RELIABILITY ANALYSIS FOR CRITICAL COMPONENTS OF RSG-GAS PRIMARY COOLING SYSTEM

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ABSTRACT

RELIABILITY ANALYSIS FOR CRITICAL COMPONENTS OF RSG-GAS PRIMARY COOLING SYSTEM. Reliability is the probability that a system will function normally when it is used for the desired time period under specific operating conditions. This study aims to analyze the reliability, distribution function of damage and rate of damage by using the frequency data of damage, downtime and time data between the damage of each component on the primary cooling system RSG- GAS. The methodology used is the test of damage distribution estimated as an exponential distribution. The exponential distribution test uses the Bartlett test. Furthermore, parameter estimation is carried out from the data distribution. Based on the parameters of the data distribution, the reliability and rate of damage can be calculated for the critical component of the primary cooling system. Critical components are components that often experience damage with high downtime. Damage data is obtained from maintenance data for core cycle of 70 until 88 (year 2010-2015). The results showed that in the primary cooling system the highest failure occurred for the primary pump component, namely JE-01 (AP01-02) with downtime = 112 (days) and failure frequency presentation = 75%. The failure rate (λ) of 0.000215438 results in the reliability value for the year 2015 of 99.83 %.

Keywords: downtime, damage frequency, reliability, maintenance, RSG-GAS

ABSTRAK

ANALISIS RELIABILITY UNTUK KOMPONEN KRITIS PADA SISTEM PENDINGIN PRIMER RSG-GAS. *Keandalan merupakan probabilitas suatu sistem akan berfungsi secara normal ketika digunakan untuk periode waktu yang diinginkan dalam kondisi operasi yang spesifik. Penelitian ini bertujuan menganalisis reliability, fungsi distribusi kerusakan dan laju kerusakan dengan menggunakan data frekuensi kerusakan, downtime dan data waktu antar kerusakan dari setiap komponen pada sistem pendingin primer RSG-GAS. Metodologi yang digunakan adalah Uji distribusi kerusakan yang diestimasikan sebagai distribusi eksponensial. Uji distribusi eksponensial menggunakan uji Bartlett. Selanjutnya dilakukan estimasi parameter distribusi data. Berdasarkan parameter dari distribusi data tersebut maka reliability dan laju kerusakan dapat dihitung untuk komponen kritis sistem pendingin primer. Komponen kritis merupakan komponen yang sering mengalami kerusakan dengan downtime tinggi. Data kerusakan diperoleh dari data maintenance untuk teras 70 sampai 88 (2010-2015). Hasil penelitian menunjukkan bahwa pada sistem pendingin primer kerusakan tertinggi terjadi untuk komponen pompa primer yaitu JE-01(AP01-02) dengan downtime= 112 hari dan presentasi frekuensi kerusakan= 75 % . Laju kerusakan (λ) adalah sebesar 0,000215438 sehingga nilai reliability untuk tahun 2015 adalah sebesar 99.83 %.*

Kata kunci: *downtime,frekuensi kerusakan, keandalan, maintenance, RSG-GAS*

PENDAHULUAN

Aging is one of the problem in the RSG-GAS system/component. In this case to ensure the availability of the system/ component of the repaired process plays a very important role. Therefore, a good reliability management is required order to predict damage to the component/ system and it can be given proper maintenance on all systems and components so as to support the aging management of RSG-GAS [1-6].

Reliability management is an activity to ensure no failure of the component/system during operation or minimize the failure and its causes for the optimization. Knowing the criticality of the component/system is expected to define the strategy and priority of the appropriate maintenance work program to improve the reliability of the RSG-GAS component/system [5, 7-10].

Maintenance pattern is one of the important factors in supporting a reactor operation. The reactor operation must be supported by reliable system/component. Those system/ component reactor operation should be carried out regular maintenance and planned. Maintenance planning following preventive condition base maintenance, monitoring the condition of the equipment periodically by always doing the analysis. This is necessary for maintenance to take place at the right time, both technically, economically and safely. The expectation of maintenance is high reliability by maximizing the life of the systems/components and the effective utilization of maintenance costs[11-15].

This research was conducted to analyze the reliability of component of RSG-GAS primary cooling system for core configuration number 70 to 88. Primary cooling system is the main system of reactor operation, so maintenance management must ensure no failure of system/component at the time of operation. Reliability analysis is performed to find out how much chance of reliability of primary cooling system components, as the basis of decision making maintenance. Reliability analysis performed on the critical component, component with the value of downtime and high damage frequency.

The purpose of this research is to conduct the process of reliability management approach by performing the functions of the distribution of failure, the rate of failure and reliability analysis using data from frequency of failure, down time and the time data between the failures of each component on the primary cooling system RSG-GAS.

The methodology used in this research is to calculate the function of failure distribution and component reliability function of primary cooling system RSG-GAS based on data of failure time from 2010-2015 maintenance data (core configuration number 70 to 88). Estimated distribution of exponential component distribution damage. These results can be used for aging RSG-GAS management system.

THEORY

Primary cooling system

The primary cooling system comprises primary pumps and heat exchangers located within the reactor primary space. These components are connected to the pond and the reactor core by means of a pipe to form a closed circuit. The insulation valves are installed in the primary cooling system piping circuit on the exit side and enter the reactor pool to avoid LOCA (Loss of Coolant Accident) occurrence in the reactor pool.

Reliability

Reliability can be defined as the probability that the system will perform according to the functionality required for a given period of time. Based on the above definition, then there are some things to note, namely:

- Probability, where the value of reliability is between 0 and 1.
- Time, an important parameter for assessing the likelihood of success of a system.
- Environmental conditions, affect the life of the system or equipment such as temperature, humidity and velocity.

This explains how the treatment received by the system can provide different levels of reliability under its operational conditions. If R(t) denotes the reliability function of a component or a system as a function of time then the relation between the reliability function R(t) and the distribution The cumulative damage or F(t) functionality is related by a formula below [7]:

$$R(t) = 1 - F(t) \quad \text{.....} \quad (1)$$

The probability distribution function is a derivative of a cumulative probability distribution. In terminology the reliability of the probability distribution function is called failure density function. The density function of this damage, denoted by f(t), can be derived from both the mainstay function and the reliability functions of the formula below:

$$f(t) = \frac{dF(t)}{dt} = -\frac{dR(t)}{dt} \quad \text{.....} \quad (2)$$

The function of reliability can be obtained from the density function of damage as written in the formulation below[6].

$$F(t) = \int_0^t f(t)dt \quad \text{.....} \quad (3)$$

and

$$R(t) = 1 - \int_0^t f(t)dt = \int_t^\infty f(t)dt \quad \text{.....} \quad (4)$$

If the density function of the damage is denoted f (t), then the damage rate can be formulated as follows:

$$\lambda(t) = \frac{f(t)}{R(t)} \quad \text{.....} \quad (5)$$

Time to Failure Distribution Test.

In this research, the distribution of component failure is estimated to be an exponential distribution. Selection of this form of distribution because the components studied are components that are mechanical then the data will tend to form exponential distribution patterns. To test that the time pattern estimation between breakage of primary pump component corresponds to the exponential distribution, goodness of fit testing time distribution between failure is performed. The stages in testing the exponential distribution are as follows:

1. Determination of the hypothesis
   H_0=exponential distribution function of failure
   H_1=damage function is not exponentially distributed
2. Determination of trust level
3. Determination of the value of λ (rate of damage) on the exponential distribution.

Test the exponential distribution using the Bartlett test by using χ^2 statistic. The test statistic is expressed in equation (6):

$$B = \frac{2n\left\{\ln\left(\frac{1}{n}(\Sigma t_i)\right) - \left[\frac{1}{n}\Sigma \ln(t_i)\right]\right\}}{\left(1 + \frac{(n+1)}{6n}\right)} \quad \text{.....} \quad (6)$$

Where:

t_i = time data between i-th damage
n = amount of damage
B= value of statistical test for Bartlett test

Exponential Distribution

The exponential distribution is used to calculate reliability that has a constant rate of damage. This distribution has a fixed rate of damage over time. Exponential distribution is easy to identify and analyze. If there is a component of a system with rate of damage occurs regularly then the failure data is included in the exponential distribution. The parameters used indicate the average value of damage that occurred. The functions of the exponential distribution are :

- The probability density function, expressed as:

$$f(t) = \lambda e^{-\lambda t} \quad (7)$$

- The cumulative distribution function, expressed as:

$$F(t) = 1 - e^{-\lambda t} \quad (8)$$

- The reability density function, expressed as:

$$R(t) = e^{-\lambda t} \quad (9)$$

- The failure rate function, expressed as:

$$r(t) = \lambda \quad (10)$$

METHODOLOGY

The methodology used in this research is to calculate the damage distribution function and component reliability of the RSG-GAS primary relief system based on data downtime and time between damage from the maintenance data of core configuration number 70 to 88 (2010-2015). The steps taken are:

1. Collecting data from downtime, frequency, percentage of damage frequency and time between damage from the primary and secondary cooling system components.
2. Downtime diagram, percentage of damage frequency of components
3. The distribution test is estimated as an exponential distribution
4. Estimation of exponential distribution parameters
5. Perform calculation of damage distribution function, failure rate and reliability function

Analysis procedure flowchart as proposed to systematize the data analysis processes is shown in Figure 1.

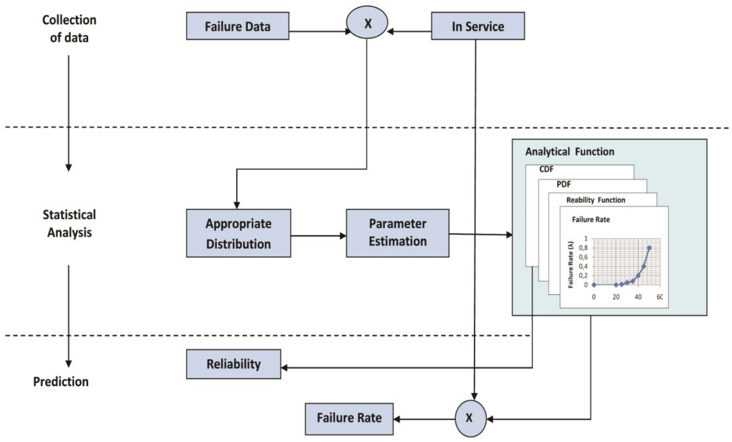

Figure 1. Analysis procedure flowchart as proposed to systematize the data analysis processes

Result of colecting maintenance data on primary cooling system of RSG- GAS analyzed are shown in Table 2. Based on Table 2 data, in addition to the above three components during the year of 2010-2015, there is no damage occured. The diagram for data maintenance of RSG-GAS primary cooling system of the for failure frequencies precentage is shown in Figure 2. While The diagram of downtime for the primary cooling system is shown in Figure 3.

Table 2. Downtime and damage frequency of maintenance data on RSG-GAS primary cooling system from 2010 to 2015 [6]

Sub System	Component	Code	Downtime (days)	Frequency of Damage	Percentage Frequency of Damage (%)
Primary cooling system	Primary pump	JE-01(AP01-02)	112	9	75 %
	Instrumentation of the primary system The ultrasonic censor water level indicator	JAA01 (CL001)	18	2	16.67 %
	Automatic trip reactor	SPR (JE-01 CT811/821/831)	6	1	8.33 %

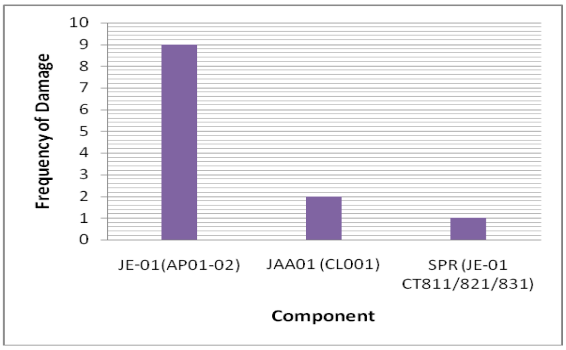

Figure 2. Percentage of damage frequency on components RSG-GAS primary cooling system from 2010-2015

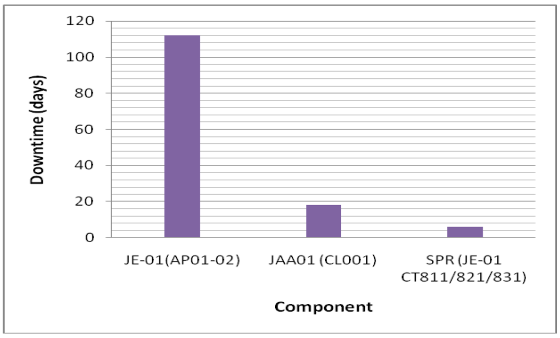

Figure 3. Downtime components of the primary cooling system RSG-GAS from 2010-2015

Based on the results of Figure. 2, the percentage of damage frequency of the primary system components RSG-GAS high category of 75 % for components JE-01 (AP01 -02), and low category of 16.67 % for JAA01 (CL001) and 8.33 % for SPR (JE-01 CT811). Based on Fig. 3, downtime components of the RSG-GAS primary cooling system high category of 112 days for component JE-01 (AP01-02), and low category of 18 days for JAA01 (CL001) and 6 days for SPR (JE-01 CT811/821/831). The mean downtime for component JE-01(AP01-02), JAA01 (CL001) and SPR (JE-01 CT811/821/831) are 12.9 and 6 days respectively.

Reliability analysis on the primary cooling system is performed for the component with the highest frequency breakdown and downtime presentation, for the JE-01(AP01-02) component. The time data between the JE -01(AP01-02) component primary pump failure for the core configuration number 70 to 88 is shown in Table 3 [5-6,8].

Table 3. Time data between damage of components JE-01 (AP01-02)

Core configuration	Date of damage	Time between failures
75	24-06-2011	0
76	13-11-2011	3408
77	8-12-2011	840
79	3-7-2012	4992
83	12-06-2013	8256
85	07-03-2014	6480
85	01-04-2014	600
87	18-02-2015	7752
88	04-08-2015	4008

From the above data, an exponential distribution matching test was performed using the formula (6). After calculation for distribution test using Chisquare (χ^2) then for time data between damage JE-01(AP01-02) component obtained value B = 4.282.

The results are compared with χ^2 tables. The test criterion is accept the hypothesis that the data is exponentially distributed if $\chi^2_{(0.975,7)} < B < \chi^2_{(0.025,7)}$ and rejected otherwise. Based on table χ^2, obtained value $\chi^2(_{0.975,7}) = 1.69$ and $\chi^2_{(0.025,7)} = 16.013$. based on these results the hypothesis is accepted, the data is exponentially distributed [9]. After the exponential distribution test is done, then exponential parameter estimation is λ (rate of damage). Exponential parameter estimation results for the JE-01 (AP01-02) component are shown in Table 4.

Table 4. Estimated exponential distribution parameters

Component	Failure rate (λ)
JE-01(AP01-02)	0.000215438

Having known the exponential distribution parameter values λ, then the next step is to determine the functions of the distribution of da-mage, and reliability functions. Functionality of damage distribution and reliability functions for JE-01 (AP01-02) components [11-12]. The failure distribution function and reliability functions for JE-01AP01-02 components can be shown in Table 5 and Figure 4-7.

Table 5. Function distribution of damage and reliability functionality of component JE-01(AP01-02) of RSG-GAS cooling system from 2010 to 2015

Periode (t)	Cumulative distribution function F(t)	Probability density function f(t)	Failure rate function (λ)	Reliability function R(t)
1	0.000215415	0.000215391	0.000215438	0.999784585
2	0.000430783	0.000215345	0.000215438	0.999569217
3	0.000646105	0.000215299	0.000215438	0.999353895
4	0.000861381	0.000215252	0.000215438	0.999138619
5	0.00107661	0.000215206	0.000215438	0.99892339
6	0.001291793	0.00021516	0.000215438	0.998708207
7	0.001506929	0.000215113	0.000215438	0.998493071
8	0.00172202	0.000215067	0.000215438	0.99827798

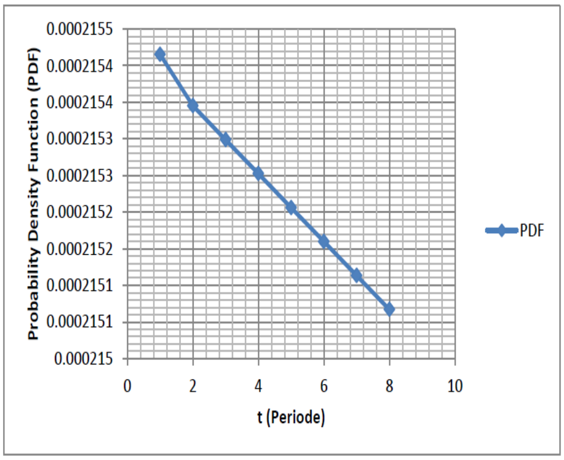

Figure 4. Probability Density Function of JE-01 (AP01-02)

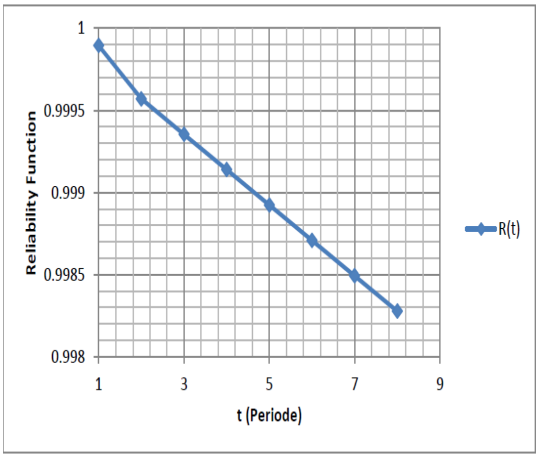

Figure 7. Reliability Function of JE-01(AP01-02)

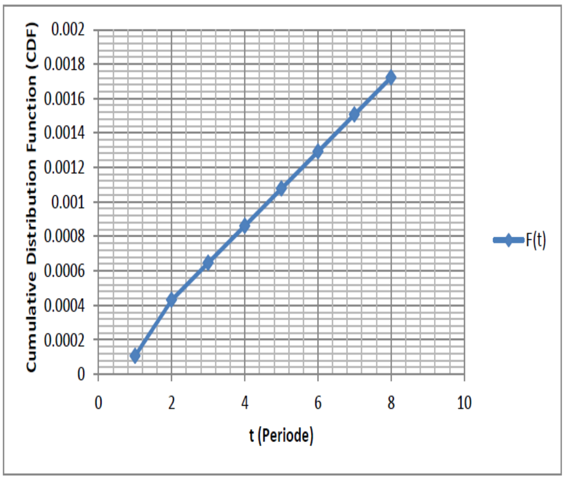

Figure 5. Cumulative Distribution Function of JE-01(AP01-02)

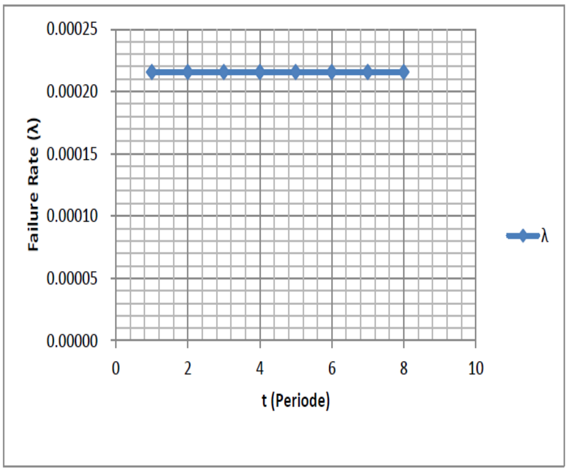

Figure 6. Failure Rate of JE-01(AP01-02)

Based on the results of the analysis of the function of the rate of damage and reliability, the damage of JE-01(AP01-02) component in the primary cooling system is exponentially distributed with a constant damage rate (λ) of 0.000215438 and decreased reliability function, in the last year evaluation for 2015 the reliability value of component 0.99827798 (99.8 %).). The component failure rate is 0.17 %. From the evaluation of the reliability value of this component can be seen that the reliability of the JE-01 (AP01-02) component in the main cooling system is still high. Preventive maintenance strategies has been done to ensure no failure of components in the primary cooling system is very good.

CONCLUSION

Analysis of reliability for core configuration number 70 to 88 during the year of 2010 -2015 in primary cooling system, obtained the highest failure result occurred at component JE-01(AP01-02) with downtime = 112 (days) and presentation damage frequency = 75 %. The damage rate (λ) of 0.000215438 with the value of reliability for the last year amounted to 99.8 %. The component has a probability 0f 0.998 to work well in the last year period. Thus it can be concluded that the reliability of the JE-01 (AP01-02) component in the main cooling system is still high. The high reliability value of a component indicates that, the maintenance strategies that have been carried out during the 2010-2015 period are good. The preventive maintenance strategy of the components in the primary cooling system that has been carried out must be maintained. If constrained by high maintenance costs then required evaluation for maintenance optimization with low cost and high reliability.

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