

# ANALYSIS OF REPLACEMENT PART TIME INTERVAL DETERMINATION OF CRITICAL IN ENGINE WATER COOLANT PUMP TYPES KRI FPB57

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## ABSTRACT

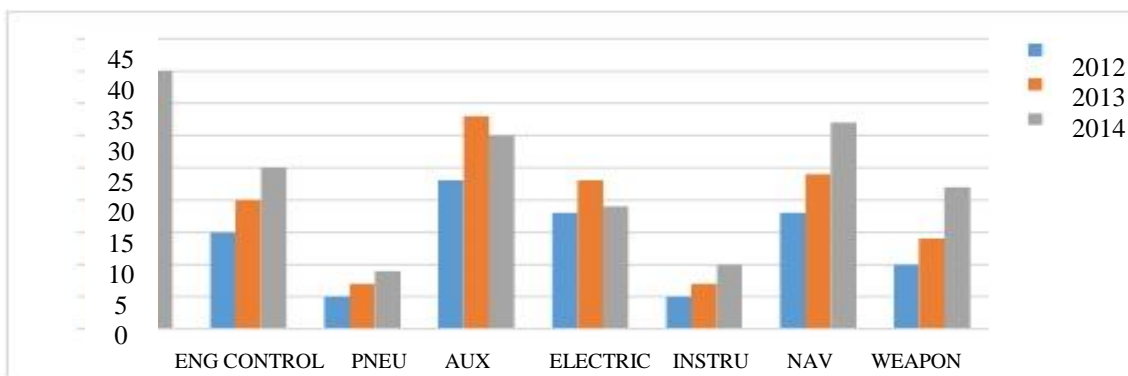
Maintenance management is required and has a very vital role for a KRI types FPB57, considering the type KRI is one Alutsista Navy who have a high frequency activity, as well as the broad range of operations support capabilities are varied so that the automatic machine is also high activity and in the end reliability will decrease. Methodology Failure Mode Effects and Criticality Analysis (FMECA) is a widely recognized tool for the study and analysis of the reliability of the design or process. Many authors in the field have emphasized specifically the usefulness of this method and its limitations. At this writing considering the lifetime of the machine and the elements therein specifically the components of the water coolant pump has had a lifetime of more than 20 years, because it can be said that the components have entered a critical period. Based on the steps Failure Mode Effects and Criticality Analysis (FMECA) through the calculation of Risk Priority Number (RPN), so we can determine the critical components of acquired 9 of 19 chances damage that has critical component is Angular Bearings, Cylindrical Bearings, Spacer Ring, Water Seal, shaft Seal, Seal Slip Ring, Impeller, O'Ring and shaft. These components if damaged can lead to engine breakdown. From the optimization results indicate that the component replacement Cylindrical Bearings have the fastest time, ie 98 days. While the replacement of components with the longest time, which is a component Impeller 134 days. Besides obtain the most optimal replacement time of each component, also produced the cost of replacement is effective, it is proved by the value of the optimal CBR. CBR value for all types of components is less than 1 ( $CBR < 1$ ).

**Keywords :** FMECA, Risk Priority Number, Reliability, Replacement Intervals, CBR.

## 1. INTRODUCTION

The readiness of the KRI type FPB57 in carrying out marine patrol operations is very important for the implementation of the Navy's main tasks, which are determined by the performance of the KRI and are influenced by inhibiting factors

such as failure on the system. Failure on the system will certainly require high costs due to production losses and delays, unplanned interventions on the system and safety hazards (Sachdeva, A, et all, 2009).



**Fig.1** Graph Comparison of FPB57 KRI Element Damage  
(Source: Armatim Ship Repair and Maintenance Service)

One of the critical elements of the FPB57 KRI type that has a high level of damage is the engine commonly referred to as the Diesel Powered Main Drive Motor (MPK). Based on the journal damage to

the system components on the KRI type FPB57 both during operation / sailing and at the base, compared to other systems on the KRI, engine damage has a high amount of damage and tends to

increase from year to year. The following is a graph of the comparison of damage to elements on the FPB57 KRI type (Engine, Control, Pneumatic, Auxiliary Motor, Electric System, Electrical Instrument, Navigation System and Weapon System).

From the picture above it can be concluded that the engine elements have a high frequency of damage and show a tendency to increase from year to year. This certainly affects directly the reliability of the FPB57 KRI engine components in its operation. Based on the description above, maintenance measures need to be focused on making decisions to determine critical components that have a high risk of damage and replacement of water coolant pump components on the FPB57 type KRI engine that is expected to reduce the breakdown period. Based on the formulation of the problems above, the objectives of the research can be taken are:

- a. Determine the type of critical component of the water coolant pump on the KRI type FPB57
- b. Determine the replacement time interval for critical components of the water coolant pump on the KRI type FPB57 engine.
- c. Knowing the replacement costs of critical components of the water coolant pump on the KRI type FPB57 engine.

Adoption is done to solve the above problems, namely the Failure Mode Effect and Critical Analysis (FMECA) methodology which is widely recognized for the analysis and reliability of design or process studies. At this writing, considering the age of the engine and the elements in it, specifically the components of the water coolant pump have a useful life of more than 20 years, because it can be said that the components have entered a critical period. Based on the steps of Failure Mode Effect and Critical Analysis (FMECA) through calculation of Risk Priority

Number (RPN), it can be determined which critical components and opportunities. The results of this study are expected to be useful for the Satrol Koarmatim in determining the water coolant pump maintenance policy on FPB57 KRI types specifically in determining the replacement intervals which will minimize the total maintenance costs which will ultimately increase the life time of FPB57 KRI engines.

## 2. MATERIAL AND METODOLOGY

### 2.1 Reliability

According to Eriyanto (1998), the system is a group of elements that are interconnected and organized to achieve a goal. System capabilities in carrying out its functions can be known from reliability. Some definitions of system reliability, namely:

a. Lewis, E.E (1991) defining system the probability that a component, device, equipment, or system will perform its intended function for specified period of time under a given set of engine conditions.

b. O'Connor, P.T.D (1995) defining, Reliability is the probability that an item will perform a required function without failure under stated conditions for a stated period of time.

c. Govil A.K (1983) defining, The reliability of system is called its capacity for failure free operation for a definitive period of time under given operation conditions, and for minimum time lost for repair and preventive maintenance.

According to Hoyland (1994), the function of reliability is a function that represents the probability that a component will not be broken in the time interval (0, t) and this is stated by the equation:

$$R(t) = 1 - F(t) = P(T > t) = \int_t^{\infty} f(t) dt$$

From some of the meanings above, system reliability is the probability that an equipment, system, or subsystem will function properly when needed on a mission or operational task at a certain time. The reliability of a system will tend to decrease with increasing age or the lifetime of the subsystem and its constituent components. However, this condition can be restored / improved by replacing the subsystem / component with the new one through appropriate maintenance activities.

## **2.2. Failure Analysis System to the Failure Modes Effects and Criticality Analysis (FMECA)**

According Rausand, M (2005) defines the FMECA is a methodology to identify and analyze:

- a. All potential failure modes of various parts of the system
- b. The effect of the failure of the system
- c. How to avoid failure and or reduce the impact of failure on the system.

Another definition of FMECA delivered by Omdahl (1988) which states that FMECA is a technique used to identify, prioritize, and eliminate potential failure of the system, design or before they reach the customer. While SEMATECH (1992) defines that FMECA is a technique for finish potential problems in the system.

FMECA was originally developed by the National Aeronautics and space Administration (NASA), which aims to improve and verify reliability of space program Hardware MIL-STD-785, entitled the Reliability Program for Systems and Equipment Development and Production to review the procedures for doing FMECA on equipment or or system. The MIL-STD-1629 is a military standard that establishes the requirements and procedures do FMECA, to evaluate and document the potential impact of any functional failure or hardware on mission success, security personnel and systems,

maintenance and system performance (Borgovini at all, 1993)

Lipol, LS at all (2011) states that Failure Mode Effects and Criticality Analysis (FMECA) is a methodology designed to:

- a. Identify potential failure modes for a product or process.
- b. Assess the risks associated with the failure modes and prioritize issues for corrective action
- c. Identify and perform corrective action to address the most serious problems.

Procedure Failure Modes Effects and Criticality Analysis (FMECA) can be broadly includes steps systematically include (Modarres, M at all, 2009):

- a. Identify all potential failure modes and their causes.
- b. Evaluation of the impact on each of failure modes in the system.
- c. Identify the method in detecting damage / failure.
- d. Identify corrective measure to failre modes.
- e. Access frequency and level of importance of the damage is important for critical analysis, which can be applied.

Meanwhile, according Zafiropoulus and Dialynas (2005), the basic steps in the conventional FMECA includes:

- a. Defining the system, which includes the identification of internal functions and interfaces, expected performance in various levels of complexity, restrictions and definitions of system failure.
- b. Perform functional analysis, which illustrates the linkage operations, and dependence functional entities.
- c. Identify failure modes and effects, all failure modes the potential of the items and interfaces are identified and their impact on the function directly, item and the system must be clearly defined.

d. Determining severity rating (S) of the failure mode, which refers to how serious the impact or effect of the failure mode.

e. Determine the occurrence rating (O) of the frequency of occurrence of failure modes and failure mode criticality analysis. Assuming that the system components tend to fail in many ways, this information is used to describe the most critical aspects of the system Desai.

f. Determining the Detection rating (D) of the control design criteria of the failure mode.

g. Risk Priority Number (RPN) Is the result of multiplying the weight of Severity, occurrence and detection. These results will be able to determine the critical components of the water coolant pump.

$$RPN = Severity (S) \times Occurance (O) \times Detection (D)$$

### 2.3 Cost Benefit Ratio (CBR)

In order to find a comprehensive measure of the lack of company activities, various indexes were developed, one of which was to find a comparison

between costs and benefits. According to Navair 00-25-403 (2003: B7) related to the cost of determining replacement time intervals using only a little or less cost, this can be determined through a formula such as the following:

$$CBR = \frac{MTBFx[(CBF \times N S) + \{C A F \times (1 - N S)\}]}{(C A F r) \times [N S + \{Kx(1 - N S)\}]}$$

Where values from CBR <1, are considered to be cost effective.

So a company activity if there is an increase in operational costs and maintenance must be compared with the benefits obtained. If the CBR is lower than 1, the company's activities are profitable.

### 2.4 Water Coolant Pump

Water Coolant Pump is pumping fresh water cooler, where it is the function of the pump as the engine coolant through the fresh water that flowed into the engine and also cools all oil-engine oil that is in the machine

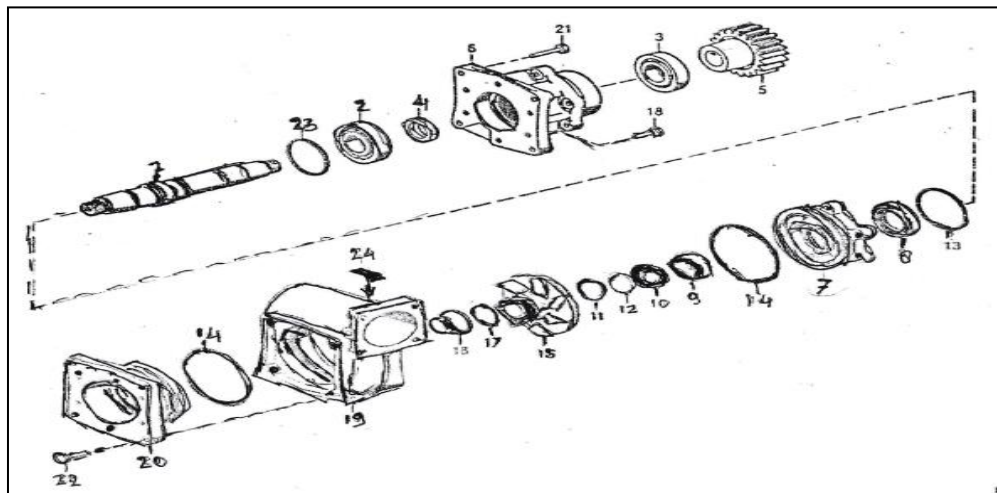


Fig.2 Water Coolant Pump

(Source : Manual Book Engine Type 16V956TB92, MTU)

- |                        |                   |                    |
|------------------------|-------------------|--------------------|
| 1. Shaft               | 9. Slip Ring Seal | 17. O'Ring         |
| 2. Angular Bearing     | 10. Counterring   | 18. Hex Bolt       |
| 3. Cylindrical Bearing | 11. Ring          | 19. Spiral Housing |
| 4. Nut                 | 12. O'Ring        | 20. Inlet Adapter  |
| 5. Drive Gear          | 13. O'Ring        | 21. Hex Bolt       |
| 6. Bearing Housing     | 14. O'Ring        | 22. Hex Bolt       |
| 7. Sealing Carrier     | 15. Impeller      | 23. Spacer Ring    |
| 8. Shaft Seal          | 16. Nut           | 24. Numplat        |
|                        |                   | 25. Whaser         |

### 3. DISCUSSION AND RESULTS

#### 3.1 Determination of critical components with FMECA

Based on Figure 2.4, that the constituent components of the water coolant pump consists of 25 components, but based on the results of interviews with the experts that no components. 25 (washer) does not need to be investigated, while the components No. 10 (countering), no. 11 (ring) and No. 12 (O'ring) is a water seal. As well as for component no. 6 (bearing housing), No. 7 (sealing ring carrier) and No. 19 (spiral housing) home of the components to be studied. From the above explanation finally obtained 19 supporting components on a water coolant pump that will be

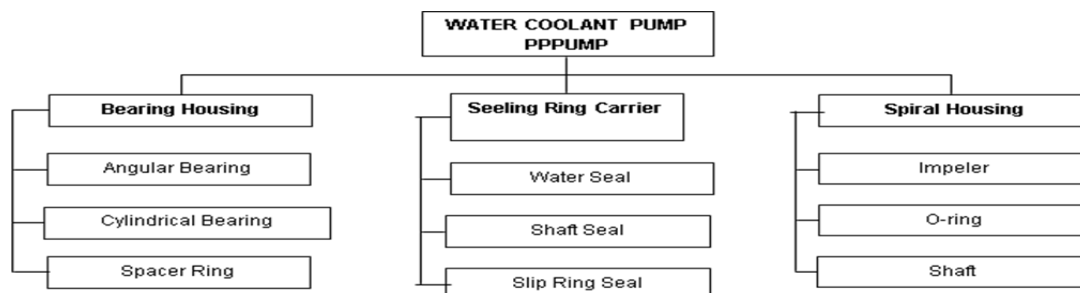
examined. Determination of critical components can be determined through the steps on FMECA, where the cumulative results of the components that have a high value RPN selected as a critical component. 9 components that can be categorized as critical components (see Table 3.1).

Besides the critical components can be determined qualitatively by looking at the effect of the damage caused to the system. If the system fails then the component referred to as a critical component, if the system does not fail, then the effect is said to be potential damage to components (a time component could be a critical component). The constituent components of water coolant pump critical categories are as follows:

**Table 1.** Critical component is based on the value of the highest RPN

Damage	Risk Priority Number (RPN)				
	PT. AIR	Pasharmat	Kabengmes	Kadepsin	Total
K1	7,958114416	8,320335292	7,651724731	7,958114416	7,972072214
K2	8,653497422	8,320335292	7,651724731	7,958114416	8,145917965
K3	3,825862366	3,914867641	4,1212853	3,036588972	3,72465107
K4	7,559526299	7,113786609	7,958114416	7,113786609	7,436303483
K5	3,107232506	3,556893304	3,556893304	2,714417617	3,233859183
K6	2,714417617	2,5198421	3,107232506	3,556893304	2,974596382
K7	3,914867641	3,634241186	3,107232506	3,634241186	3,57264563
K8	8,572618882	8,276772529	8,962809493	8,276772529	8,522243358
K9	4,160167646	4,160167646	4,57885697	3,77976315	4,169738853
K10	7,268482371	7,559526299	6,95205329	7,651724731	7,357946673
K11	8,276772529	7,651724731	8,276772529	7,958114416	8,040846051
K12	4,481404747	3,914867641	4,160167646	4,30886938	4,216327353
K13	7,663094324	8,14325285	7,398636223	7,113786609	7,579692501
K14	7,230426793	7,559526299	7,829735282	7,488872387	7,52714019
K15	7,113786609	7,047298732	7,047298732	7,368062997	7,144111768
K16	2,289428485	2,620741394	2,620741394	1,817120593	2,337007967
K17	3,301927249	2,884499141	2,620741394	1,817120593	2,656072094
K18	1,817120593	1,44224957	2,289428485	1,817120593	1,84147981
K19	2,289428485	2,884499141	1,587401052	2,620741394	2,345517518

The constituent components of water coolant pump is as follows:



**Fig.3** Diagram of the constituent components Coolant Water Pump

### 3.2 Development of models

Model to get the time interval replacement optimal critical component of each component can be described as follows:

#### a. Inputs

- Date component failure (TTF), see appendix 3.
- Percentage change intervals components against premature damage;  $K = 50\%$ .
- Cost of Replacement item and other damaged items
- The cost of replacement component (CRC), see appendix
- parameter distribution (weibull 3 parameters); , See Annex 6.

#### b. Equations

- Mean Time Between Failure (MTBF)

$$MTBF = \frac{1}{N_f} \sum_{i=1}^{N_f} (t_{fi} - t_{fi-1})$$

where:

tf = time required until the occurrence of damage (flight hours)

Nf = Number of components that have been damaged.

- The cost of replacement before damage ( $C_{BF}$ )

$$C_{BF} = (t_{BF} \times C_M) + C_{RC}$$

- The cost of replacement after damage ( $C_{AF}$ )

$$C_{AF} = (t_{AF} \times C_M) + C_A$$

#### c. Constrain

- Percentage of equipment can survive for-replacement interval ( $N_s$ )  $50\% \leq N_s \leq 99\%$

- Long before damage repair (TBF)  $5 \leq TBF \leq 15$  (in hours)
- Long repair after damage (TAF)  $1 \leq TAF \leq 5$  (in hours)
- Values to Reliability ( $R(t)$ );  $0.99 \leq R(t) \leq 1,00$ 
  - Labor costs ( $C_M$ )
  - Organic Labor Cost Levels ( $C_{MO}$ );  $C_{MO} = \$10.00$
  - Labor costs Intermediate ( $C_{MM}$ );  $C_{MM} = \$20.00$
  - Labor costs Depo Levels ( $C_{MD}$ );  $C_{MD} = \$35.00$

#### d. Output (Decision Variabel)

The time interval component replacement.

#### e. Objective Function

Minimize Cost Benefit Ratio:

$$CBR = \frac{MTBF \times [(C_{BF} \times N_s) + \{C_{AF} \times (1 - N_s)\}]}{(C_{AF} \times t_r) \times [N_s + \{K \times (1 - N_s)\}]}$$

Where :

CBR = Cost Benefit Ratio

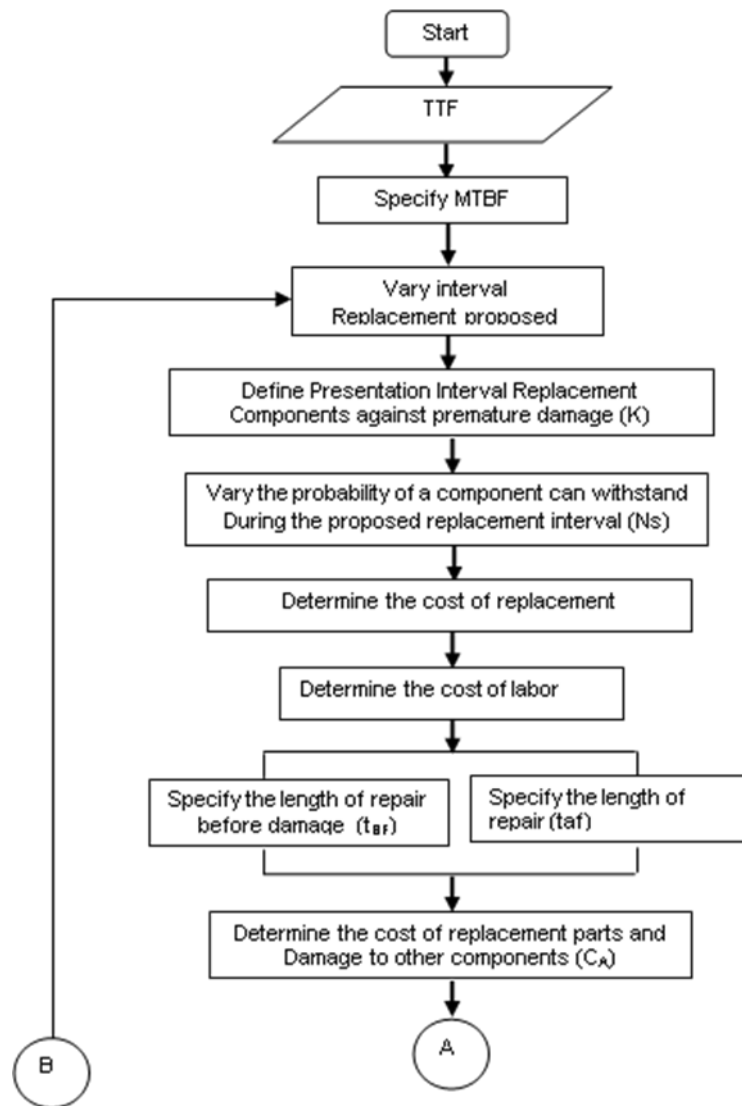
MTBF= Mean Time Between Failure

$C_{BF}$  = Cost of rework/replacement before failure

$N_s$  = Percentage of equipment can last as long as the replacement interval

$C_{AF}$  = Cost of rework/replacement after failure

K = The percentage of component replacement intervals against premature damage.



**Fig.4** Flowchart Optimization Model Development Time Interval Replacement

### 3.3 Analysis

Based on the steps Failure Mode Effects and Criticality Analysis (FMECA) in Table 3.1, it is automatically determined in this paper can be a critical component in accordance with the cumulative result of a number of Risk Priority

Number (RPN) is from 19 chance of damage to the components that have gained 9 criticality namely Angular Bearings, Cylindrical Bearings, Spacer Ring, Water Seal, Shaft Seal, Seal Slip Ring, Impeller, O'ring and Shaft

**Tabel 2.** Critical Components Based RPN Value

No	Part	Rank	RPN
1	ANGULAR BEARING	4	7,97
2	CYLINDRICAL BEARING	2	8,14
3	SPACER RING	7	7,43
4	WATER SEAL	1	8,52
5	SHAFT SEAL	8	7,35
6	SLIP RING SEAL	3	8,04
7	IMPELLER	5	7,57
8	O'RING	6	7,52
9	SHAFT	9	7,14

Optimization of the results obtained by determining the time interval replacement intervals earlier replacement is Cylindrical bearing that is 98 days while the longest time on Impeller replacement

interval is 134 days, from the results of this optimization indicates the Reliability of each component are experiencing criticality is at  $0.99 \leq R(t) \leq 1$ .

**Table 3.** Value Reliability Each component After Optimization

No	Part	MTBF (Day)	Time Replacement (t <sub>r</sub> )	Reliability
1	ANGULAR BEARING	283	121	0,990000843
2	CYLINDRICAL BEARING	282	98	0,990000634
3	SPACER RING	282	103	0,990000664
4	WATER SEAL	290	126	0,990000253
5	SHAFT SEAL	288	126	0,990000506
6	SLIP RING SEAL	282	128	0,990000200
7	IMPELER	270	134	0,99000016
8	O-RING	308	131	0,990000224
9	SHAFT	306	131	0,990000494

Based on the time interval replacement in mind that the cost of replacement parts is efficient,

it is characterized by the value of the Cost Benefit Ratsio (CBR) optimal, CBR value is <1.

**Table 4.** Calculation Results Component Replacement Cost Optimization

No	Part	Time Replacement (t <sub>r</sub> ) (Day)	Cost Before Failure	Cost After Failure	CBR
1	ANGULAR BEARING	121	\$ 12.100	\$ 80.100	0,3753
2	CYLINDRICAL BEARING	98	\$ 12.100	\$ 80.100	0,4629
3	SPACER RING	103	\$ 7.550	\$ 80.050	0,2837
4	WATER SEAL	126	\$ 4.550	\$ 80.050	0,1593
5	SHAFT SEAL	126	\$ 3.550	\$ 80.050	0,1283
6	SLIP RING SEAL	128	\$ 2.625	\$ 80.050	0,0941
7	IMPELLER	134	\$ 18.675	\$ 80.050	0,5135
8	O-RING	131	\$ 2.550	\$ 80.050	0,1018
9	SHAFT	131	\$ 18.175	\$ 80.175	0,5778

#### 4. CONCLUSIONS AND SUGGESTIONS

From analysis and discussion that has been done in previous chapters, some conclusions can be made as follows:

- a. Based on the steps failure mode effects and criticality analysis (FMECA) through the calculation of risk priority number (RPN), so we can determine the critical components of acquired 9 19 chances damage critical components that have that angular bearings, cylindrical bearings, spacer ring, water seal, shaft seal, slip ring seal, impeller, o'ring and shafts.
- b. In the optimization calculation using the program solver excel against all critical components result interval replacement optimal time (tr). the results of the analysis show that the component has a cylindrical bearing early replacement to maintain

the reliability that is 98 days. whereas the replacement of components with the longest time, that 134 days is a component of the impeller.

- c. Based on the table optimization can be seen that the cost of replacement parts is efficient, it is characterized by the value of cost benefit ratsio (CBR) optimal, value cbr <1. This case shows that the costs incurred in the maintenance of a component to be replaced before the components are broken and no effect all other components, is much more efficient, when compared to the replacement of the faulty component after component.

Based on the efforts that have been made in this study, the authors feel the need to give suggestions:



- a. The need for follow-up and updating of the results of research that method of determining the replacement interval can contribute to the maintenance efforts and increase endurance at sea for kri types di jajaran Koarmatim FPB57 during surgery.
- b. The need for evaluation of treatment methods kri fpb57 types that have been implemented over the years, so that the weapon system readiness owned by the Navy is able to support its core functions, namely maintaining state sovereignty and enforce the law at sea.
- c. For a similar study researchers can then use other methods.

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