INTERNATIONAL JOURNAL OF LATEST TECHNOLOGY IN ENGINEERING, MANAGEMENT & APPLIED SCIENCE (IJLTEMAS)
ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XIII, Issue VIII, August 2024

Preventive Maintenance Planning for Machines Computer Numerical Control (CNC) Type Hurco Vmx24 to Improve Reliability Using the Reability Centered Maintenance (RCM) Method (Case Study)

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DOI: https://doi.org/10.51583/IJLTEMAS.2024.130820

Received: 05 September 2024; Accepted: 10 September 2024; Published: 18 September 2024

Abstract: This paper presents the results of the analysis of Computer Numerical Control (CNC) machine components that result in decreased machine efficiency in the production system with the Reliability Centered Maintenance (RCM) approach. Utilized to improve the performance of machine components. The machine has not been maintained regularly so that at any time the machine can experience damage which results in losses to the company's income. so that an analysis is designed for maintenance planning management activities with the methodology of identifying and analyzing failure factors using the Failure Mode Effect Analysis (FMECA) worksheet, Logic Tree Analysis (LTA), and finally the Action Road Map. The results of the analysis carried out are divided into three categories of maintenance actions, namely, Condition Direction (CD) maintenance, Time Directed (TD) maintenance, Finding Failure (FF) maintenance with a periodic checking interval of 2 times within a period of 12 days.

Keywords- Failure Mode Effect Analysis (FMECA), Reliability Centered Maintenance (RCM), Downtime Mechine, Inspection time interval, Maintenace Mechine

I. Introduction

Maintenance is a factor in maintaining the capability and reliability of a machine to ensure the production system works according to its function [1]. Operational smoothness is supported by various aspects, one of which is the aspect of machine reliability in the production system.

Various treatment methods were developed by researchers. To overcome this problem, it is necessary to implement a maintenance system using the Reliability Centered Maintenance (RCM) method. RCM is a method used to develop failure management policies with the aim of maintaining the functional performance of physical assets [2]. The RCM work stage is to ask seven questions to each component or engine system. The first stage of the RCM process is collecting detailed information on machine components. After the system selection is made, a System Diagram and Functional Diagram Block (FGD) are created by developing a system work breakdown structure (SWBS) [3]. The first four questions will be identified through the Failure Mode and Effect Analysis (FMECA). FMECA is the preparation of a worksheet to determine the function, failure mode, cause of failure and effects of failure and produces a Risk Priority Number (RPN) used to determine the most critical category of machine components, which is obtained from determining the values RPN= Severity x Occurrence x Detection, with numeric scale 1-10 [4]. After the RPN value is known, it is continued with the Logic Tree Analysis (LTA) structure. LTA aims to determine the priority of each damage mode by providing questions (Evident, safety, Outage), so that a category is obtained for each component [5]. The final stage of the RCM process is Action Selection. This stage is to determine the right action category for each failure mode with the Action Selection Road Map, Action categories (Condition Directed, Time Direct, and Finding Failure) [5].

Reliability parameters and functions are divided into several distributions used in determining the calculation of Mean Time to Failure (MTTF) and Mean Time to Repair (MTTR). MTTF is the average failure time value of a system or component. MTTF is only used on components or tools that are frequently damaged and must be replaced with new ones [6]. while MTTR is based on the duration of component replacement and repairs [6]. To determine MTTR and MTTF, you must first carry out distribution tests such as (Weibull, Exponential, Lognormal and Normal Distributions) [6].

II. Experiment Setup

A. Data Selection

The stages in preparing the analysis begin with collecting information about the machine system and machine components, frequency of machine damage, and machine downtime data.

B. Time to Failure and Time to Repair calculations

Time to Failure is calculated from the time the component is completed being repaired until the start of the component being repaired, while Time to Repair is calculated from the start of the component being damaged until the component is completed being repaired.

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TABLE 1. SUMMARY OF TTF AND TTR CALCULATIONS

Component	Failure Start Date	Repair Completion Date	Initial Time of Damage	Damage Completion Time	*Time to Failure*	*Time to Repair*
Suction Filter	2/1/2019	2/1/2019	08.00	08.30	112	0,5
balls crews	21/1/2019	21/1/2019	14.00	16.30	16,2	2,5
…	…	…	…	…	…	…

Example calculation of Suction Filter components

B. Time to Failure (TTF) calculation stage:

- Machine working 8 hours a day, and 5 days a week
- Date 2/1/2019, 08.00 o'Clock – Date 21/1/2019, 08.30 o'Clock (13 Timework x 8 hours = 104 Hourse).
- Date 02/1/2019 08.00 o'Clock – 08.30 o'Clock = 7,5 o'clok.
- Date 21/01/2019 14.00 o'Clock – 16.30 o'Clock = 0,5 hours

So the time between damage to the date 2/01/2019 – 21/01/2019 is (104 hours + 7,5 hours + 0,5 hours = 112 hours)

C. Time to Repair (TTR) calculation stage:

- Date 2/1/2019, 08.00 o'clok – 08.30 o'clok = 0,5

The results of the TTF and TTR calculations then determine the distribution, the selection of distribution data is taken from the smallest index of fit value using Minitab 16 software. After the distribution is known, a Goodness of Fit Test is carried out to ensure that the selected data distribution truly represents the data. Next, determine the MTTF and MTTR values, and calculate the availability based on the inspection frequency.

D. Reliability Centered Maintenance (RCM)

The first step is to collect component structure information on the HURCO VMX24 CNC machine and create a Work Breakdown Structure (SWBS) System by assigning.

1) Failure Mode and Critical Analysis (FMECA)

Project : Failure Mechine					Version :1					Date :23 Mei - 24 Ju		
Code Componen	Name Componen	Fungsional Kompon	Failure Mode	Failure Cause	Local Effects	Global Effect	RPN S	RPN O	RPN D	RPN	Criticality	Risk Category
A1	Tool Magazine	Tool storage place	Tool Disc Jammed	No cleaning done, Lack of	Cannot change tools automatically	The machine can run by changi	8	2	5	80	High	Tolerable

Fig.1. Worksheet FMECA mesin CNC HURCO VMX24

2) From figure 1 it can be seen for filling Failure Mode and Critical Analysis (FMECA).

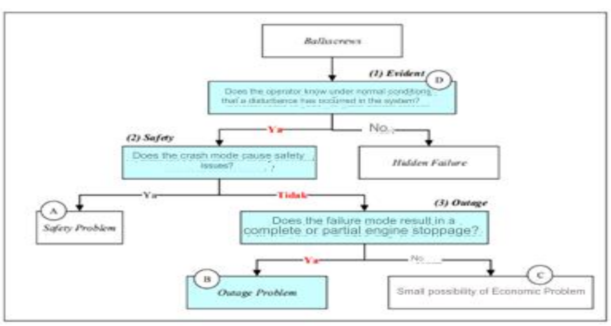

Fig.2. Flowchart for compiling LTA components of Ball Screw

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3) Logic Tree Analysis (LTA)

Example of Filling in LTA Diagram the Axes system stops operating, using the following four questions:

- Evident, does the operator know that under normal conditions there has been a disturbance in the system? **YES**
- Safety, does this damage mode cause safety mode? **NO**
- Outage, does this damage mode cause the entire machine to stop or part of the machine to stop? **YES**

Then Category B (Outage Problem) is obtained, if component failure causes the entire machine to stop or part of the machine to stop.

2) Action Selection

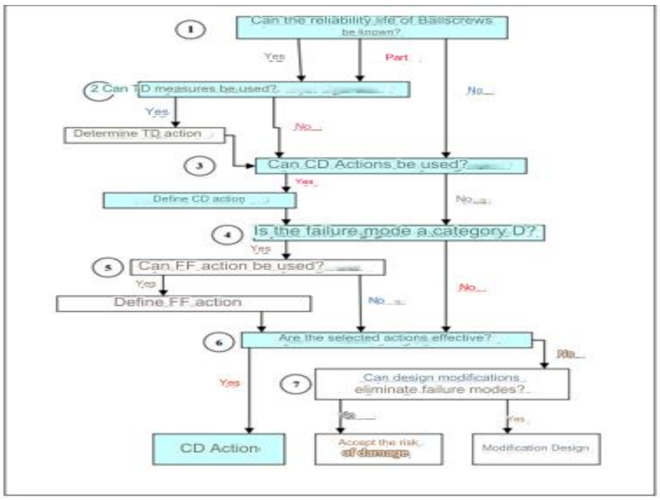

Fig.3. Road Map for Preparation of Axes Component Maintenance Actions

The final stage in the RCM process, to determine the selection of appropriate actions for the damage mode of each specific component by answering questions on the action selection roadmap.

Example of filling in the Action Selection Roadmap

- The Axes system stops operating

- The component that may cause damage is the Ball screw.

- The function of the Ball screw is to change the rotational motion or smooth the rotational motion.

- Damage Mode is Ball screw Aus

Selection Guide (Guiding questions) for the damage model are:

- Can the reliability life of the ball screws be known? Partially
- Can Time Directed actions be used? **No**
- Can Condition Directed actions be used? **Yes**
- Is the failure mode included in category D? **No**
- Question no. 5 is skipped because question no. 4 is **“No”**
- Is the selected action effective? **Yes**

The selected category is Condition Directed (CD) an action aimed at detecting. If symptoms of damage are found, then it is continued with repair or replacement of components.

III. Results and Discussion

A. Data Processing Analysis

After calculating Time to Failure (TTF) and Time to Repair (TTR), the results of the distribution test were carried out to calculate the Index of Fit for the time between failures (r). The test results from the calculation of each distribution for the 2019 TTF data were the Weibull distribution which had the smallest presentation of 0.639; while for the 2020 TTF results, the Lognormal

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distribution was 1.067. Furthermore, for the calculation of Time to Repair (TTR), in 2019 the Lognormal distribution had the smallest presentation of 1.061, while for the 2020 TTR results, the Lognormal distribution was 2.277.

Next, a Goodness of Fit test was carried out. The results for Time to Failure (TTF) in 2019 obtained a Weibull distribution, with a p-value of 0.25, so the results of the test were P-Value> 0.05, so the TTF data was distributed Weibull. Meanwhile, for the 2020 TTF goodness test, with a p-value of 0.884, the test result is P-Value > 0.05, so the TTF data used is Lognormally distributed.

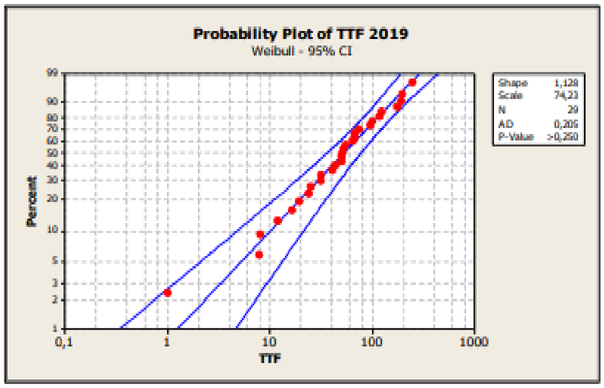

Fig.3. 2019 Goodness of Fit Time to Failure Test

The results of the Index of Fit (r) TTR in 2019 obtained a lognormal distribution, with a p-value of 0.086, so the test results are P-Value> 0.05, so the TTF data is distributed lognormally. The goodness test of the Time to Failure distribution in 2020 obtained the results of a Lognormal distribution, with a p-value of 0.086, so the test results are P-Value> 0.05, so the TTF data is distributed Lognormally.

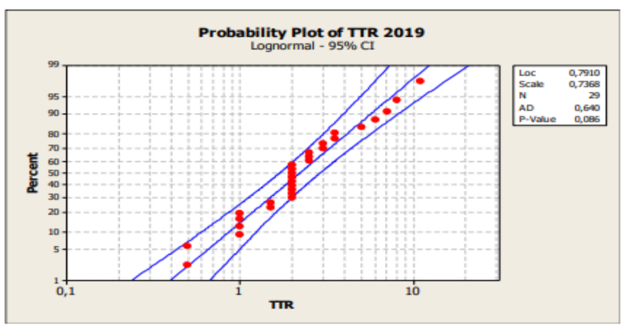

Fig.4. 2020 Goodness of Fit Time To Failure Test

Next, the calculation of Mean Time to Failure (MTTF) in 2019 was carried out, the Weibull distribution parameters were β (shape parameter) and α (scale parameter). as follows:

(α = 74,23 ; β = 1,128)

MTTF $= 74{,}23.\Gamma(1 + \frac{1}{11{,}128!})$

MTTF =71,05449439 jam

Determination of Mean Time to Failure (MTTF) value in 2020 The parameters of Lognormal distribution are s (variance parameter) and tmed (location parameter). The following is the calculation of MTTF:

(Exp = 2,71828183 ; tmed = 4,464 ; S= 1,091)

MTTF $= 2{,}71828183\ (4{,}464 + (0{,}5\ x 1{,}091^2))$

$= 12136{,}02785$ Jam

Next, the Mean Time to Repair (MTTR) calculation for 2019 was carried out. The parameters of the Lognormal distribution are s (variance parameter) and tmed (location parameter), so the result obtained is 1.0376 hours. while the determination of the MTTR value in 2020 with the Lognormal distribution parameter is 1.15

B. Determination of Frequency and Time Interval of Inspection

Determine the average operating time per month, then the calculation is carried out:

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- Working days per month = (1 week; 5 working days) = 5 x 4 = 20 working days
- Working hours per day = 8 hours / day

R = 20 x 8

= 160 hours

Average time to perform inspection, then the calculation (i) and calculation (Ti) are carried out

- Average 1 inspection = 1 hour

I = 1 / 160 = 0.00625

Ti = 1 / 0.00625 = 160

Determining the average time of damage

- number of damages during 1 year = 29; Number of months in one year = 12 months

K = 29 / 12 = 2.416666667

Next, the calculation of the optimal inspection frequency:

n = √ (2.416667 x 160)/154.1912949

= 1.58357428 ~ 2

Finally, the calculation of the inspection time interval:

ti= 160 / 1.5837428

=101.0372561 Hours

C. Realibility Centered Maintenance (RCM)

Collecting information in the form of systems and components which are then used to create a System Description and Function Block Diagram (FBD).

Table 2. Data Sistem Dan Komponen Mesin Cnc Hurco Vmx24

System	Code System	Componen	Code Component
Automatic Tool Changer (ATC)	A	Tool Magazine	A1
Table	B	Table	B1
Axes	C	Ball screws	C1
Spindle Head	D	Bearing Spindle	B1
		Motor Spindel	B2
Air Service Unit	E	Filter Unit	E1
		Selang Udara	E2
		Piping Lubrican	E3
Coolant &Chip Devices	G	Pump Coolant	G1
		Selang Coolant	G2
		Suction Filter	G3
Electrical Devices	H	Electrical Panel	G4
		Control System	G5

The next stage is filling out the FMECA worksheet, that there are 12 components that have a frequency of damage. The results of the RPN calculation show three main components that have the highest RPN values, namely components (Pump Coolant, ball screws, and air hoses) with a very high level of criticality and are unacceptable, while for components (Bearing Spindle, Spindle motor, Hose, Piping Lubricant, Suction Filter, Filter unit, Electrical Panel, Control System and Tool Magazine) with a high level of criticality can still be tolerated.

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Next, the compilation of Logic Tree Analysis (LTA) then obtained the failure category of each machine component, component categorization is done based on considerations made in the question structure, the following are the results of the categorization:

- Category A (Safety Problem) failure mode that can cause safety problems to operators and the environment. Based on the results of the study, there is no machine component included in this category.
- Category B (Outage Problem) failure mode that results in all or part of the system affecting operations. Components included in this category (Filter Unit, Electric Panel, Air Hose, Coolant Hose, Suction Filter, Tool Magazine, Control System, Pressure Switch).
- Category C (Economic Problem) components that do not cause failure of all or part of the system but cause losses to the company because the function of the component is reduced. Based on the results of the study, no machine components are included in category C.
- Category D (hidden Failure) is a component whose failure function is realized and difficult to detect by the operator because it is hidden from the operator's sight. Components included in this category are (ball screws, Spindle Motor, Coolant Pump, Spindle Bearing).

Action selection is the final process in the RCM process. Based on the results of action selection for components that experience failure in machine components, several selection actions are obtained, namely:

- Condition Directed (CD), Maintenance Actions The planned CD maintenance actions are: (Ball screws, Spindle Bearings, Air Hoses, Pressure Switches, Coolant Hoses, Electrical Panels, Control Systems, and Filter Units). Example: Inspection of the Spindle Bearing component is carried out by visually inspecting the physical condition of the bearing to avoid bearing cracks, Inspection of the temperature condition of the bearing by providing high temperature lubricant which can cause the bearing to break or burn, Inspection of the grease on the bearing to reduce rotational friction on the bearing)
- Time Directed (TD) maintenance actions aim to avoid component failures that are more focused on replacement activities carried out periodically. Components planned with this maintenance action are: (Suction Filter, Coolant Hose). for example, the Coolant Hose component. Component replacement is carried out when cracks are found during inspection by looking at the component's lifespan.
- Finding Failure (FF) of components planned with this maintenance action (Tool Magazine, Spindle Motor, Spindle Bearing, Pump Coolant). example of maintenance of Coolant Pump components. Checking the speed of the Coolant component pump in flowing coolant fluid when operating decreases or not, if the working speed decreases, then check the condition of the coolant pump.

IV. Conclusion

Based on the results of data processing and discussion that has been done, it can be concluded that a machine must be maintained thoroughly with a predetermined time interval because if one component dies, the machine cannot run. It was found that the inspection interval time was carried out twice a month. with a period of 101.037 hours equivalent to 12 days. To find out which components are classified as critical on the CNC HURCO VMX24 machine, it was obtained from the Failure Mode and Critical Analysis (FMECA) which was seen from the highest Risk Priority Number (RPN) on each machine component. The optimal maintenance actions in the Reliability Centered Maintenance (RCM) method on the CNC HURCO VMX24 machine were concluded to be Condition Directed (CD), Time Directed (TD) and Finding Failure (FF).

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