Reliability analysis of component of affination centrifugal 1 machine by using reliability engineering

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Abstract. Problems that appear in a company that produces refined sugar, the production floor has not reached the level of critical machine availability because it often suffered damage (breakdown). This results in a sudden loss of production time and production opportunities. This problem can be solved by Reliability Engineering method where the statistical approach to historical damage data is performed to see the pattern of the distribution. The method can provide a value of reliability, rate of damage, and availability level, of an machine during the maintenance time interval schedule. The result of distribution test to time inter-damage data (MTTF) flexible hose component is lognormal distribution while component of teflon cone lifthing is weibull distribution. While from distribution test to mean time of improvement (MTTR) flexible hose component is exponential distribution while component of teflon cone lifthing is weibull distribution. The actual results of the flexible hose component on the replacement schedule per 720 hours obtained reliability of 0.2451 and availability 0.9960. While on the critical components of teflon cone lifthing actual on the replacement schedule per 1944 hours obtained reliability of 0.4083 and availability 0.9927.
Keywords: Reliable, Reliability, Maintenance

1. Introduction

In 2015 Indonesia's national sugar demand reached 5.7 million tons and is projected to increase 5% per year. Increased demand for sugar in line with population growth and number of food, beverage and pharmaceutical industries (Ministry of Agriculture, Directorate General of Plantation). High consumption levels are not matched by the availability of available sugars. Some of the contributing factors are the availability of limited raw materials due to minimal land. Besides the limited processing plants in Indonesia and the company's unpreparedness of factory operation. Operational unpreparedness is caused by shortages or delays in raw material supply, downtime due to damage to production machinery, and stalled energy supply. As a manufacturing company, consumers' complain should be avoided. Improvement in quality and quantity of product have to be prioritizied [1].

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This research is conducted in a refined sugar manufacturing company. The company has only been operating for 3 years, but downtime or loss of production time due to machine failure is still common. Table 1 shows the breakdown frequency ≥ 4 times and downtime of production machine in 2016.

Table 1. Breakdown Frequency and Downtime of Production Machine in 2016

Machine	Breakdown Frequency	Total *Downtime* (minute)	Category
Stirrer For Affination Mingler	5	480	A
Affination Centrifugal 1	15	1020	B
Affination Centrifugal 2	14	540	B
Affination Centrifugal 3	15	560	B
Pressure Filters For Second Filtration 1	5	435	B
Pressure Filters For Second Filtration 2	7	525	B
Brown Liquor 2 Pump 1	7	1635	C
Spent Regenerant Pump 1	4	250	C
Spent Regenerant Pump 2	5	325	C
Refined Massecuite Receiver 1	6	300	A
Refine Massecuite Centrifugal 1	9	660	B
Refine Massecuite Centrifugal 2	16	1110	B
Refine Massecuite Centrifugal 3	13	740	B
Refine Massecuite Centrifugal 4	4	170	B
A-Massecuite Centrifugal	5	175	B
C-Massecuite Centrifugal 2	4	200	B
Vibrating Grade B	7	1600	C
Co2 Gas Compressor With Gas Sparator	4	370	B

Table 1 shows the centrifugal affination machine of one of the machines with the highest damage frequency. In addition, the machine is also included in category B where if the damaged machine can reduce the amount of production. Based on these considerations, research is needed on the reliability of the centrifugal affination machine. Loss of production time (downtime) can have an impact on reducing the amount of production which it should be targeted, until it caused financial loss and lost profit opportunities. Decreasing production time happen because of the production process stopped while maintenance team repairing or replacing the damage machine and component [2].

The company has been implementing maintenance system in preventive maintenance and corrective maintenance to eliminate downtime. However, machine maintenance with the replacement of machine components is still corrective because there is no regular replacement scheduling. Replacement of components by correctively will show in a loss of production time is longer than preventive because it has not been predicted before so there is no preparation step repair for damage to the machine. Some studies shows that high frequency oh downtime happen due to applied traditional maintenance [3],[4],[5].

Preventive maintenance of the company is still based on experience and predictions without any theoretical calculations. This leads to a decrease in machine reliability due to unpredictable and uncontrollable the failure rates. Therefore it is necessary to schedule regular component replacement scheduling and identification of component damage sources to improve machine reliability [6].

Improved reliability (reliability) machine / component can be done by lowering the rate of failure of the machine / component through the approach of Reliabilty Engineering. Reliabiliy Engineering method is a statistical approach in analyzing the reliability of a machine / equipment. The lower failure rate achieved, the higher reliability obtained. This can have an impact on reducing maintenance costs due to increased reliability. In addition it can reduce the loss of production time (downtime) and production targets achieved [7].

Research on the reliability of tuber and bottomer machine at PT. X uses the machine age distribution data to know the pattern of machine damage. Test results obtained by tuber machine with optimum preventive time every 27 days and minimum cost of 40.92 million rupiah while the bottomer machine has optimum preventive time every 72 days and minimum cost of 55.61 million rupiah [8].

The research analyzes the damage of Screw Press machine based on the calculation of reliability function, failure rate and Mean Time Between Failure (MTBF). The results obtained an optimum time interval for the components of Screw Press machine. Decrease in cost before and after scheduling ranged from 6.96 to 45.57% [9]. Based on previous research references, reliability analysis of production machine at this company is performed to obtain the optimum component replacement time interval and decrease maintenance cost based on machine failure analysis.

2. Methodology

The type of research used is causal research, is research that aims to describe systematically, factually and accurately about the facts and properties of a particular object or population to investigate the causal relationships that occur and possible factors (cause) causing the consequences. The results of this type of research are expected to minimize downtime and maintenance costs.

The object of research observed is an Affination Centrifugal 1 machine, covering the extent of damage and maintenance activities performed on the machine. Data collection methods used in this study is through direct observation and interviews with the company. Data processing methods used in this study are [10],[11],[12] :

1. Identify the machine and its critical components and sources of damage.
2. Testing distribution patterns, parameter calculations, and MTTF.
3. Determination of the level of reliability and rate of damage critical component.

This research stage can be described briefly through block diagram. Block diagram of this research can be seen in Figure 1.

3. Results and Discussion

3.1. Identification of Critical Types and Components as well as the Failure Sources

The selection of critical components that will be the focus of research is done using the Pareto 80/20 rule. Figure 2 shows the Pareto Diagram of the damage of the Affination Centrifugal 1 machine component. Pareto diagrams are used to identify the most important issues. The diagram above shows 80% loss of production time caused by 20% broken components [11]. Thus there are 2 types of critical components that become the focus of research problems that is flexible hose and teflon cone lifthing. The result of the identification of the cause of the damage of the flexible hose component on the affination centrifugal 1 machine can be seen on the Cause and Effect Diagram (Fish Bone Diagram) [11]. The Cause and Effect Diagram can be seen in figure 3.

3.2. Distribution Testing, Parameter Calculation and MTTF

The distribution test is performed on the time interval data between the damage and the average time of repair of critical machine components. The distribution types used are normal, lognormal, weibull, and exponential distributions [12]. The best distribution is the one with the greatest index of fit. Table 2 shows the recapitulation of selected distributions of time data between damages of critical machine components.

Table 2. Recapitulation of the Best Distribution Time between Critical Components Damage

Component	Distributions	Index of Fit	Selected Distribution
Flexible Hose	Normal	0.8972	Lognormal
	Lognormal	0.9831	
	Eksponensial	0.9772	
	Weibull	0.9688	
Teflon Cone Lifthing	*Normal*	0.9766	*Weibull*
	Lognormal	0.9443	
	Eksponensial	0.9243	
	Weibull	0.9803	

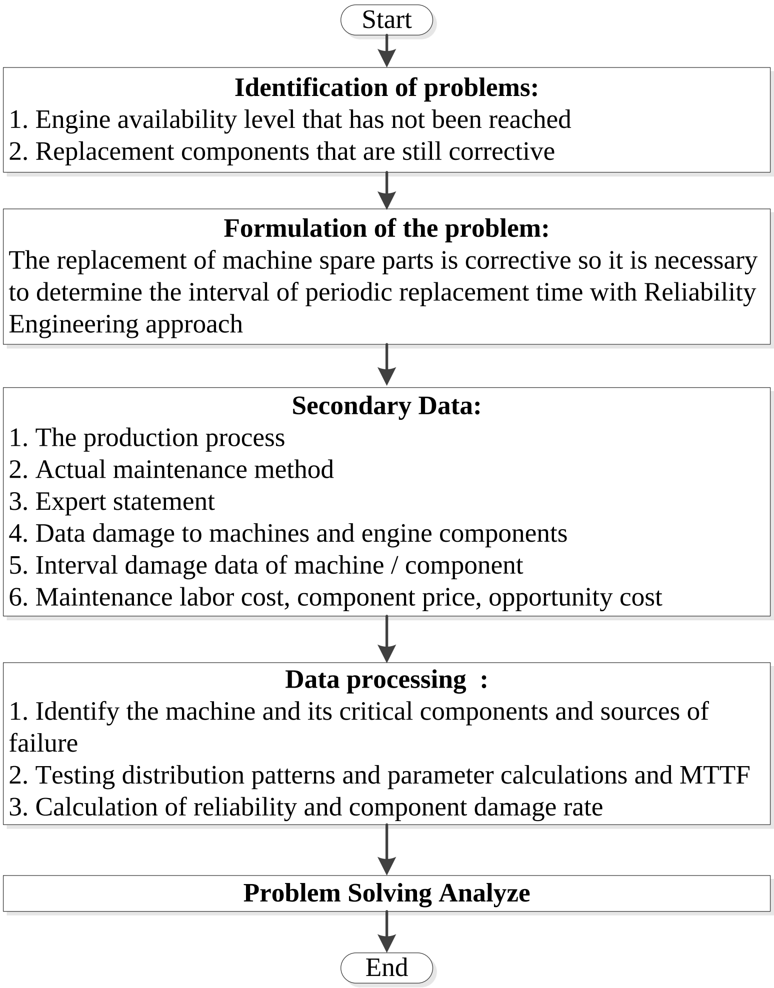

Figure 1. Block Diagram of Research

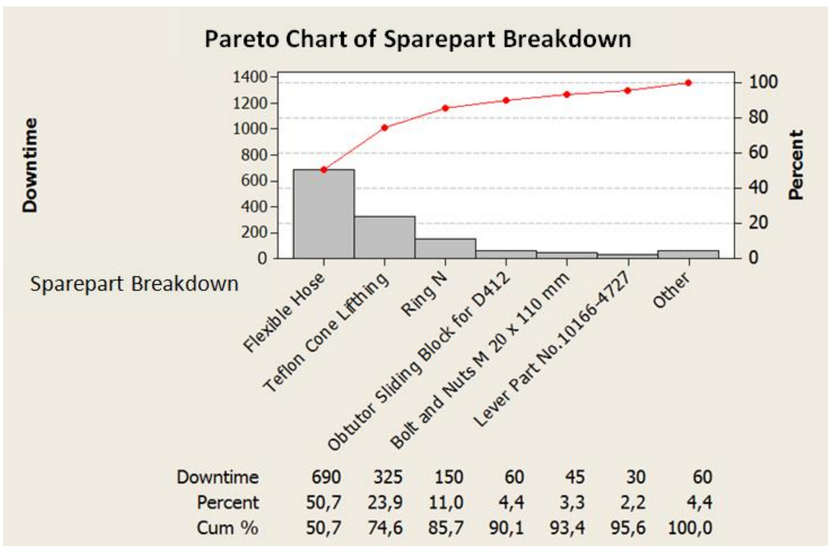

Figure 2. Critical Components of Pareto Diagram

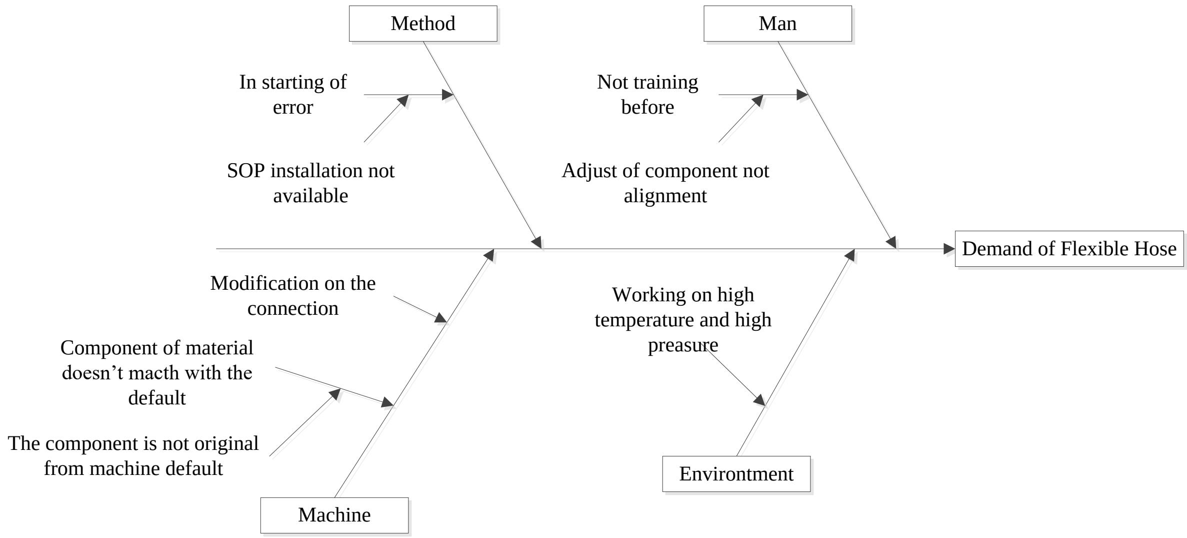

Figure 3. Cause Diagram Due to the Cause of Flexible Hose Component Damage

The identification of the cause of damage to the flexible hose component in the affination centrifugal 1 machine can be seen on the Cause and Effect Diagram (Fish Bone Diagram) in Figure 4.

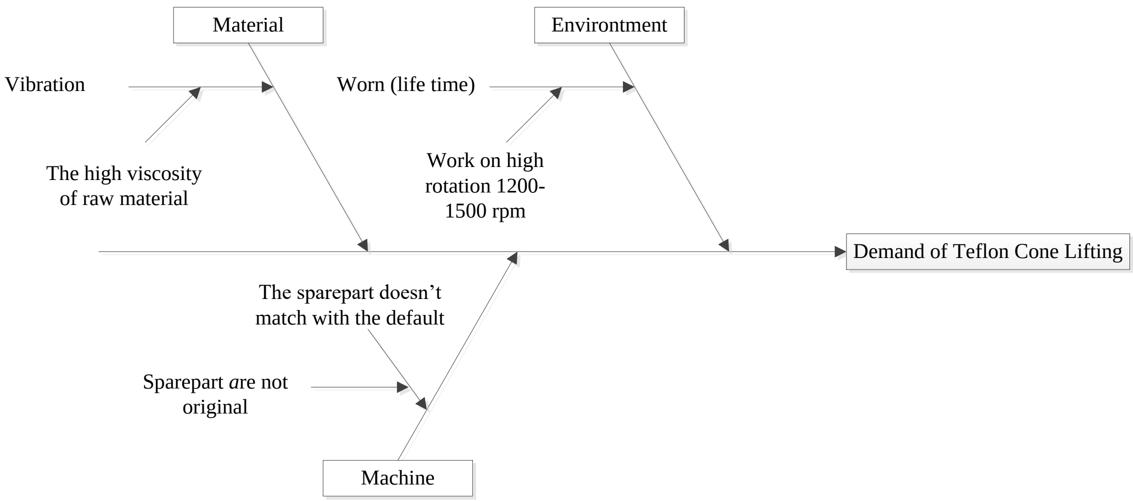

Figure 4. The Cause Due to Damage Diagram of Teflon Cone Lifthing Component

Table 3 shows the best recapitulation of the data distribution of the average time of repair of critical machine components.

Table 3. Recapitulation of the Best Distribution Time Average of Critical Component Repair

Component	Distributions	Index of Fit	Selected Distribution
Flexible Hose	*Normal*	0.7378	Eksponensial
	Lognormal	0.7378	
	Eksponensial	0.8435	
	Weibull	0.6446	
Teflon Cone Lifthing	*Normal*	0.5746	*Weibull*
	Lognormal	0.5746	
	Eksponensial	0.3644	
	Weibull	0.6746	

Distribution parameter calculations are performed on the best distribution of time between damage and average time of repair. Table 4 shows the parameters and MTTF distribution results of the selected time between critical component breakdowns.

Table 4. Results Calculation of Parameters and Time Interruption (MTTF) Critical Components

Time Interruption (MTTF)			
Component	**Distribution**	**Parameters**	**MTTF (hour)**
Flexible Hose	Lognormal	$\hat{s}$ = 1.4027 $\hat{t}_{med}$= 271.59	726.31
Teflon Cone Lifthing	Weibull	β = 1.3042 θ =2115.3665	1953.9641

Table 5 shows the best parameters and MTTF distribution results for the average time of critical component repair.

Table 5. Parameter Calculation Results and Average Time Improvement (MTTR) Critical Components

Average Repair Time (MTTR)			
Component	**Distribution**	**Parameters**	**MTTR (hour)**
Flexible Hose	Eksponensial	λ = 0.6476	1.5441
Teflon Cone Lifthing	Weibull	β = 13.0461 θ =10.1008	9.7381

3.3. Calculation of Reliability Value and Rate of Machine Damage

Calculation of reliability and damage rate using the distribution parameters of MTTF The calculation of the reliability value of each component is as follows [13],[14],[15],[16] :

1. Flexible Hose Components
   Time interval data between damage of Lognormal distributed components
   Parameter : MTTF= 726.31 hour
   : $\hat{s}$ = 1.4027
   : $\hat{t}_{med}$ = 271.59

   Then calculation of reliability value of machine component is:
   a. Probability Density Function f (t).
   $$f(t) = \frac{1}{\sqrt{2\pi}st}\exp\left[-\frac{1}{2s^2}\left(ln\frac{t}{\hat{t}\text{med}}\right)^2\right]$$
   $$= \frac{1}{\sqrt{2\pi}1.4027(726.31)}\exp\left[-\frac{1}{2(1.4027)^2}\left(ln\frac{726.31}{271.59}\right)^2\right]$$
   $$= 0.0003$$
   b. Cumulative Distribution Function
   $$F(t) = \Phi\left(\frac{1}{s}ln\frac{t}{\hat{t}\text{med}}\right) = \Phi\left(\frac{1}{1.4027}ln\frac{726.31}{271.59}\right)$$
   $$= \Phi(0.7012)$$
   $$= 0.7580$$
   c. Reliability Value Function
   $$R(t) = 1\text{- }\Phi\left(\frac{1}{s}ln\frac{t}{\hat{t}\text{med}}\right) = 1\text{- }0.7580$$
   $$= 0.2419$$
   d. Damage Rate Function h (t)
   $$\lambda(t) = \frac{f(t)}{R(t)} = \frac{0.0003}{0.4721}$$
   $$= 0.0006$$

Based on calculations obtained that after 726.31 hours (30 days) the use of flexible hose components reliability value is 0.2419.

2. Teflon Cone Lifthing Components

Time interval data between damage of Weibull distributed components

Parameter : MTTF= 1953.9641 hour (81 days)
: β = 1.3042
: θ = 2115.3665

Then calculation of reliability value of machine component is:

a. Probability Density Function f (t).

$$f(t) = \frac{\beta}{\theta}\left(\frac{t}{\theta}\right)^{\beta-1} e^{-(\frac{t}{\theta})^{\beta}} = \frac{1.3042}{2115.3665}\left(\frac{1953.9641}{2115.3665}\right)^{1.3042-1} e^{-(\frac{1953.9641}{2115.3665})^{1.3042}}$$

$$= \frac{1.3042}{2115.3665}\left(\frac{1953.9641}{2115.3665}\right)^{1.3042-1} e^{-\left(\frac{1953.9641}{2115.3665}\right)^{1.3042}}$$

$$= 0.00024$$

b. Cumulative Distribution Function

$$F(t) = 1- e^{-\left(\frac{t}{\theta}\right)^{\beta}} = 1- e^{-\left(\frac{1953.9641}{2115.3665}\right)^{1.3042}}$$

$$= 1- 0.4058 = 0.5941$$

c. Reliability Value Function

$$R(t) = e^{-(\frac{t}{\theta})^{\beta}} = e^{-(\frac{1953.9641}{2115.3665})^{1.3042}}$$

$$= 0.4058$$

d. Damage Rate Function h (t)

$$\lambda(t) = \frac{f(t)}{R(t)} = \frac{\beta}{\theta}\left(\frac{t}{\theta}\right)^{\beta-1}$$

$$= \frac{1.3042}{2115.3665}\left(\frac{1953.9641}{2115.3665}\right)^{1.3042-1}$$

$$= 0.0006$$

Based on calculations obtained that after 1953.9641 hours (81 days) the use of components of teflon cone lifthing reliability value is 0.4058.

4. Conclusion

Based on the research that has been done, obtained the following conclusions:

1. The critical machine that became the research priority is the Affination Centrifugal 1 machine is one of the machines that have the greatest damage frequency during the period of January 2014-January 2017 with flexible hose flexible component and teflon cone lifthing.
2. Testing the distribution of intermediate time data between damage (MTTF) flexible hose component is obtained by lognormal distribution while component of teflon cone lifthing is weibull distribution. The test of the distribution of the mean time of improvement (MTTR) obtained flexible hose component is exponential distribution and the teflon cone lifthing componentis weibull distribution. MTTF calculation obtained maintenance schedule with component replacement per 726.31 hours usage for flexible hose and per 1953.9641 hours usage for teflon cone lifthing.
3. Calculation of the reliability of critical components by using the best distribution parameters obtained by 0.2419 (24.19%) with a 0.0006 damage rate for the flexible hose component. While for component of teflon cone lifthing obtained reliability equal to 0.4058 (40.58%) with damage rate 0.0006.

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5. References

[1] J P Rishi, Dr. Ramachandara C G and Dr. T. R Srinivas 2016 Keys to Succeed in Implementing Total Preventive Maintenance (TPM) and Lean Strategis *IJMTST* **2** pp.25-30

[2] Yang Li, Xiaobing Ma, Rui Peng, Qingqing Zhai and Yu Zhao 2017 A Preventive Maintenance Policy Based On Dependent Two-Stage Deterioration And External Shocks *Reliability Engineering And System Safety* **160** pp.201-211

[3] Kumar Saureng, Raj Bhushan and Shubham Swaroop 2017 Study of Total Productive Maintenance & It's Implementation Approach in Steel Manufacturing Industry: A Case Study of Equipment Wise Breakdown Analysis *IRJET* **4** pp.608-613

[4] Wang Zhenyou, Cuntao Xiao, Xianwei Lin, and Yuan-yuan Lu 2017 Single Machine Total Absolute Differences Penalties Minimization Scheduling with a Deteriorating and Resource-Dependent Maintenance Activity *The Computer Journal* pp.1-11

[5] Maleki Hamed and Yang Yiangjie 2017 An Uncertain Programming Model For Preventive Maintenance Scheduling *Grey Systems: Theory and Application* **7** No.1 pp.111-122

[6] Aven, Terje 2017 Improving the Foundation and Practice of Reliability Engineering *Journal of Risk and Reliability* **23 I** (3) 295-305

[7] Compare, Michele, Michele Bellora and Enrico Zio 2017 Aggregation of Importance Measures For Decision Making In Reliability Engineering *Journal of Risk and Reliability* pp.1-13

[8] Satria Hikmawan, *et.al.* 2016 Optimasi Preventive Maintenance pada Mesin Tuber dan Bottomer dengan Metode Analisis Reliabilitas di PT.X *Journal FMIPA Institut Teknologi Sepuluh November (ITS)*

[9] Yuhelson, *et.al*. 2010 Analisis Reliability dan Availability Mesin Pabrik Kelapa Sawit PT. Perkebunan Nusantara 3 *Journal Universitas Sumatera Utara* No. **6**

[10] Besterfield, H. Dale 1995 *Quality Control* (Southern Illinois: College of Engineering Southern Illinois University)

[11] Charles E. Ebeling 1997 *An Introduction to Reliability and Maintanability Engineering* (Singapore: Thetatayo McGraw-Hill Book Co.)

[12] Kapur, KC. and Lamberson, L. R. 1977 *Reliability in Engineering Design* (New York: John Wiley & Sons)

[13] Lina Alhmoud and Bingsen Wan 2017 A Review Of The State-Of-The-Art In Wind-Energy Reliabilty Analysis *Renewable and Sustainable Energy Reviews*

[14] Miguel Angel Navas, Carlos Sancho and Jose Carpio 2016 Reliability Analysis in Railway Repairable System *Int. Journal of Quality & Reliability Management* **34** Issue: 8 pp.1373-1398

[15] Rajkumar B Patil, Basavraj S. Kothvale, Laxman Yadu and Shridhar G. Joshi 2016 Reliability Analysis of CNC Turning Center Based on The Assessment of Trends in Maintenance Data *Int. Journal of Quality & Reliability Management* **34** Issue:9 pp. 1616-1638