Implementation of Machinery Failure Mode and Effect Analysis for CNC Machines in Valve Manufacturing Industry

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Abstract

Failure Mode and Effects Analysis (FMEA) is a pro-active quality tool for evaluating potential failure modes and their reasons. It helps to prioritization of the failure modes and to corrective measures for the avoidance of cataclysmic failures and improvement of the quality. In this paper, an attempt has been made to implement machinery FMEA in valves manufacturing unit of GG Valves, Udaipur, Rajasthan, India. The failure modes and their causes identifying for all CNC machines, the three key indices (Severity (S), Occurrence (O) and Detection (D)) we reassessed and the statistical analysis of failures was carried out with help of Machinery Failure Mode and Effects Analysis (MFMEA) worksheet. Finally, the necessary corrective actions were recommended.

Keywords: CNC machine failures, MFMEA, RPN, severity, occurrence, detection

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INTRODUCTION

Failure data of CNC machine in GG Valves industry is the basis of this work, as a data source where the CNC machines are being used for the machining of the valves. This work aims to identify the problems in manufacturing and maintenance, especially in manufacturing stage takes corrective actions, so that the reliability of the machine can be maintained.

The Failure Mode and Effect Analysis (FMEA) approach helps in identification of occasions of malfunction of equipments. FMEA shows the causes and effects of potential failure modes. It also helps to identify the occurrence of failures in CNC machines. This technique was firstly used by NASA in 1960s.

The first applications in automotive industry were held by Ford Motor Company. This method enables the manufacturing process to increase its efficiency. The FMEA identifies the corrective measures and possible failure modes by prioritization of possible failure modes with the help of a template. [1]

There are many other advantages of FMEA as given below:

- Identify and prevent safety hazards
- Minimize loss of product performance or performance degradation
- Improve test and verification plans
- Improve process control plans
- Consider changes to the product design or manufacturing process
- Identify significant product or process characteristics
- Develop preventive maintenance plans for in-service machinery and equipment
- Develop online diagnostic techniques

LITERATURE REVIEW

The literature survey is the brief review of the accredited researchers and scholars which have published on the topic of study. The purpose of the literature review is conveying about the ideas and knowledge established on the topic with a view of strengths and weakness. The literature review, which must be defined by the guiding concept, may cover research reports, introduction of a paper.

Ambekar worked on Failure Mode and Effects Analysis (FMEA) which is a procedure of product development and operations management for analysis of potential failure modes within a system for classification by the severity and likelihood of the failures. A successful FMEA activity helps a team to identify potential failure modes based on past experience with similar products or processes, enabling the team to design those failures out of the system with the minimum of effort and resource expenditure, thereby reducing development time and costs.

Degu and Moorthy was performed that the failure modes and their causes were identified for each machine, the three key indices (Severity, Occurrence and Detection) reassessed and the analysis was carried out with the help of Machine Failure Mode and Effect Analysis (MFMEA) Worksheet. The research work results in a considerable machine downtime and disrupting the continuous production of pipes.[2]

Yang adopted evidence theory to aggregate the risk evaluation information of multiple experts. However, all individual and interval assessment grades were assumed to be crisp and independent of each other in the proposed model. It did not considerate the occasion in FMEA where an assessment grade may represent a vague concept or standard and there may be no clear cut between the meanings of two adjacent grades.

Braglia developed the conventional scores for O, S and D were normalized as the local priorities of the causes with respect to O, S and D respectively, and the weight composition technique in the AHP was utilized to synthesize the local priorities into the global priority, based on which the possible causes of failure were ranked.

Zammori and Gabbrielli worked according to the ANP/RPN model, O, S and D were split into sub-criteria and arranged in a hybrid (hierarchy/network) decision structure that, at the lowest level, contains the causes of failure. Starting from this decision-structure, the RPN was computed by making pair-wise comparisons.

The VIKOR method, which was developed for multi-criteria optimization for complex systems, to find the compromise priority ranking of failure modes according to the risk factors in FMEA applied by Liu. In the methodology, linguistic variables, expressed in trapezoidal or triangular fuzzy numbers, were used to assess the ratings and weights for the risk factors O, S and D. [3]

METHODOLOGY

The specification of CNC machines used in GG Valves industry, for the data collection is as given in Table 1.

In the present work, the failure data of CNC machines have been collected from GG Valves industry and analysis of data has been performed by conventional FMEA approach. The data of CNC machine failures at the regular interval of time has been collected.

The following parameters are used for the data collection of failures of the CNC machines:

Failure date and time, Failure phenomenon, Cause analysis, Repairing process of failure, Repairing time of failure, Downtime of machine, Model, size and numbers of the breakdown component

Table 1. *Specification of CNC Machines.*

Machine no.	Name of CNC lathe	Specification				
		Max. turning length (mm)	Max. turning diameter (mm)	Length between centres (mm)	No. of tools on turret	Turning speed (RPM)
L-01	Daewoo Puma 10-HC	525.8	370.8	525.8	10	35-3500
L-02	LMW-P20T.L3	250	320	350	8	45-4300
L-03	LMW-P20T.L5	440	380	550	8	35-3500

The traditional Failure Mode and Effect Analysis (FMEA) approach is a pro-active quality tool for evaluating potential failure modes and their causes. It helps in prioritizing the failure modes and recommends corrective measures for the avoidance of catastrophic failures and improvement of the quality of product.

Step 1: Identification of components and associated functions
Step 2: Identification of failure modes
Step 3: Identification of effects of the failure modes (Severity, S)
The severity of the failure estimated using an evaluation scales from 1 to 10 for machine downtime in hours shown in Table 2.
Step 4: Identification of cause of the failure mode (Occurrence, O)
The occurrence is based on knowledge of the failure mode and prioritize for an evaluation scale as 1-10 for Mean Time between Failure (MTBF) in hours shown in Table 3.
Step 5: Current Design Control (Detection, D)
The use of evaluation scale shown in Table 4
Step 6: Calculate Risk Priority Number (RPN)

RPN is the indicator for the determination of proper corrective action on the failure modes. The Severity, Occurrence and Detection is ranking levels resulting in a scale from 1 to 10. After deciding the Severity, Occurrence and Detection numbers, the RPN was calculated by multiplying of Severity (S), Occurrence (E) and Detection (D).

$$RPN = S \times O \times D$$

The small value of RPN is always better than the high value of RPN. According to the values of RPN, the failure mode was categorized and then proper remedial action was taken on the CNC machine failures with high level of risks.

Table 2. *Criteria for Ranking Severity (S) in FMEA.*

Effect	Severity criteria	Ranking
Hazardous without warning	Very high severity ranking: affects operator, plant or maintenance personnel	10
Hazardous with warning	High severity ranking: affects operator, plant or maintenance personnel	9
Very high downtime	Downtime of more than 8 hours.	8
High downtime	Downtime of more than 4–7 hours	7
Moderate downtime	Downtime of more than 1–3 hours	6
Low downtime	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	3
Very minor effect	Process parameters variability within upper/lower control limits	2
No effect	Process parameters variability within upper/lower control limits	1

Table 3. *Criteria for Ranking Occurrence (O) in FMEA.*

Probability of 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

Table 4. *Criteria for Ranking Detection (D) in FMEA.*

Detection	**Detection by design controls**	**Ranking**
Absolute uncertainty	Very high remote chance a Machine controls will not or cannot detect potential cause of failure mode	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	8
Very low	Very low chance a machinery/design control will detect a potential cause/mechanism and subsequent failure mode	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	5
Moderately high	Moderately high chance a machinery/design control will detect a potential cause/mechanism and subsequent failure mode.	4
High	High chance a machinery/design control will detect a potential cause/mechanism and subsequent failure mode	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

RESULTS AND DISCUSSION

The results show that the Risk Priority Number (RPN) of the failure modes is calculated in Table 5. The results summarized in MFMEA worksheet revealed that the Risk Priority Number (RPN) was the highest (RPN=225) for the play in coupling for the turret head, mainly owing to the degree of severity of the failure in disrupting the entire production, excessive MTBF and difficulties in detection. The next priority should be given to the alignment disorder of turret heat (RPN= 216), mainly because of its criticality in affecting further processing.[4–6]

Table 5. *MFMEA Worksheet for CNC Machine Failures of GG Valves Industry.*

Subsystem	Part name	Failure mode	Potential effects	S	Potential cause	O	Current controls	D	RPN	Rank
Mechanical system	Turret head dismantling	Alignment disorder	Gun metal bush damage	9	Improper fitment	6	Replacing the gun-metal bush	4	216	II
Mechanical system	Turret head dismantling	Play in coupling	Coupling bearing damage and loose fasteners	9	Jerk/accident, lubrication oil	5	Replacing the all damaged bearing	5	225	I
Electronic system	Turret head dismantling	Indexing time mismatch	I/O parameter and sensor setting disorder	9	High input currents and sensor in fault	5	Reset the I/O parameter	3	135	IV
Coolant system	Coolant Tank	Low pressure of coolant	Low viscosity lubricant changed	7	Blockage the coolant flow line	5	Remove chips present in lubricant	3	105	V
Coolant system	Coolant pump	Improper work	Damage/ burn motor winding and contactor relay	7	Faulty supply	5	Rewinding the motor coil	4	140	III
Electronic system	Feed servo system	Parameter disorder	PLC unit reorder and I/O parameter change	7	Faulty supply, contactor relay burn	6	Replacing the contactor relay	1	42	IX
Electrical system	Feed servo system	Overload/power fluctuated	Connections and supply unit checked	7	Faulty supply, stabilizer card burn	5	Replacing the stabilizer card	2	70	VII
Hydraulic system	Hydraulic table	Changing table turns slowly	Damaged oil seals replaced	6	Damage the oil seal, leakage in hydraulic flow line	5	Ensure the proper checking of hydraulic flow line	2	60	VIII
Hydraulic system	Hydraulic function	Oil leaks from cylinder	Oil pipes cleaned, damaged oil seals replaced	6	Leakage in hydraulic cylinder	5	Ensure the proper checking of hydraulic flow line	3	90	VI

This work would help the concern industry and the industries which rely majorly on the CNC machines for their manufacturing process. Many work on failure analysis are done some of them are complex, very difficult to examine the problems and use many assumptions to satisfy the results. The ranking can be used for the decision making managers, arranging the inspection and maintenance of the equipment properly, which can optimize the maintenance resources and avoid the risk.

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