they can be effective additives as well. The triacylglycerol structure of the additives allows for the adsorption of metal. Additionally, the triacylglycerol structure also allows the formation of tribofilm [10]. This tribofilm allows for the reduction in wear and friction which allows for smoother operation in industrial applications.

In future applications, one might consider the application of vegetable oil additives in other industries that may not have a high risk of environmental impact. Other than being used in lubricants, vegetable oil can also be used to make polymers. Future research can be done on vegetable oil-based polymers and how they can be used in lubrication [10].

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