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Application of Failure Mode Effect Analysis for Improved Scheduling in Maintenance of Machines

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Abstract**: *Maintenance of machines is crucial measures in order to have stable and improved work flow. Any kind of failure might result in complete failure of the machine. Hence it becomes essential to identify the vulnerable failures that might occur in the components of any machine. The present work is carried out in order to improve the scheduling in maintenance of a lathe machine. Different components of the machine are studied in this research. "Failure mean effective analysis (FMEA)" method is applied to identify the failures associated with the components of the machine. Risk priority number is calculated based on which the components are provided with ranks. The rank signifies the flow of maintenance for all the components. The results reveal that the flexure bearing needs the least maintenance as it has the highest rank.***

Keywords : FMEA, machines, maintenance, scheduling, failures.

I. INTRODUCTION

Machines are defines as a mechanism depending on the functional requirements of manufacturing organization. Regardless of the type of machines used by manufacturing organization, all machines must be able to achieve a task. Machines used can be classified as an instruments used in manufacturing process such as lathe, Drilling, Milling, Rolling etc. formerly operated manually now a days most of the machines are computerized commonly known as Computerized Numerical Control (CNC)[1].The spontaneous period of time that required machines are not accessible for production is termed to be a time period. There are lots of reasons or possibilities of failure Machine failures could occur because of a range of reasons like fatigue, aging, wear out, excessive stress, vibrations, operator error, etc. Machine failures will be generally classified as mechanical, electrical and hydraulic/pneumatic.[2].

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A. Maintenance Engineering

The process of optimization of the machines which accomplish the target within time period and economically to provide better reliability, availability of it is known as maintenance engineering.

It could be a procedures including theories and practical to plan and implement the machineries [3] This process is carried out to enhancing the operating the whole process economically to endure the margins of profit and consistency. The engineers working in the maintenance department have the knowledge of such theories. Maintenance engineering includes maintenance of specific machineries their mechanism, proper planning, implementing daily production routine and preventive maintenance. It also includes the, logistics, probability and statistics. [4]. A schematic representation of maintenance in machines is depicted in Fig.1.

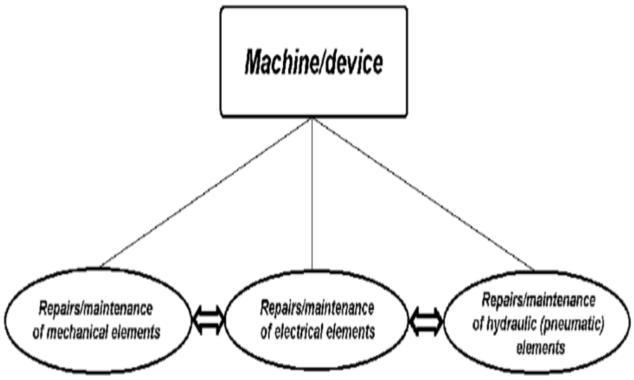

Fig. 1.Machine mainteance

Maintenance of machineries is a regular part of a manufacturing process of any manufacturing industries or organization as it doesn't make any impact on production. Sometimes the defects occur to be seems visually or handled manually the maintenance performed by the outside vendors and approaching equipment or production before their failure require.[3] In a production or manufacturing industries, well planned maintenance engineering is necessary for smooth and safe production rate. Maintenance engineering not only regulate the existing mechanism of machineries, it also enhanced the mechanism and helps it to keep updated and there is no need of any maintenance. [5]

B. Purpose of Maintenance

The process of developing a methodology to identifying the areas of improvement, the potential benefits of using the statistics to model reliability, the major cause of downtime , to distribute the time period of repairing the accidental maintenance and to develop a methodology for failure data in daily basis for each and every type of machineries such that the repair time and failure distributions can be assembled to the corrective measurements, coherent time distribution of repair and time need for accidental maintenance, outrage time and the probability of root data analysis for calculating the probability of development[6].The purpose of maintenance is to provide consistency and maintainability in any manufacturing organization plays a crucial role in ensures, the production rate increase is and there could be no stoppage in manufacturing process as well as in quality assurance [7]. The basic steps involved in maintenance are shown in Fig.2.

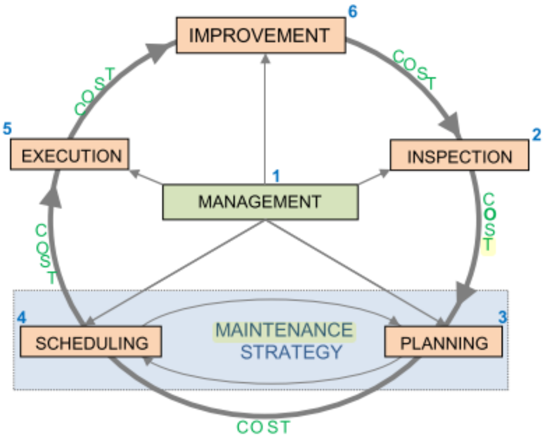

Fig. 2.Basic Steps for mainteance

C. Proposed Methodologies to analyse the failure data in maintenance (FMEA)

It may be classified in two sectors: "Breakdown failures and Accuracy failures it is also affected by the operating conditions, could be dirt, moisture content and the proper ability to handle the machineries by the technician etc. also affected by operations such as surface finish and tolerances. [8]"

- "Direct Reversion Techniques, Exponential Distribution Method (EDM), Weibull Distribution Method (WDM), Rayleigh Distribution Method (RDM), Gauss Distribution Method (GuDM), Gamma Distribution Method (GaDM), Least Square Method (LSM), Lognormal Distribution Method (LDM) [9]
- Support Vector Machine (SVM)
- Kernel Method
- G-R Curves Analysis
- Failure Mode and Effect Analysis (FMEA) –
- Multi-Criteria Decision Making (MCDM) - ME-MCDM, Evidence Theory, Fuzzy AHP/ANP, Fuzzy TOPSIS, D-S Theory and Prospect Theory, Grey Theory, DEMATEL, Intuitionistic Fuzzy Set, D-S Theory and D-Numbers, Ranking Technique VIKOR
- Mathematical Programming (MP) - Linear Programming DEA/Fuzzy DEA
- Artificial Intelligence (AI) - Rule-Base System, Fuzzy Rule-Base System, Fuzzy ART Algorithm, Fuzzy Cognitive Map
- Integrated Approaches (IA) - Fuzzy AHP-Fuzzy Rule-Base System, WLSM-MOI-Partial Ranking Method, OWGA Operator-DEMATEL, IFS-DEMATEL, Fuzzy OWA Operator-DEMATEL, 2-Tuple-OWAOperator, FER-Grey Theory, Fuzzy AHP-Fuzzy TOPSIS, ISM-ANP-UPN
- Other approaches – Cost Based Model, Monte Carlo Simulation, Minimum Cut Set-theory (MCS), Boolean Representation Method (BRM), Digraph and Matrix approach, Kano Modal, Quality Functional Development (QFD) Probability Theory[10]"

D. Failure Mode and Effect Analysis (FMEA)

Assembling the prospective failures in system , designs , processes and services before their occurrence with a proper removal or reduction the danger related to the machineries a new study of engineering and technology used is known to be as failure mode and effect analysis (FMEA).The particular methodology is also known as dynamic risk assessment and the purpose includes to calculate possible examination and therefore the principles of FMEA is a procedure to identify the prospective threats. To find out critical analysis it's additionally stated as a failure mode, effects, and criticality analysis. FMEA is a technique to define dynamic risk assessment and the application includes to calculate the possible studies and therefore the principle of FMEA is to identify potential menaces alongside the central system as in critical situation it's used for a criticality analysis, it's additionally stated as a failure mode, effects, and criticality analysis. The application used of this analysis active in the field of production engineering of automobile, and mechanical and electronic products. [8]Besides finding the solution before their occurrence it works on the proactive handling the system. It stress on the prevention the most and common responsibility and analysis tools for product and process both been widely employed in a multiple sectors of production and manufacturing industries giving and ease and perceptibility. (Rakesh,Jos and Mathew, 2013)It shows the probability of failures and the factors responsible to arise the failures and properties of these modes. This methodology is finding the controls and reduced the problems related to the failures. It is basically instrumentally and machineries will malfunction, it examines the possible issues and their effects on rate of production in manufacturing process in earlier stages. [12]In the primary stage it is developed in 1960s for automobile sector and known to be its proper functioning in consistency. It will be used to improvise the safety and consistency of a system by detecting the major possible failure modes and takes preventive actions within the design stage. It is used to analyse the effects of breakdown modes and possible. This application includes finding out the probability of "failure modes, possible effects of these failure modes arranging and provides the resolution". [13]

There are several benefits of FMEA as given below:

- Calculation and stop safety menaces
- Improve the rate of production and routine manufacturing process
- To get the better result in assessment and certification strategies.
- Advance and control strategies

- Changes to the product style or manufacturing method
- Calculate the better techniques and providing best features of analysis.
- Inventory the machineries and assets for in-service
- Develop on-line analytical methodology

It is an analytical analysis by proficient functional team of materials which is assigned for complete analyses of product styles and manufacturing processes, earlier within a given time period development method. Its objective is to find the root cause analysis before handed over. This analysis methodology provides guidance for the series of entire actions strategies which will reduce the risk to the machineries and rate of production in manufacturing process. [14]

E. FMEA Types (Design, Process and System)

Designs involves the product into smaller part as subassemblies and mechanism to calculate the prospective failure models and its causes for each and every areas and parts of machineries parts, determines the current control to their causes and finally risk that effects assessed followed by the failure effects to the product and end users. Process is used to solve the problems due to manufacturing process. [15] Initialize by process flow chart that indicates the process of manufacturing of product step by step. The mode of failure and its causes are identified and present controls calculated and system looks for potential programs and bottle necks in larger process, such as entire production lines. [16]. The Fig.3. shows the different types under the FMEA.

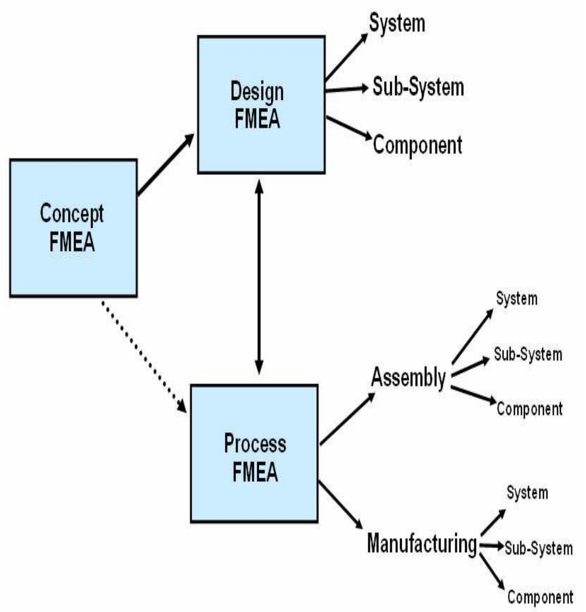

Fig. 3.FMEA types

II. LITERATURE REVIEWS

Yang [17] Presented a book for IMLE abbreviated as improved maximum likelihood estimation method through increasing changed failure data. The square of the gross total of observed correct value has been designed and extended by verified by the orthogonal experiment as it has been virtually generated computationally as comparison to ICM and MLE this method is appropriate and consistent for modelling CNC machines tools taken less time and provides exact ratio [18] proposed to creates the corrective nature of CNC mechanism from performance point of view and focus on major issues. The methodology represented the calculating "Risk Priority Number based on FMEA, which can be used to arranging the failure modes of CNC machines". [19]

An idea of an assembled model provides consistent to the CNC machines tools on the assembly model. "This is a new idea of an assembly model which provide consistency prosed by the CNC machines tools as it is based on the assembly errors and consistent control flow analysis, key assembly process that could be calculate mathematically by the new integration method of QFD, FMECA, and fuzzy theory, then assembly consistency and observation system started using analytically to calculate the real time key assembly process and control analysis, along with models and examples to demonstrate the effectiveness and correctness of the whole procedure.[15]

It could be successfully active in functional , compound and technical system for example in the case of the casting machines in high pressure where it attains substantial results providing consistent with provide better quality of operation in mentioned in technical system within minimal maintenance and provides the feedback to the technicians who are works in maintenance field."

Dastjerdi [12] presented a new method for NC machine tools to evaluate consistency. The cox proportional hazards prototypes a model that is activate in NC machine tools to identify the connection between NC machines tools consistency and also corresponds operating operations. Within the parameter estimating method, a two-step estimation technique is applied.

That is, the coefficients of operating condition covariates are first calculable by the partial probability estimation technique, and then the maximum probability estimation technique is employed to estimate the parameters of the baseline failure rate operate

III. METHODOLOGY

The FMEA work is carry out in lathe machine used in the manufacturing industry. The failures of the lathe machines normally occur in the failure in mechanism of product which results the slowdown in production rate causes directly disturbance in the maintenance of machine. The possibilities of equipment failure are predictable, particularly for lathe machine. A lathe is a complex machine which has number of components attached together and performing different operations.

Failure in any of the components leads to complete failure of machining operations performed on lathe. This is necessary to identify the risky mechanism under regular maintenance and which require periodic maintenance.

The current study is carried out on a Lathe machine in order to schedule the maintenance sequence. A number of components are highlighted which are responsible for smooth working of the machine.

These components are studied under FMEA approach to identify and plan the maintenance order of the lathe machine. The Fig.4 shows the process flow of methodology carried out in the current work.

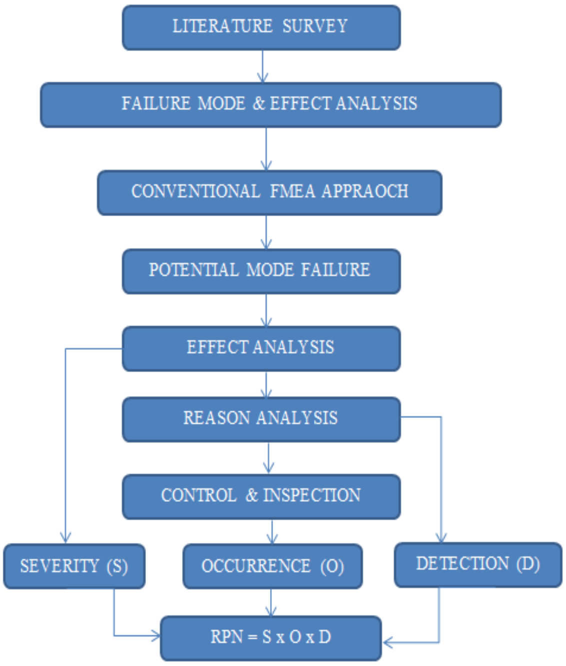

Fig. 4.Methodology Process flow chart

A. Analysis Approach

The approach of this methodology is widely engaging in improving consistent and safe of a compound mechanism to calculate and eliminate the possible threats for the mechanism. It also provides a salient features for plan of action for rise. The criterion for ranking severity is shown in Table I.

Table- I: Criteria on the basis of the SEVERITY (S) in FMEA

Effect	Severity Criteria	Ranking
Hazardous without warning	Very high severity ranking: Affects operator, plant or maintenance personnel; safety and/or effects non-compliant.	10
Hazardous with warning	High severity ranking: Affects operator, plant or maintenance personnel; safety and/or effects non-compliant.	9
Very high downtime or defective parts	Downtime of more than 8 hours.	8
High downtime or defective parts	Downtime of more than 4-7 hours.	7
Moderate downtime or defective parts	Downtime of more than 1-3 hours.	6
Low downtime or defective parts	Downtime of 30 minutes to 1 hour.	5
Very low	Downtime up to 30 minutes and no defective parts	4
Minor effect	Process parameters variability exceeds upper/lower control limits; adjustments or process controls need to be taken. No defective parts.	3
Very minor effect	Process parameters variability within upper/lower control limits; adjustments or process controls need to be taken. No defective parts.	2
No effect	Process parameters variability within upper/lower control limits; adjustments or process controls not needed or can be taken between shifts or during normal maintenance visits. No defective parts.	1

The "severity of the failure was estimated using an evaluation scales from 1-10 for machine downtime in hours. The minimum point indicates a minimal limit, whereas a maximum point indicates maximum severity of the failure.

B. Identification of Reason analysis (Occurrence, O)

The occurrence was identified based on in depth analysis of failure mode and by based on preference calculate it on scale of 1-10 for Mean Time between Failure (MTBF) in hours , where 1 shows the possibilities of occurrence, whereas scale 10 shows very high possibilities to the occurrence of failure. The criterion for ranking occurrence is shown in Table II.

Table- II: Criteria in order to rank the OCCURRENCE (O) in FMEA

Probability of Failure Occurrence	Possible Failure Rates Criteria	Ranking
Very high: Failure is almost inevitable	Intermittent operation resulting in 1 failure in 100 production piece or MTBF of less than 1 hour.	10
	Intermittent operation resulting in 1 failure in 100 production pieces or MTBF of less than 2 to 10 hours.	9
High: Repeated failures	Intermittent operation resulting in 1 failure in 1000 production pieces or MTBF of 11 to 100 hours.	8
	Intermittent operation resulting in 1 failure in 10,000 production pieces or MTBF of 101 to 400 hours.	7
Moderate: Occasional failures	MTBF of 401 to 1000 hours.	6
	MTBF of 1001 to 2000 hours.	5
	MTBF of 2001 to 3000 hours.	4
Low: Relatively few failures	MTBF of 3001 to 6000 hours.	3
	MTBF of 6001 to 10,000 hours.	2
Remote: Failure unlikely	MTBF greater than 10,000 hours.	1

C. Control and inspection (Detection, D)

The detection of the failure which occurs due to the problem in any one of the parameters mentioned above. The scale 1 shows the maximum failure detection i and the possibility of failure reaching to the customer is very low. The scale 10 indicates the chance of detection is minimum and the possibility of failure reaching to the customer is very high. The criterion for ranking detection is shown in Table III.

Table- III: Criteria on the basis of the DETECTION (D) in FMEA

Detection	Detection by Design Controls	Ranking
Absolute uncertainty	Machine controls will not and/or cannot detect potential cause/mechanism and subsequent failure mode; or there is no design or machinery control.	10
Very remote	Very remote chance a machinery/design control will detect a potential cause/mechanism and subsequent failure mode.	9
Remote	Remote chance a machinery/design control will detect a potential cause/mechanism and subsequent failure mode. Machinery control will prevent an imminent failure.	8
Very low	Very low chance a machinery/design control will detect a potential cause/mechanism and subsequent failure mode. Machinery control will prevent an imminent failure.	7
Low	Low chance a machinery/design control will detect a potential cause/mechanism and subsequent failure mode. Machinery control will prevent an imminent failure.	6
Moderate	Moderate chance a machinery/design control will detect a potential cause/mechanism and subsequent failure mode. Machinery control will prevent an imminent failure and will isolate the cause. Machinery control may be required.	5
Moderately high	Moderately high chance a machinery/design control will detect a potential cause/mechanism and subsequent failure mode. Machinery control will prevent an imminent failure and will isolate the cause. Machinery control may be required.	4
High	High chance a machinery/design control will detect a potential cause/mechanism and subsequent failure mode. Machinery control will prevent an imminent failure and will isolate the cause. Machinery control may be required.	3
Very high	Very high chance a machinery/design control will detect a potential cause/mechanism and subsequent failure mode. Machinery controls not necessary.	2
Almost certain	Design control will almost certainly detect a potential cause/mechanism and subsequent failure mode. Machinery controls not necessary.	1

D. Calculation of Risk Priority Number (RPN)

After deciding the Severity, Occurrence and Detection numbers, the RPN is deliberated by multiplication of Severity (S), Occurrence (O) and Detection (D).

Risk Priority Number = Severity X Occurrence X Detection

i.e. **RPN** = **S** x **O** x **D** (1)

IV. RESULTS AND DISCUSSIONS

The following Results are obtained from the analysis. The Risk Priority Number (RPN) calculated in the proposed work is shown in Table IV.

Table- IV: Calculation of RPN number

S.No.	Failure Mode	O	S	D	RPN	RANK
1	Valves	4	6	7	168	VI
2	Flexure Bearings	6	6	7	252	VIII
3	Piston shafts	3	4	10	120	V
4	Coil former	4	8	1	32	II
5	Lock nut	3	4	7	84	IV
7	O-ring	3	6	3	54	III
8	Connecting tubes	1	6	3	18	I

Hence, depending on the rank obtained the probable maintenance required for the present machine is connecting tubes as it has the least rank as I". The Table-V below shows the order of maintenance for the machine based on the ranks obtained.

Table- V: Rank Allocation

S.No.	Machine components	RPN	RANK
1	Connecting Tubes	18	I
2	Coil former	32	II
3	O-ring	54	III
4	Lock nut	84	IV
5	Piston shafts	120	V
6	Valves	168	VI
7	Flexure Bearings	252	VIII

V. CONCLUSION

Mechanical maintenance of machine is very important to have un-delayed operation of work. Applications of FMECA technique is successfully carried out in mechanical maintenance of the machine. The conclusion drawn from the results show that, connecting tubes needs to be maintained at the initial phase as it ranked I from the analysis followed by coil former which is ranked II. Similarly, O-ring, Lock nut, Piston shafts, valves and flexural bearings are ranked as III, IV, V VI, and VIII. Therefore, the flexure bearing needs the least maintenance as it has the highest rank. Thus keeping in mind the ranks obtained the scheduling for maintenance can be plotted with regards to the machine.

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