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Maintenance and Repair of Ship Propeller Shafts

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***Abstract* - The propeller shaft is one of the most important components in ship construction so this component is given complete and clear standards for technical design, maintenance and repair. in Indonesia, the standard used as a reference is the standard from PT. The Indonesian Classification Bureau (BKI) is the party authorized to issue ship classification certificates in Indonesia. Every five years for passenger ships and cargo ships, ship propeller shafts must be maintained and repaired. This research examines the maintenance and repair process of propeller shafts on passenger and cargo ships, KMP Kirana I. The repair method for the propeller shaft is by coating composites on areas that are eroded due to corrosion and wear. From the results of the inspection when the propeller shaft was removed, it was discovered that the clearance between the shaft and the ship's bushing was greater than the BKI standard. After repairs were carried out with the addition of composite material, the clearance returned to meeting BKI standards.**

Keywords: ship, maintenance, repair, propeller shafts, composite.

I. INTRODUCTION

A shaft is a rotating part, usually with a circular cross-section, that is used to transmit power or motion. The shaft is the axis of rotation, or oscillation, of elements such as gears, pulleys, flywheels, cranks, sprockets, and the like and controls the geometry of their movement. An axle is a non-rotating part that carries no torque and is used to support rotating wheels, pulleys, and the like. An automotive axle is not a true axle. Non-rotating shafts can be easily designed and analyzed by static analysis subject to fatigue loads.

Shaft loss can cause undesirable effects such as stress concentration. Sharp changes in the shape of the shaft geometry (discontinuity) can cause stress values that are greater than expected. This can be a source of difficulty for designers [1]. In addition, a large clearance width can cause vibration effects on the ship's shaft. If left unchecked, this effect can cause failure of the shaft so this effect endangers the ship's operations [2].

There are several conditions that make shaft maintenance necessary. Some of these conditions are the shaft clearance width being too large and damage to the shaft. On the shaft that was observed, the shaft had a clearance width that was too large and there was damage to the shaft.

From the problems above, the author will explain the stages of evaluating and handling these problems. The evaluation stage consists of calculating the clearance width and determining the method for repairing damage to the aft section. Calculation of clearance width will follow the rules of the Indonesian Classification Bureau (BKI) Volume I: Classification and Survey Regulations.

The clearance checking process is a process that must be carried out by every offshore vessel that is actively operating. Clearance checks and damage evaluations are carried out every five years by BKI officers. The rules regarding checking clearance according to BKI guidelines can be seen in the points below:

a) Water lubrication shaft clearance (lignum vitae bearing)

1. New installation
   Between $0.003D + 0.2\ mm$ and $0.004D + 0.50\ (mm)$
   Where D is the diameter of the shaft lining
2. Maximum clearance
   $0.01D + 2.5\ mm$

b) Oil lubrication shaft (white metal bearing)

1. New installation
   General clearance:
   $0.001D + 0.3\ mm$ and $0.001D + 0.50\ (mm)$
2. Maximum clearance
   $0.0015D + 0.65\ mm$
3. Maximum wear tolerance for shaft lining
   - In the bearing area: 25% of shaft thickness.
   - In the bearing area: 25% of shaft thickness.

From the results of checking the clearance and damage, results will be obtained in the form of a record containing the clearance of the ship being checked. The ship whose clearance will be checked is KMP Kirana I which uses seawater lubrication shafts. Figure 1 shows the model of the propeller shaft on the KMP Kirana I ship.

The notations T (Top), B (Bottom), PS (Portside/Left side), and SB (Starboard/Right side) indicate a diameter measurement point that is straight across the axis and divided

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into four lines, with the aim of getting a good circumference line. when repairs are completed. For points a and b, only additional points can be divided into four pieces in the middle of the main point, namely T, B, PS, and SB.

The after, centre, and before positions indicate the location of the bearing entry (bush) which is at three points on the shaft, namely the beginning, middle, and end. The before position is the part close to the motor and the after is the part close to the propeller.

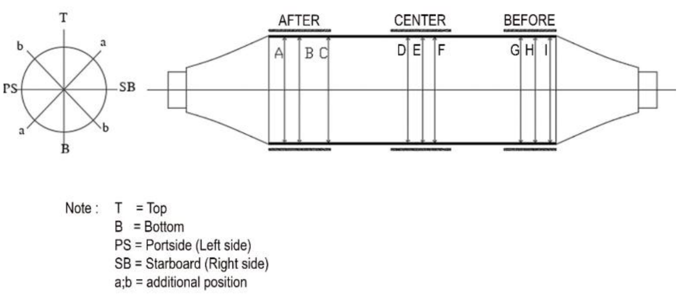

Figure 1: Propeller shaft model

When the shaft was lifted, many wear points were found on the shaft. Wear indicates the start of defects in the shaft [3]. Wear is the result of friction generated between the shaft and other rubbing machine elements. Wear is usually caused by shaft misalignment and improper maintenance [4]. At the time of observation, the damage that occurred was 15mm of shaft loss with a layer of rust around it. This layer of rust occurs due to the corrosive working environment of the shaft in the form of seawater.

This research aims to examine the process of maintenance and repair of the propeller shaft on the KMP Kirana I, which is one of the passenger and cargo ships operating in the Indonesian maritime area, carried out at PT Janata Marina Indah.

II. METHODOLOGY

There are many methods to repair the damage that occurs to the shaft, each with its own advantages and disadvantages. Several methods for shaft repair include thermal spraying/flame spraying [5] and forming techniques.

Thermal spraying is a collective term for a series of processes in which a coating material is heated rapidly in a hot gas medium and simultaneously projected at high speed onto the surface of a prepared substrate, where it is deposited to produce the desired coating thickness [6]. The type of thermal spray that is usually used to repair shafts is the flame spraying method. Flame spraying is the oldest process among other thermal spraying processes [7]. This process has several advantages, including low capital investment, high levels of efficiency and deposition, easy operation and equipment maintenance costs. Flame spray uses flammable gas as a heat source to melt the coating material. A wide variety of materials can be deposited in rod, wire, or powder form as coatings using this process. Flame spray guns and most components are sprayed manually [8]. The adhesive strength of this method reaches 20 – 40 MPa with a porosity level of 10% – 20%.

The forming technique method is an additive method using composite materials. Adhesive composites are a type of multipurpose adhesive material, which belongs to a special group used for the repair and regeneration of machine parts and devices. Composite materials are a type of material with extraordinary properties, such as light weight, high strength-to-weight ratio, high stiffness-to-weight ratio, and greater geometric design flexibility [9]. The manufacturing process of this product is based on chemo-setting adhesives for metals where the most frequently used are epoxy adhesives and contain relatively large amounts of fillers and extenders. The most common fillers are metals [10].

One of the materials commonly used in the forming technique method is a type of supermetal composite material, which is 100% solid and can work in cold conditions. This epoxy composite is reinforced with a silicon steel alloy. This material can be used for a variety of applications including bonding, shimming, forming, rebuilding, wrapping, patching, sealing and filling.

This material will not shrink when used in service, making it possible to achieve precise dimensions and geometry. This type of composite can ensure lasting in-service performance, by accounting for temperature and pressure fluctuations, loading and compression, impact and abrasion. This material has a working life of five years, so it is often used by professionals for maintenance processes. Composite specifications commonly used by companies for propeller shaft repairs are shown in Table I. The main advantages of this type of composite are as follows:

a) Versatile durable repair composite
b) Fully machinable using conventional tools
c) Application and drying at room temperature - does not involve hot work
d) Simple mixing ratio
e) Reduces health and safety risks as it is solvent-free
f) No shrinkage, expansion or distortion
g) Excellent adhesion to metals including stainless steel, carbon steel, aluminium, brass and copper
h) It can stick to many other natural and synthetic materials including glass and wood

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i) Excellent corrosion and chemical resistance
j) Excellent electrical insulation characteristics

After knowing the repair options and the characteristics of existing repair methods, the repair method will be selected by considering several factors such as the working environment of the ship's shaft, costs and work time. In the previous problem identification, it has been concluded that the factors that can influence shaft work are, namely, the shaft work environment. The ship's shaft works in the sea so it has an atmosphere with a high level of salinity. This salinity level can increase the rate of rusting. Apart from that, shafts also work with various loads.

Table1: Composite Specifications Used for KMP Kirana I Propeller Shaft Repair

Characteristics	Category	Characteristic Value	Information
Friction Resistance	H10 Wheel (Wet)	$852mm^3$	Friction resistance with a load of 1 kg
	CS17 Wheels (Dry)	$24mm^3$	
AdhesionTensile Shear	MildSteel	$19.2MPa$	Tested to ASTM D1002 with degreased strips, and grit blasted to form a 3-4 mil profile
	Brass	$11.4MPa$	
	Copper	$14.2MPa$	
	StainlessSteel	$20.4MPa$	
	Alumunium	$13.4MPa$	
Pull OffAdhesion	Ambientcure	$22.3MPa$	Tested to ASTM D 4541 / ISO 4624 with grit-blasted steel base
	Post-cure	$20.5MPa$	
Chemical Resistance	Once completely ready (cured)	Resistance to acids and bases in concentration 20%	
Processing time	Until it is ready to be installed	2days	Based on observations at PT. JMI

III. RESULTS AND DISCUSSION

The results of the clearance measurement process before repair, stages of the repair process, and clearance measurements after the repair process are explained in this chapter.

3.1 Clearance Measurement Results before the Repair Process

Data on the results of clearance measurements between the diameter of the bush and the diameter of stock after the ship has been in operation for five years are shown in Table 2 in units of mm. Table 3 presents comparative data on clearances that occur on ships after five years of operation with the maximum clearance standards permitted by the official institution in Indonesia, namely BKI.

Clearance is calculated from the difference between the bush diameter and the stock diameter at each position as shown in Figure 1 previously. For example, in the "After" position, section "A" at point T-B, the bush diameter is 225.97mm and the stock diameter is 220.05mm, so the clearance between the two is 5.92mm.

In Table 3 it can be seen that the clearance on the ship has exceeded the permitted standard limits so repairs need to be carried out to restore the clearance to the standards permitted by BKI. For example, the standard clearance from BKI for the "After" position of section "A" at point T-B is 4.70mm, while the measurement results show it is 5.92mm.

Table 2: Clearance Data before Repair (mm)

Before/ After Repair		After			Center			Fore		
Starboard / Portside		A	B	C	D	E	F	G	H	I
Dia. Of bush	T-B	225,97	225,32	225,95	225,54	225,77	226,02	226,60	226,87	
	PS-SB	224,80	224,35	223,82	223,32	223,76	223,96	223,78	224,28	
	a-a	225,18	224,56	224,40	224,32	224,30	224,54	226,54	226,62	
	b-b	225,49	225,07	225,23	225,20	225,20	225,21	224,18	224,83	
Dia. Of stock	T-B	220,05	219,50	219,95	220,05	220,63	219,00	219,17	195,62	
	PS-SB	220,25	219,95	220,20	220,03	220,70	219,35	219,98	195,97	
	a-a	220,15	219,52	220,05	220,06	220,70	219,93	219,99	195,78	
	b-b	220,27	220,00	220,40	220,13	220,69	219,34	219,97	196,38	
Clearance	T-B	5,92	5,82	6,00	5,49	5,14	7,02	7,43	31,25	
	PS-SB	4,55	4,40	3,62	3,29	3,06	4,61	3,80	28,31	
	a-a	5,03	5,04	4,35	4,26	3,60	4,61	6,55	30,84	
	b-b	5,22	5,07	4,83	5,07	4,51	5,87	4,21	28,45	

Table 3: Clearance Data on Ships before Repair compared with Maximum Clearance Standards permitted by BKI (mm)

Before/ After Repair		After			Center			Fore		
Starboard / Portside		A	B	C	D	E	F	G	H	I
Clearance	T-B	5,92	5,82	6,00	5,49	5,14	7,02	7,43	31,25	
	PS-SB	4,55	4,40	3,62	3,29	3,06	4,61	3,80	28,31	
	a-a	5,03	5,04	4,35	4,26	3,60	4,61	6,55	30,84	
	b-b	5,22	5,07	4,83	5,07	4,51	5,87	4,21	28,55	
Clearance BKI	T-B	4,70	4,70	4,70	4,70	4,71	4,69	4,69	4,46	
	PS-SB	4,70	4,70	4,70	4,70	4,71	4,69	4,70	4,46	
	a-a	4,70	4,70	4,70	4,70	4,71	4,70	4,70	4,46	
	b-b	4,70	4,70	4,70	4,70	4,71	4,69	4,70	4,46	

3.2 Propeller Shaft Repair Process to Restore Clearance to Meet BKI Standards

The shaft that was evaluated during practical work had damage in the form of loss of parts and shaft. This loss occurs due to friction between the shaft and the bearing in that part. Apart from erosion, rusting occurs on this part which is caused by long-term contact with seawater. The condition of the damaged shaft is shown in Figure 2.

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Figure 2: Shaft loss in the after section

To overcome these two problems, technicians repaired them using composites. This composite is a 2-part composite for metal repair and resurfacing based on solventless epoxy resin reinforced with silicon steel alloy.

Before applying the composite to the shaft, the damaged part needs to be cleaned of rust and smoothed so that the surface is flat. The smoothing process is carried out by peeling off the existing rust and roughness using a lathe. This process is carried out by rotating the shaft on a lathe and levelling it using a lathe chisel, as shown in Figure 3.

Figure 3: The process of smoothing the shaft with a lathe

After smoothing, the damaged shaft will be cleaned using solvent and degreaser as well as alcohol. The purpose of this cleaning is to remove the remaining rust and paint that is still attached to the part. This process is shown in Figure 4.

Figure 4: Cleaning rust and remaining paint

After all the dirt has been cleaned, the far right and left parts of the damaged shaft are given masking tape so that the composite does not stick to the undamaged parts. Composite application begins by mixing the base with the solidifier. The mixture is then applied to the rotating shaft and then reinforced with gauze to strengthen the composite structure as shown in Figure 5. The next process is the drying process of the coating on the shaft. During the drying process, the shaft must always be in rotation so that the applied layer does not experience creep. The shaft was rotated at a speed of 13 rpm for 4 hours.

Figure 5: Application of composites to the propeller shaft

After the composite is dry, the shaft will then be unloaded from the lathe and placed in the workshop. At the repair shop, the shaft will be inspected before being reinstalled on the ship.

Apart from damage to the shaft, there is also damage to the bearing due to friction that occurs between the shaft and the bearing. Bearing erosion is also a factor in widening clearance. Unlike shafts, bearings cannot be repaired if they are damaged so new bearings must be purchased. The new bearing will then be machined to form an eccentric profile. This profile creation aims to adjust the alignment of the shaft on the ship. This process is shown in Figure 6.

Figure 6: Bearing adjustment using a lathe

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3.3 Clearance Measurement Results after the Repair Process

After the shaft repair process and bearing replacement, the clearance is then checked. Shaft clearance is measured again to determine shaft suitability. Data on clearance measurements between the diameter of the bush and the diameter of the stock after repairs are displayed in Table 4, in units of mm.

Table 5 presents data comparing the clearance that occurs on ships after repairs with the maximum clearance standards permitted by the official institution in Indonesia, namely BKI. In Table 5 it can be seen that the clearance that occurred on the ship has been restored so that it meets the standard limits permitted by BKI. For example, the "After" position of section "A" is at point T-B, where previously the diameter of the bush was 225.97mm, now it is 221.52mm, which is the effect of replacing the old, damaged bushing with a new bushing. The diameter of stock in this position was previously 220.05mm, because there is no wear element, the dimensions are constant. In several other parts, the diameter of the stock changes after adding composite to cover the worn parts. So the clearance at this point is 1.47mm.

The clearance value in the "After" position of section "A" at the T-B point has changed from 5.92mm to 1.47mm, making it meet BKI standards where the clearance in this position cannot be more than 4.70mm. This is shown in Table 5.

Table 4: Clearance Data after Repair (mm)

Before/ After Repair		After			Center			Fore		
Starboard (Kanan)		A	B	C	D	E	F	G	H	I
Dia. Of bush	T-B	221,52	221,38	221,40	221,84	221,72	221,64	221,07	221,03	
	PS-SB	221,48	221,37	221,36	221,80	221,66	221,56	221,75	221,07	
	a-a	221,42	221,40	221,38	221,79	221,62	221,58	221,46	221,12	
	b-b	221,49	221,42	221,44	221,81	221,69	221,61	221,51	220,89	
Dia. Of stock	T-B	220,05	219,50	219,95	220,05	220,63	219,00	219,17	219,45	
	PS-SB	220,25	219,95	220,20	220,03	220,70	219,35	219,98	219,46	
	a-a	220,15	219,52	220,05	220,06	220,70	219,93	219,99	219,45	
	b-b	220,27	220,00	220,40	220,13	220,69	219,34	219,97	219,44	
Clearance	T-B	1,47	1,88	1,45	1,79	1,09	2,64	1,90	1,58	
	PS-SB	1,23	1,42	1,16	1,77	0,96	2,21	1,77	1,61	
	a-a	1,27	1,88	1,33	1,73	0,92	1,65	1,47	1,67	
	b-b	1,22	1,42	1,04	1,68	1,00	2,27	1,54	1,45	

Table 5: Clearance Data on Ships after Repair compared with Maximum Clearance Standards permitted by BKI (mm)

Before/ After Repair		After			Center			Fore		
Starboard / Portside		A	B	C	D	E	F	G	H	I
Clearance	T-B	1,47	1,88	1,45	1,79	1,09	2,64	1,90	1,58	
	PS-SB	1,23	1,42	1,16	1,77	0,96	2,21	1,77	1,61	
	a-a	1,27	1,88	1,33	1,73	0,92	1,65	1,47	1,67	
	b-b	1,22	1,42	1,04	1,68	1,00	2,27	1,54	1,45	
Clearance BKI	T-B	4,70	4,70	4,70	4,70	4,71	4,69	4,69	4,46	
	PS-SB	4,70	4,70	4,70	4,70	4,71	4,69	4,70	4,46	
	a-a	4,70	4,70	4,70	4,70	4,71	4,70	4,70	4,46	
	b-b	4,70	4,70	4,70	4,70	4,71	4,69	4,70	4,46	

IV. CONCLUSION

After operating for five years, the KMP Kirana I propeller shaft experienced dimensional damage where the clearance between the shaft and bearing increased so that it exceeded the limits set by BKI.

Forming method Techniques using super metal composites can be applied to the shaft properly to restore the shaft dimensions. Bearings cannot be repaired, they can only be replaced with new ones. After repairing the shaft and installing new bearings, the clearance between the propeller shaft and bearing has returned to BKI standards.

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