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Characteristics Biolubricant Enriched with Nanoparticle Additives: a Review

Zhahra Hanif Sholiha*, Gaguk Jatisukamto

Department of Mechanical Engineering, Faculty of Engineering, University of Jember, Jember, 68121, East Java, Indonesia
Corresponding author:zhahrahanifsholiha95@gmail.com

ABSTRACT

The engine movement mechanism is a system composed of machine elements that contact or rub against each other between these surfaces. Surfaces that rub against each other will cause a friction force that causes wear on the surface, so it requires energy to fight the friction force. Lubricants are needed to reduce friction and reduce wear rates, where lubricants are generally made of mineral materials. Lubricants made from synthetic materials are non-renewable and cause environmental problems. The development of biolubricants as lubricating materials based on animal fats or vegetable oils is continuously being carried out. This study aims to observe the potential of biolubricants based on reviews from various previous research journals. The use of additives in biolubricants is also studied whether the addition of these additives can improve the characteristics of biolubricants. This study shows that the addition of certain additives to biolubricants can improve the characteristics of biolubricants.

Keywords: *Biolubricant, coefficient of friction, lubricants, viscosity, wear rate*

I. Introduction

Improving a friendly environment and efficiency resistance is important in the engine movement mechanism. Development of biolubricants as environmentally friendly lubricants continues to be developed to meet green tribology standards. The use of mineral-based lubricants is generally dominated by the automotive sector, which is about 80%, while the rest comes from synthetic materials and other materials [1]. The lubricating properties of mineral materials are non-renewable and can cause environmental problems. Research studies on lubricants from biological materials are continuously being carried out in order to obtain lubricants from biological materials that are better than lubricants from mineral substances. Sources of lubricants from biological materials consist of soybeans, cocoa, coconut, jatropha, palm oil, which generally can be grown in tropical areas [2]. Biolubricants play an important role in supporting the green tribology program. Green tribology is green tribology, namely the coverage of tribology related to friction, wear and lubrication to support environmental sustainability. The United States has used one-third of its energy needs to deal with energy caused by friction. The greater the frictional energy in a movement mechanism will lead to greater energy consumption and the resulting environmental impact [4]. The main review of green tribology aims to preserve and improve the quality of the environment and avoid global warming [5].

The criteria and characteristics of a lubricant must meet six basic standards, namely: viscosity index, total base number, pour point, flash point [6]. Biolubricant which has a low

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viscosity value can be improved by adding additives, its characteristics as a biolubricant become better. Lubricant is a substance that is applied between two surfaces in contact with each other to reduce the friction force and wear rate on the two surfaces [7]. Research on the use of cultivable biological materials as biochemical base materials continues to be studied. Lubricant substitution from biological materials as a substitute for mineral materials continues to be developed to preserve nature and to increase public awareness of the importance of a green environment [8]. Lubricating materials with nano-scale particles are very intensively developed so that the lubricants can reduce friction and wear. The lubrication mechanism is divided into two types: (a) Direct lubrication mechanism and (b) Indirect lubrication mechanism.

Nanoparticles are added to lubricating oil to improve its tribological properties, which can reduce the coefficient of friction and wear [9]. Figure 1. shows the lubrication mechanism between two contact surfaces for nano particle lubricants.

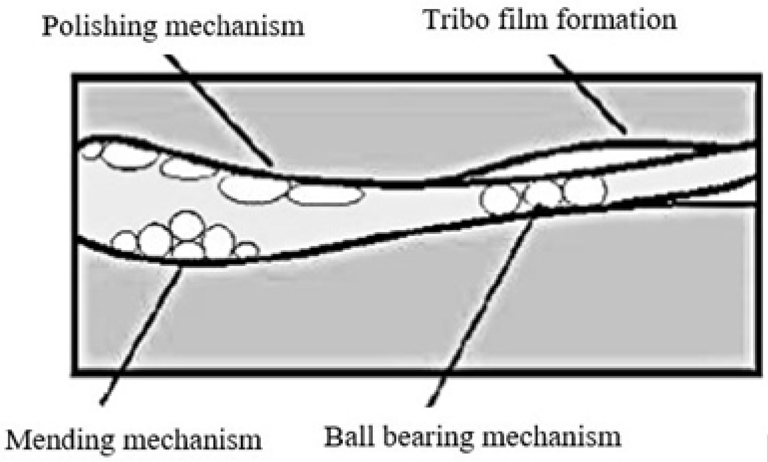

Fig. 1. Lubrication mechanism on two contact surfaces for lubricating nanoparticles [9].

The basic ingredients for the manufacture of lubricants are classified into three types, namely mineral lubricants, synthetic lubricants and also biolubricants (vegetable oils and animal oils). Biolubricant was used as a test material in this study. Biolubricant, namely animal and vegetable lubricants obtained from animal and plant fats. Lubricants are generally made from mineral oil. The difference between mineral lubricants and animal and vegetable lubricants is that animal and vegetable oils contain unsaturated compounds [10]. The advantage of biolubricant lies in its ability to lubricate and has good properties on wet and humid surfaces when compared to mineral oil. The lubricant layer will provide effective protection against friction. The use of vegetable lubricants are expected to improve the characteristics of lubricants that are environmentally friendly.

II. Research on Lubricants

a. The Effect of Lubricant Variation on Viscosity and Coefficient of Friction and Wear Rate

The main function of a lubricant is to reduce friction and wear that occurs on moving objects rubbing against each other. The science of tribology is a very important part of knowing the characteristics and its application in the engineering field [11]. Tribology is the science of friction, wear, and lubricants. Viscosity is one of the physical properties of a lubricant which indicates the viscosity of the lubricant [12]. The viscosity of the lubricant affects the friction efficiency of the contact surface. The greater the viscosity of a lubricant, the greater the drag force. Stokes law states that a large viscosity causes a large friction force [13]. The friction force is proportional to the viscosity value of the lubricant. Based on the equations of the friction mechanism formula and the Stokes law, the coefficient of friction is inversely proportional to the friction force and viscosity [14-15].

Table 1. Variations in viscosity and coefficient of friction and wear rates [16-21]

Lubricant	Viscosities (cSt) @100C	Friction (coF)	Wear (mm)
SAE 10W/40	4.700	0.108	0.510
SAE 15W/40	6.500	0.105	0.500
SAE 20W/40	7.800	0.107	0.510
Mineral Oil	13.689	0.093	0.765
SAE 40	15.000	0.114	0.520
Soybean Oil	7.889	0.112	4.998
Palm Oil	8.644	0.105	4.175
Jatropha Oil	8.040	0.095	3.000
Stamping Oil	11.400	0.075	0.650

Research on the correlation between the viscosity of 100^{O}C (cSt) and the coefficient of friction (coF) can be seen in Figure 2. The graph shows that the greater the viscosity value of a lubricant causes the lower friction coefficient value. The results of research regarding the correlation of viscosity and friction coefficient are in line with the equation of the friction mechanism and the law of Stokes, namely the greater the viscosity value, the smaller the friction coefficient value. The results of the wear test research can be seen in Figure 3. The graph shows the same trendline as Figure 2, namely the greater the viscosity value of a lubricant, the lower the wear value [16-21].

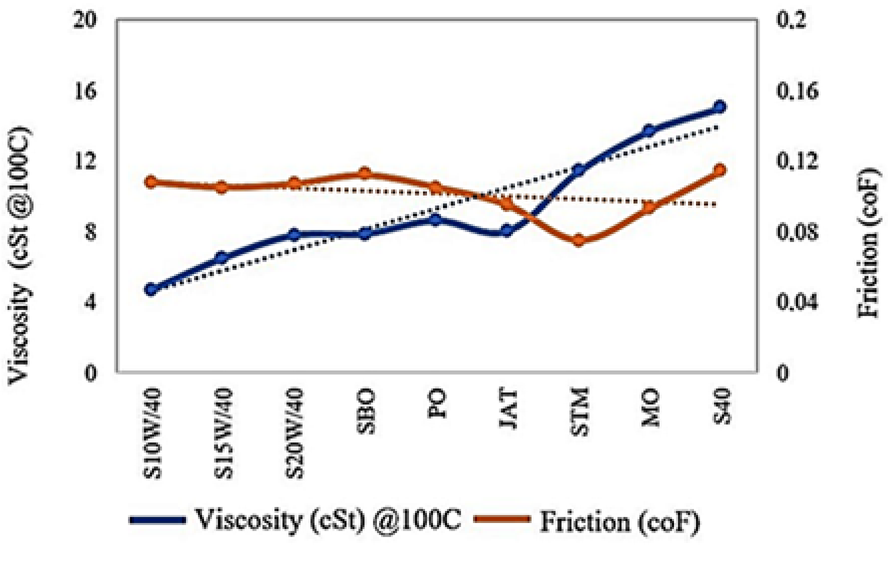

Fig. 2. Graph of Viscosity - Coefficient of friction [16-21]

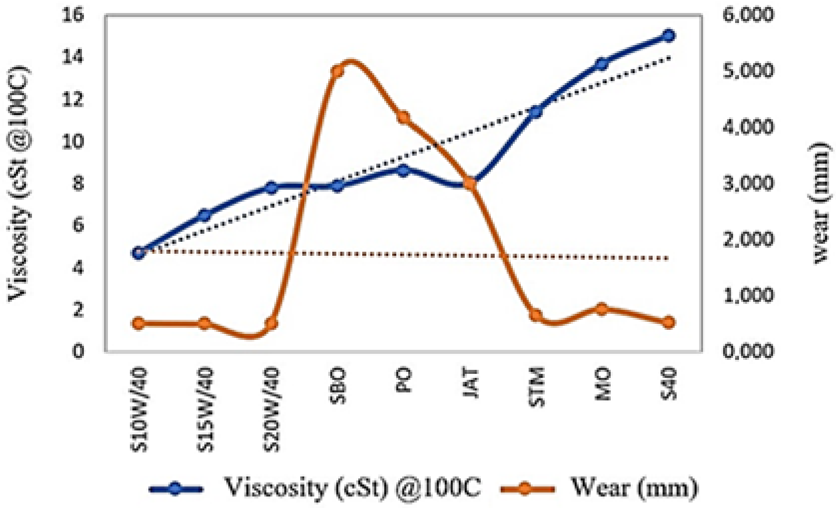

Fig. 3. Graph Viscosity – Wear [16-21]

b. *Effect of Additives on Characteristics*

Armuggam et al. [22] studied the effect of Rappassed Oil plus TiO_2 additives and found that the power value was reduced by 15%. Biolubricant based on vegetable oil added with TiO_2 additive experienced a 58.1% decrease in wear value from pure organic oil [24]. Charo et al. [23] investigated mineral oil SAE 10W30 plus additive MoS_2 obtained 20% reduced wear value. Mineral Soybean Oil coupled with CuO additives resulted in a reduced wear value of 12% [24]. Paraffinic oil with the additive MoS_2 decreased the coefficient of friction by 64% [25].

Table 2. Effect of additives on biolubricants on decreasing friction coefficient and decreasing wear rate [24-28]

Lubricant	Additives	Reduction of friction	Reduction of wear
Paraffinic Oil	MoS_2	64%	-
Vegetable Oil	TiO_2	-	58.1%
Rapeseed Oil	CuO	40%	-
Rapeseed Oil	TiO_2	-	15%
Palm Oil	TiO_2	15%	11%
SAE 10W30	TiO_2	-	15%
SAE 20W40	MoS_2	-	20%
SAE 5W30	MoS_2	50%	-
Polyalphaolefins	MoS_2	40%	-
Soybean Oil	CuO	-	12%
SAE 10W40	Titanium	32%	-
SAE 20W40	Graphene oxide	32%	-
SAE 15W40	Graphite	36%	-

Sharma et al. [26] studied vegetable oil with TiO_2 added to get a reduced wear value of up to 58.1% compared to pure oil. Rapessed oil with added CuO additives decreased the coefficient of friction by 40% [26]. Sgroi et al. [27] studied synthetic oil SAE 5W30 added with MoS_2 additives to get a decrease in the value of the friction coefficient of 50%. Polyalphaolefins added with the additive MoS_2 resulted in a 40% reduction in the strength value [28]. Singh et al. 2019 [29] examined the tribological performance of SAE 10W/40 and SAE20W/40 lubricants with the addition of titanium additives and graphene oxide. These additives can reduce the friction coefficient by 32%. Improved friction behavior of SAE 15W-40 lubricants with the addition of graphite particles. The addition of graphite to SAE 15W-40 lubricant can reduce the friction coefficient from 33-36% [29].

c. Characteristic Biolubricant

Characteristics of biolubricant can be observed from the test results. There are several characteristics in a biolubricant, namely Kinematic viscosity, Viscosity index, Total base number. The characteristic values of some biolubricants are shown in Table 3.

Table 3. Characteristics biolubricant [30]

Properties	Soybean oil	Sunflower Oil	Rapeseed Oil	Castor Oil	Palm Oil
Kinematic viscosity @40°C (cSt)	32.93	40.05	45.6	220.6	40.24
Kinematic viscosity @100°C (cSt)	8.08	8.65	10.07	19.72	7.89
Viscosity Index	219	206	216	220	110
Total base number (mgKOHg^-1)	0.61	-	1.4	1.4	-
Pour point (°C)	-9	-12	-12	-27	-21
Flash point (°C)	240	252	240	250	220

d. Test Methods

The method in testing that can be used to evaluate the tribological properties of a lubricant can be seen in Table 4, done by various researchers on lubricating oil.

Table 4. Summary of test methods [31-35]

Lubricant	Test Methods
Variation of lubricants: (1) Lubricant SAE 40; (2) Jatropha oil (mixture)1%, 2%, 3%, 4%, 5%	Four ball tribotester
Variation of lubricants: (1) Lubricant oil; (2) Parafin oil; (3) Biolubricant + TiO_2	Four ball tribotester
Variation of lubricants: (1) Commercial oil stamping; (2) Comercial oil hydraulic; (3) Jatropha oil; (4) RBD palm oil; (5) Palm fatty acid	Four ball tribotester
Variation of lubricants: (1) Mineral oil; (2) Synthetic oil; (3) Biolubricant	Comparison of data and results of previous research
Variation of lubricants:	Repricoating ratio 1:1

Lubricant	Test Methods
(1) Jatropha Oil; (2) RBD Palm Olein; (3) Palm Fatty Acid Distillate; (4) Stamping oil; (5) Hydraulic oil	
Variation of lubricants: 1. Crude Jatropha Oil / CJO 2. Syntethic ester (SE) 3. MJO1 (JME:TMP = 3.1:1) 4. MJO3 (JME:TMP = 3.3:1) 5. MJO5 (JME:TMP = 3.5:1)	Fourball tester based on ASTM D4172
Variation of lubricants: (1) Soybean oil; (2) Sunflower oil; (3) Jatropha oil; (4) Palm oil; (5) Jojoba oil	Comparison of data and result of previous research
Variation of lubricants: 1. SAE 10W40 2. SAE 20W40	The preparation method is by adding nanoparticles as a synthesis material, a four ball tester and data comparison of previous research results
Variation of lubricants: 1. Jatropha oil / SJO (100) 2. Mineral oil / EMO (100) 3. B20 (SJO 20 : EMO 80)	Four ball tribotester
Variation of lubricants: 1. Soybean oil 2. Sunflower oil	1. Ring compression test 2. Finite element simulation
Variation of lubricants: 1. SAE40 2. JO10 (Jatropha oil 10% : SAE40 90%) 3. JO20 (Jatropha oil 20% : SAE40 80%) 4. JO30 (Jatropha oil 30% : SAE40 70%) 5. JO40 (Jatropha oil 40% : SAE 40 60%) 6. JO50 (Jatropha oil 50% : SAE 40 50%)	1. Cygnus wear testing four ball Tester
Variation of lubricants: 1. SAE40 80% + Molybdenum Dysulfide 20%	Electrostatic charge solid lubricant spray techniques
Variation of lubricants: 1. SAE 40 2. Palm oil	Observation of tool temperature, wear and surface roughness of the lathe is a basic reference for research.
Variation of lubricants: 1. Canola oil + 1.5% graphene	Observation of the properties and results of grinding using a precision machining process
Variation of lubricants: 1. Mineral oil (5CST) 2. Biolubricant (RSO)	1. KEYENCE vk-x200 laser scanning microscope (CLSM) 2. X-ray absorption near edge structure spectroscopy (XANES) 3. Fluorescence yield (FY) 4. Total electron yield (TEY)
Variation of lubricants: 1. SAE 15W-40 2. SAE 15W-40 + graphite	Linear reciprocating tribometer
Variation of lubricants: 1. Jatropha oil + Ethylcellulose (CO/EC) 2. Sunflower oil + Ethylcellulose (HOSO/EC)	1. Measurement of density and viscosity using a controlled-strain rotational rheometer 2. Temperature analysis using differential scanning calorimetry Research on tribological properties using EHL and stribeck-curve.
Variation of lubricants: 1. SAE 15W-40 2. SAE 20W-50	Fourball Tester based ASTM D4172 and ASTM D2783

Lubricant	Test Methods
Variation of lubricants: 1. Biofuel + SAE 20W-40 2. Biofuel + biolubricant rapeseed	Measure smoke emission levels using the AVL 43 smoke meter and AVL DI gas analyzer
Variation of lubricants: 1. Mineral oil – Additives 2. Mineral oil + 10% TMPTO – T10 (Trimethylolpropane Trioleate) 3. Mineral oil + 15% TMPTO – T15 4. Mineral oil + 20% TMPTO – T20 5. Mineral oil + 50% TMPTO – T50	Engine test use 43cc brush cutter 2-stroke engine
Variation of lubricants: 1. Jatropha oil / SJO (100) 2. Mineral oil / EMO (100) 3. B20 (SJO 20 : EMO 80)	Four ball tribotester

III. Conclusions

Based on previous research studies on the use of additives in biolubricants, the following conclusions are the vegetable oil derived from plants can be used as a biolubricant, but pure biolubricant has a low viscosity so that the lubricant function as a film layer between two contact surfaces is lower when compared to mineral oil; Additives need to be added to pure biolubricants to improve their viscosity, so as to reduce the friction coefficient and wear rate on the contact surface; The ability of additives to improve biolubricant characteristics varies greatly depending on the type of biolubricant and additives used; The addition of MoS_2 additives to paraffinic oil can reduce the value of the largest coefficient of friction, namely 64%, when compared to the combination of additives + biolubricants as follows: TiO_2 + Vegetable Oil; CuO + Rapeseed Oil; TiO_2 + Rapressed Oil; TiO2 + palm oil.

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