Journal Of Harmonized Research (JOHR)

Journal Of Harmonized Research in Engineering
2(1), 2014, 187-193

ISSN 2347 – 7393

Original Research Article

FAILURE CAUSE ANALYSIS OF CNC MACHINE BY AHP & MCDM APPROACH

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Abstract: During the operation of these machine tools, different kinds of failures are faced by the industry. The failure causes of CNC machine with the identification of critical sub-system based on the failure data analysis for different type of machine tools has been carried out in this paper. Moreover, simple additive weight (SAW), the simplest and still the most widely used Multiple Attribute Decision Making (MADM) method, was used to identify each CNC machine failure. These failures were then used to create a quality inspection order, so that the machine with the lowest failure could be inspected before the machine with the highest failure.

Key Words: - CNC, Failure cause, MADM.

Introduction:-

During the last decade, computerized numerical control (CNC) the breakdown of a single CNC lathe may result in the production of an entire workshop being halted and repairs are more difficult and expensive when a breakdown occurs [1]. The failure data may indicate on which element the condition monitoring system should concentrate for proper functioning. Sometimes, the failure data may present a complicated picture and one may not be able to clearly identify critical subsystems. In such cases application of various techniques like Analytic Hierarchy Process (AHP), Simple Additive Method (SAW), and Weighted Product Method (WPM) can be useful to determine the critical components system in machine. In this context, it was decided to collect machine tool failure data from industries and apply techniques like graph theory to determine the critical sub-systems in a machine tool .This project is based on application of AHP, SAW, and WPM to machine tool failure data [2]. The CNC system and some electronic components, such as contactor

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Received on: February 2014
Accepted after revision: February 2014

switches, relays, regulators and buttons are fixed in a cabinet. Other electronic components, such as limit switches, proximity switches and encoders are located on the machine [3]. Here, MADM methods are apply for the selection of failure causes in CNC machine. Dogra et al. studied about the effect of tool geometry i.e. tool nose radius, rake angle, variable edge geometry and their effect on tool wear, surface roughness and surface integrity of the machined surface during turning. The greater negative rake angle gives higher compressive stress which deeper affected zone below machined surface [3]. Rao et al. have worked on the selection of material for wind turbine blade from the alternative material. They applied MADM (Multiple attribute decision making method) such as TOPSIS and fuzzy set theory and from the analysis they observed that if the wind turbine blades are made out of composite materials using carbon fibers, then they possess the high stiffness, low density and long fatigue life [7]. Abhang et al. studied about selection of best lubricant in turning operation from alternative lubricants by using MADM methods. They applied TOPSIS and AHP model and conclude that lubricant index evaluate and ranks best lubricant during steel turning operation and combined TOPSIS and AHP method provides a convenient approach for solving complex MADM problems in manufacturing domains [8]. In problem can be tackled with several schemes and decision algorithms such as genetic algorithms, fuzzy logic, utility functions and multi attribute decision making (MADM) methods. In the genetic algorithm is applied to optimize the access Failure cause with the goal of selecting the maximum failure cause. In this thesis proposed a network selection scheme based on utility function which takes more key factors for failure cause in CNC machine.

Materials and Methods

Multi-criteria decision making (MCDM) is the decision-making technique by considering some alternatives options. The Multiple Attribute Decision Making (MADM) comes to elections, in which mathematical analysis is not needed. This type of MCDM can be used for the election in which there is only a small number of alternative courses. The MADM is used to solve problems in discrete spaces, typically used to solve problems in the assessment and selection of limited number of alternatives. The MADM approaches are done through two stages, namely:

- Perform aggregation of the decisions that responds to the decisions corresponding to all destinations on each alternative
- Perform alternatives ranking based on the aggregation of the decision makers.

MADM is evaluated against the alternative m_i (i = 1,2 ,...., m) against a set of attributes or criteria m_j (j = 1,2 ,...., n) where each attribute are not mutually dependent with each other. Decision matrix of each alternative on each attribute, X is given as:

$$X_{ij} = \begin{array}{c} \\ 1 \\ 2 \\ 3 \\ \vdots \\ n \end{array} \begin{array}{c} \begin{array}{cccc} 1 & 2 & \dots & m \end{array} \\ \begin{bmatrix} b_{11} & b_{12} & \dots & b_{1n} \\ b_{21} & b_{22} & \dots & b_{2n} \\ b_{31} & b_{32} & \dots & b_{3n} \\ \vdots & \vdots & \ddots & \vdots \\ b_{m1} & b_{m2} & \dots & b_{mn} \end{bmatrix} \end{array}$$

Where b_{ij} is an alternative performance rating in relation to the j^{th} attributes. Weight value indicates the relative importance of each attribute, given as W:

$$W_j = \{ w_1 , w_2, w_3, \dots, w_m \}$$

Performance rating (X) and weight value (W) represent the core values corresponding to the absolute preference of the decision makers.

Analytic hierarchy process (AHP)

One of the most popular analytical techniques for complex decision-making problems is the analytic hierarchy process (AHP), which decomposes a decision-making problem into a system of hierarchies of objectives, attributes (or criteria), and alternatives.

Step 1: Determine the objective and the evaluation attributes. Develop a hierarchical structure with a goal or objective at the top level, the attributes at the second level and the alternatives at the third level.

Step 2: Determine the relative importance of different attributes with respect to the goal or objective. Construct a pair-wise comparison matrix using a scale of relative importance. The judgments are entered using the fundamental scale of the analytic hierarchy process. Find the relative normalized weight (W_j) of each attribute by calculating the geometric mean of the i^{th} row, and normalizing the geometric means of rows in the comparison matrix. This can be represented as:

$$GM_j = \left[\prod_{j-1}^{m} b_{ij}\right]^{\frac{1}{m}} \dots\dots\dots\dots\dots\dots\dots\dots.. (1)$$

$$W_j = GM_j / \sum_{j=1}^{m} GM_j \dots\dots\dots\dots\dots\dots\dots (2)$$

Where i= 1,2 3, …………..n and

j= 1,2,3, …….m

The geometric mean method of AHP is commonly used to determine the relative normalized weights of the attributes, because of its simplicity, easy determination of the maximum Eigen value, and reduction in inconsistency of judgments.

Step 3: The next step is to obtain the overall or composite performance scores for the alternatives by multiplying the relative normalized weight (W_j) of each attribute (obtained in step 2) with its corresponding normalized weight value for each alternative and summing over the attributes for each alternative. Here, each attribute is given a weight, and the sum of all weights must be 1. Each alternative is assessed with regard to every attribute. The overall or composite performance score of an alternative is given by Equation 3.

$$P_i = \sum_{j=1}^{m} W_j(m_{ij}) \dots\dots\dots\dots\dots\dots\dots\dots (3)$$

Where (m_{ij}) normal represents the normalized value of m_{ij}, and P_i is the overall or composite score of the alternative X. The alternative with the highest value of P_i is considered as the best alternative.

Simple Additive Weighting (SAW) Method

This is also called the weighted sum method and is the simplest and still the widest used MADM method. Here, each attribute is given a weight, and the sum of all weights must be one. Each alternative is assessed with regard to every attribute. The overall or composite performance score of an alternative is given by Equation 3.

It was argued that SAW should be used only when the decision attributes can be expressed in identical units of measure (e.g., only dollars, only pounds, only seconds, etc.). However, if all the elements of the decision table are normalized, then SAW can be used for any type and any number of attributes. In that case, Equation1will take the following form:

$$P_i = \sum_{j=1}^{m} W_j(m_{ij})_{normal} \dots\dots\dots\dots\dots\dots\dots\dots (4)$$

Where (m_{ij}) normal represents the normalized value of m_{ij}, and P_i is the overall or composite score of the alternative Ai. The alternative with the highest value of P_i is considered as the best alternative.

Weighted Product Method (WPM)

This method is similar to SAW. The main difference is that, instead of addition in the model. There is multiplication. The overall or composite performance score of an alternative is given by Equation 3.

$$P_i = \prod_{j=1}^{m} [(m_{ij})_{normal}]^{w_j} \dots\dots\dots\dots\dots\dots\dots (5)$$

The normalized values are calculated as explained under the SAW method. Each normalized value of an alternative with respect to an attribute, i.e., (mij) normal, is raised to the power of the relative weight of the corresponding attribute. The alternative with the highest Pi value is considered the best alternative [8].

Failure Data Collection and Analysis

The present work required CNC machine failure data from industries. This kind of information was not easily available with the local industries. Therefore initially literature was referred to check availability of data. Failure data were collected from Simplex industries Raipur & Bhilai Engineering Corporation a period of three years on two CNC machines such as lathe and machines. It contained the following information:

- Machine number
- Date of repair.
- Failure effect.
- Repair time.
- Down time.
- Date of hand-over.
- Causes of failure.

The data was collected from maintenance department of industries, type of sub system maintenance are shown in Table 1 and Table 2. Fig 1 Shows the Failure causes failure frequency and downtime of CNC lathe machine. Weights are shown in Table 2 collected from simplex industries Raipur.

Table 1:- Daily Maintenance

S. NO.	SUB SYSTEM	TYPE OF CHECK	TIME
1	. Lubrication system	Check for oil level, pressure	At the start of the work
2	Chuck	Greasing the master jaws, Tighten the jaws	At the start of the work
3	Cutting tools	Tighten the tool blocks, tools and inserts	At the start of the work
4	Hydraulic oil level	Check for level	Replenish if needed
5	Pressure gauge	Check system pressure, Check for chuck pressure	As per requirement
6	Coolant level	Check for level	Replenish if needed
7	External wiring and Cables	Check for disconnections and damage to sheath	As per requirement

Table 2:- Periodic Maintenance

S. NO.	SUB SYSTEM	TYPE OF CHECK	TIME
1	Coolant	Check for condition	Replace as required
2	Hydraulic system	Return line filter replacement, Check condition of oil and replace	6 months
3	Motors	Check for rigid (proper) mounting	6 months
4	Chuck	Overhaul the chuck	1 month
5	Electrical elements	Check for proper working of push button switches, electrical cabinets, Electrical contacts	3 months
6	Headstock	Clean labrynth holes	1 month
7	Lubricating system	Check for proper working	1 month

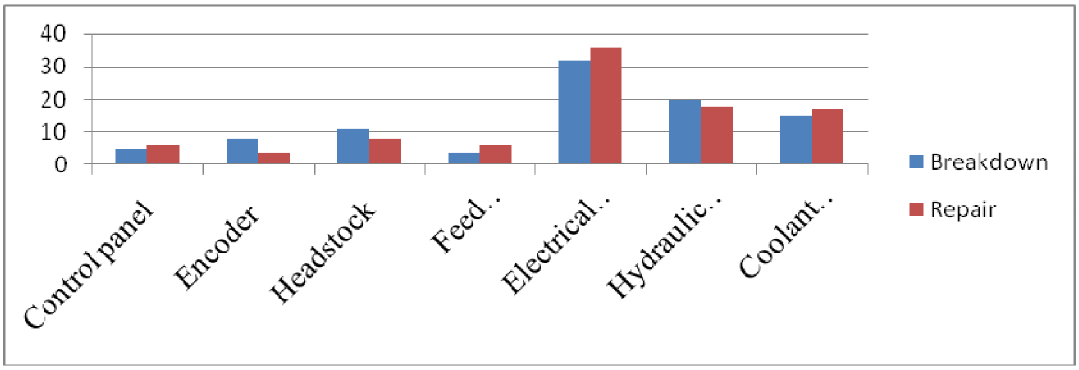

Fig. 1 CNC Lathe machine sub-system failure frequency and Downtime

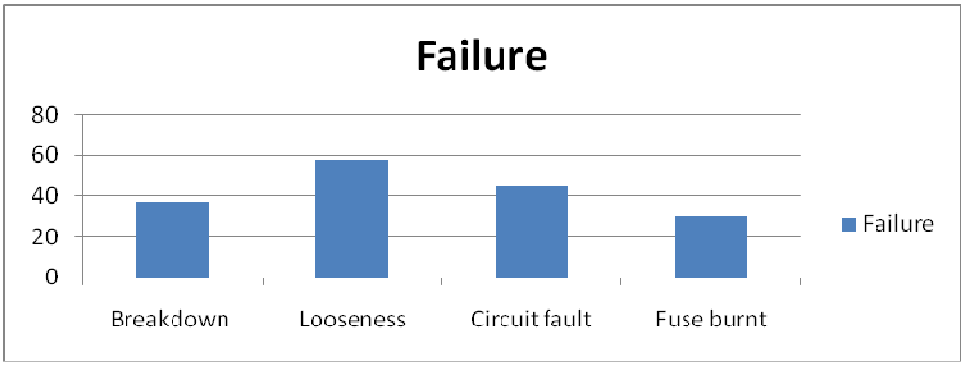

Fig 2 Failure Mode of CNC Lathe

Result and Discussion

Various steps of the methodology were carried out of these MADM was applied to the data obtained from industry. The various failure causes are taken as sub-system of each machine as described in the methodology. For CNC lathe machine these are Control panel (CP), Encoder (EN), Headstock (HS), feed mechanism (FM), Electrical System (ES), Hydraulic system (HS) and Coolant system (CS). Based on the failure data given in Fig. 2 the severity judgment values are assigned to these failures causes by using a severity conversion. Severity table is converting into matrix form which is shown below.

$$X = \begin{bmatrix} 0 & 1 & 2 & 2 \\ 0 & 2 & 4 & 1 \\ 4 & 5 & 3 & 3 \\ 1 & 2 & 4 & 6 \\ 9 & 8 & 9 & 8 \\ 4 & 5 & 6 & 2 \\ 2 & 7 & 3 & 4 \end{bmatrix}$$

For this calculation use Analytical Hierarchy Process (AHP) as a well-known Multi-Attribute Decision Making (MADM) method. In this thesis, AHP method is suggested for helping the decision maker to decide the relative importance weights of attributes in a systematic manner. The relative importance geometric mean (GM_j) by using AHP will be calculating:

$$GM_j = [2.11, 2.47, 2.36, 2.26]$$

Obtain the separation measures. The separation of each alternative from the ideal weight wj is given by equation 2.

$$W_I = [0.23, 0.26, 0.26, 0.25]$$

Obtain the weighted normalized matrix $(m_{ij})_{normal}$. This is obtained by the division of each element of the column of the matrix X_{ij} with its associated higher weight $(X_j)_{max}$.

Hence, the elements of the weighted normalized matrix $(m_{ij})_{normal}$ are expressed as:

$$(m_{ij})_{normal} = \begin{bmatrix} 0 & .13 & .22 & .25 \\ 0 & .25 & .44 & .13 \\ .44 & .63 & .33 & .38 \\ .11 & .22 & .44 & .75 \\ 1 & 1 & 1 & 1 \\ .44 & .63 & .66 & .25 \\ .22 & .88 & .33 & .5 \end{bmatrix}$$

Apply Saw Method on CNC Lathe Data

As explain in SAW methods theory, value of these four attributes are normalized and weights (w_1,w_2....w_4) of attributes such as breakdown, Looseness, Circuit fault and fuse. The SAW method also suggests that among the failure causes of CNC machine the Electrical system are most critical system. A set of alternatives is made in the descending order in this step, according to the value of P_i indicating the most preferred and least preferred feasible solutions. P_i may also be called as overall or composite performance. Greater the P_i weight shows the highest failure cause in CNC lathe in Table 3.

Table 3 Weight of CNC Lathe sub system (SAW)

Failure causes	Weight (P_i)
Control panel	0.1535
Encoder	0.2119
Headstock	0.4458
Feed mechanism	0.3844
Electrical System	1.0000
Hydraulic system	0.4991
Coolant system	0.4902

Weighted Product Methods on CNC Lathe Data

The weights used in the SAW method are also used in weight product method (WPM) and the values of Pi are calculated by given equation (5) as shown in Table 4. The overall performance score (i.e. finding of maximum failure cause, in this problem) for failure cause is calculated using the normalized data of the attribute given in normalized matrix for the given weights of the attributes (W_i).

Table 4 Weight of CNC Lathe sub system (WPM)

Failure causes	Weight (P_i)
Control panel	1.97
Encoder	2.11
Headstock	3.24
Feed mechanism	3.01
Electrical System	4.00
Hydraulic system	3.32
Coolant system	3.26

Result

The result obtained from SAW and WPM for these two CNC machines indices are compiled and compares in Table 5.

Table 5 Result Comparisons of CNC Lathe Machine

Failure Causes	Comparision Table			
	Saw Index (P_i)	Rank	WPM Index (P_i)	Rank
Control panel	0.1535	7	1.97	7
Encoder	0.2119	6	2.11	6
Headstock	0.4458	4	3.24	4
Feed mechanism	0.3844	5	3.01	5
Electrical System	1.0000	1	4.00	1
Hydraulic system	0.4991	2	3.32	2
Coolant system	0.4902	3	3.26	3

- For the data obtained from SAW method the most critical system for CNC lathe machine is Electrical system, Hydraulic system, Coolant system, Headstock, Feed Mechanism, Encoder and Control Panel. This ranking is obtained by SAW method used.

- Obtained data from WPM method the ranking are similar to SAW method which is Electrical system, Hydraulic system, Coolant System, Headstock, Feed Mechanism, Encoder and Control Panel. This ranking is obtained by WPM methods used.
- The ranking of various systems for the same types of machine are different types of sub system for the failure mode. This may be attributes to the variation in amount of uses of each machine, the maintenance system in each industry etc.

Conclusion

This paper proposes a way to find failure causes of CNC machines which based on the quality inspection of data from maintenance department taken for a number of machines. The failure data have been collected and analyzed systematically for commonly used CNC machine

Lathe Machine Rank

- SAW - Electrical system, Hydraulic system, Coolant system, Headstock, Feed Mechanism, Encoder and Control Panel.
- WPM - Electrical system, Hydraulic system, Coolant system, Headstock, Feed Mechanism, Encoder and Control Panel.

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