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Defilement of Oil Quality of Final Drive Rear Right Excavator in Eleven-Ton Class Heavy Equipment Due to The Component Wear and Visualization on Website

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ABSTRACT

Laboratory S.O.S Oil is a labor that could see the characteristics of the final *drive oil* completely, that the quality of the oil used to lubricate the system in *final drive* can be known as the condition of *final drive*. Data from *S.O.S Oil* Laboratory can be used as a reference in conducting in-depth analysis by *engineer* related to the condition of machine's *final drive*. If the condition of the *final drive* can be known due the operation, it will ease the heavy equipment technicians to perform *Preventive Maintenance*. The writer's current research will focus first on the analysis of oil quality defilement caused by wear of the components of *final drive*. The inner components of the *final drive* which streamed by lubricant are highly could cause wear and tear by friction between the materials operating in the *final drive's* working *system*[5]. The oil on the final drive has specifications or properties that would affect *final drive performance*. The oli used in final drives uses *single gread oils* such as *S.A.E 50*, which are applied to *final drives* of eleven-ton excavators[6]. The wear of components in the final drive will be seen from the quality of the *final drive* oil, if the wear occurs is greater, the work of anti-wear additives on the oil is begins to decrease that there must be a solution and analysis obtained. Test results will be obtained based on test data from *the S.O.S. Laboratory*. The Laravel framework with Model-View-Controller (MVC) architecture is used to create this website for visualization the result.

1. Introduction

The course that studies final drives is Powertrain, which is a system that transmits power from the engine to the final drive[1]. Maintenance is defined as the work of keeping something in proper condition[18]. *S.O.S (Schedule oil sampling)* an activity to assist heavy equipment unit users in early detection of equipment damage by taking *oil samples* and *coolant* to reduce repair costs and *downtime*. Final drive oil sampling interval every 500 hours[15]. The main to be considered during oil sampling is to take *representative* oil, to ease the process of checking materials on the system due to wear and foreign material entering the system[5]. To prevent premature damage to the final drive, daily inspection and periodic maintenance must be carried out on the Front Final Drive Planetary Gear[16]. Contamination of the oil must be controlled within permitted limits up to the maximum limit in order to maintain a longer oil life and prevent oil changes before the specified schedule[11].

The oil inspection process at *S.O.S Laboratory* includes checking the wear rate on the inner components of the *Final Drive* that are fed by oil[2]. If the rate wear of the components in the Final Drive rubbed against each other is getting bigger without the unit user or the heavy equipment technicians know, it will cause the *performance of the Final Drive* become not optimal, it will cause great damage to the *Final Drive*, such as a final drive oil leak. Based on the results of several studies, it was found that the cause of oil leaks was wear on the guard so that dirt or soil could enter, resulting in direct friction with the final drive and pressing on the floating seal[19]. Major damage to the *final drive* could lead a large maintenance cost incurred by the owner of the heavy equipment unit and the heavy equipment unit cannot operate or used for a long period of time that the unit is unproductive or cannot be utilized. To longer the service life of the *final drive* to be maintained properly, periodic checking of the condition of the final drive oil is needed, so that the oil function can work optimally as a lubricant from the *final drive* work system. Please note that the particle count of new hydraulic, transmission and final drive lubricants (oil) is 16/13 or cleaner[8].

Scheduled Oil Sampling briefly stated as S.O.S used to translate into Indonesian as "periodic oil sampling". The purpose of this activity is to take oil samples in machine parts or *final drives* to be analyzed in the laboratory to determine the condition of the oil itself and the condition of the system where the oil previously worked. In the next development, *laboratory S.O.S* is also capable of checking new oil and other fluids used in heavy equipment operations, namely fuel and cooling water. So, the name *laboratory S.O.S* changed to "*Fluid Analysis Laboratory"*. In this meeting session, the discussion will only be devoted to the S.O.S program that analyzes used oil on the *final drive.*

Lubricants on heavy equipment have a wide range of functions. The specific function for each lubricant depends on the needs of the components in the lubricant components. Some of the functions of lubricants are as follows[3]:

a. Transfer heat
b. Prevents corrosion
c. Continuing Energy
d. Muffle shock loads.
e. Reduces strain on the contact area.
f. Control the deposit.
g. Control contaminants.
h. Control friction.
i. Resists oxidation.

The final drive compartment is the most difficult compartment to lubricate[4]. *Final drive* oil must be able to control harmful products from friction between components entering the oil. The result of this friction can increase wear.

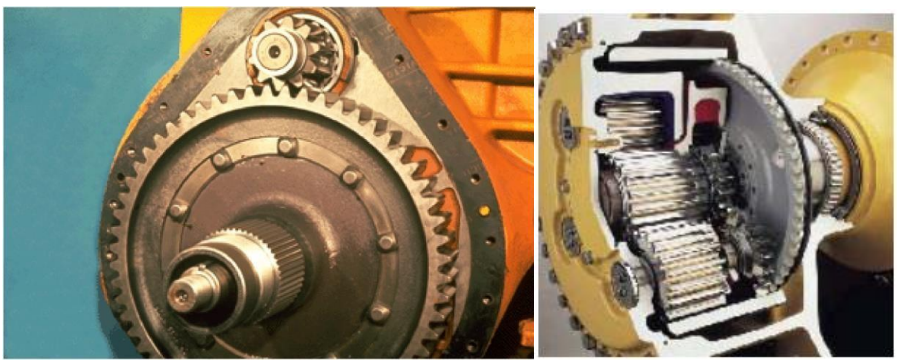

Figure 1. Heavy Equipment Unit *Final Drive*

Lubricants Composition

Heavy equipment lubricants are made by combining base stocks and additives. In general, the composition of the mixture is 85% base stocks and 15% additives.

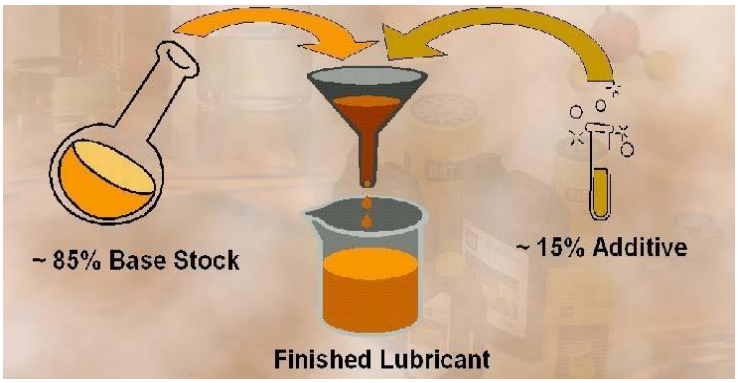

Figure 2. The composition of the mixture of *base stocks* and *additives*

Base stock is the main raw material of lubricating fluid. Many processes must be passed to extract lubricant base stock from crude oil sources. The quality of crude oil and its process will determine the performance of the base stocks. In some cases, base stocks are the result of synthesis from oil sources apart of crude oil, so they are called synthetic base stocks. These synthetic base stocks have higher production costs. For machine lubricants, base stocks must be supplemented by additives to protect heavy components, control deposits, and increase friction ability.

In general, there are three types of base stocks are known:

a. Conventional
b. Highly refined conventional
c. Synthetic

Each type of *base stock* requires certain types of *additives* to provide maximum performance. Conventional and *highly refined base stocks* use *crude oil* as raw material. The type and process of refining conducted will determine the quality of *base stocks*. *Synthetic base stocks* are made of a wide variety of oil sources. The characteristics of this type of *base stocks* are that they have oxidation resistance at high temperatures and have good flowability at low temperatures. *Synthetic base stocks* still require *additives* if they will be used as lubricants on heavy equipment.

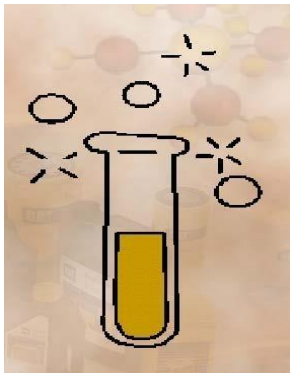

Figure 3. Mixing Lubricant into Base Stocks

Additives for machine lubricants are mixed into *base stocks* on a controlled conditions at a mixing plant[5]. *Additives* for machine lubricants are manufactured by four main suppliers, those are:

a. Afton
b. Infinum
c. Lubrizol
d. Oronite

Table 1. Types of *additives* and their functions

Additives	Function
Detergents	Decrease the emergence of deposit, controlling the corrosion.
Dispersant	Keeping so that the soot does not clot, control the napless, decrease the emergence of sludge, controlling the viscosity increase.
Anti-oxidants	Inhibit the oxidation.
Anti-Wear	Decrease the napless by coating the surface with the film oil.
Viscosities modifier	Increase the viscosity at high temperature.
Friction modifier	Increase the performance of clutch and brake.

Oil *additives* are complex chemical mixtures specifically designed to improve oil performance. Generally, instruments of the oil laboratory can detect several components made up the mixture of additives. Elements that can be found in additives are: Ca, Mg, Zn, P, Si, Mo, B, Ba. Some of the functions of lubricants are to transfer heat, prevent corrosion, transmit power, reduce shock loads, reduce tension in contact areas, control deposits, control contaminants, control friction, fight oxidation, the engine can be said to be in good performance if it is able to be used in its function. according to the planned time[10].

Laravel

Laravel is an open-source PHP-based web framework that has been extensively accepted by developers all over the world and is used to create online applications. The Model-View-Controller (MVC) architecture principle is used by Laravel [22]. When compared to the generic MVC pattern, the structure of the MVC pattern in Laravel differs slightly. There is a routing mechanism in Laravel that acts as a link between user requests and the controller. Therefore, the controller does not immediately accept the request [23].

2. Methods

The tests are designed to test the oil's ability to control deposits and maintain oil consumption at acceptable levels. Other *final drive* makers used to create additional tests for existing API classifications.

2.1 Stages of the Research

a. Excavator *final drive* oil sampling conducted five times
b. Sampling is conducted every multiple of 1000 Hours [Hr]
c. The samples obtained will be tested in the *S.O.S laboratory*
d. The result of data in the *S.O.S laboratory* will be processed into a trend graph
e. Graphs of test results will be analyzed based on relevant theories.

2.2 Location of the Research

Table 2. Location of the Research

No	Owner/Location	Activity
1	The Unit of Excavator Heavy Equipment, Department of Living Environment. West Sumatera Province/**Payakumbuh Landfil**	Taking the sample from oil

2	*S.O.S Laboratory (Scheduled Oil Sampling)* PT Trakindo Utama – Commercial Plots Techno Park Blok B No 1, Sector XI BSD City, Tanggerang 15317, Indonesia.	The sample test of the final drive oil, Excavator Heavy Equipment Unit 11 tons class.

2.3 Observed/measured Variable

Table 3. Observed/Measured Variables

Wear Metal (ppm)	Contaminant (ppm)	Viscosity (Centistokes)
a. AL (Aluminium)	a. K (Potassium)	V100 (Viscosity
b. PQI (Particle Quantifier Index)	b. Si (Silicon)	at 100 C)
c. Cr (Chromium)	c. Na (Sodium)	
d. Pb (Lead)		
e. Fe (Iron)		

The research model used is the analysis of *S.O.S. laboratory* test results. Data collection techniques of the *results of the S.O.S laboratory* will be analyzed by relevant theories in related to the factory standards. The flow characteristics of an oil are measured by viscosity numbers. Where viscosity or consistency is defined as the resistance of the fluid to flow. The viscosity performance of heavy equipment lubricants is identified with viscosity grade. The viscosity required in a compartment. SAE J300 is used to determine the viscosity required for: engine oil, drivetrain oil and hydraulic oil. SAE J306 is used to determine the viscosity required for gear oil[5].

Table 4. Gear Oil Viscosity
Automotive Gear Lubricant Viscosity Classifications – SAE J306

SAE Viscosity Grade	Max Temperature for Viscosity of 150.000 cP (^{0}C)[1,2]	Kinematic Viscosity st 100^{0}C (cSt)[2] min[4]	max
70W	-55[5]	4.1	-
75W	-40	4.1	-
80W	-26	7.0	-
85W	-12	11.0	-
80	-	7.0	<11.0
85	-	11.0	<13.5
90	-	13.5	<24.0
140	-	24.0	<41.0
250	-	41.0	-

[1]Using ASTM D 2983.
[2]Additional low-temperature viscosity requirements may be appropriate for fluids intended for use in light-duty synchronized manual transmissions.
[3]Using ASTM D 445.
[4]Limit must also be met after testing in CEC L-45-T-93, Method C (20 hours).
[5]The precision of ASTM D 2983 has not been established for determinations made et temperature below -40^{0}C. This fact should be taken into consideration in any producer concumer relationship.

Almost every laboratories are capable to measure the kinematic viscosity in a new and used oil. Measurement of kinematic viscosities could find an indication of contamination or oxidation in a used oil. Viscosity measurements in a low temperature or "high shear rate viscosity" are rarely performed in *laboratory analysis*. The measurement of these two units is more complicated and requires special testing equipment.

3. Result and Discussion

a) Wear Metal

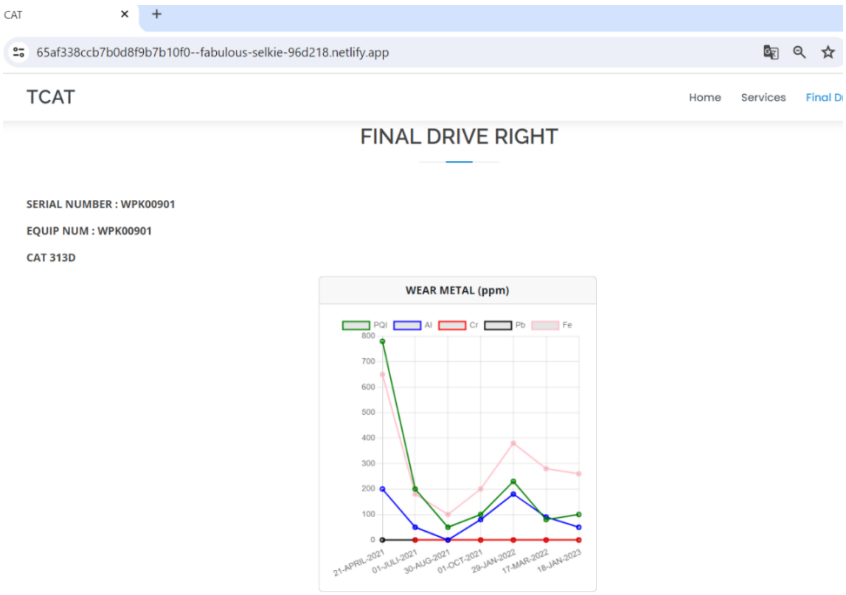

Figure 4. Wear Metal Chart

It can be seen from the graph of figure 4, related to wear metal, there are chemical ingredients of *Aluminum*, Chromium, *Iron, Particle Quantifier Index,* and *Lead* sourced from the occurrence of *wear metal*. The graph shows an increase in Fe elements indicate the increased of wear on rotating gears, shafts and bearing elements. The smallest Fe value was 110 ppm in the period of August 20th, 2021, and the highest value was 620 ppm in the period of April 21th, 2021. The cause of high Fe values is the wear of *Final Drive* components. This is different in engines where the cause of high Fe values is the result of wear of the liners, gears, valve train and crankshaft components. The cause of the increase in the Fe particle value is due to friction which continuously occurs in the working process of the final drive components [17].

b) Contaminant

Figure 5. Contaminant Chart

The most often elements tested by S.O.S services are silicon, iron, lead, copper, aluminum, chrome, molybdenum, canned and sodium. All are metallic elements except silicon and sodium. As figure 5 above, you can see a significant difference between Si and K, Na. High silicon in the period of April 21th, 2021, indicates the presence of dirt entering. It happens as these components used to work under environmental conditions that vary from dry and dusty conditions to wet and muddy conditions.

c) Viscosity

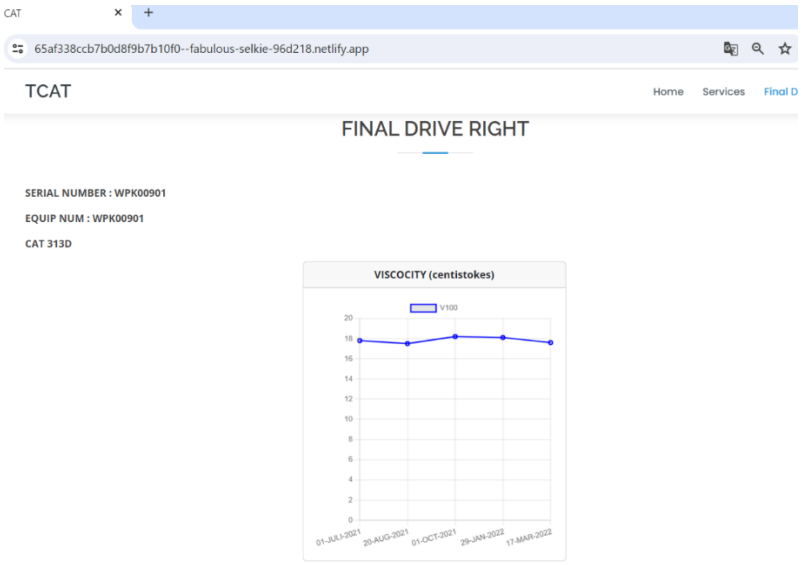

Figure 6. Viscosity Chart

Oil viscosity is also an important thing in oil formulations. Low viscosity oil in final drive could damage gears and bearings. Conversely, high-viscosity oil will not be able to flow at low temperatures, it will cause a lack of lubricant supply in certain parts and accelerate wear. The decrease in oil viscosity is due to the close proximity of liquid molecules (such as oil) with strong cohesive forces between molecules, and the resistance to relative movement between adjacent fluid layers is related to these intermolecular forces [12]. As temperature increases, this cohesive force decreases and results in reduced resistance to movement [13]. This is because viscosity is an index of resistance, so viscosity decreases with increasing temperature. The industry introduced the FD-1 oil specification for final drive and axle lubricants under the name FDAO (Final Drive and Axle Oil). The goal is to increase the life of gears & bearings in final drives and axles [20]. This final drive oil uses SAE 50 with a general viscosity limit of 15.8–22 (centistokes) [7], seen from the graph above, it shows that the viscosity condition of this final drive oil is still good.

4. Conclusion

From the results of tests conducted on eleven-ton class *Final Drive* oil, it can be concluded that: *Final Drive Excavator* eleven-ton class owned by the West Sumatra Provincial Environmental Office located in Payakumbuh is still in good condition, due to the absence of *Final Drive* defilement beyond *specifications* determined (*Wear Metal, Contaminants and in terms of Viscosity of Oil)*. From the results of the research obtained, the greatest influence of changes in oil quality due to the use is the wear of *Final Drive* components, such as gears, shafts, and rotating bearing elements. As it viewed from the contaminant, we can see the high level of silicon (Si) in *Final Drive* oil that have been tested, high Silicon levels indicate the presence of dirt entering, therefore when changing the final drive oil every 500 hours and when checking the *Final Drive* oil level, the condition of the final drive, tools, and surroundings have to be clean[14]. As for the viscosity of the oil is still on the range of viscosity limits in general.

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