Analysis and selection of skf bt2-8131 a roller bearing lubricant for the vertical roller mill at pt. solusi bangun indonesia tuban factory

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Abstract— In the industrial world, friction between machine elements such as bearings can affect the performance and service life of components, making lubrication systems based on tribology principles very important. This study analyzes the selection of lubricants for SKF BT2-8131 A roller bearings in a Vertical Roller Mill owned by PT. Solusi Bangun Indonesia, Tuban Factory, with the aim of determining a better lubricant than before and identifying the type of lubricant film formed. The research process involved collecting machine operational data and lubricant specifications, as well as calculating the kappa value and Streibeck curve to determine the type of lubricant layer, such as boundary, mixed, or full film lubrication. The results showed that Pertamina Masri RG 460 lubricant with a kappa value of 1.29 was selected because it had adequate technical performance and was more economical, although Mobil SHC 600 460 lubricant with a kappa value of 1.73 was also recommended if technical performance was the main priority. The results were validated by calculating the predicted bearing life to ensure optimal efficiency and performance.

Keywords— Lubrication, bearings, Vertical Roller Mill, Viscosity Ratio, Bearing Life.

1. INTRODUCTION

In the industrial world, there are various elements or parts that serve to support production activities. Therefore, the products used must be suitable to prevent material and non-material losses. Movement in these components or machines causes various problems that result in damage, such as excessive vibration, friction between moving components, wear and tear, heat in component surfaces, and others [1].

The science that can overcome these losses is included in the field of tribology. Tribology is the science that studies friction, lubrication, and wear on interacting surfaces. The movements produced are divided into two types, namely static and dynamic movements [2]. This science can be applied to various things to overcome losses due to friction and wear on components [3].

A widely used application in the industrial world is bearings. Bearings are components used to regulate the relative movement of two components and support the shaft so that it continues to rotate on its axis. The function of these bearings is to reduce friction between two moving surfaces [4].

However, bearings alone are not durable enough when subjected to heavy loads to support large moving loads. Therefore, a good lubrication system is needed to prevent wear and tear on these components.

A lubrication system can reduce the friction that occurs in bearings and extend their service life. Each lubricant has its own characteristics based on the load used, the rotation of the rotating object, the operating temperature, and the viscosity of the lubricant. [5]

Therefore, research is needed to determine the optimal use of lubrication for specific conditions to overcome excessive wear and heat due to heavy loads and minimize the losses incurred as a result. In this study, the researcher will analyze the process of selecting a better lubricant than the one currently used, and this lubricant will be used in the SKF BT2-8131 A *bearing* lubrication system used as a bearing on *the main roller* of *the Vertical Roller Mill* owned by PT. Solusi Bangun Indonesia Tbk, Tuban Factory.

2. Previous Researches

2.1 Lubrication

Lubrication is a solution to minimize friction between two surfaces that come into contact. This is done by coating the surface with oil or lubricant. Lubricant itself is defined as a substance inserted between two surfaces that rub against each other to reduce the amount of friction that occurs [6]. Friction is the resistance that arises due to the interaction of two surfaces that encounter each other. This friction can hinder movement and generate unwanted heat and cause higher vibrations or exceed normal limits [7].

2.1.1 Basic Lubricant Materials

The main ingredients in lubricants consist of two components, namely base oils and additives. Generally, lubricants are composed of 90% base oil and 10% additives. Based on the type of base oil, lubricants can be divided into several categories, such as: [8], [9]

- Mineral Oil
- Mineral Synthetic
- Biodegradable Oil

2.1.2 Properties of Lubricants

Lubricants also have several properties that affect their performance, such as: [6], [10], [11]

- Viscosity
- Viscosity Index
- Pour Point
- Flash Point
- Lubricity
- Stability
- Additive Content

2.1.3 Lubricant Layer

Choosing the right type of lubricant is crucial because it directly affects the condition of the lubricant film that is formed, which in turn plays an important role in maintaining the durability of engine components by reducing friction, preventing wear, maintaining temperature stability, and protecting against contamination. There are three main types of lubricant layers, namely Full Film Lubrication, where the lubricant completely separates the moving surfaces and is further divided into hydrodynamic, hydrostatic, and elastohydrodynamic; Mixed Film Lubrication, where the lubricant only partially separates the surfaces and direct contact between surface asperities still occurs; and Boundary Film Lubrication, which is a condition where the amount or viscosity of the lubricant is insufficient so that friction between surfaces still occurs, which usually appears in conditions of near lubrication failure [12].

2.1.4 Determining the Type of Lubricating Oil

To determine the type of lubricant film formed in a system, the Streibeck curve is used as an analytical tool that describes the relationship between the coefficient of friction and operational parameters such as lubricant viscosity, surface speed, and working load. This curve not only helps identify the type of lubrication, whether it is boundary, mixed, or full film lubrication, but also evaluates the overall performance of the lubricant, including its ability to reduce friction, prevent wear, and maintain machine stability. To obtain more accurate results, this curve can be combined with viscosity ratio or kappa value (k) calculations, which is the ratio between the actual lubricant viscosity (v) and the required viscosity (v_1), providing a quantitative indicator of the lubricant's ability to form a protective film layer between contact surfaces [4], [13].

Determining actual viscosity and rated viscosity is an important step in analyzing lubricant performance in machine lubrication systems. Actual viscosity can be calculated using an operational viscosity calculator, the Ubbelohde-Walther formula (ASTM D341), or a viscosity graph, taking into account the operating temperature of the components and the characteristics of the lubricant used. Meanwhile, rated viscosity is determined based on the average diameter of the component (dm) and rotational speed (n), which is then analyzed through a graph to ensure the viscosity of the lubricant is suitable for operational requirements. After both values are obtained, the viscosity ratio or kappa value (k) is calculated, which is the ratio between actual viscosity and rated viscosity, to assess the lubricant's ability in to form a protective layer.

This kappa value indicates the type of lubricant film formed: boundary ($k \approx 0.7$), mixed ($k \approx 1$), or full film lubrication ($k \geq 4$). With this method, lubricant selection becomes more precise and tailored to the operational conditions of the machine, as was done in the main roller lubrication system at the Vertical Roller Mill of PT. Solusi Bangun Indonesia Tuban Factory [5].

2.2 Bearing

Bearings are a type of bearing that is widely used in rotating machines, such as electric motors, turbines, gearboxes, roller machines, and many more. The main function of this component is to reduce friction between rotating elements and surrounding elements. Bearings also have another function, which is to support high radial loads [14].

2.2.1 Bearing Components

Roller bearings consist of three main components that work together to ensure optimal performance, namely rings, rolling elements, and housings. The rings consist of an outer ring and an inner ring equipped with raceways, which serve to keep the rolling elements in their tracks and are usually made of hard materials such as steel or chrome alloys to withstand pressure and wear.

The rolling elements, which can be balls, rollers, cylinders, or needles, play an important role in reducing friction between two relatively moving surfaces, with the shape and material selected based on the type of load and space requirements. Meanwhile, the casing serves to keep the rolling elements in position so that they do not rub directly against each other, as well as to increase the efficiency and stability of movement, with strong but lightweight materials such as steel, brass, or polymers. The combination of design and materials of these three components greatly determines the efficiency, durability, and service life of bearings in various industrial working conditions [15].

2.2.2 Bearing Classification

In general, bearings are classified based on the direction of the load and the design of the mechanism in reducing friction between moving components. Based on the direction of the load, there are three main types: [16], [17]

- Radial bearing
- Thrust bearings
- Combined load bearings

Meanwhile, based on their design and working mechanism, bearings are divided into slider bearings (sliding bearings) and roller bearings (rolling bearings). Slider bearings work with a mechanism of direct friction between lubricated surfaces and are suitable for high loads and low speeds, while roller bearings use rolling elements such as balls or rollers to reduce friction, making them more efficient and ideal for high speeds and pressures. The selection of the right type of bearing must be adjusted to the operating conditions, working load, and durability requirements of the system. [17]

2.2.3 Calculation of Average Bearing Diameter

Average diameter is an important parameter in bearing design and kinematic analysis calculations, as it is used to determine the linear speed of rolling elements, contact frequency, and to understand load distribution. Working on rolling elements. This value represents the effective size of the rolling elements that play a role in the movement and dynamic load on the bearing. In the context of this study, the average diameter calculation is used as the basis for determining the rated viscosity value, which is one of the key parameters in lubrication analysis [18].

$$d_m = \frac{1}{2}\,(D + d)$$

2.2.4 Bearing Life Prediction Calculation

Bearing life is influenced by various crucial factors such as installation methods, operating conditions, lubrication system, alignment level, as well as design and working environment. All these factors must be carefully considered as they directly affect the durability and efficiency of the bearing during its service life. To estimate bearing life, two main approaches can be used, one of which is manual calculation based on technical data from the manufacturer's catalog, which considers parameters such as working load, rotational speed, lubricant viscosity, and environmental conditions. This approach is important to ensure reliable bearing performance, while also helping to develop a more planned maintenance schedule to reduce the risk of damage and sudden shutdowns [19].

Before calculating the bearing life, there are variables that must be known in advance, namely the dynamic equivalent load value of the bearing used. The following is the calculation of the dynamic equivalent load of the SKF BT2-8131 A bearing: [20].

$$P = X.Fr + Y.Fa$$

The values of X and Y are obtained as follows: [21]

$$L_{10} = (\frac{C}{P})^{\mathrm{P}}$$

$$L_{10h} = (\frac{C}{P})^{\mathrm{P}}\ \mathrm{x}\ \frac{10^6}{60_n}$$

Bearings operate under real conditions that are influenced by environmental and operational factors, such as lubricant layers, dust, moisture, and foreign particles that can cause contamination and accelerate damage. In heavy industries such as cement, these conditions are even more extreme, making proper lubrication and maintenance very important. To accurately determine the life of a bearing, calculations that take these actual conditions into account are required [21].

$$L_{10\mathrm{mh}} = \mathrm{a1}.\ ^{\mathrm{a}}SK.\ \mathrm{L10h}$$

In calculating bearing life based on actual conditions, the researchers used the SKF Bearing Assist application to determine the service life factor (a SKF). This application was developed by SKF Group to help users determine the performance and estimated service life of bearings based on actual operational data. The process involves searching for the bearing type, selecting the bearing rating life calculation menu, and then inputting data such as radial and axial forces, rotational speed, operating temperature, lubricant type, and viscosity. After all data is entered, the application will calculate and display a SKF value that describes the bearing life under actual conditions [18].

2.3 Vertical Roller Mill

The Vertical Roller Mill (VRM) is a machine designed to efficiently grind and dry materials with high moisture content in a single unit, and is commonlly used to process cement raw materials, stories, bara, pozzolan, slag, and cement itself. The main process carried out is material size reduction (comminution), which aims to ensure the final size is suitable for the next processing stage for product efficiency and quality. In this system, the main component used in the grinding roller section is a tapered roller bearing, which can withstand both radial and axial loads simultaneously. This bearing is very important because it can distribute the load evenly and work reliably under heavy conditions, making it the ideal choice for maintaining machine reliability and productivity in the material processing industry [22].

2.3.1 Lubrication System in Vertical Roller Mills

The main roller in a Vertical Roller Mill uses oil lubrication rather than grease because the system adopts a closed lubrication circulation that is more effective in managing heat during operation. In this system, oil continuously flows to the bearing area to lubricate moving components while absorbing heat from friction and workloads, then flows back to the cooling system before being reused. This process keeps the bearing temperature stable, prevents overheating, improves lubrication efficiency, and extends bearing life. Therefore, the use of oil in this system is very important to maintain optimal performance and machine reliability under heavy and continuous operating conditions.

The lubrication system in a Vertical Roller Mill is very important to ensure optimal performance and long equipment life. Here are some of the main components in Lubrication system in Vertical Roller Mill: [23]

- Electric Motor
- Oil
- Oil Filter with Non-return Valve
- Gate Valve
- Pressure Gauge
- Oil Cooler
- Analog Temperature Sensor
- Hydraulic Motor
- Adjustable Flow Rate Valve

3. METHOD

3.1. Research Flow

Based on the issues raised in this study, several procedures were carried out to ensure that the research could be conducted efficiently, such as: [24]

1. Literature Study
2. Field Observation
3. Problem Formulation
4. Data Collection
5. Comparison of Lubricant Specifications
6. Calculation of Viscosity Ratio for Each Type of Lubricant
7. Calculation of Bearing Life Prediction
8. Analysis of Lubricant Selection Results

3.2. Research Location and Time

This research was conducted at PT. Solusi Bangun Indonesia Tuban Plant, one of the leading companies in cement production in Indonesia, during a four-month period from January to April 2024. During this time, data and information were collected to support analysis focusing on operational processes and relevant technical aspects. This research aims to make a real contribution to improving the efficiency and operational performance of the factory through a measurable and applicable technical approach.

3.3 Materials and Equipment Used

In this study, the researcher used several tools and materials during the research process. The tools used by the researcher were a laptop with Microsoft Word software and several catalogs of 8 types of comparative lubricants used in the study. The materials used in the study are as follows: [25], [26]

1. Tapered Roller Bearing SKF BT2-8131 A
2. Castrol Alphasyn EP 320
3. Pertamina Masri FLG Series
4. Pertamina Masri RG Series
5. Mobil SHC 600 Series
6. Shell Omala S2 GX Series

4. RESULT AND DISCUSSION

4.1. Kappa Value Calculation

Technical calculations, such as kappa values for evaluating bearing lubrication conditions, require complete and accurate data, particularly operating temperature and bearing rotational speed. This data is important to ensure that the evaluation results for bearing performance and service life reflect actual conditions. In this study, performance data for SKF BT2-8131A bearings was used as the basis for further analysis.

4.2 Kappa Value Calculation for Standard Machine Lubricants

The selection of lubricants for the Main Roller Vertical Roller Mill began with calculating the kappa value of the default lubricant, namely Castrol Alphasyn EP ISO VG 320, while the SKF BT2-8131 A bearing required a minimum viscosity of 90 mm²/s. With complete lubricant specification and bearing performance data, researchers can calculate the kappa value, where the minimum value required is 1 to form a mixed lubrication layer.

4.2.1 Calculating the Average Diameter (d_{mean})

$$dm = \frac{(460mm+860mm)}{2}$$

$$dm = 660mm$$

4.2.2 Determining the Rated Viscosity Value

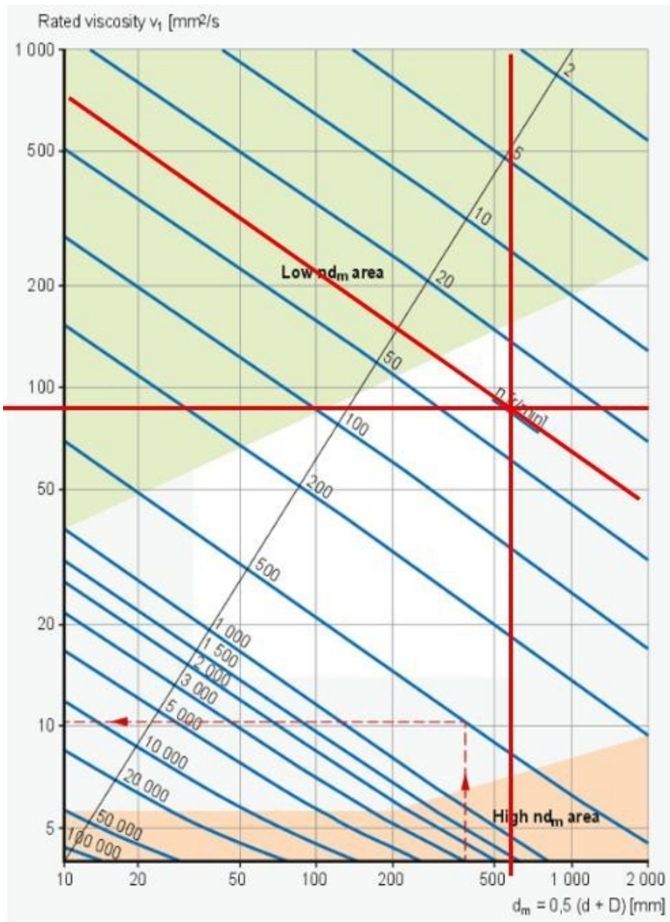

Figure 1 Rated Viscocity Graph Configuration

With an average bearing diameter of 660 mm and a roller speed of 32 rpm, an analysis was performed using a graph of the relationship between diameter, rotational speed, and viscosity to determine the optimal lubrication requirements. The results showed that the required rated viscosity value was 90 mm²/s to ensure the formation of a minimum lubricant layer under mixed film lubrication conditions to prevent direct contact between.

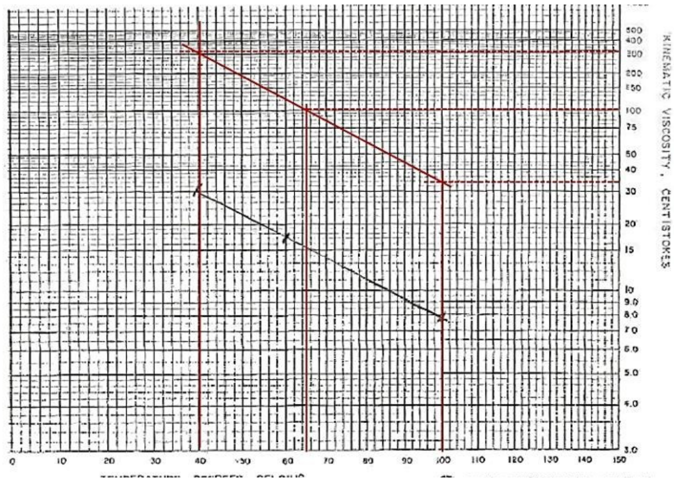

Figure 2. Actual Viscosity Graph Configuration

To calculate the actual viscosity of the lubricant, the bearing operating temperature data of 65 °C and the ISO VG 320 lubricant type with a kinematic viscosity of 320 mm²/s at 40 °C are used. Based on the projection of the data onto the viscosity graph, the actual viscosity value obtained is 103.4 cSt.

4.2.3 Calculation Using the Kappa Value Formula

Kappa value for Castrol Alphasyn EP 320:

$$ViscosityRatio\ (k) = \frac{103.4}{90}$$

$$ViscosityRatio\ (k) = 1.15$$

Based on the kappa value calculation, the lubricant layer formed was in a mixed film lubrication condition, which requires lubricants with extreme pressure properties to support bearing performance. Therefore, the researcher considered the use of lubricants with ISO VG 320 and ISO VG 460 as candidate comparative lubricants.

4.2.4 Kappa Value Calculation for Comparative Lubricants

Table 2 Kappa Value of Each Comparative Lubricant

LUBRICANT TYPE	*KAPPA VALUE*					
ISO VG 320	OPERATING TEMPERATURE (°C)					
	50	55	60	65	70	75
Castrol Alphasyn 320	2.17	1.74	1.40	1.15	0.95	0.79
Masri FLG 320	1.98	1.53	1.20	0.95	0.77	0.62
Masri RG 320	1.96	1.51	1.18	0.94	0.76	0.62
SHC 600 320	2.26	1.84	1.51	1.25	1.05	0.89
Omala S2 GX 320	2.00	1.54	1.21	0.96	0.78	0.64
LUBRICANT TYPE	*KAPPA VALUE*					
ISO VG 460	OPERATING TEMPERATURE (°C)					
	50	55	60	65	70	75
Castrol Alphasyn 460	3.10	2.47	1.99	1.62	1.33	1.11
Masri FLG 460	2.79	2.12	1.64	1.29	1.03	0.83
Masri RG 460	2.80	2.12	1.64	1.29	1.03	0.83
SHC 600 460	3.20	2.58	2.10	1.73	1.44	1.21
Omala S2 GX 460	2.79	2.13	1.64	1.29	1.03	0.83

4.2.5 Bearing Life Calculation

Every machine has operating hours as an indicator of operational age, as do components such as bearings. In this study, bearing life calculation was performed as additional data to support lubricant selection, using the average kappa value of all comparison lubricants as the basis for calculation. The force comparison value is greater than the e value, so the formula used by the researcher is as follows:

$$P = X.Fr + Y.\ Fa$$

$$P = 0.67 \times 1104 + 1.8 \times 1155$$

$P = 2778.5\ kN$

The calculation for the bearing life of SKF BT2-8131 A is as follows:

$$L_{10} = \frac{9350^3}{2778.5}$$

$$L_{10} = 57.07$$

Conversion calculation to hours:

$$L_{10h} = 57.07 \text{ x } \frac{10^6}{60 \text{ x } 32}$$

$$L_{10h} = 29{,}724 \text{ hours}$$

The following is the bearing life calculation based on actual conditions:

Castrol Alphasyn EP 320:

$$L_{10mh} = 1 \times 0.72 \times 29{,}724$$

$$L_{10mh} = 21{,}401.2 \text{ hours}$$

After calculating all the comparative lubricants, the researchers obtained data on the actual age, bearing as follows:

Table 1. Comparison Table of Actual Bearing Life from Comparable Lubricants

Actual Life of SKF BT2-8131 A Bearings Based on Specific Lubricants			
ISO VG	Lubricant	Actual Age	
		Hour	Year
320	Castrol Alphasyn 320	21401,2	2,7
	Masri FLG 320	17834,4	2,2
	Masri RG 320	17834,4	2,2
	SHC 600 320	22887,5	2,8
	Shell Omala S2 GX 320	18131,6	2,2
460	Masri FLG 460	23481,9	2,9
	Masri RG 460	23481,9	2,9
	SHC 600 460	29426,7	3,6
	Shell Omala S2 GX 460	23481,9	2,9

4.3 Discussion

4.3.1 Evaluation of Kappa Value Calculation Results for Each Comparator Lubricant

Types of comparative lubricants, an overview of the effectiveness of each lubricant in forming a protective layer suitable for application in Vertical Roller Mill (VRM) machines was obtained. Mobil SHC 600 460 lubricant showed the best performance with a kappa value of 1.72, indicating the formation of a mixed lubricant layer and resistance to oxidation and high temperatures thanks to its synthetic properties. Shell Omala S2 GX 320, although the best mineral lubricant in the ISO VG 320 class, only achieved a kappa value of 0.96, placing it within the boundary lubrication zone and making it less suitable for this application. Conversely, Shell Omala S2 GX 460 and Pertamina Masri RG 460 show a kappa value of 1.29 and are equipped with extreme pressure additives, making them suitable for use as VRM main roller lubricants because they can form a stable mixed lubricant layer.

Overall, synthetic lubricants with an ISO VG 320 are technically suitable for use, but mineral-based lubricants with higher viscosity grades (ISO VG 460) proven providing performance better in forming a mixed lubricant layer. This is very important in bearing areas that operate under high loads and low speeds, such as in VRMs. Therefore, for heavy-duty working environments, ISO VG 460 mineral lubricant is more recommended than its ISO VG 320 counterpart because it provides optimal protection against wear, maintains lubricant layer stability, and extends bearing component service life.

4.3.2 Impact of Kappa Values on Bearing Life

A high kappa value indicates better lubrication conditions because it signifies the formation of a thick and stable lubricant film between metal surfaces in the bearing system. This layer prevents direct contact between metals, thereby reducing the risk of wear and extending component life. In addition, a high kappa value correlates positively with an increase in SKF value, which is a factor that reflects an increase in bearing life based on actual conditions. Therefore, selecting a lubricant with a high kappa value is very important for maintaining the reliability of the lubrication system and extending the operational life of bearings, especially in harsh working environments such as Vertical Roller Mills.

Based on the calculation results, the standard Castrol Alphasyn EP 320 lubricant produced a bearing life of approximately 21,401.2 hours. The same calculation was also performed on the comparison lubricant, and the results showed that lubricants with higher kappa values than the standard tended to provide longer operational life. Thus, the kappa value not only reflects lubrication quality but also serves as an important indicator in estimating the overall durability of the bearing. These results are an important reference in the process of selecting more efficient and strategic lubricants for heavy industrial applications.

From the comparative lubricant analysis, Mobil SHC 600 ISO VG 460 showed the best performance with the highest kappa value and a bearing life of 29,426.7 hours, far above that of standard lubricants. In contrast, Shell Omala S2 GX 320 has a kappa value below 1, resulting in a bearing life of only around 18,131.6 hours, or 3,269 hours shorter than standard lubricants. Meanwhile, Pertamina Masri RG 460 and Shell Omala S2 GX 460 have the same kappa value and are estimated to provide a bearing life of 23,481.9 hours, which is also better than standard lubricants. These findings highlight the importance of selecting lubricants with the appropriate viscosity and characteristics to optimize performance and extend component life.

4.3.3 Technical and Economic Evaluation

Table 3. Technical and Economic Evaluation Based on Specific Lubricants

Technical and Economic Evaluation Table Based on Specific Lubricants						
ISO VG	Lubricant	Kappa Value	Actual Life	Price	Price/Time	Availability
			Year	Rupiah	Rupiah/Month	
320	Castrol Alphasyn 320	1.15	2.7	58,999,900	1,852,603	Indonesia
	Masri FLG 320	0.94	2.2	10,999,900	414,476	Indonesia
	Masri RG 320	0.94	2.2	11,999,900	452,156	Indonesia
	SHC 600 320	1.25	2.8	99,999,900	2,936,098	Singapore
	Shell Omala S2 GX 320	0.96	2.2	12,999,900	481,807	China
460	Masri FLG 460	1.30	2.9	11,999,900	343,411	Indonesia
	Masri RG 460	1.30	2.9	12,999,900	372,028	Indonesia
	SHC 600 460	1.72	3.6	109,999,900	2,512,002	Singapore
	Shell Omala S2 GX 460	1.30	2.9	13,999,900	400,646	China

After analyzing the kappa value and operational life of the bearings, the researchers concluded that three lubricants—Mobil SHC 600 460, Shell Omala S2 GX 460, and Pertamina Masri RG 460—are worthy of consideration as the primary lubricants for the main rollers of the Vertical Roller Mill. All three demonstrated good lubrication performance with high kappa values, which directly correlates with increased bearing life. However, this study not only highlights technical aspects, but also considers non-technical factors such as price and local availability of lubricants, to ensure implementation efficiency and supply sustainability in industrial operations.

From an economic and logistical standpoint, Mobil SHC 600 460 is a synthetic lubricant with the best technical performance, but it also has the highest price tag at Rp. 109,999,900 and is manufactured in Singapore. Shell Omala S2 GX 460, although imported from China, is offered at a lower price of around Rp. 13,999,900. Meanwhile, Pertamina Masri RG 460 is the most economical choice at IDR 12,999,900 and has the advantage of distribution because it is produced locally in several cities in Indonesia. These differences in price and production location play a major role in determining the suitability of lubricants, not only in terms of performance but also in terms of logistics efficiency and operational cost savings.

Considering technical performance, price, and availability, the researchers concluded that Mobil SHC 600. 460 is suitable for use if the main priority is maximum lubrication performance and long bearing life. However, when considering the balance between technical aspects, price, and availability, Pertamina Masri RG 460 lubricant is the best choice for application at PT. Solusi Bangun Indonesia. In addition to its robust technical performance, this lubricant is also more economical and readily available, making it an ideal solution to replace standard lubricants deemed too expensive for production operations.

5. CONCLUSION

5.1 Conclusion

1. The standard lubricant used in the Vertical Roller Mill machine, Castrol Alphasyn EP 320, has a kappa value of 1.15, indicating mixed film lubrication conditions. The lubricant layer from the comparison lubricant is not significantly different and still has the same lubricant layer as the standard lubricant, which is mixed film lubrication.
2. After calculating comparative lubricants, there are several lubricants that can be applied, including SHC 600 460 with a kappa value of 1.72, as well as Shell Omala S2 GX 460 and Pertamina Masri RG 640, which both have a kappa value of 1.3.
3. The researcher concluded that Pertamina Masri RG ISO VG 460 has the best criteria among other mineral lubricants, with an economical price and good local availability. However, Mobil SHC 600 460 has the highest technical performance (kappa value and thermal stability), but at a very high price. Making it less suitable for the purpose of lubricant replacement efficiency at PT. Solusi Bangun Indonesia.

5.2 Recommendation

1. The researcher's recommendation to PT. Solusi Bangun Indonesia Tuban Factory is to consider replacing Castrol Alphasyn EP 320 lubricant with Pertamina Masri RG 460, as it has a kappa value that meets mixed lubrication standards, is more affordable, and has good local availability. However, if the company prioritizes lubricant service life and less frequent replacement, synthetic lubricants such as Mobil SHC 600 ISO VG 460 can also be considered with a re-evaluation of the budget. The company is also advised to regularly monitor lubricant conditions and maintain the oil filtration and cooling systems to ensure optimal lubrication performance.
2. For further research, the researchers suggest considering system compatibility aspects, particularly lubricant pumps, with the selected lubricant type, as well as reviewing machine conditions based on the limitations set in this study to obtain more accurate and applicable results.

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