

# ANALYSIS OF REPLACEMENT PART TIME INTERVAL DETERMINATION OF CRITICAL WATER IN ENGINE 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 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.

Of 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 Interval, CBR.

## 1. Introduction

Indonesia is a maritime country, the country that most of the regions are islands separated by oceans. So KRI as one element of the Integrated Fleet Weapon System has a strategic role to be able to realize the success of the main tasks of the Navy in the region to uphold the rule of law and national jurisdiction waters of Indonesia. KRI types FPB57 (Fast Patrol Boat) is one of the main tools of weapons systems (Alutsista) Navy which has a high-frequency activity, as well as the broad range of operations support capabilities are varied.

Determining the appropriate measures to carry out the treatment in order to prevent damage is not an easy thing. The measures need to be synergized between technical requirements and strategic management (Sachdeva et al, 2009). Determination of critical components and the time interval replacement of damaged / malfunctioning by using the method FMECA is important in this writing, so that the engine KRI not experience a break down while conducting marine operations.

KRI maintenance budget constraints is one of the types of triggers FPB57 implemented during this maintenance is

restricted to the user guide technical order in which underestimated the residual lifetime of a component or in other words as long as the component has not been damaged then these components will still be used. This at a time, it will result in a sizeable penalty cost if the policy is applied continuously carry out maintenance will result in a high financial burden. According to (Kim Jaehoon at all, 2013), the research optimization maintenance tasks can improve the efficiency, reliability and safety of the brake system Railways. In connection with this study required a maintenance activities (maintenance task) are optimum, namely the achievement of the level of component reliability by determining the replacement interval of critical engine components KRI FPB57 types.

**2. Damage Model.**

According Hoyland (1994), Model destruction of a component or system in general, can be expressed in equation (1). Figure 2.1 shows the relationship between the state variables  $X(t)$  with a time of TTF damage.

$$X(t) = \begin{cases} 1 & \text{jika komponen berfungsi pada waktu } t \\ 0 & \text{jika komponen gagal pada waktu } t \end{cases} \quad (1)$$

where:

$X(t)$  = The relationship between the state variables representing the condition of the components at time  $t$

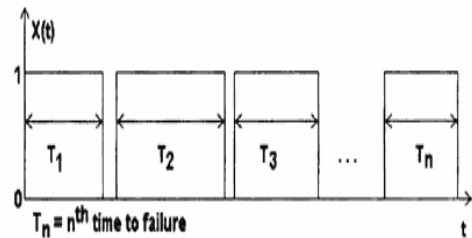


Figure 2.1. The relationship between the variables and the time between failures of a component (source: Hoyland, 1994)

Time decay,  $T$ , of a failure mode can follow one of the distributions such as normal, exponential, Weibull, or other distributions.

Model of damage can be determined by collecting data damage from failure modes are analyzed. Illustration of data damage a component can also be seen in Figure 2.1.

**2.1 The cumulative distribution function (CDF) and density function (PDF)**

Assuming that the TTF continuously distributed with probability density function (pdf)  $f(t)$ , then the probability that a component will fail in the interval  $(0, t)$  can be expressed by the equation:

$$F(t) = P(T \leq t) = \int_0^t f(t) dt \quad (2)$$

where:

$F(t)$  = the cumulative distribution function (cdf) of the random variable  $T$ . Probability density function (pdf) of the random variable  $T$  can be determined from equation (2) by taking the derivative of  $F(t)$  against  $t$  as shown in equation (3).

$$\begin{aligned} f(t) &= \frac{d}{dt} F(t) = \lim_{\Delta t \rightarrow 0} \frac{F(t + \Delta t) - F(t)}{\Delta t} \\ &= \lim_{\Delta t \rightarrow 0} \frac{P(t < T \leq t + \Delta t)}{\Delta t} \end{aligned} \quad (3)$$

**2.2 Reliability Function**

According Hoyland (1994), the reliability function is a function that represents the probability that a component will not be damaged in the time interval  $(0, t)$  and it is expressed by the equation:

$$R(t) = 1 - F(t) = P(T > t) = \int_t^{\infty} f(t) dt \quad (4)$$

Equation (2) can also be referred to as non-mainstay function (Unreliability) and is expressed by  $Q(t)$

**2.3 Failure Rate**

Basically the damage that occurs in a system is a deviation from the proper circumstances, either directly or indirectly result of the operation of these systems. Damage that occurs during the operation showed damage rate (failure rate) of the system. According to Abdullah Alkaff (1992), the rate of damage to denote the number of damage that occurs per unit time. Suppose from an experiment to a number of components / equipment similar number  $N(0)$  are operated simultaneously, noting how many components are still in operation at the time  $t$ , for example  $N(t)$ . Then, noting the number of components that are still in operation at the

time  $t + \Delta t$ , eg expressed by  $N(t + \Delta t)$ . Thus obtained:

- The number of damaged components in the interval  $(t, t + \Delta t)$  are:

$$N(t) - N(t + \Delta t) \quad (5)$$

- The number of damaged components per unit time is:

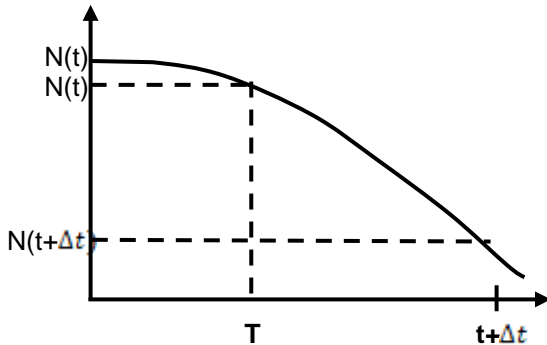
$$\frac{N(t) - N(t + \Delta t)}{\Delta t}$$

(6)

- The amount of damage relative per unit time is

$$\frac{N(t) - N(t + \Delta t)}{N(t)\Delta t} \quad (7)$$

In the graph can be described as follows:



**Figure 2.2.** Failure Rate  
(source : Hoyland, 1994)

If taken shortly observation, namely to near 0 ( $\Delta t \rightarrow 0$ ), it will obtain the rate of destruction of  $\lambda(t)$ , namely:

$$\lambda(t) = \lim_{\Delta t \rightarrow 0} \frac{N(t) - N(t + \Delta t)}{N(t)\Delta t} \quad (8)$$

$$\lambda(t) = \lim_{\Delta t \rightarrow 0} \frac{\frac{N(t) - N(t + \Delta t)}{N(0)} - \frac{N(t)}{N(0)}}{\frac{N(t)}{N(0)} \Delta t} \quad (9)$$

$\frac{N(t)}{N(0)}$ : The proportion of the number of components that are still in operation up to the time  $t$ .

$\approx$  Probability of equipment / components that are still in operation at the time  $t$

$\approx R(t)$  = the reliability of the equipment / components. so that:

$$\lambda(t) = \lim_{\Delta t \rightarrow 0} \frac{R(t) - R(t + \Delta t)}{R(t)\Delta t} \quad (10)$$

$$\lambda(t) = \frac{-1}{R(t)} \lim_{\Delta t \rightarrow 0} \frac{R(t + \Delta t) - R(t)}{\Delta t}$$

$$\lambda(t) = -\frac{R'(t)}{R(t)} = \frac{f_r(t)}{R(t)}$$

then :  $\lambda(t) = -\frac{R'(t)}{R(t)} \quad (11)$

$$\int_0^t \lambda(x) dx = -\int_0^t \frac{R'(x)}{R(x)} dx = -\int_0^t \frac{dR(x)}{R(x)}$$

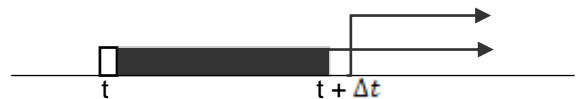
$$= -\ln R(x) \Big|_0^t = \ln R(t) + \ln R(0) = -\ln R(t)$$

So  $R(t) = \exp\left(-\int \lambda(x) dx\right) \quad (12)$

Function  $\lambda(t)$  (failure rate) above the rate of decay is called a moment, which is better known as a function of the damage (Hazard Function / Instantaneous Failure)  $h(t)$ , and  $\int_0^t h(t) dt = H(t)$  is called Integrated Hazard Function.

Failure rate can also be written as follows:

$$\lambda(t) = \lim_{\Delta t \rightarrow 0} \frac{R(t) - R(t + \Delta t)}{R(t)\Delta t} = \lim_{\Delta t \rightarrow 0} \frac{P(T > t) - P(T > t + \Delta t)}{P(T > t)\Delta t}$$



**Figure 2.3** Failure Rate  
(Source : Hoyland, 1994)

$$= \lim_{\Delta t \rightarrow 0} \frac{P(t < T \leq t + \Delta t)}{P(T > t)\Delta t}$$

$$= \lim_{\Delta t \rightarrow 0} \frac{P(T > t \text{ dan } T \leq t + \Delta t)}{P(T > t)\Delta t} ;$$

because  $P[B/A] = \frac{P(A \cap B)}{P[A]}$

$$= \lim_{\Delta t \rightarrow 0} \frac{P(T \leq t + \Delta t | T > t)}{\Delta t} \quad (13)$$

With the approach can be written:

$$\lambda(t)\Delta t \approx P(T \leq t + \Delta t | T > t)$$

: Represents the probability of the components that until now have not yet broken and no later than  $\Delta t$  the longer

### 3. Probability Distributions

#### 3.1 Weibul Distribution

Weibull distribution is widely used in the reliability analysis, especially to perform calculations component life. This type of distribution is also one of the most widely used distributions field of engineering, reliability, this is because the distribution has the ability to model the data differently and more by setting the value of shape parameter  $\beta$ . According to Jardine (1973), Weibull distribution can be presented in the form of two or three parameters. Pdf function of the third parameter Weibull distribution is expressed by

$$MRL(t) = \frac{1}{R(t)} \left[ MTTF - \int_0^t R(t) dt \right] \quad (14)$$

Where :

$\beta$  = parameter form,  $\beta > 0$   
 $\eta$  = Parameter Scale,  $\eta > 0$   
 $\gamma$  = location parameter,  $\gamma \leq \_$  when damage first.

Weibull distribution reliability function can be expressed by:

$$f(t) = \frac{\beta}{\eta} \left( \frac{t-\gamma}{\eta} \right)^{\beta-1} e^{-\left(\frac{t-\gamma}{\eta}\right)^\beta} \quad (15)$$

Weibull reliability distribution function can be expressed by

$$R(t) = e^{-\left(\frac{t-\gamma}{\eta}\right)^\beta} \quad (16)$$

Laju kerusakan dapat dinyatakan dengan :

$$\lambda(t) = \frac{\beta}{\eta} \left( \frac{t-\gamma}{\eta} \right)^{\beta-1} \quad (17)$$

If  $\gamma = 0$  then obtained a Weibull distribution with two parameters.

If  $\beta > 1$ , then at  $t = \text{large}$  pdf pdf equal to zero as well as the rate of destruction is equal to zero, consequently the value of reliability  $R(t) = 1$ , see equation (15) to pdf and equation (16)  $R(t)$  and the equation (17) to  $\lambda(t)$ . The larger the value  $\eta$  a component, then the probability of broken components will be smaller (equation 16). If the value  $\eta$  component A is greater than the component B, then the value of the reliability of components and a faster decline than the component A.

#### 3.2 Exponential distribution

The exponential distribution is widely used in engineering reliability, because it can present the distribution of the time distribution phenomenon that failure of a component / system. According to Abdullah Alkaff (1992), the exponential distribution density function is expressed in the equation:

$$f(t) = \lambda e^{-\lambda t} ; t > 0, \lambda > 0 \quad (18)$$

and the cumulative distribution function is:

$$F(t) = 1 - e^{-\lambda t} \quad (19)$$

Where:

$t$  = Time

$\lambda$  = *Constan failure rate*

Reliability function is :

$$R(t) = 1 - F(t) = e^{-\lambda t} \quad (20)$$

Failure Rate :

$$\lambda(t) = \frac{f(T)}{R(t)} = \lambda \quad (21)$$

$$MTTF = \int_0^{\infty} R(t) dt = \frac{1}{\lambda} \quad (22)$$

### 3.3 Normal distribution

According to Jardine (1973), the normal distribution (Gaussian) is useful for menggambarkan pengaruh accretion can specify the time when the time between failures associated with the uncertainty, the normal distribution has the following formula:

$$f(t) = \frac{1}{\sigma\sqrt{2\pi}} \exp\left[-\frac{(t-\mu)^2}{2\sigma^2}\right]$$

for  $-\infty \leq t \leq \infty$  (23)

Where :

$\sigma$  = the standard deviation of the random variable T

$\mu$  = the average of the random variable T

And the cumulative distribution function is:

$$F(t) = \frac{1}{\sigma\sqrt{2\pi}} \exp\left[-\frac{(t-\mu)^2}{2\sigma^2}\right] dt$$

Reliability function of the normal distribution is

$$R(t) = \int_t^{\infty} \frac{1}{\sigma\sqrt{2\pi}} \exp\left[-\frac{(t-\mu)^2}{2\sigma^2}\right] dt \quad (24)$$

The rate of destruction of the normal distribution can be obtained using the equation:

$$\lambda(t) = \frac{\exp\left[-(t-\mu)^2 / 2\sigma^2\right]}{\int_t^{\infty} \exp\left[-(t-\mu)^2 / 2\sigma^2\right] dt} \quad (25)$$

## 4. 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:

- Identify potential failure modes for a product or process.
- Assess the risks associated with the failure modes and prioritize issues for corrective action
- 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 analysis kekritisan. Assuming that the system

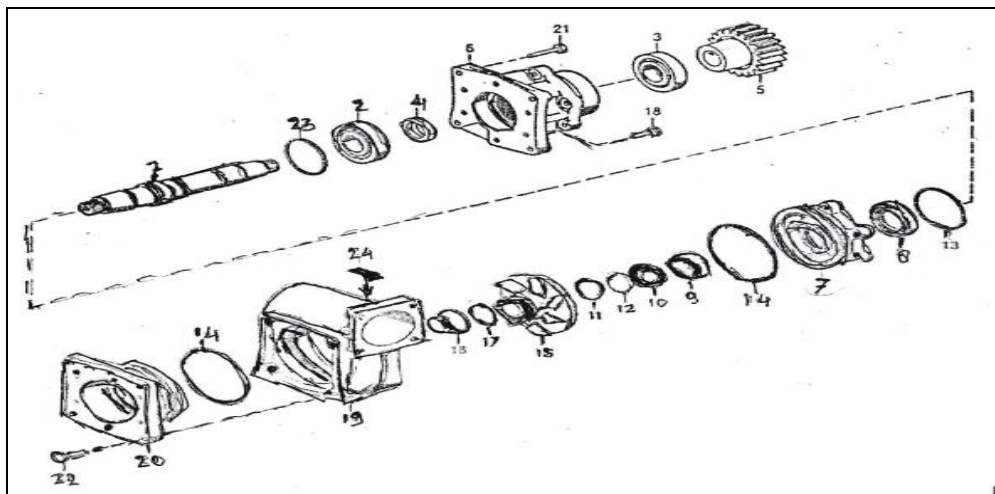
components tend to fail in many ways, this information is used to describe the most critical aspects of the system Desai.

- 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.

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

### 5. 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..



**Figure 5.1** Water Coolant Pump

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

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

**6. METHOD**

**6.1 Determination of critical components with FMECA**

Based on Figure 5.1, 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 6.1)

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 6.1** critical component is based on the value of the highest RPN

Kerusakan	Risk Priority Number				
	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:

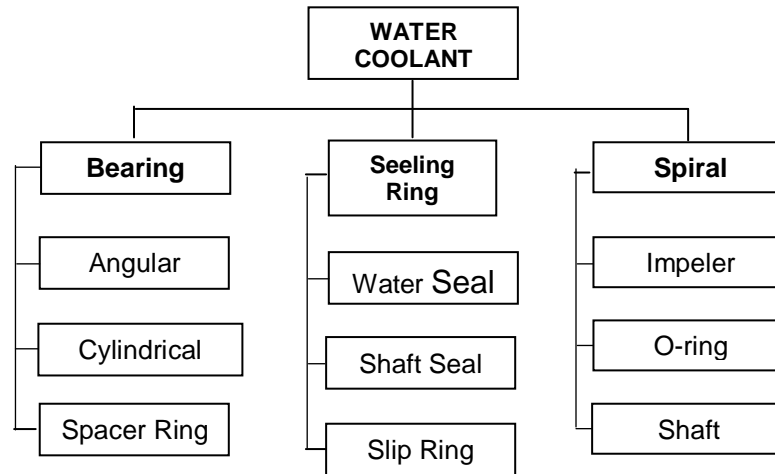


Figure 6.1 Diagram of the constituent components Coolant Water Pump

### 7. development of models

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

- **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.

- **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 ( $C_{AF}$ )

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

- **Constrain**

- Percentage of equipment can survive for-replacement interval (Ns)  $50\% \leq N_s \leq 99\%$
- 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 ( $C_{MD}$ );  $C_{MD} = \$35.00$

- **Ooutput (Decision Variabel)**

The time interval component replacement.

- **Fungsi objektif (Objective Function)**

Minimize Cost Benefit Ratio:



$$CBR = \frac{MTBFx[(C_{BF}xN_s) + \{C_{AF}x(1 - N_s)\}]}{(C_{AF}xI_r)x[N_s + \{Kx(1 - N_s)\}]}$$

Where :

CBR = Cost Benefit Ratio

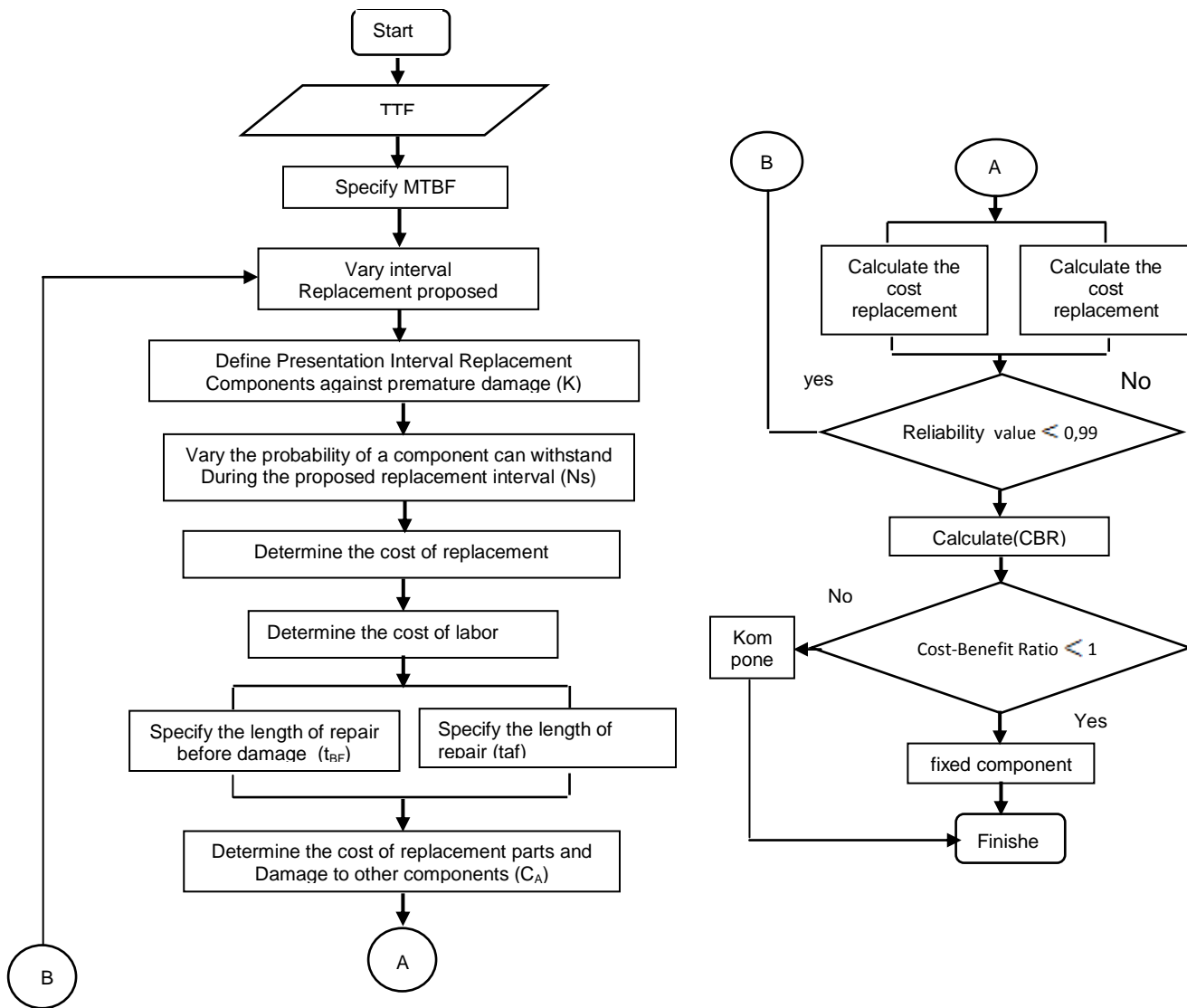
MTBF = Mean Time Between Failure

C<sub>BF</sub> = Cost of rework/replacement  
before failure

N<sub>S</sub> = Percentage of equipment can  
last as long as the replacement  
interval

I<sub>C<sub>AF</sub></sub> = Cost of rework/replacement  
after failure

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



**Figure 7.1** Flowchart Optimization Model Development Time Interval Replacement

## 8. Analysis Results and discussion

Based on the steps Failure Mode Effects and Criticality Analysis (FMECA) in Table 6.1, 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

**Table 8.** Critical Components Based RPN Value

No	Komponen	Rangking	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 8.2** Value Reliability Each component After Optimization

No	Komponen	MTBF (Hari)	Waktu Penggantian (t)	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 8.1** Calculation Results Component Replacement Cost Optimization

No	Nama Komponen	Waktu Penggantian $t_r$ (Hari)	Biaya Penggantian Sebelum kerusakan	Biaya Penggantian Setelah kerusakan	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

## 9. Conclusions and suggestions

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

1. 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.
2. In the optimization calculation using the program solver excel against all critical components result interval replacement optimal time ( $t_r$ ). 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.

3. 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:

1. 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.

2. 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.
3. For a similar study researchers can then use other methods.

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