Journal of Physics: Conference Series

PAPER • **OPEN ACCESS**

Product Quality Control with Six Sigma and Preventive Maintenance

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Abstract. PT. X is a garment company in Cimahi, West Java which consists of four departments, namely texturizing, twisting, weaving and dyeing printing. Research focused weaving department with identifying the cause of the defect with six sigma method Define, Measure, Analyze, and Improve. Based on the identification issue using the steps define, measure and analyze known that the causes of defective products is declining performance nozzle and pump components resulting in less water pressure or excess. In addition, not component replacement for a worn shedding motion so that a malfunction of kamran. Therefore, the purpose of this study was to schedule preventive maintenance on spare nozzle, pump and kamran. Improve these problems by creating a preventive maintenance schedule by age replacement method. Based on the results obtained scheduling data processing component replacement on the machine water jet loom is; (1) The components of the pump will be replaced every 150 days, (2) Components kamran 71 days and (3) Components nozzle 82 days.

1. Introduction

PT. X is a garment company in Cimahi, West Java which consists of four departments, namely texturizing, twisting, weaving and dyeing printing. Department is a texture creation texturizing yarn, twisting the yarn preparation department is spin yarn from being hairy in the knitting process. Department of weaving is a weaving manufacture of semi-finished fabric (gray cloth) and dyeing is a dyeing and printing process is a process where the tasting. This research focused in weaving department with identifying the cause of the defect with the six sigma method and above it.

1.1 Define

PT. X producing various kinds of gray fabric in the weaving department uses water jet loom machine. Process water jet loom machine contained five movements, namely shedding, picking, weft insertion, beating up, letting off, and taking up. During 2018 the production of gray cloth are the number of defects is above the tolerance limit of the company that is defective feed neps.

Neps feed defect is their arch/loop weft threads in the fabric caused by the launch of the feed is not perfect. Weft threads are threads which are arranged horizontally straight on a fabric and yarn warp yarns are arranged vertically straight while the yarn. These two threads are crossed with each other so as to form a woven fabric.

1.2 Measure
Measure phase ie the stage to test the defect type standard six sigma phase approach is to calculate the value of DPO, DPMO and Sigma to feed neps defect type. Based on the calculation, DPO value of 0.0799 and amounted to 79.929 and the value DPMO sigma value of 3. Types of defects have been selected under the sigma value of 3.25 or 15% disability established by the company.

1.3 Analyze
In the analyze phase is carried out to analyze the type of feed neps approach analyzerie FMEA (Failure Mode and Effect Analysis). FMEA result data obtained from questionnaires to the head of maintenance, production and supervisors are presented table 1 below;

Table 1. FMEA (Failure Mode and Effect Analysis)

This type of failure	source of failure	As a result of the failure	Cause	Score			RPN	Recommendation
				S	O	D		
feed neps	Lack of feed checking launch conducted by the operator during the production process underway	At the direction of the feed contained spools of thread	The operator does not focus	9	6	7	378	The need for periodically checking during the process
	Hairy weft yarns for not installing a cap on the jumbo bobbins		The raw material is not within specifications	9	8	6	432	The need for checking feed raw material before the process, when their feathered feed the raw materials to be replaced
	Nozzle and pump performance decline caused by lack of turnover in spare parts		Lack of or excessive water pressure	9	9	9	**729**	Necessary to schedule preventive maintenance on the nozzle and pump spare parts
	Shedding motion of wear due to lack of turnover		Malfunctions kamran	9	9	9	**729**	Necessary to schedule preventive maintenance on spare kamran

Based on identification in Table 1 are major causes of disability acquired neps feed. The cause of most dominant factor is the engine in the absence of preventive maintenance, so that the damage caused by an emergent resulting engine of defects. Based on the results of the highest RPN value weft fabric neps defects caused by performance engine components and pump nozzle declines and shedding motion component wear. This happens due to lack of maintenance and replacement of components which are scheduled to cause excessive water pressure or less as well as damage to kamran function. So the purpose of this study is to make a schedule repair or replacement of components of the nozzle, pump and kamran.

2. Method

2.1 Six Sigma

According to Schroeder et al [1] Six sigma accordance with the meaning, is the distribution (variation) of the average (mean) a process or procedure. Six sigma is applied to minimize the variation (sigma). Six Sigma as a measurement system using Defect per Million Opportunities (DPMO) as the unit of measurement. DPMO is a good measure for the quality of the product or process, for directly correlated with disabilities, costs and time wasted.

Table 2. Relationship Sigma and DPMO

Taraf Sigma (σ)	Defects per million opportunities	Probability Without Disabilities
1	690,000	30.9%
2	308.000	69.2%
3	66.800	93.3%
4	6.210	99.4%
5	320	99.98%
6	3.4	99.9997%

Source: Pande & Holpp [2]

The advantages possessed six sigma compared to other methods, among others:
DPO (Defect per Opportunity) or failure per one occasion. Number of defects adapted to the occasion defect per unit of the development of the concept of Defect per Unit plus the opportunity variables. To calculate the DPO is used as follows:

$$\text{DPO} = \frac{\textbf{Total production defects}}{\textbf{Number of productions inspected}} \quad (1)$$

DPMO (Defect per Million opportunity): the size of the failure shows the number of defects or failures per one million opportunities. The target of six sigma quality control of 3.4 DPMO. DPMO calculated by the equation:

$$\text{DPMO} = \frac{\text{DPU x 1 million}}{\textbf{Probability of damage}} \quad (2)$$

According [2], the implementation of Six Sigma quality improvement consists of five steps using the DMAIC or Define, Measure, Analyze, Improve and Control.

Define DMAIC is the initial stage in which the stage is done is set a target of six sigma quality improvement activities. In the define phase of defining the characteristics of the system performed as well as an action plan that will be done to process upgrade. Measure is a logical follow-up to define stepsand is a bridge to the next step.

Analyze is a third operational steps in six sigma quality improvement programs. There are several things that must be done at this stage are: (1) determine the stability and capability (capability) of key processes, (2) Establish performance targets of the characteristics of quality (CTQ) and (3) identify sources and root causes of quality problems.

Improve In this step implemented an action plan to implement the Six Sigma quality improvement. The plan describes the resource allocation and priority or alternatives do. Six sigma quality improvement team must decide the target to be achieved, why the action plan is carried out, whereby the action plan will be carried out, Control is the last operational phase in efforts to improve quality based on Six Sigma.

Failure Mode and Effect Analysis (FMEA) is a structured procedure to identify and prevent as much as possible modes of failure. A failure mode is any one that is included in defects or failures in the design, conditions beyond the limits established specifications, or changes in the product that causes disruption of the function of the product.

There are three components in defining the priorities of failure, namely:

- Severity (Sev) is a bad influence or risk will be borne by the customer as a result of failure caused. Rating assessment provided from the lowest value to the highest value of 1 to 10, where 10 is the worst impacts.
- Occurrence (Occ) is the possibility that the cause is going to occur and result in the form of failure during use of the product. With estimated that a possibility of occurrence on a scale of 1 to 10.
- Detection (Det) is a measurement of the ability or failures control that may occur. RPN (Risk Priority Number) is a mathematical formula that is composed of a set of effects (severity), the possibility that the cause will cause failures related to the effects (occurrence) and the ability to detect a failure before it reaches the consumer (detection), The calculation formula RPN defined with the following formula:

$$RPN \quad Occ\ Sev\ x = x\ Det \tag{3}$$

RPN value is used to identify the most serious risks that lead to corrective action. In the FMEA process, the type of failure that has the highest RPN value will be evaluated first to determine a control plan that aims to eliminate or reduce the effects of such failures.

2.2 Maintenance Management

Treatment as that activity or component/system that is broken will be restored or repaired within a certain condition in a certain period. According [3]. Care is closely related to the two most important issues are the activities of damage preventive maintenance and corective maintenance. In the process of the action consists of several activities, such as:

- Inspection
- Light
- Substitution Component
- Comprehensive Improvement

Preventive maintenance is the activities maintenance and care taken to prevent damage to the unexpected and find conditions or circumstances that can lead to the production facilities were damaged when used in the production process. The purpose of preventive maintenance is directed to maximize availability and minimize the cost of an increase in reliability, with the scope of activities could only cover the area and expanded to other areas and public facilities. The activities conducted in preventive care are as follows; Replaced by new and Imperfect preventive maintenance

Corrective maintenance is the maintenance and care activities performed after the occurrence of a damage to facilities or equipment that result can not function properly. This maintenance activity is not scheduled, depending on the condition of a component or system itself. Reliability is the probability that a component/system will inform a function that takes a period of time when used in operating conditions According [3]. In general, the concept of reliability can be described in a Bathtub Curve that explains the life cycle of items/components.

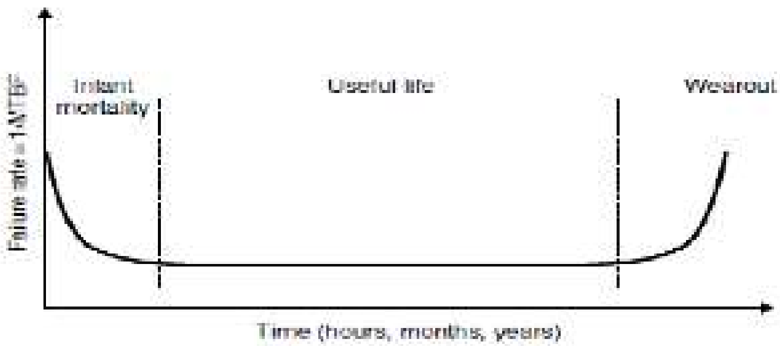

Figure 1. Bathtub Curve

Reliability is the probability that the equipment is working satisfactorily by function over a longer period of time and under certain conditions. Statistically ata reliability function R (t) is defined as the probability of a component is still functioning in the specification at the time t, can be expressed mathematically as follows:

$$R(t) = P(x > t) \tag{4}$$

Where x is the age of the components.

If f(x) states and the probability density function f(x) dx represents the probability of a component will fail in the interval $(x, x + \Delta x)$ and the number of the probability function and cumulative distribution function of reliability equal to one, then obtained the following equation:

$$F(x) = P(x < t) \tag{5}$$

So that the probability to be operating in the specification or reliability function can be expressed mathematically as follows:

$$R(t) = 1 - P(x < t) \tag{6}$$

The rate of damage to a machine or component at time t is the magnitude of the probability that the machine or components will be damaged in the next interval. While at the time t the machine or machine component dala good condition. Mathematically the damage rate function can be described as follows:

$$\text{r (t)} = \lim_{\Delta t \to 0} \frac{R(t) - R(t + \Delta t)}{\Delta t R(t)} = \frac{1}{R(t)} \{-(d / dt) R(t)\} \tag{7}$$

$$\text{r (t)} = \frac{f(t)}{r(t)} = \frac{f(t)}{1 - F(t)}$$

If r(t) increases with time, the function of the rate of damage to the ascending and vice versa, if r(t) decreases with time so as a damage rate decreased.

2.3 Distribution of Damage

Basically, there are several forms of distribution of the damage that can be used in treatment policies, such as Exponential distribution, Weibul, Normal and Log Normal. The distributions have a constant decay rate is also called exponential probability distribution. The exponential distribution is an important distribution on distribution reliability. Another distribution that can be used is weibull distribution, normal and log-normal. The third distribution function of damage rate is not constant so that it provides an alternative that can be used in addition to the distribution of exponential decay that already exist.

Exponential distribution has a constant rate of damage, do not depend on time. Thus, the probability of occurrence of damage to a part or tool does not depend on the age of the equipment. Weibull distribution have decreased the rate of damage toβ <1, the rate constant for the damage β = 1 and the rate of damage rise to β > 1. Normal distribution has a rate of damage being up since age tools, which means that the probability of damage to the equipment or component rises with age components. The normal distribution has two parameters, namely the average and standard deviation.

Lognormal distribution knows two parameters: s as a parameter t_{med} shape and location is the middle value of the time of the crash. This distribution is defined only for positive t value, and therefore better suited as a damage distribution. Lognormal distribution has some form and according to According to Jardine [3], is often also present data in accordance with the distribution weibull. Damage Identification Distributionis to show through the test statistic in terms of accepting or rejecting a hypothesis that damage or repairs under study originated from a specific distribution. Identification of distribution can be done in two phases, namely Index of Fit (r) and Goodness of Fit Test.

2.4 Index of Fit

According to Jardine [3] the early identification of downtime and repair time can be done in a way, ie with probability plots and probability plots are used when the sample size is too small or can be used for data that is incomplete. The second way is by the method of least-squares curve fitting. It is this method that will be used in data processing. This method was considered more accurate than the probability plots for subjectivitas to assess the alignment of a line to be reduced. In the method of least-squares curve fitting, distibusi with an index value of fit terbesarlah will be selected to be tested by using Goodness of Fit Test. Calculations on the method of least-squares curve fitting is:

$$\mathrm{F}(t_i) = \frac{l-0,3}{n+0,4} \quad (8)$$

Note:
i = the time data to t
n = r = number of data destruction

$$\text{Index of fit } (r) = \frac{n\sum_{i=1}^{n} x_i y_i - (\sum_{i=1}^{n} x_i)\,(\sum_{i=1}^{n} y_i)}{\sqrt{[n\sum_{i=1}^{n} x_i^2 - (\sum_{i=1}^{n} x_i)^2]\,[n\sum_{i=1}^{n} y_i^2 - (\sum_{i=1}^{n} y_i)^2]}} \quad (9)$$

Where n is the amount of damage done. In determining the distribution that will be used to calculate MTTF, MTTR, and reliability. The process should be done is to find the value of r for each distribution so disapatkan largest r value which will then be tested again according to the hypothesized distribution. Compatibility Test Distribution (Goodness of Fit Test) is comparing two opposing hypotheses, namely:

H_0: The data damage or repairs approached a certain distribution

H_1: Data of damage or repair is not up to a certain distribution

This test consists of a statistical calculation based on the observed data is then compared with the value of criticism in the table. In general, if the test statistic is less than the critical value, then accept H0 and if otherwise then accept H1. According According to Jardine [3] testing to be performed is Bartllet Test for Exponential distribution. Kolmogorov-Smirnov test for Normal and Lognormal distribution and Mann for weibull distribution.

2.5 Method of Age Replacement Method

According [3] In this method, the replacement action at the time of operation has reached the age that has been set is equal tp. If the time interval tp there is no damage, then do the replacement as a corrective measure. Replacement measures tp age calculation starts all over again by taking reference from the time it began to operate the system again after the treatment action.

The model has two age replacement replacement cycle of prevention, namely (1) the prevention cycle that ends with the preventive replacement activities, (2) the cycle of damage that ends in destruction activities. Both age replacement cycle of the model can be seen clearly in the picture below:

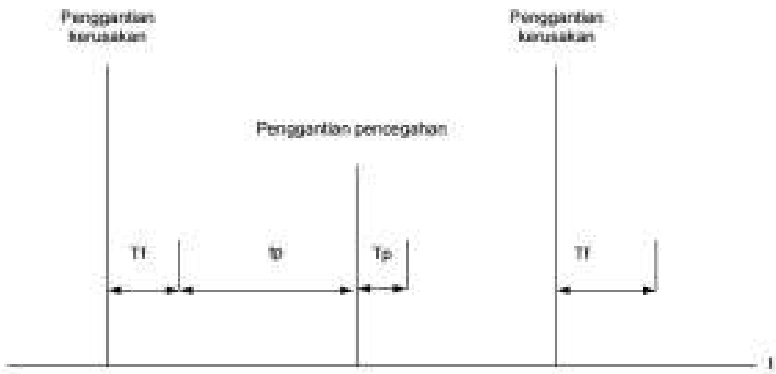

Figure 2. Age Model Replacement

t_p : is the time interval of preventive replacement per unit time.
C_f : is the cost required for replacement due to damage.
C_p: is the cost incurred for the replacement activities

$$\text{Then } C(t_p) = \frac{\textbf{Total expected change in cost per cycles}}{\textbf{cycle length expectations}} \tag{10}$$

Cycle length expectation fault conditions is also a summation and downtime repair the damage with an average interval of damage or M (tp), where M (tp):

$$M(t_p) = \left(\frac{t_p}{\alpha}\right)^{\beta} \tag{11}$$

So that the inspection interval determination model by minimizing downtime criteria are as follows:

$$C(t_p) = \frac{C_p.R(t_p)+C_f[1-R(t_p)]}{(t_p+T_p).R(t_p)+[M(t_p)+T_f][1-R(t_p)]} \tag{12}$$

Note:
t_p is the time interval of preventive replacement.
T_p is the time required to perform preventive replacement.
T_f is the time required to perform the replacement of the damage.
C_p is the cost of preventive care.
C_f is the cost of replacement of the damage.
R (tp) is the probability of occurrence of preventive replacement at the time tp.
M (tp) is the average time of the damage if preventive replacement of the tp.

3. Result and Discussion

Date of damage to each component is the data used to obtain damages interval between components, aim to know the lifespan of the components that will be used in preventive maintenance care policy. Here is a breakdown date data and intervals of engine damage Water Jet Loom.

Table 3. Data Interval Damage

	Nozzel		**Kamran**		**pump**	
No.	Damage taggal	interval	Damage taggal	interval	Damage taggal	interval
1	March 07, 2016		March 27, 2016		May 21, 2016	
2	May 09, 2016	63	May 19, 2016	53	November 18, 2016	181
3	August 11, 2016	94	August 03, 2016	76	May 23, 2017	186
4	November 8, 2016	89	November 14, 2016	103	December 06, 2017	197
5	January 18, 2017	71	March 08, 2017	114	May 16, 2018	161
6	June 07, 2017	140	June 28, 2017	112	November 7, 2018	175
7	September 29, 2017	114	October 05, 2017	99		
8	March 15, 2018	167	January 29, 2018	116		
9	July 28, 2018	135	April 11, 2018	72		
			August 03, 2018	114		

Data destruction is necessary to identify the distribution of the index calculation of fit (r) to determine the pattern of distribution of time intervals damage. The R value will be selected as the appropriate distribution. Distribution used in the identification phase of this distribution is the exponential distribution, Weibull, Log Normal and Normal as follows:

Table 4. Summary of Results Selected Distribution

Component	**type Distribution**				**distribution Selected**
	exponential	**Weibull**	**Normal**	**Log**	

				Normal	
nozzle	0965	**0982**	0958	0969	Weibull
pump	0942	**0995**	0992	0956	Weibull
Kamran	0777	**0956**	0927	0907	Weibull

Based on the calculation interval selected distribution is distribution weibull, it is necessary to prove the distribution of the test that is test Mann. Sample calculations used component is component nozzle with declare that the nozzle distribution H_0 and H_1 weibull stated that the nozzle is not distributed weibull. Here as for the recapitulation of Mann test calculations for each component and Summary of Parameter Calculation of Distribution

Table 5. Summary of Calculation Mann

No.	Component name	S Calculate	S Table	α	β
1	pump	0541	0860	186 116	13 772
2	Kamran	0247	0760	105 939	3,848
3	nozzle	0709	0710	122 296	3,133

Based on the selected distribution which weibull distribution, the parameters must be searched to determine the replacement of components is α and β. Sample calculation of the components used is nozzle. As an example of calculation of the distribution parameters interval damage to the components of the nozzle. The recapitulation data distribution parameter calculation of each component as follows: After performing the calculation of derived parameters parameter values α and β for determining the maintenance schedule which aims to find a date that has a value of cost (Ctp) minimum to perform maintenance activities. Sample calculation used is a component nozzle, while the other components are presented the results only;

Table 6. Calculation Component Maintenance Schedule

tp	cp	cf	Alpha	beta	M (tp)	R (tp)	1-R (tp)	C (tp)
79	Rp1,203,508	Rp 1,418,608	122 296	3,133	0.2543463	0.7754233	0.2245767	Rp 20.408
80	Rp1,203,508	Rp 1,418,608	122 296	3,133	0.2645696	0.7675362	0.2324638	Rp 20.386
81	Rp1,203,508	Rp 1,418,608	122 296	3,133	0.2750692	0.7595196	0.2404804	Rp 20.373
82	Rp1,203,508	Rp 1,418,608	122 296	3,133	0.2858489	0.7513761	0.2486239	Rp 20.370
83	Rp1,203,508	Rp 1,418,608	122 296	3,133	0.2969127	0.7431089	0.2568911	Rp 20.375
84	Rp1,203,508	Rp 1,418,608	122 296	3,133	0.3082645	0.734721	0.265279	Rp 20.390
85	Rp1,203,508	Rp 1,418,608	122 296	3,133	0.3199082	0.7262157	0.2737843	Rp 20.413

Translation of calculation for tp = 82:

$$M(82) \;=\; \left(\frac{t_p}{\alpha}\right)^{\beta} == \left(\frac{82}{122,296}\right)^{3,133} .2858$$

$$R(82) = exp\left(-\frac{t_p}{\alpha}\right)^{\beta} = .7513$$

$$F(82) = 1 - R(82) = 1 - 0,7513761 = 0,2486$$

$$C(82) = \frac{C_p\ (R_{(tp)}) + C_f(1 - R(tp))}{(t_p + T_p)R(tp) + (M(tp) + T_f)(1 - R(tp))}$$

$$= \frac{1203508\ (0,7513) + 1418608\ (0,2486)}{(82 + 0,026)0,7513 + (0,2858 + 0,042)(0,2486)} = \text{Rp. } 20\ 370$$

Below is a recapitulation of determining the age replacement policy:

Table 7. Summary of Calculation Engine Maintenance Schedules Water Jet Loom

Component	Cpi	Cfi	α	β	tp	C (tp)
pump	Rp1,140,137	Rp1,637,215	186 116	13 773	150	Rp8,174
Kamran	Rp1,744,594	Rp2,242,447	105 939	3,848	71	Rp32,087
nozzle	Rp1,203,508	Rp1,418,608	122 296	3,133	82	Rp20,370

4. Conclusion
Based on the results of data processing can be deduced as follows that the scheduling of replacement parts in the engine water jet loom is; (1) The components of the pump will be replaced every 150 days, (2) Components kamran 71 days and (3) Components nozzle 82 days.

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