Investigation on Centrifugal Pump Shaft: A Comparison Study of the SME and the Imported Product

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Abstract :

The implementation of the ASEAN-China Free Trade Agreement (ACFTA) forces the small and medium enterprises to have a high competition between the manufacturer from China and the ASEAN member countries. One of the competitions occurs on the market of centrifugal pump for fisherman ship. The SME product, made in Tegal, has a lower price but also has a short lifespan. The imported product is now preferred by the fisherman due to its better performance and its longer lifespan. The main problem of the SME pump comes from the excessive wear at the pump shaft, indicated by a collection of deep scratch at two locations in pump shaft. This paper investigates the cause of the excessive wear at the SME pump shaft and compares the quality of the SME and imported shaft by conducting material characterization, mechanical testing, and design evaluations. The chemical composition, hardness property, tensile strength, geometrical analysis and bearing design of the both shaft products are compared. Results show that the SME product uses a higher quality material shaft but ignores the good engineering design in developing the fisherman pump shaft product. The absence of the bearing mounting design on the shaft, the lack of lubricant volume and the low quality of the seals on the SME pump product induce the undesirable wear on the pump shaft. The improvement of the shaft design is required to increase the quality of the SME pump.

Keywords: centrifugal pump, imported product, shaft, wear, SME product

1. Introduction

The implementation of the ASEAN-China Free Trade Agreement (ACFTA) forces the small and medium enterprises to have a high competition between the manufacturer from China and the ASEAN member countries. One of the competitions occurs on the market of centrifugal pump for fisherman ship. The pump, made by small and medium enterprises (SME) in Tegal, Central Java, has a lower price but also has a short lifespan. The imported product, comes from Malaysia, is now preferred by the fisherman due to its reliability performance and its longer lifespan. The price of the imported pump is three times higher than the SME product but it has an optimal operation time 4-5 times longer. Figure 1 depicts the pumps made by SME and the imported product.

(a) (b)

Figure 1. A pump for a fisherman ship: (a) made by SME and (b) imported product.

The longer life span of the centrifugal pump for the fisherman ship is preferable by fisherman due to its efficiency. The longer life span for the pump means the fishermen need to bring only 1 pump during their works in the middle of the Indonesian ocean without worrying about a problem with their pump. The longer lifespan means the longer period to change their broken pump with the new one. The pump replacement reduces the fisherman time to sail.

An initial observation has been made on the SME pump to analyze the causes of the shorter lifespan. Visual observation has been made on the SME pump components. The components of the pump, consist of impeller, shaft, bearing system, pulley, impeller housing and pump housing, are shown in Figure 2. The main problem of the SME pump comes from the excessive wear at the pump shaft, indicated by a collection of deep scratch at two locations in pump shaft, as depicted in Figure 3. The excessive wear at the shaft induces the vibration and noise in the pump during its rotation and reduce the pump performance.

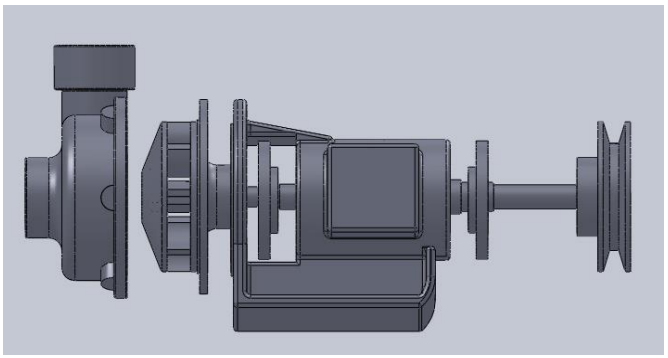


Figure 2. The main components of the pump for a fisherman ship.

Figure 3. The failure of the shaft of the fisherman ship pump after three months operation.

Previous investigations, related with the wear on the shaft, conducted by many researcher on the different case of the shaft system, such as: engine camshaft **[1]** contact between main shaft and bearing in sugar cane milling **[2]**, contact between shaft and slider bearing with a heavy load system **[3]**, shaft on railway axles **[4]** and shaft on the pump system **[5]**. The researchers reported that the wear on shaft is one of the important parameter due to its crucial function of the shaft in carrying the load **[1]**. The excessive wear on the shaft influences the other moving part on the rotating system.

This paper investigates the cause of the short failure on the SME shaft pumps by comparing the chemical compositions, mechanical properties, and design of the SME pump and the imported pump. The lifespan of the pumps is controlled by the design and the quality of the pump shaft. The improvement step on the pump shaft is required to increase the quality of the SME pump.

2. Material and Methods

The research methodology in this paper consists of two steps: investigate the quality of SME pump shaft and observe and evaluate the design of the SME pump. Firstly, in order to collect the information about the quality of the SME shaft pump the chemical composition, hardness and the tensile strength test are conducted. The spectrometer is employed to determine the chemical composition of the SME pump shaft. Some of the important chemical elements of the SME pump shaft are reported and compared with the imported pump shaft. The Rockwell hardness machine is used to check the hardness of the material whereas the universal testing machine is used to check the tensile strength. The specimen of the tensile stress test follows the ASTM E8 standard.

Secondly, in order to collect the information about the design evaluation, the geometrical analysis and bearing system arrangement are investigated. The geometrical analysis on SME pump shaft is conducted by measuring the SME pump shaft and compared with the imported pump shaft product. The bearing system

arrangement is important to be evaluated because the location of the excessive wear is precisely on the location of the bearing system. The evaluation is conducted by observe the bearing type, position, assembly and lubrication. A detailed visual observation is required to complete the evaluation.

3. Result and Discussion.

3.1. Chemical compositions

The results of the spectrometer test for both of the pump shafts are listed in Table 1. Only the dominant elements of the stainless steel are reported in this table whilst the other is neglected due to the small contributions. From the chemical composition, Fe is the main element with the additional element such as: Manganese, Chromium, Nickel and Copper. It is concluded that both of the pump shafts are made from the austenitic stainless steel. Most of the chemical elements on the SME pump shaft are higher than imported pump shaft which indicates that the SME pump shaft is able to receive higher load, has a higher hardness, and has higher corrosion resistance.

Table 1. The chemical contents of the SME and imported pump shaft

Shaft	Fe	C	Si	Mn	Cr	Ni	Cu
SME	71.2	0.124	0.340	10.8	14.6	1.23	1.35
Import	76.2	0.07	0.27	9.83	12	0.99	0.2

3.2. Tensile strength

The average values of the tensile strength are reported in this section. The tensile strength of SME pump shaft is 808 MPa, 11 % higher than the imported pump shaft, 723 MPa. This fact indicates that the SME pump shaft able to receive the radial and axial load higher than imported pump shaft.

3.3. Hardness

The average values of the hardness test are reported in the HRC scale in this section. The hardness of SME pump shaft, 30 HRC, is 20 % higher than the imported pump shaft, 24.5 HRC. This fact indicates that the SME pump shaft has a higher scratch resistance.

3.4. Geometrical Analysis

This section discusses the geometrical analysis comparison of the SME pump shaft and the imported pump shaft. Figure 4 and 5 depicts the geometry of the SME shaft and imported shaft, respectively. The length of the SME pump shaft is 270.5 mm, 10 mm longer than imported pump shaft. However, a lower in the diameter dimension is found on the middle of the SME shaft, 22 mm. It is 3 mm lower than the middle diameter of the imported pump shaft. The other founding reported in this geometrical analysis of the pump shaft is the existing of the gradual diameter on the pump shaft.

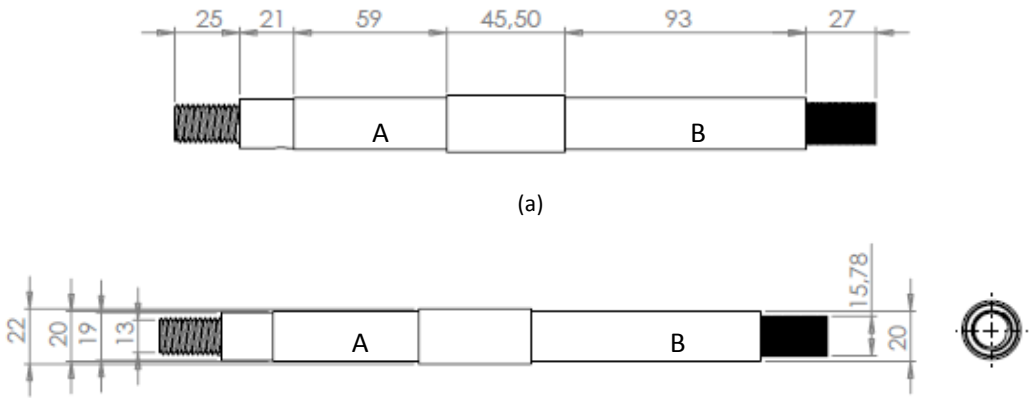
3.5. Bearing System

The bearing system of the SME shaft consists of 4 set of ball bearings. The bearings are located in two positions, as shown in Figure 6 (a). The bearing system of the imported shaft consists of 2 taper roller bearings. The bearings are located in two positions, as shown in Figure 6 (b). The higher number of bearing on the rotating shaft can results in a good load distribution along the shaft line. However, it also potentially creates problems when the bearing design system does not properly well-planned.

In SME shaft design, two bearings are located on the left side (A) and two bearings are located on the right side (B). Between these two bearings, no different shaft diameter was found which implies that these bearing able to slide over shaft axis its rotation. Contrary to the SME pump shaft, at the imported pump shaft, two taper roller bearings are located on the left side (A) and right side (B) and have a different shaft diameter that stops bearing to slide along the shaft axis during its rotation.

Grease is used in SME shaft to lubricate the bearing system. However, only small amount of grease is found when the pump housing was opened which means that the lubricant can not functioned as expected due to the

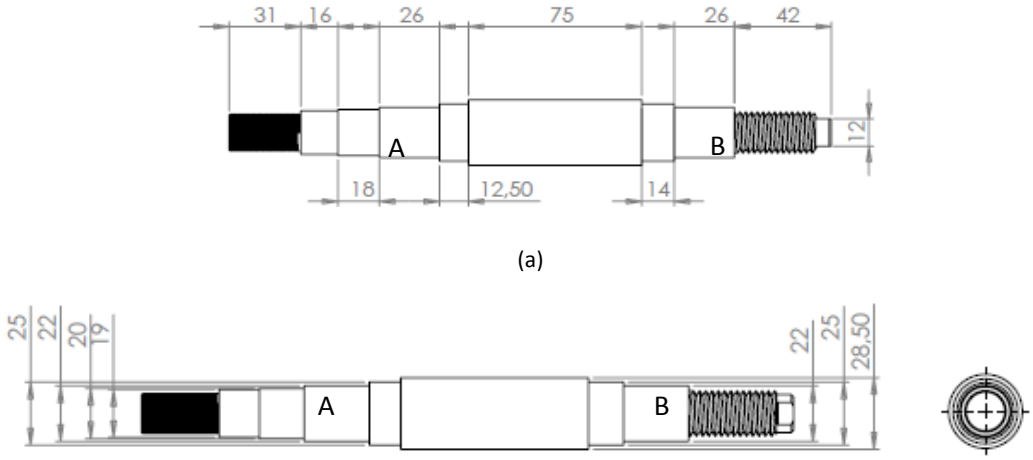
lack of lubricant. A low viscosity of oil is used in imported shaft to lubricate the bearing system. The oil fulfills the pump housing. The seals on the left side and right imported shaft work well to maintain the oil in the pump housing. Contrary with the imported seals, the seals in SME pump shaft have low quality, indicated with its waviness surface on the both sides.



(a)

(b)

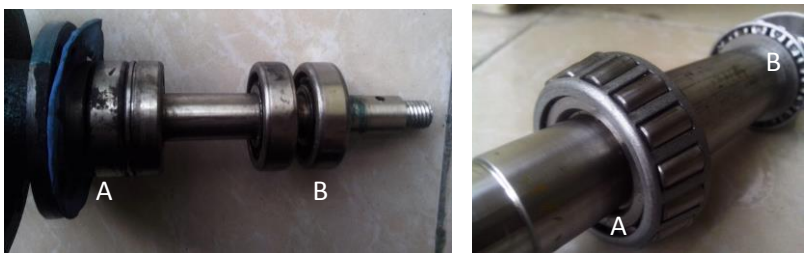
Figure 4. The geometry of the SME pump shaft.



(a)

(b)

Figure 5. The geometry of the imported pump shaft.



(a) (b)

Figure 6. The bearing system at: (a) the SME pump shaft and (b) imported pump shaft.

The main issue in this paper is the fail of the SME pump shaft in maintaining its good performance during transmitting the power from the engine to the water impeller. The fail of the SME pump shaft is indicated by the excessive wear on the bearing track on the left and right sides of the shaft. Initially, the researchers diagnose that the material in SME pump shaft had a low quality and did not support to receive the radial load along the bearing tracks. This initial diagnosis is then rejected by the experiment facts that the chemical compositions, the tensile

strength and the hardness on the SME pump shaft show the better quality than the imported pump shaft. The combination of the chemical elements in the SME pump shaft results in a higher tensile strength and wear resistance than the imported pump shaft. The material quality of the SME pump shaft is higher than the imported pump shaft.

Then the investigation is followed with the design evaluation on the SME pump shaft. Firstly, in the geometrical analysis, it was found that the radius of the SME pump shaft at the location where the bearing is set (in A and B position in Figure. 4-5) and at the middle of the shaft is smaller than the imported pump shaft. This affects the strength of the shaft in receiving the bending stress and the torsion during working. However, the case of failure on the SME pump shaft due to bending stress and radial stress is not found which implies that, so far, the radius of the shaft is able to receive the stresses. As recommendation, a further investigation in calculating the stresses during the rotation of the pump is should be considered with finite element analysis or analytical solutions.

Secondly, the evaluation on the bearing system covers the shaft and bearing design, the lubrication system and the lubrication seal performance. It was found that the bearing system on the imported pump shaft was designed better than the SME pump shaft. This conclusion is concluded by several facts. First, the imported pump shaft has a gradual diameter on the bearing track. The gradual diameter has an important function in avoiding the bearing slide over the axis shaft during rotating. In order to mounting the bearing on the proper location, some techniques are offered, as shown in Figure 7 (a-c) **[6]**.

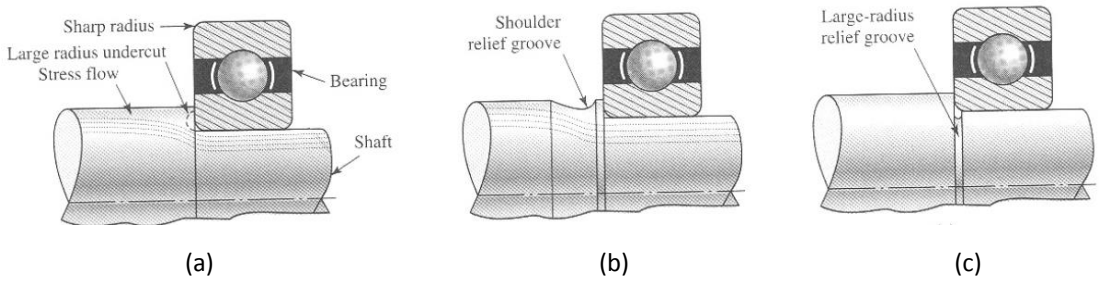


Figure 7. The bearing mounting design **[6]**.

The design on the SME pump shaft uses the same level of diameter for the two parallel bearings on the left and right sides. This allows the bearings sliding along the axial line on the shaft surface when the axial load is higher than the ability of the pump housing to hold the bearings at the proper location. The excessive wear on the SME pump shaft surface indicates that the bearing slide over the shaft during rotation. The inner race of the bearing rubs the shaft surface during sliding. Initially low wear was found on the shaft surface then gradually it becomes higher because the diameter reduction on the shaft surface results in a small vibration during its rotation. The small vibration and the sliding movement of the bearing induce the excessive wear on the SME pump shaft.

The SME pump shaft used four sets of ball bearings and the imported pump shaft used two sets of tapper roller bearings. The tapper roller bearing is designed to receive the higher radial load, but however, four sets of ball bearing is relatively adequate to receive the radial load on the centrifugal pump. The difference in bearing selection is not a main problem in producing the wear on the shaft but the design of the shaft to hold the bearings from the axial movement is a problem.

Actually, the wear mechanism can be reduced by the good performance of the lubrication system. However, lubricant does not work well in the SME pump shaft due to the lack of the grease and the bad performance of the sealing system. The selection of the grease to lubricate the bearing is correct [7, 8], however, the lack of the grease volume makes its function in reducing the friction in the bearing cannot be performed. Some of the ball bearing surfaces are covered with the grease and some others are not. The sealing system is also important in determining the good lubrication. The low quality of the sealing system allows some air (or maybe water) to circulate on the pump housing. The grease is getting dry when some air is circulate on the pump housing and causes the low lubrication performance.

In the imported pump shaft, the low viscosity oil is selected in maintaining the low friction performance at the bearings. It is supported with the good quality of the seal system to avoid the oil out of the pump housing. With these combinations, the low friction performance is showed during the bearing rotation and reduces the

possibility to produce excessive wear. This makes the imported pump shaft has a longer lifespan, compared to the SME pump shaft.

This research implies the importance of the design on the mechanical system. The high quality of the material, means the higher production cost is needed, becomes useless due to the bad design system. An engineering design in manufacturing process requires a technical skill and a wide perspective of technology. Most of the SME in Indonesia has low technical skill and low technology application. These phenomena are also discussed in the previous paper **[9, 10]**. They already feel proud when they able to create or imitate a product without considering the engineering design properly which causes a low quality product.

4. Conclusion

The causes of the excessive wear on the shaft surface at the SME pump have been investigated in this paper. A series of tests, namely chemical composition test, tensile strength test and hardness test, show that the quality of shaft material of the SME pump is higher than the imported product. However, the high quality of material is not followed with the good bearing design system. The absence of the gradual diameter in the SME pump shaft allows the bearings to slide along the axial surface during its rotation. The sliding contact of the bearings and the shaft induces wear on the shaft surface and the wear is gradually developed into an undesirable condition. In the case of the SME pump shaft, the fail of the shaft does not cause by the low quality of the material but causes by the absent of a good engineering design. The absent of the good engineering design in this case can be caused by the low quality of their technical skill or their choice in producing the low price and low level product. These reasons are normally found in the SME characteristic in manufacturing industries in Indonesia. However, if SME does not preparing their self to change their mindset, the product from China and ASEAN able to buried their product. Nowadays, the customer does not only think about the price but also the quality and effectiveness.

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