International Research Journal of Innovations in Engineering and Technology (IRJIET)

ISSN (online): 2581-3048
Volume 6, Issue 6, pp 51-58, June-2022
https://doi.org/10.47001/IRJIET/2022.606007

Reliability Analysis and Lifetime Prediction Using Weibull Method on Critical Components of Railway Braking System with Air Brake System

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Abstract - **Train is the main means of land transportation used almost all over the world, including Indonesia. This means of transportation has multiple comparative advantages, is low in pollution, saves land and energy, and is mass in nature. The train is currently a means of transportation that is in great demand by the public. When compared to other means of transportation, trains are considered to be more economical, orderly and safe. One of the most important factors in driving safety is the need for effective brakes. Namely brakes that can be operated to slow down or stop a vehicle with the shortest possible braking distance under various travel conditions for a short period of time without compromising the stability of the vehicle. Most of the trains in the world are equipped with a braking system that uses compressed air as a force to push the blocks to the wheels or the bearings to the discs, also known as an air brake system. The braking system on the train is very important, therefore proper maintenance is needed. With the aim of increasing reliability, proper maintenance systems are needed to minimize downtime. Weibull is an appropriate method to determine which includes critical and non-critical parts and is often used in determining the level of failure or damage from the data pattern formed. The results obtained from testing 1 unit of the Air Brake System using the Weibull Method have the same 4 critical components, namely the Brake Cylinder, Brake Coupling, Isolating Cock, Distributor Valve. MTTF values of Brake Cylinder, Brake Coupling, Isolating Cock, Distributor Valve are 285 hours, 405 hours, 589 hours, 835 hours. The reliability values of Brake Cylinder, Brake Coupling, Isolating Cock, Distributor Valve are 43%, 41%, 49%, and 46%, respectively. Periodic Maintenance obtained based on the hour meter (HM) of each Air Brake System.**

Keywords: Air Brake System, Downtime, Weibull, Reliability, Lifetime Prediction.

I. PRELIMINARY

Train is the main means of land transportation used almost all over the world, including Indonesia. This means of transportation has multiple comparative advantages, is low in pollution, saves land and energy, and is mass in nature (Supriadi, 2001). The train is currently a means of transportation that is in great demand by the public. When compared to other means of transportation, trains are considered to be more economical, orderly and safe. The increasing need for rail transportation means there is a need for development that leads to the development of railways.

One of the most important factors in driving safety is the need for effective brakes. These are brakes that can be operated to slow down or stop the vehicle with the shortest possible braking distance in various travel conditions for a short period of time without compromising vehicle stability (Dedi Koswara, 2015). Most of the trains in the world are equipped with a braking system that uses compressed air as a force to push the blocks to the wheels or the bearings to the discs, also known as an air brake system. The braking system on the train is very important, therefore proper maintenance is needed. An air brake system that has been operating for a long time needs to be evaluated for reliability to determine the reliability of the system and the causes of failure/damage to each component. The security and safety of the operation of a machine will be fulfilled if the existing system functions according to predetermined specifications.

To ensure that the air brake system can operate properly and optimally, it is necessary to have a good maintenance system. Because the smoothness of the production process is affected by the treatment applied. A poor maintenance system will cause the air brake system to be easily damaged and will be very dangerous for passengers and goods transported by the train. Damage to a system is something that is often encountered and needs to get serious treatment (Asmeati, 2015). With the aim of increasing reliability, an appropriate maintenance system is needed to minimize downtime (Chu &

ISSN (online): 2581-3048
Volume 6, Issue 6, pp 51-58, June-2022
https://doi.org/10.47001/IRJIET/2022.606007

Ke, 2011). The use of the weibull method is the right method to determine the critical and non-critical parts (A. Nugroho et al., 2016).

II. RESEARCH OBJECT AND METHODOLOGY

2.1 Air Brake System

The brake system is a system that is on the vehicle and is a system that has a very important role for the vehicle; it is called important because the brake system is a vital system that keeps the vehicle from damage caused by collisions or collisions when the vehicle is moving (Agung Maulana, Yahan Nurhadi, 2010). The higher the speed of the vehicle, the worse the impact of damage on the vehicle if it does not use the brake system. The bad impact that occurs is not only on the product of the vehicle but also on the passengers who are in the vehicle, and can even cause death.

Air Brake System is a braking system that utilizes compressed air or compressed air to move the brake pads. The principle of air brake braking utilizes the compressed air force. The principle of Air Brake System is shown in Figure 1.

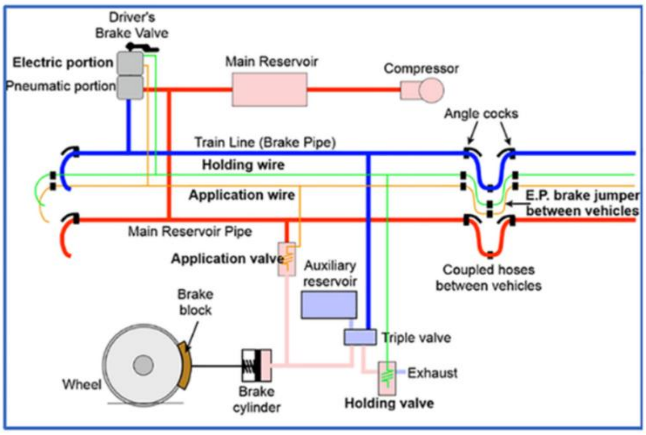

Figure 1: Air Brake System

2.2 Data Collection

Data collection is carried out by conducting direct interviews with workers and operating manuals regarding how the unit on the Air Brake System works, as well as details of the form of components and the amount of use of Air Brake System components over a period of time. Other data is also in the form of a list of damage to engine components, time of use/damage to Air Brake System components.

2.3 Selection of Critical Components with Weighting Factor Table

Determination of the critical components contained in the turbine system is to use the Critical Analysis approach which is a method to determine the critical value of a component so that the results of the assessment can be used as input in engine maintenance. The steps that must be taken are:

1. Estimated critical components in the system.
2. Compilation of component criticality table.

2.4 Testing Time Distribution between Damage

In the problem of component inventory control related to component life characteristics, the time pattern between component failures is estimated to be in the form of a Weibull distribution. There are two parameters used in this distribution, namely which is called the scale parameter and which is called the shape parameter. Weibull distribution is often used in determining the level of failure or damage, which determines the level of damage from the data pattern formed, is the parameter value. The values of which indicate the rate of damage are in the following table (Ebeling, 1997).

Table 1: Parameter Values In Weibull Distribution

Score	Damage Rate
0 <<1	Damage rate reduction (DFR)
= 1	Exponential Distribution
1 << 2	Increased damage rate (IFR), Konkaf
= 2	Rayleigh Distribution
> 2	Increased breakdown rate (IFR), Convex
3	Increased breakdown rate (IFR), close to the normal curve

To test the distribution of time between damage to a component, a two-parameter Weibull distribution test was used which was developed by the Mann group. The distribution test was carried out to determine whether the damage time interval (TTF) data used was in accordance with the selected damage distribution, namely the Weibull distribution. The Mann test is used because it can be used for small data samples and the calculation process is simpler. The stages of this test are (Ebeling, 1997).

Ho = Two-parameter Weibull distribution
H1 = Initial hypothesis (Ho) is wrong

$$S = \frac{\sum_{i=(r/2)+1}^{r-1}\left[\frac{X_i+1-M_i}{M_i}\right]}{\sum_{i=1}^{r-1}\left[\frac{X_i+1-M_i}{M_i}\right]} \qquad (1)$$

Information:

Xi = ln ti
r = Number of damaged spare parts
r/2= an integer that is r/2
Mi= Table
Sα = Two-parameter Weibull distribution table
Ho will be accepted if the value of Sα test < Sα table and vice versa if Sα test > Sα table then Ho is rejected.

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2.5 Determination of Time Distribution Parameters between Damage and Reliability Functions

If it has been proven that the inter-damage pattern has a two-parameter Weibull distribution, then the parameters for the distribution between the damage are determined, namely and by means of linear regression Y = a + bt. After the parameters and are obtained, the two-parameter Weibull reliability functions can be determined. Systematically, the calculation of each distribution function includes:

- The calculation of the failure density function.
- Reliability function.
- Damage rate function.
- Cumulative distribution function.

2.6 Determination of Reliability / Reliability of Each Critical Component

To determine reliability in operational terms, a more specific definition is needed, namely a description of non-confusing and observable failures, identification of time units, and (Ebeling, 1997).

There are four significant elements in the concept of reliability including:

1. Probability (opportunity): Each item has a service life that is different from other items. A group of items can have a definite mean age. This makes it possible to identify the distribution of damaged items, so that the age of the item can be estimated.
2. Performance (performance): Defining reliability as a system performance characteristic where a good system must be able to show satisfactory performance if operated.
3. Time: Reliability is expressed in a period of time. One's chances of living next year will be different from one's chances of living ten years from now. Likewise with the reliability of an item, therefore a clear identification of the time is needed.
4. Condition: Explain that the treatment received by a system will have an effect on the level of reliability.

2.7 Determining the Mean Time to Failure (MTTF) of the Critical Part

Mean time to failure (MTTF) is the average time to failure of a fault distribution where the average time is the expected value of identical units operating under normal conditions. MTTF which is often used to express the expected number E (t) is defined by the probability distribution function f(t) (Ebeling, p24:35), which is as follows:

$$MTTF = E(t) = \int_0^\infty t.f(t)dt \qquad (2)$$

For, $f(t) = \frac{dF(t)}{dt} = -\frac{dR(t)}{dt}$

So that: v

$$MTTF = \int_0^\infty R(t)dt \qquad (3)$$

i. Weibull Distribution MTTF

$$MTTF = \theta\Gamma\left(1 + \frac{1}{\beta}\right) \qquad (4)$$

Where (1+1/β) → (x)=gamma function table

ii. MTTF Lognormal Distribution

$$MTTF = t_{med}\, e^{\frac{s^2}{2}} \qquad (5)$$

2.7 Preparation of Periodic Maintenance

After analyzing the lifetime prediction value, periodic maintenance of critical components can be arranged to reduce unit downtime. By arranging periodic maintenance, it is hoped that the braking operation will be maximized because the air brake system unit can reduce downtime.

III. RESULTS AND DISCUSSION

3.1 Air Brake System Component Damage Data

Not all of these Air Brake System components were damaged until they reached HM (hour meter) for 12 months from June 2020 to June 2021. The data in table 2 is the overall data on the damage to the Air Brake System components that have been filtered according to the amount of damage experienced.

Table 2: Component Damage Data Air Brake System

NO	COMPONENT	FREQ FAILURE
1	BRAKE COUPLING	14
2	HOSE CONNECTION	4
3	BRAKE CYLINDER	24
4	SLACK ADJUSTER	3
5	OPERATING VALVE	5
6	ISOLATING COCK	9
7	FLOW THROTTLE	4
8	VALVE DISTRIBUTOR	7
9	BRACKET	2
10	WATER RESERVOIR	2

3.2 Determination of Critical Components with Critical Analysis Approach Method

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From the data part, critical parts can be selected again based on the frequency of damage. So that critical part data can be generated as follows:

Table 3: Weighting Critical Component

No	Component	Damage Frequency	Impact	Repair Process	Price	Total
1	BRAKE COUPLING	10	10	9	7	36
2	HOSE CONNECTION	4	6	5	3	18
3	BRAKE CYLINDER	10	10	10	10	40
4	SLACK ADJUSTER	3	4	4	5	16
5	OPERATING VALVE	5	8	6	7	26
6	ISOLATING COCK	10	10	5	8	33
7	FLOW THROTTLE	4	7	6	5	22
8	VALVE DISTRIBUTOR	9	10	7	9	35
9	BRACKET	2	2	3	2	9
10	WATER RESERVOIR	2	1	2	6	11

Information:

1 - 3 Low
4 - 6 Medium
7 - 10 High

Based on table 3 above, it can be concluded that the critical components are as follows:

Table 4: Critical Component

NO	COMPONENT	FREQ FAILURE
1	BRAKE CYLINDER	24
2	BRAKE COUPLING	14
3	ISOLATING COCK	9
4	VALVE DISTRIBUTOR	7

From table 3, it can be seen that the components that have a high frequency of damage, so it can be concluded that the critical components of the Air Brake System are the Brake Cylinder, Brake Coupling, Isolating Cock, and Distributor Valve.

3.3 Damage Distribution Test and Determination of Distribution Parameters

3.3.1 Index of Fit of TTF (Time to Failure) Critical Component

Calculation of index of fit is performed on each critical component with weibull and lognormal distributions. The calculation of the index of fit uses the correlation coefficient formula with the Least Square method. The distribution chosen is the distribution with the largest index of fit value.

In addition to using manual calculations, to calculate the index of fit (r) value from the damage time data, it can also be done using Minitab 19 software. The purpose of this test is to make it easier to determine the selected distribution, which will produce a correlation coefficient value) and the Anderson-Darling value of the time data based on each distribution. The distribution chosen is the distribution that produces the largest Correlation Coefficient value and the smallest Anderson Darling value. (Ugiana, 2016, p13). Table 4 shows the distribution selected after being processed with the MiniTab 19 software.

Table 5: Anderson-Darling value of each critical component

Name of Part	AD Value (Anderson Darling)		Preferred Distribution
	Weibull	Lognormal	
BRAKE CYLINDER	0.889	1.063	Weibull
BRAKE COUPLING	1.338	1.398	Weibull
ISOLATING COCK	1,680	1,803	Weibull
VALVE DISTRIBUT OR	2.120	2.138	Weibull

From Table 5 it can be concluded that all critical components use the Weibull distribution.

3.3.2 Determination of Weibull Distribution Parameters

Determination of damage time and Weibull distribution parameters to determine the reliability value of critical pump components, parameter determination using MiniTab19 software. Table 6 is the parameter of the Weibull distribution which is processed using the MiniTab19 software.

Table 6: Weibull Distribution Parameters

Unit	Name Spare Part	Shapes	Scale
1	BRAKE CYLINDER	1.59318	287,777
1	BRAKE COUPLING	1.37443	442,570
1	ISOLATING COCK	2.79775	661,384
1	VALVE DISTRIBUTOR	2.17775	943,365

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3.4 Analysis of MMTF (Mean Time to Failure) Critical Components

MTTF which is often used to express the expected number E(t) is defined by the probability distribution function f(t) (Ebeling, p24:35) according to equation (4).

Table 7: MTTF Calculation Results for Each Component

Name of Part	Weibull		MTTF (Hours)
	Shapes	Scale	
BRAKE CYLINDER	1.59318	287,777	258
BRAKE COUPLING	1.37443	442,570	405
ISOLATING COCK	2.79775	661,384	589
VALVE DISTRIBUTOR	2.17775	943,365	835

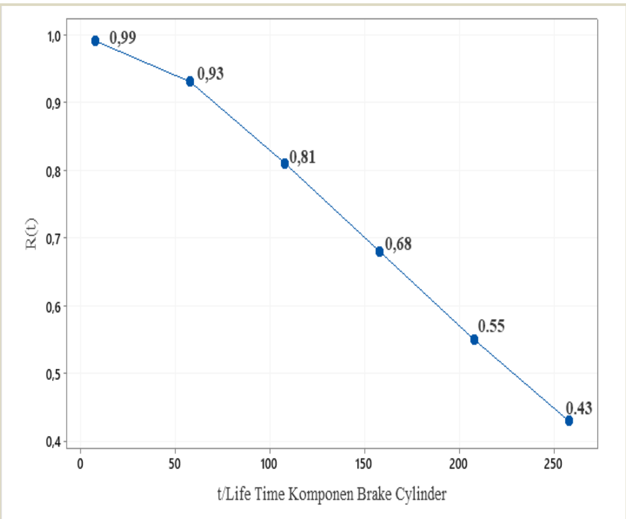
3.5 Analysis of the Reliability Function of Critical Components

Based on the TTF data distribution test, the critical component of the selected distribution is the Weibull distribution. Then the formula used to determine Reliability is:

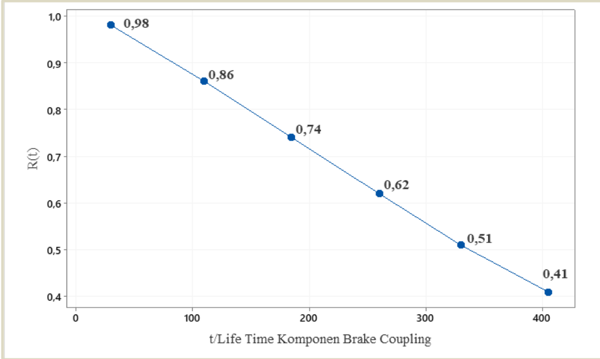
$$R(t) = Exp\left(-\frac{t}{\theta}\right)^{\beta} \qquad (6)$$

Where t = component time at failure.

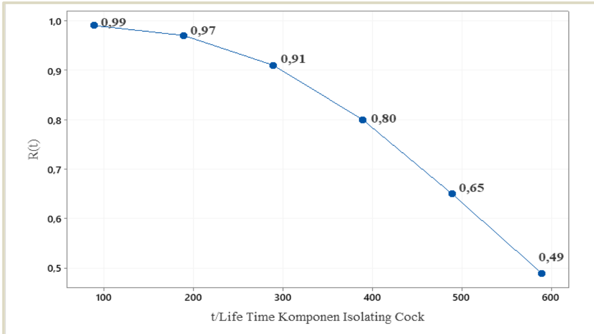
Based on calculations using equation (6), calculations are made for several HM (Hour Meters). The following is a graph of the reliability function of each component.



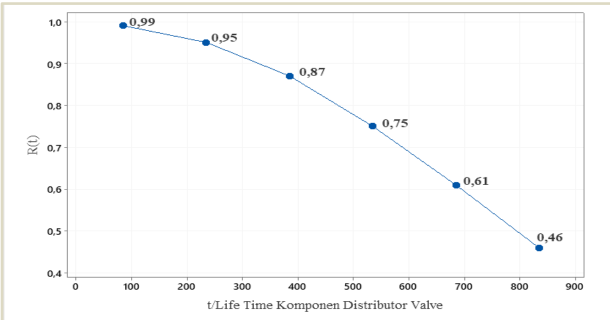
(a)



(b)



(c)



(d)

Figure 2: Graph of Component Reliability Function (a) Brake Cylinder, (b) Brake Coupling, (c) Isolating Cock, (d) Distributor Valve

3.6 Preparation of Periodic Maintenance of Critical Components

Maintenance activities carried out periodically or within a certain period of time. Determination of the period of periodic maintenance can be done based on time intervals (for example, carrying out maintenance every one month, every four months or every one year), and based on the length of working hours of the product machine as an activity schedule, for example every hundred hours. The preparation of the Critical Component Periodic Maintenance below is based on the MTTF (Mean Time to Failure) value of each critical component. The following is the Periodic Maintenance Schedule:

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Volume 6, Issue 6, pp 51-58, June-2022

https://doi.org/10.47001/IRJIET/2022.606007

Table 7: Periodic Maintenance Schedule for Critical Components

HM	*Periodical Service* (PS)	Component Name
50		
100		
150		
200	PS-1	brake cylinder
250		
300		
350	PS-2	brake coupling
400		
450	PS-3	brake cylinder, isolating cock
500		
550		
600		
650	PS-4	brake cylinder, distributor valve, brake coupling
700		
750		
800	PS-5	brake cylinder
850		
900		
950	PS-6	isolating cock, brake coupling
1000		
1050	PS-7	brake cylinder, brake coupling
1100		
1150		
1200		
1250	PS-8	brake cylinder
1300		
1350	PS-9	distributor valve, brake coupling
1400		
1450	PS-10	isolating cock, brake cylinder
1500		
1550		
1600		
1650	PS-11	brake cylinder, brake coupling
1700		
1750		
1800		
1850	PS-12	brake cylinder, isolating cock
1900		
1950		
2000		
2050	PS-13	distributor valve, brake coupling, brake cylinder
2100		
2150		
2200		
2250	PS-14	brake cylinder
2300		
2350	PS-15	brake coupling, isolating cock
2400		
2450	PS-16	brake cylinder
2500		
2550		
2600		
2650	PS-17	brake coupling, brake cylinder, distributor valve
2700		
2750		
2800		
2850	PS-18	brake cylinder, isolating cock
2900		
2950		
3000	PS-19	brake coupling
3050		
3100	PS-20	brake cylinder
3150		
3200		
3250		
3300	PS-21	brake cylinder, brake coupling, isolating cock, distributor valve

IV. CONCLUSION

From this study, several conclusions were obtained regarding the Critical Component Calculation Method of Lifetime Prediction and Reliability on Air Brake Systems using the Weibull Method, namely:

1. Selection of components with Critical Analysis method using critical parts table to determine the criticality level of each component. Then the same critical components are produced for each Air Brake System, namely: Brake

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Cylinder, Brake Coupling, Isolating Cock, Distributor Valve.

2. By using the Weibull method, the lifetime prediction of each component is obtained by calculating MTTF (Mean Time to Failure), namely the critical component of the Brake Cylinder is 258 hours, Brake Coupling is 405 hours, Isolating Cock is 589 hours, Distributor Valve is 835 hours.
3. Based on the MTTF (Mean Time To Failure) value, a periodic maintenance schedule can be arranged for each critical component, namely the Brake Cylinder on HM 206, 412, 618, 824, 1030. Based on the MTTF (Mean Time To Failure) value, a periodic maintenance schedule can be arranged for each critical component, namely Brake Coupling on HM 326, 652, 978, 1034, and 1360. Based on the MTTF (Mean Time To Failure) value, a periodic maintenance schedule can be arranged for each critical component, namely Isolating Cock on HM 471, 942, 1413, 1884 , and 2355. Based on the MTTF (Mean Time To Failure) value, a periodic maintenance schedule can be arranged for each critical component, namely Distributor Valve on HM 668, 1336, 2004, 2672, and 3340.
4. By using the Weibull method, the lifetime prediction of each component is obtained by calculating Reliability, namely the critical component of the Brake Cylinder is 0.43 or 43% at 258 hours, Brake Coupling is 0.41 or 41% at 405, Isolating Cock is 0.49 or 49% at 589, Distributor Valve is 0.46 or 46% at 835 hours.

REFERENCES

[1] Ardian, A. (2010). Machine Maintenance and Repair. Ministry of National Education Yogyakarta University Mechanical Engineering, December, 1–77.

[2] Chu, YK, & Ke, J.-C. (2011). Mathematical and Computational Applications,. 16(3), 702–711. [4] JJ Kim and JD Lee, Cor. J. Met. mater. 46, 809 (2008).

[3] Chien-Yu Peng. (2014) Reliability Analysis Using MiniTab. Institute of Statistical Science, Academia Sinica.

[4] Ebeling, CE (1997). Intro to Reliability & Maintainability Engineering (p. 486).

[5] Gio, PU, & rosmaini, elly. (2018). Learn to Process Data with SPSS, MINITAB, R, MICROSOFT EXCEL, EVIEWS, LISREL, AMOS, and SMARTPLS. https://doi.org/10.31227/osf.io/2z79c

[6] Hidayat, R., Ansori, N., & Imron, A. (2010). Planning for Maintenance Activities Using the Reability Centered Maintenance (Rcm) Method II. MACARA of Technology Series, 14(1), 7–14. https://doi.org/10.7454/mst.v14i1.443

[7] Kurniawan, H. (2016). No Title □ □. 111. http://library1.nida.ac.th/termpaper6/sd/2554/19755.pdf

[8] Liao, M., & Shimokawa, T. (1999). A new goodness-of-fit test for Type-I extreme-value and 2-parameter Weibull distributions with estimated parameters. Journal of Statistical Computation and Simulation, 64(1), 23–48.https://doi.org/10.1080/00949659908811965

[9] Mekonnen, Y., Aburbu, H., & Sarwat, A. (2018). Life cycle prediction of Sealed Lead Acid batteries based on a Weibull model. Journal of Energy Storage, 18(March), 467–475. https://doi.org/10.1016/j.est.2018.06.05

[10] Nugroho, A., Haryadi, GD, Ismail, R., & Kim, SJ (2016). Risk based inspection for atmospheric storage tanks. AIP Conference Proceedings, 1725. https://doi.org/10.1063/1.4945509

[11] Peng, C.-Y. (2014). Part II Reliability Analysis. 2010.

[12] R. Hoffmann.(2016). Towards the Automated Verification of Weibull Distributions for System Failure Rates. Conference Papers. University of St Andrews.

[13] S. Pandi, H. Santosa, JM (2014). Design of Preventive Maintenance on Corrugating Machines and Messin FLEXO at PT. Surindo Teguh Gemilang. Scientific Journal of Widya Teknik, 13(1), 54–57.

[14] Subbarao, B., Ramjee, DE, Devaiah, DM and Prasad, DTS, 2017. Investigation into Flow Field of Hydraulic Axial Pump Impeller. International Journal of Engineering and Manufacturing Science, 7(2), pp.309-318.

[15] Tupan, JM, Camerling, BJ, & Amin, M. (2019). DETERMINATION OF CRITICAL COMPONENT MAINTENANCE SCHEDULE ON MTU 12V2000G65 MACHINE AT DISTRIBUTED PLTD PT PLN (PERSERO) TUAL AREA (Case Study: PLTD Wonreli). Arika, 13(1), 33–48. https://doi.org/10.30598/arika.2019.13.1.33

[16] Wahyuningtyas, N., & Suryanto, H. (2017). Analysis of Biodegradation of Bioplastics Made of Cassava Starch. Journal of Mechanical Engineering Science and Technology, 1(1), 24–31. https://doi.org/10.17977/um016v1i12017p024

[17] Zhang, DZ, & Prosperetti, A. (1994). Ensemble phase-averaged equations for bubbly flows. Physics of Fluids. https://doi.org/10.1063/1.868122

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Volume 6, Issue 6, pp 51-58, June-2022
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Citation of this Article:

Sulistyo, Nazaruddin Sinaga, Gunawan Dwi Haryadi, Dwi Basuki Wibowo, "Reliability Analysis and Lifetime Prediction Using Weibull Method on Critical Components of Railway Braking System with Air Brake System" Published in *International Research Journal of Innovations in Engineering and Technology - IRJIET*, Volume 6, Issue 6, pp 51-58, June 2022. Article DOI https://doi.org/10.47001/IRJIET/2022.606007

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