Re-design and Upgrade Bearing Materials Traveling Drum Screen in Muara Karang Combined Cycle Power Plant Block 1

Abstract. The cooling system in the Steam Turbine Generator (STG # 1.0) is adjusted to the cleanliness conditions of seawater, using Traveling Drum Screen (TDS) as a filter. In January 2019, Traveling Drum Screen (TDS) suffered bearing and fuse bolt damage until STG # 1.0 was stopped with a potential loss of 28.59 billion rupiah. The position of the TDS bearing below the surface of the sea makes monitoring difficult. To overcome the problems in TDS bearings, an innovation was made in the form of redesign & upgrading bearing materials. The replacement of TDS bearing material from Pertinax to Pokhout Wood (Lignum vitae) is very appropriate because the material is capable of self-lubrication in seawater and has more strength. In addition to upgrading the material, a redesign of the bearing is also carried out, which is adding a grease groove so that the optimal lubrication process and use finite analysis software to find out safety factors design. By using simulation software, the results show the bearing design with Pokhout material has a safety factor of 1.28 and Pertinax has a safety factor of 0.85. This shows that the re-design and upgrade of materials that have been carried out can increase the safety factor bearing and can reduce the possibility of failure of the bearing.

1. Introduction
Muara Karang Combine Cycle Power Plant Block 1 have capacity of 500 MW, It is tasked with providing electricity supply in the DKI Jakarta area. Muara Karang Combine Cycle Power Plant Block 1 consists of 3 Gas Turbine Generators (GTG), 3 Heat Recovery Steam Generators (HRSG), and 1 Steam Turbine Generator (STG). Steam Turbine is driven by steam produced by HRSG to produce electricity and requires primary cooling through a condensation process. Seawater as the main cooler gets some filtering processes to be free of garbage. One equipment that serves to filter seawater is the Traveling Drum Screen (TDS).

TDS has functions to filter seawater that flows from siphon outlets to the Circulating Water Pump well. TDS is driven by a motor whose speed is reduced by a gearbox to a low speed and continued by a pinion gear. TDS load is supported by 2 journal bearings that work below sea level so that materials with good corrosion resistance and wear resistance are needed, more details are shown in Figure 1. In addition, routine maintenance is needed to support TDS operating normally. One of the preventive maintenance that is done is grease injection as a bearing lubricant.
Based on the Pareto Frequency Failure, bearing damage is the biggest contributor to the failure value in damage to the TDS system. Bearing damage has occurred twice in the past year, namely in January and June 2019 (Figure 2). Traveling Drum Screen (TDS) suffered bearing and fuse bolt damage until STG # 1.0 was stopped with a potential loss of 28.59 billion rupiahs. Bearings located below sea level cannot be monitored for conditions when TDS is operating, so they can only be monitored when stopped or overhaul. If the line greasing is damaged, we can be sure that there is no lubrication on the bearing which results in large friction. Bearing damage makes the TDS operation abnormal or unbalanced so that the rotation of rotation from the pinion to rack gear is inhibited. The non-rotation of the TDS makes the mesh surface covered with rubbish, which makes the water pressure very large and makes the fuse bolt broken. When the TDS is lifted due to broken fuse bolt, the garbage is not filtered which causes plugging on the condenser. These conditions make STG must stop.

Figure 1. Traveling Drum Screen

Figure 2. Traveling Drum Screen bearing damage
This paper begins with RCFA to determine the source of the TDS problem details are shown in Table 1, the next step is determine bearing material based on strength, corrosion resistance and followed by the calculation of pressure velocity (PV), where PV value ≥ PV material. The next step is determination of TDS bearing design based on stress analysis simulation. In the final stage with the manufacture, installation of TDS bearings and monitoring material replacement and re-design of the journal bearing are done so that the same thing is not repeated. Pertinax / Phenolic material was replaced by Pokhout (Lignum vitae) because it has self-lubrication properties and good corrosion resistance. Re-design of the grease channel is also carried out so that the lubrication process in the bearing is more optimal by adding inlet holes from 1 to 3.

Many studies relating to journal bearings. In paper [1], Study on tribological properties of novel biomimetic material for water-lubricated stern tube bearing. In paper [2], Effect of spherical-convex surface tecture on tribological performance of water-lubricated bearing. A new rubber/UHMWPE alloy for water-lubricated stern bearings is presented in paper [3]. In paper [4], Influence of water and oil immersion on the tribological properties of Excentrodendron hsienmu. In paper [5], Finite-element analysis of laminated rubber bearing of building frame under seismic excitation.

2. Basic Theory

2.1. Bearing

Bearing is a machine element that supports a shaft that has a load, so that rotation or alternating motion can take place smoothly, safely, and has a long life. In general, bearings can be classified based on construction and mechanism when dealing with the friction that occurs, namely:

a. Rolling bearing/roller bearing: Between the two surfaces is placed rolling elements such as balls, rollers, tapers, and others. Sliding bearing: Often also called plain bearing uses a sliding mechanism, where the two-component surfaces move relative to each other. there is lubricant as the main component to reduce friction between the two surfaces. Slider bearings are divided into two, including:

1) Journal bearings/sleeve bearings, have a cylindrical shape and withstand radial loads (which are perpendicular to the axis of the shaft).
2) Thrust bearings, generally have a flat shape and can withstand loads in the direction of the axle axis (axial load).

2.2. Bearing Material

Bearing materials must have sufficient hardness and strength to withstand the load, therefore there are...
various types of bearing materials whose selection is based on the size of the load and the operating environment. For example, in combustion engines, bearing materials must be strong and have self-heal capability while corrosion-resistant materials are needed in bearings that work in high oxidation environments.

2.3. PV Factor
The load factor PV has considerable influence on determining the bearings useful operating life. PV is determined by multiplying the specific bearing load or pressure(p) by the sliding speed (v). Bearing materials are rated by a PV limit, with the PV limit representing the highest combination of load and speed under which the bearing material will operate. The PV unit of measure is N/mm² x m/s. The PV Factor Calculation Steps are as follows [6]:

A. Bearing Calculation length

\[ L = D \times \left( \frac{L}{D} \right) \]  

Annotation:

\( L \): length of the journal bearing  
\( D \): diameter of the journal bearing  
\( L/D \): specific ratio

B. Pressure on the bearing

\[ P = \frac{F}{L D} \]  

Annotation:

\( P \): pressure the bearing gets  
\( F \): force on the bearing

C. Speed of the bearing

\[ V = \frac{\pi D \times n}{12} \]  

Annotation:

\( V \): linear velocity on the surface of the journal bearing  
\( n \): rotation of the drum screen

D. PV Factor

\[ PV \text{ factor} = P \times V \]  

Annotation:

\( PV \text{ factor} \): pressure velocity factor

3. Methodology
This paper begins with RCFA to determine the source of the TDS problem, the next step is determine bearing material based on strength, corrosion resistance and followed by the calculation of pressure velocity (PV), where PV value ≥ PV material. The next step is determination of TDS bearing design based on stress analysis simulation. In the final stage with the manufacture, installation of TDS bearings and monitoring. The methodology can be seen in Figure 3.
4. Result and Discussion

4.1 Comparison of mechanical properties

Life time TDS bearing is short and the difficulty of the maintenance carried out because it is required to stop Steam Turbine makes the need for an innovation to extend the lifetime of the bearing. The innovation made is by replacing bearing materials. From several alternative materials, wood pokhout or lignum vitae was chosen because it has the highest oil content of 6.22%. This becomes an important factor because if there is a failure in the lubrication system (grease), bearings with pokhout material are able to lubricate themselves so that there is no failure of the TDS operation. In addition, Pokhout was chosen because it has been widely used as a ship propeller bearing and its mechanical properties tend to be better than other wood commonly found in Indonesia. Data on mechanical properties of several bearing materials are presented in table 2.

Table 2. Comparison of material mechanical properties

| No | Mechanical Properties | Present condition | Alternatif I: Pertinax | Alternatif 2: Lignum Vitae (Pokhout) | Alternatif 3: Jackfruit | Alternatif 4: Bronze |
|----|-----------------------|-------------------|-----------------------|-------------------------------------|------------------------|----------------------|
| 1  | Density (kg/m³)       | 1450-1550         | 1139                  | 0,795                               | 7500                   |
| 2  | Tensile strength (kg/cm²) | 299,7          | 425,2                 | 89,011                              | 5608,44                |
| 3  | Shear strength (kg/cm²) | -               | 140,15                | 94,04                               | 5486                   |
| 4  | Hardness (%)          | 90 (shore D)     | 791,33 (kg)           | 252,05 (kg)                         | 170-220 (HV)          |
| 5  | Oil content (%)       | -                 | 6,22                  | 4,437                               | -                      |
| 6  | Corrosion             | ✓                 | ✓                     | ✓                                   | ✓                      |

Figure 3. Flowchart re-design and upgrading bearing materials on the Traveling Drum Screen
4.2. PV Factor calculations
The PV factor obtained from the calculation is a condition so that the bearing design can be used. Based on material properties data as in Table 3, the PV factor of Lignum vitae is 12000 psi-fpm while the required value (design value) is 9559.004 psi-fpm so that based on Lignum vitae design calculations it can be used as a TDS journal bearing replacing the previous material.

Table 3. Lignum vitae material properties as bearings

| Attributes              | Wood Bearings |
|------------------------|---------------|
| PV rating              | 12,000        |
| Max speed              | 500 sfpm wet  |
| Max Load               | 1000 psi      |
| Max operating temperature | -50 to +180F |
| Friction               | 0.07-0.11     |

4.3. Re-design Bearing
Based on its mechanical properties, the next step to determine bearing strength is to conduct a stress analysis simulation on the Autodesk Inventor software. The simulation aims to design and determine the bearing design strength that has been made. In this step, it is done by comparing the old bearing design and the new design as in Figure 4.

In the old bearing design, there is 1 grease hole and 1 groove as a place for grease to enter the interior of the contact point between the bearing and the shaft. Whereas in the new design, there are 3 holes to insert the grease and 3 grooves through which the grease enters to lubricate the shaft. The new design aims to ensure that grease entering the journal bearing can be spread evenly to all bearing surfaces that come in direct contact with the shaft. The design of the initial journal bearing with pertinax material has a grease lubricating capacity to fill the bearing of 0.074 liters. Whereas the new design with pokhout material has a higher lubrication capacity of 0.177 liters.

Based on the existing manual book and drawing drum screen [7], it is known that the total weight of the traveling drum screen is 9000 kgs. The load given by the entire drum screen assembly is received by the shaft on two sides, so that the load is known, namely:

\[ P = \frac{9000 \text{ kgs} \times 9.8 \text{ m/s}^2}{2} = 44.145 \text{ N} \]

While the radius which acts as a point of force on the TDS shaft is known to have a slope angle of 10°. Therefore, the force applied to the pivot can be determined by making a free body chart of the force diagram on the pivot first.
From Figure 5, it can be seen that on the x-axis, the total load produced is zero. That is because the Fx1 and Fx2 styles eliminate each other. While the load used in the stress analysis is obtained from the calculation of load P multiplied by cos10° that is equal to 43,483.2 N. The load is received axle on both sides in front of each journal bearing as in Figure 6.

Based on the simulation results (Figure 7), it is seen that the addition of holes and grooves to the grease lubrication system does not cause stress concentration, so it is safe to apply. With a load of 43,483.2 N in the shaft and each of the two journal bearings, the stresses obtained in the old design and the new design are relatively the same. In the old design, the maximum load obtained was 1,849 Mpa at the closest location to the drum screen load. Whereas in the new design, the bearing receives a maximum load of 2.168 MPa in the same section as the old bearing design.

Based on Figure 8, it can be seen the safety factor in both bearing designs, where the safety factor bearing with Pertinax / phenoly3 material has a lower value than Pokhout. Bearing design with Pokhout material has a safety factor of 1.28 and Pertinax has a safety factor of 0.85. This shows that the re-design and upgrade of the material that has been done is able to increase the bearing safety factor and can reduce the possibility of failure on the bearing.
Figure 8. Safety factor simulation results (a) Existing journal bearings and (b) new journal bearings

The implementation of this innovation work began in August 2019 until now, accounting for 1 year since TDS has been operating with new bearing materials and designs. In addition, based on the reference obtained pokhout material as a propeller bearing has a long lifetime because it has self-lubrication properties.

5. Conclusion

This paper explains the re-design of a bearing traveling drum screen will reduce the risk of disruption of the main cooling system due to increased TDS performance by reducing the friction that arises between the drum screen shaft and the drum screen bearing. By using simulation software, the bearing design results obtained with Pokhout material having a safety factor of 1.28 and Pertinax having a safety factor of 0.85. This shows that the redesign and material improvement that has been done can increase the safety factor of the bearing and can reduce the possibility of bearing failure.

This innovation has been implemented in Muara Karang Combine Cycle Power Plant Block 1 for 1 years. The benefit of this method in Muara Karang has reduced the unplanned maintenance frequency and increased the reliability of steam turbine operations so as to minimize the potential financial loss due to the failure of STG # 1.0 operation of 28.59 billion rupiah.

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