Reliability Centered Maintenance of Circular Loom

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Abstract

Today's customers demand not only product variety but also expect quick delivery of products. In order to meet these challenges from customers, manufacturing companies will have to ensure timely availability of raw materials, cutting tools, machine tools, people etc. Thus, availability of machine tools is one important factor that determines whether the customer's demand can be met by the manufacturing company or not. Availability of machines means machine should be available whenever its service is required. In order to increase the machine availability or machine uptime, maintenance is done. Thus, maintenance would help in extending the useful service life of the machine tools. In industries, maintenance of certain machine tools is done at regular intervals. This type of maintenance is known as preventive maintenance. For certain machine tools, maintenance will be done after the breakdown of machine tool. This type of maintenance is called breakdown maintenance. The main constraint faced by many manufacturing companies is that there is a limitation on the maintenance budget. This has made many manufacturing companies start thinking in new ways for solving maintenance problem. In this context, reliability centered maintenance (RCM) assumes special significance. The objective of RCM is to bring down the maintenance cost. RCM, while focusing is on system's functionality, will also help in achieving safety aspect and reliability aspect of the system. Expert choice software is employed for AHP computation. The application of RCM technique in the maintenance of circular loom is not reported in Literature. In this context the current research assumes special significance. Research findings presented in this paper are going to help both academicians and researchers.

Keywords

Reliability, Reliability Centered Maintenance, Maintenance, Analytical Hierarchy Process, ANP, AHP

1. Introduction

Today for meeting the customer's expectations, the availability of machines is very much essential. If a machine becomes un available, then there will be down time and associated waiting time of work-in-process. That is the components will have to wait for subsequent processing. Amount of waiting time is determined by the severity of the problem faced by the machine tool. In this scenario, there will be idle time of the machine tool operator as well. Sometimes, when a machine goes down it may impact other machines down the manufacturing line. This situation clearly shows that the productivity of the manufacturing line will be adversely affected. When the productivity of a manufacturing line goes down, it will result in delayed product deliveries to the customer. This would result in customer dissatisfaction and company's company will lose its reputation. This clearly shows te importance of machine maintenance. Thus, the productivity of a manufacturing line depends on the availability of machines. For increasing the machine availability, selection of a right maintenance policy is very much essential. Maintenance policy indicates the type of maintenance that is required for a given machine in the manufacturing line. Depending upon the type of machine, every machine will be subjected to one or other type of maintenance. Companies at times face the problem in selecting a particular type of maintenance for a given machine tool. Selection of right maintenance policy also results in reduced maintenance cost. Aditionally, by selecting right type of maintenance for a give machine, will bring down the workplace related accidents and this will enhance employee wellbeing and comfort level. When a machine becomes available. It would help a machine tool operator in meeting his production targets. Thus, it will make the operator happy and enhance his productivity.

If a machine becomes unavailable, it would cause problems to the people in production planning and control (PPC) department. As and when a machine goes down or becomes non-operational, it becomes the responsibility of the PPC department to decide about the processing of the component on the next available machine. This means there is a change in the production schedule. This problem becomes even more complicated when multiple machines fail. Rescheduling some time becomes very complicated. Rescheduling may sometime increase the waiting time for processing a job. Also, there may be traffic jams in the shop floor. Due to the sudden changes in the production sequence while manufacturing a product. In this context, the present research work will assume special significance.

Maintenance can be classified based on time and condition (Ben et al. 2016, Hilber 2018). There is a huge need for reducing the maintenance cost of machines in general and textile industry in particular. Not much work has been reported in literature, about the maintenance of circular loom. This has motivated us in focussing on maintenance of circular loom. The research findings provide guidelines for selecting maintenance policies for circular loom.

2. Literature review

In 1950, aerospace industries (Jesús 2017) have realized that conventional maintenance techniques are no longer capable of meeting the expectations concerning cost and safety. This is the main reason behind the emergence of RCM.

Birnbaum (1969) and Barlow et al. (1975) proposed a technique of identifying components which are critical to a machine. Also, when these critical components become dysfunctional it would result in customer dissatisfaction (Jeyamala et al. 2013). Saaty (1996) has proposed a new technique called Analytic network process (ANP) for identifying the critical components. Many researchers have been working using ANP as a tool for taking decisions (Dorri 2014, Sadeghi and Manesh 2012, Tajadod et al. 2011). AnaTang et al. (2017) came out with a new tool for the identification of components which are critical to a machine. They have demonstrated how by using their framework, effective maintenance is possible. A new method was proposed by Moslemi et al. (2017). This method has been used for arriving at optimum schedule for maintaining an equipment. Chu et al. (2009) and Li et al. (2004) proposed a method for solving maintenance related problems. Using these techniques, they demonstrated how to prioritize activities related to maintenance of a distribution system. Verma et al. (2010) have shown how by making use of ANN safety as well as reliability of a distribution system. They have demonstrated how maintenance frame work can be successfully deployed.

Hamzeh et al. (2015) and Marton et al. (2016) have explored how to solve maintenance related problems of an aging distribution system. They demonstrated how aging will affect maintenance function. They proposed strategies required for solving maintenance problems.

Carnero et al. (2017) have conducted a detailed study on electric power systems and proposed appropriate strategies for dealing with maintenance problems. Silvestri et al. (2012) have studied a manufacturing organization and proposed a maintenance framework for enhancing safety at the workplace. Wang et al. (2001) have studied a CNC machine in detail and proposed a technique for assessing the reliability in effective fashion. Carot et al. (2000) in their study, had used non-repairable parts and performed sensitivity analysis for assessing the relative prominence of different parts of a complex network. Thus, it is evident that RCM technique was not explored for the maintenance of circular looms. In this context, the current research work becomes very significant. The research outputs are very much useful for both academicians and practitioners in pursuing further research.

3. Methodology

The current research work uses the steps described in the following paragraphs.

3.1 System Selection

Circular loom (consisting of Electric cutter, Reed ring, Swing lever, Shuttle, Deflector pulley), is considered as a system -case study for the current research work.

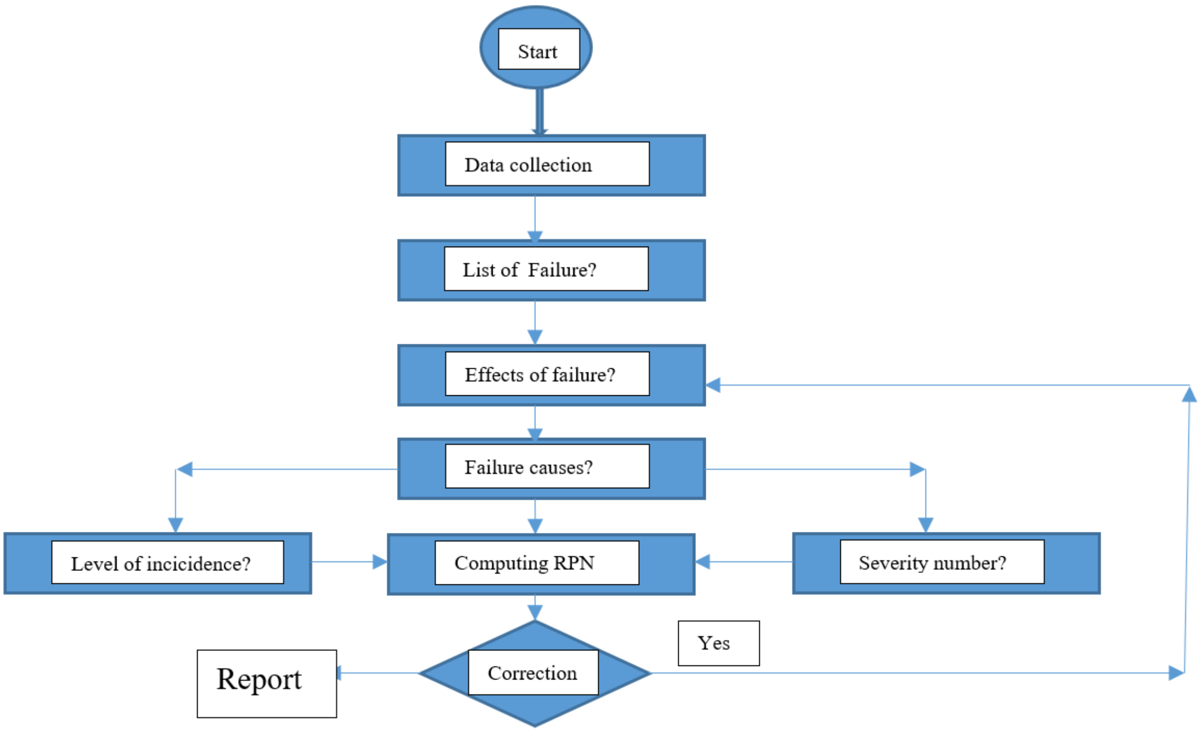

Figure 1 Failure Mode Effects Analysis

3.2 Identification of Critical Parts

Analytical hierarchy process (AHP) makes it possible to assign weights to multiple alternatives. That is, it helps in selecting or classifying alternatives. Thus, it would help in identifying the critical components. The technique was developed by Saaty (1980) in the 1970s. Many researchers have been working on this technique since then. Analytical Hierarchy Process has to follow principles- given problem is set-up in a hierarchical manner, by paired comparison, relative weights are determined, logical consistency through measurements.
Expert choice software is used for making calculations related to AHP process. The technique helps in calculating the weights for different decisions. The technique makes use of expert's experience in quantifying weights of various decisions through pairwise comparisons. After conducting interviews with experts and based on their feedback, the following criteria clusters are identified: (1) Cost: A component is considered critical if it has higher maintenance cost in comparison to other components,(2) Complexity: A machine with large number of components with high failure rates is considered more critical, (3) Maintainability: A machine with large downtime is considered more critical than others, (4) Safety: It is important to consider the safety aspect while identifying components which are critical to the functioning of a module.

In AHP process the following metrics are used for determining the extent of compatibility existing in the judgement. This is required because, many a times the judgements usually depend upon the state of the person making the judgement and also depends upon the extent of understanding of the given situation.

$$Compatibility\ Index(CI) = \frac{\lambda max-n}{\mathrm{n}-1} \quad (1)$$

In Equation (1), n, represents the matrix aspect; the numerator shows the extent of in compatibility existing in the matrix (Saaty, 1996).

Ratio of Compatibility is calculated by using the equation (2)

$$CR = \frac{CI}{\mathrm{RI}} \quad (2)$$

If CR <=00.1 matrix is said to be compatible.

3.3 Failure- Mode- Effect- and Criticality Analysis (FMECA)

FMECA would help identifying failure modes having high probability and severity of consequence. This would help in understanding where most focus is required as well as maximum value creation is possible. Failure mode effect analysis steps is presented in a flow chart (Figure 1). Table 1 shows the suggested guidelines for failure mode possibility. For, example, if for a given component, there is a very remote possibility of failure mode occurring during the service life of the component, then a rating of 1 is awarded. On the other hand, if there is a high probability of failure mode happening, during the service life of the component, then a rating of 3 is awarded.

Table 2 shows the suggested guidelines for the end effect possibility. That is, even when a component is subjected to the failure mode, if the probability that end effect happening is highly unlikely, then a rating of 1 is awarded. Similarly, on the other hand, when a component is subjected to the failure mode, if there is a very strong probability of end effects happening then a rating of 3 is awarded.

Table 1 Failure mode possibility

Category	**Description**	**Factor**
Not Expected	Failure mode will not occur during the life time	1
Possible	Failure mode is possible (during product life time)	2
High	Failure mode is highly possible (during product life time)	3

Table 2 End effect possibility

Category	**Description**	**Factor**
High	Even though a failure mode is occurring failure end effect will not happen	1
Medium	The possibility of reaching failure mode end effect is remote	2
Low	Failure end effect is highly possible	3

Table 3 shows the suggested guidelines for failure mode consequence. If the predicted downtime for a given component is less than one hour; if failure of the component results in no injuries; if there is very less waste is expected from a component failure; if the cost of replacing the component is less than Rs.500; if the human intervention required is less than a grade of 1 is awarded. Conversely, if the failure of a component creates an equipment downtime of greater than 6Hrs.; if the component's failure is unsafe for the operator in the working environment; if the component failure results in severe waste; if the cost of replacing the component is going to cost higher than Rs.5000; if higher human intervention is required then a score of 3 will be awarded.

Table 3 Failure mode consequence

	Consequences		
	Marginal	**Medium**	**Critical**
DT	Less tha one	one to six	Greater than six
S	No Injuries	Not severe	severe
W	Less	medium	highest
SC	<500 Rs	500 to 5000	>5000 Rs
I	Low	Medium	high
Factor	1	2	3

Index (Table 3): Downtime: DT; Safety: S; Waste: W; Spare Part Cost: SC; Intervention: I;

Table 4 shows the results obtained after pair-wise comparison process. Here each entry in this table is made by comparing the property on the left side of matrix and the one on the top of the matrix. While filling values, a scale of 1-9 is followed. As per this scale, rating '1' means 'important' and rating '9' means very much important. When one of the above rating is given to element 'k' when compared with 'l' then a rating of '1/rating' will be assigned to 'l'.

Table 4 Pairwise Criteria Matrix

	Cost	**Complexity**	**Maintainability**	**Safety**
Cost	1.00	0.20	3.00	4.00
Complexity	5.00	1.00	8.00	5.00
Maintainability	0.33	0.13	1.00	2.00
Safety	0.25	0.20	0.50	1.00

3.4 Selection of Maintenance Task

This step determines the most appropriate policy required for maintaining a component. This is based on the analysis described in the last section.

4. Results and discussions

Table 5 shows the list of components of circular loom along with function, possible mode of failure and consequence of failure.

Table 5 Components of Circular loom

Sl.No	Name of the component	Function	Failure mode	Failure effect
1	Electric Cutter	open fabric	Plastic jammed/Current	Fire hazard
2	Reed Ring	weaving	Wear and tear	Loss of production
3	Swing Lever	Guideway for shuttle and centre	warp bar/bearing	Wastage
4	Shuttle	weaving function up down	Wheel/Brake	Wastage
5	Deflector Pulley	moving of belt	Shaft/Bearing	Wastage

Table 6 Factor Comparison (Cost)

Cost	A	B	C	D	E
A	1.00	2.00	2.00	8.00	9.00
B	0.50	1.00	1.00	4.00	5.00
C	0.50	1.00	1.00	4.00	5.00
D	0.13	0.25	0.25	1.00	2.00
E	0.11	0.20	0.20	0.50	1.00

Note: A: shuttle; B: electric cutter; C: reed ring; D: swing lever; E: deflector pulley

Table 6 shows the pair-wise comparison results obtained with regard to cost for various components of circular loom. Numbers in these tables signifies which component is more important than other component with regard to the cost.

Table 7 Factor Comparison (Complexity)

Complexity	A	B	C	D	E
A	1.00	4.00	8.00	3.00	6.00
B	0.25	1.00	3.00	0.50	2.00
C	0.13	0.33	1.00	5.00	4.00
D	0.33	2.00	0.20	1.00	3.00
E	0.17	0.50	0.25	0.33	1.00

Note: A: shuttle; B: electric cutter; C: reed ring; D: swing lever; E: deflector pulley

Table 7 shows the pair-wise comparison results obtained with regard to complexity for various components of circular loom. Numbers in these tables signifies which component is more important than other component with regard to the complexity.

Table 8 Factor Comparison (Maintainability)

Maintainability	A	B	C	D	E
A	1.00	5.00	7.00	2.00	0.33
B	0.20	1.00	0.50	0.33	0.14
C	0.14	2.00	1.00	0.20	0.11
D	0.50	3.00	5.00	1.00	0.25
E	3.00	7.00	9.00	4.00	1.00

Note: A: shuttle; B: electric cutter; C: reed ring; D: swing lever; E: deflector pulley

Table 8 shows the pair-wise comparison results obtained with regard to maintainability for various components of circular loom. Numbers in these tables signifies which component is more important than other component with regard to the maintainability. Similarly, Table 9 shows the pair-wise comparison results obtained with regard to safety for various components of circular loom. Numbers in these tables signifies which component is more important than other component with regard to the safety factor concerned.

Table 9 Factor Comparison (Safety)

Safety	A	B	C	D	E
A	1.00	0.20	4.00	0.50	6.00
B	5.00	1.00	6.00	4.00	8.00
C	0.25	0.17	1.00	0.20	3.00
D	2.00	0.25	5.00	1.00	7.00
E	0.17	0.13	0.33	0.14	1.00

Note: A: shuttle; B: electric cutter; C: reed ring; D: swing lever; E: deflector pulley

Tables 10 shows the overall importance of the different components of the circular loom. and Table 11.0 shows the final ranking of different components. From Table 10 it is clear that shuttle component has highest ranking of all components selected for analysis. In this research work, AHP is done once with
(Table 1) Failure mode possibility; then with (Table 2) End effect possibility and finally (Table 3) Failure mode consequence

Table 10 Overall Ranking

A	0.422548
B	0.173827
C	0.175652
D	0.135877
E	0.092094

Note: A: shuttle; B: electric cutter; C: reed ring; D: swing lever; E: deflector pulley

Table 11 Criticality Analysis

Part	Criticality
B	45
A	54
C	7
D	45
E	45

Note: A: shuttle; B: electric cutter; C: reed ring; D: swing lever; E: deflector pulley

4.2 Selection of Maintenance policy

Table 12 shows the the different components in the circular loom- shutter, electric cutter, swing lever, deflector pulley and read ring. As can be seen from the table, for the purpose of performing maintenance of the shuttle component, preventive maintenance policy is preferred. Table 11 (criticality analysis) showed that the shuttle component (A) has the more criticality rating. This means that shuttle component is considered as most critical of all the components. As can be seen from Table 11, the criticality rating obtained for the shuttle component is 54. Similarly, after performing criticality analysis (Table 11) shows that Electric cutter has the criticality rating of 45. Hence, it was kept next to the shuttle component. What it means is that electric cutter is also a critical component. Thus, from Table 12, it can be seen that preventive maintenance policy is preferred for maintaining the electric cutter component. Similarly, swing lever also has a criticality rating of 45 (Table 11). Swing lever is also considered critical component and hence Table 12 shows that for maintain swing lever, preventive maintenance policy is preferred. After criticality analysis (Table 11) it is observed that deflector pulley has a criticality rating of 45. Thus, from Table 12, it can be seen that preventive maintenance is preferred. Table 11 shows that after criticality analysis, the criticality rating obtained for the reed ring is 7. This clearly shows that it is nowhere near to the ratings obtained for other parts of circular loom. Table 12 shows that for reed ring reactive or breakdown policy is preferred as it is not a critical component. The integrity of the results obtained from Table 12 was verified with experts.

Table 12 Maintenance Policy selection

Sl. No	Name of the component	Type of policy selected
1	A	Preventive Maintenance
2	B	Preventive Maintenance
3	D	Preventive Maintenance
4	E	Preventive
5	C	Reactive Maintenance

Note: A: shuttle; B: electric cutter; C: reed ring; D: swing lever; E: deflector pulley

5. Conclusion

Maintenance (preventive/reactive) helps in extending the useful life of the machine tools in a manufacturing company. In the present research work, a circular loom in a textile company is considered as a case study. An effort is made to apply the analytical hierarchy process for selecting the appropriate policy for maintaining the different components of a circular loom. Enhancing the availability will ensure meeting customer orders. A circular loom consisted of different components. In the textile company (case study), budget of maintenance was limited. Thus, it was not possible to focus on all the components of circular loom for enhancing the availability of the circular loom. In this context critical components had to be identified for reducing the maintenance cost. For identifying

Analytical hierarchy process (AHP) makes it possible to assign weights to multiple alternatives. Thus, it helps in selecting or classifying alternatives. The technique helps in calculating the weights for different decisions. The technique makes use of expert's experience in quantifying weights of various decisions through pairwise comparisons. After conducting interviews with experts and based on their feedback, the following criteria clusters are identified: (1) Cost cluster -A component is considered critical if it has higher maintenance cost in comparison to other components; (2) Complexity cluster -A machine with large number of components with high failure rates is considered more critical; (3) Maintainability cluster -A machine with large downtime is considered more critical than others; and (4) Safety cluster -It is important to consider the safety aspect while identifying components which are critical to the functioning of a module.

Pair wise comparisons have showed the relative importance of each component with respect other components. Overall importance and the criticality analysis showed that certain components -shutter, electric cutter, swing lever and deflector pulley are critical for the effective functioning of the circular loom. As these components are critical and since the availability of the circular loom depends on these components, preventive maintenance policy is preferred over breakdown maintenance. Certain components e.g., reed ring had scored less criticality rating. Thus, reed ring is not considered as a critical component of the circular loom. Also, breakdown maintenance is preferred. The current research work showed that not all components require same type of maintenance policies. Thus, by focussing only on critical components of circular loom, there will be a reduction of total maintenance cost.

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