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Application of Fmea Method in a Manufacturing Organization focused on Quality

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Abstract- Successful and long-term operation of any manufacturing organization is conditioned its total production potential. If the organization wants to be able to compete, the customer must supply the products in the required quantity and quality. Toensure product quality is essential to remove errors respect. Their resources. In the quality management system is used a lot of quality management tools. One is the FMEA method, applied in product design but also in the process of its implementation.The failure modes and effects analysis (FMEA) is a procedure in 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.

***Index Terms*-FMEA, Risk, RPN, Occurrence, Servity.**

I. INTRODUCTION

Failure Modes and Effects Analysis (FMEA) is a tool widely used in the automotive, aerospace, and electronics industries to identify, prioritize, and eliminate known potential failures, problems, and errors from system under design before the product is released. FMEA proves to be one of the most important early preventive actions in system, design, process, or service which will prevent failure and errors from occurring and reaching customer. FMEA's are conducted in the product design or process development stages, although conducting an FMEA on existing products or processes may also yield benefits. A failure mode is defined as the manner in which component, sub system, system, process etc, could potentially fail to meet the design intent. FMEA used to solve problems due to manufacturing process. FMEA method is used to calculate RPN for each failure mode and then proposed recommended actions to reduce the RPN. The basic steps are to identify the root of the cause and potential problems that could occur, and then derive RPN which can direct improvment effort to the area of greatest concern. This work mainly includes application of proess Fmea in a manufacturing unit producing crank shaft. The case industry is situated in Kerala. Process FMEA is used to solve problems due to manufacturing process. It starts with a process flow chart that shows each manufacturing steps of a product. The potential failure modes at each work station are listed. Then the effect of each of failure is described in detail. The Quantification of the potential effects of each failure is done as; the severity (s) of the potential causes or Mechanism of failure, occurrence (o) or frequency of the failure and detection (d) probability of the failure. Quantification of the overall risk by risk priority number (RPN) is then calculated. The Responsible departments and corresponding actions are then determined.

II. LITERATURE REVIEW

The FMEA technique was first reported in 1920's but it's use has only been significantly documented since the early 1960's [9].FMEA was developed by Grumman aircraft cooperation in 1950 and 1960's and it was first applied to the naval aircraft control system at Grumman [7].Formal application began in aerospace industry (mid 1960's) and now widely used in automotive industry [9]. Considering the history related to the concept, Hovnark and Norel (in 1994) proposed guidelines for design work, analysis of product features, product design review and team-building to design work, tools like design for assembly (DFA) ,FMEA and quality function deployment (QFD) [1]. Tench and case (in 2004) found that FMEA was a quality improvement and risk assessment tool [1].dong and kno (in 2009) proposed a state of art approach to enhance FMEA assessment capabilities [1].A 3D warning approach for product development risk management by combining graphical evaluation, review technique and FMEA by wu et al (in 2010) [1]. In the history related to the design of FMEA, Jana Kiram and Keats (in 1995) found that it is a useful tool in design process and was ignored in most process [1]. Cassanelli et al (in 2006) applied FMEA during the design phase of an electric motor control system for heating/ventilation/HVAC vehicles [1].In the manufacturing sector, Dale and Shaw (in 1990) reported the findings of the questionnaire survey on the use of FMEA in UK motor industry [1]. Aravanitogannis and Varzakas (in 2007) used FMEA model for the risk assessment of potato chips and strudel manufacturing and they also applied the same in corn curl manufacturing (in 2009) [1]. Oldenholf (in 2011) explored the consistency of FMEA in the validation of analytic procedures, carried out by 2 different teams [1]. FMEA activity helps a team to identify potential failure modes, based on part experienced with similar products or process. Failure modes are any errors or defects in a process design or item, especially those that affect the customer and can be potential or actual. Effect analysis refers to studying the consequence of failures. The FMEA is used to analyze

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concept in the early stages before hard ware is defined. FMEA analyzes potential modes, potential effects, potential causes, and accesses current process control and determines a risk priority factor. [1]FMEA is a systematic method of identifying and preventing system, product and process problems before they occur. FMEA proves to be one of the most important early preventive actions in system, design, process, or service which will prevent failure and errors from occurring and reaching customer. FMEA's are conducted in the product design or process development stages, although conducting an FMEA on existing products or processes may also yield benefits. A failure mode is defined as the manner in which component, sub system, system, process etc. Could potentially fail to meet the design intent. [2]A failure mode and effect analysis is a methodology in a product development and operation management for analysis of potential failure modes with in a system for classification by the severity and like hood of the failure. Before starting with an FMEA, it is important to complete some pre-work to confirm that robustness and part history are included in the analysis [10] FMEA used to solve problems due to manufacturing process. Start with a process flow chart that shows each of the manufacturing steps of the product. A few logical but important thoughts come in mind: minimize the severity of the failure, reduces the occurrence of the failure mode, improve the detection [11] FMEA is powerful design tool that provides a means to compare, from a risk point of view, alternative machine system configuration. FMEA is also used for considering designs improvements for a technology which is changing or increasing in rating. FMEA is formalized but subjective analysis for the systematic identification of possible root causes and failure modes and the estimation of their relative risks. [8]An FMEA is an anticipating thought process designed to utilize as much the knowledge and experience of the organization as possible towards the end of addressing potential issues defined in new product. To achieve the greatest value, the FMEA should be performed before failure mode has been unknowingly planned in to a product and process. FMEA procedure should be list of defined actions that will either prevent the occurrence of a problem through a design or process change, or improve the chances of detection of a problem through monitoring, if it does occur in the future. [15]Process FMEA is used to solve problems due to manufacturing process. It starts with a process flow chart that shows each manufacturing steps of a product [13] FMEA is a systematic, proactive method for evaluating a process to identify where and how it might fail and to assess the relative impact of different failures, in order to identify the parts of the process that are most in need of change. [10]The FMEA process is an ongoing, bottom up approach typically utilized in three areas of product realization and use, namely design, manufacturing, service[14]FMEA is commonly used in a variety of industries for risk management where simple quantification of risk is insufficient, and where identification root causes risk and means of mitigation are paramount. Outcome of the FMEA of the FMEA is a list of recommendations to reduce overall risk to an acceptable level, and can be used as a source for designing a control strategy. [15]FMEA is comprehensive engineering technique that manufactures are able to improve quality, reliability, and safety of their product through applying technique. In particular FMEA technique is used to identify, define, and eliminate known and potential failures, problems and errors in the product, programs, system and service before they reach the customer. [9] FMEA method is used to calculate RPN for each failure mode and then proposed recommended actions to reduce the RPN. The basic steps are to identify the root of the cause and potential problems that could occur, and then derive RPN which can direct improvement effort to the area of greatest concern. [4]The maximum value of possible RPN is 1000 (10*10*10) and 100 is 10% of this amount with statistical confidence 90%. [12]FMEA is used with in a company risk management program to prevent customer being subjected to unacceptable faults and thus to avoid customer dis satisfaction. [13]

III. OBJECTIVE OF THE PROJECT

Analysing the potential failure modes and their causes in crankshaft manufacturing process, evaluate the effect of each failure mode on the process, suggesting necessary measures for eliminating or reducing the risk.

IV. SCOPE OF THE PROJECT

Enhancing the productivity of a manufacturing firm by exploring the process Fmea. Reducing the failure occurs during manufacturing process and increasing the productivity in the firm.

V. PROJECT METHODOLOGY

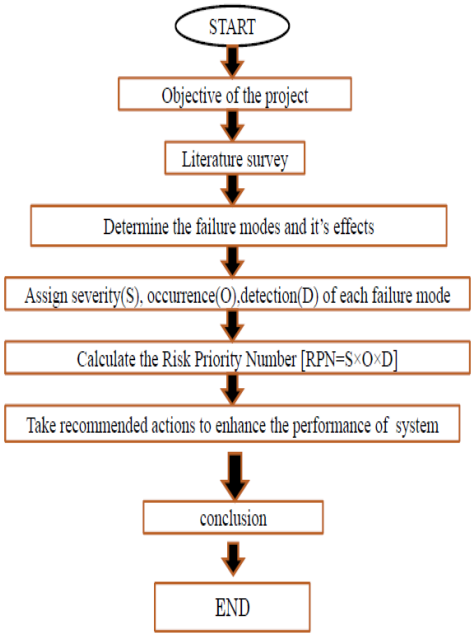

Fig 1: Project methodology

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Methodology is one of the most important elements to be considered to make sure the fluent of the project and get expected result. In other words the methodology can be described as framework where it contains the elements of the work based on the objectives and a scope of the project. A good framework can get the overall view of the project and get the data easily. This included literature study, determine failure mode and its effect, calculate the RPN value, take recommended actions.

VI. WORK DONE

A. Crank shaft manufacturing steps

The figure below shows the detailed steps in the production of crank shaft

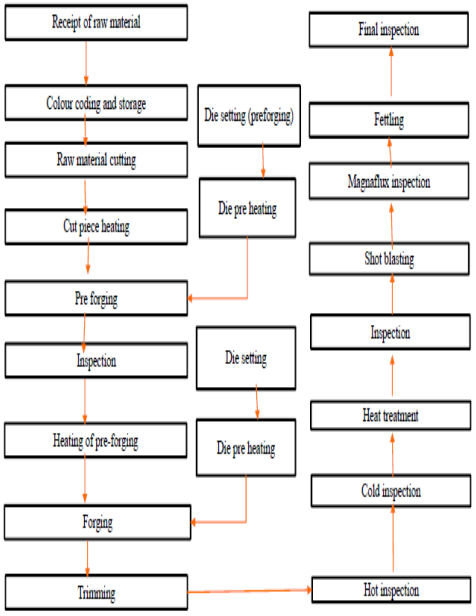

Fig 2: Crank shaft manufacturing steps

B.Application of Process FMEA in manufacturing process

The figure below shows the FMEA flow chart

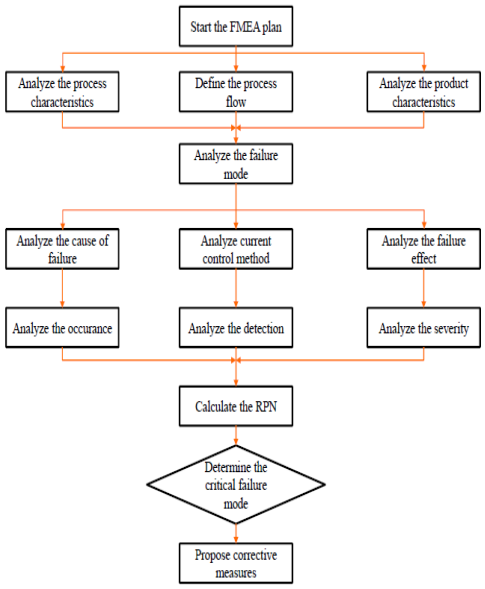

Fig 3: FMEA flow chart

Occurrence of failure in receipt of raw material

OPN NO.	OPERATION DESCRIPTION	FAILURE MODE	CAUSES	OCCURENCE
110	Receipt of raw material	Non conforming material	Raw material manufacturing defects	2
		Non confirming size	Raw material manufacturing defects	2
		crack	Raw material manufacturing defects	2
		Non conforming to the specification	Raw material manufacturing defects	2

Table 1: Occurrence of failure in receipt of raw material

Occurrence of failure in raw material cutting

OPN NO.	OPERATION DESCRIPTION	FAILURE MODE	CAUSES	OCCURENCE
120	Raw material cutting	Cut weight high	Section variation	2
			Cutting accuracy	2
		Cut weight low	Section variation	2
			Cutting accuracy	2

Table 2: Occurrence of failure in raw material cutting

Occurrence of failure in die setting (pre forging)

OPN NO.	OPERATION DESCRIPTION	FAILURE MODE	CAUSES	OCCURENCE
130	Die setting (pre forging)	Misaligned dies	Improper die setting	4
			Dimension deviation in dovetail , cross key , sow block and ram	1

Table 3: Occurrence of failure in die setting

Occurrence of failure in die preheating

OPN NO.	OPERATION DESCRIPTION	FAILURE MODE	CAUSES	OCCURENCE
140	Die pre - heating	Die crack / damage	Improper temperature	3

Table 4: Occurrence of failure in die preheating

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Occurrence of failure in cut piece heating

OPN NO.	OPERATION DESCRIPTION	FAILURE MODE	CAUSES	OCCURENCE
150	Cut piece heating	Low heat	More number of pieces / charge	5
			Location of cut pieces in the furnace	5
			Furnace maintenance	4
			Operator skill	4
		High heat	Location of cut pieces in the furnace	5
			Furnace maintenance	3
			Operator skill	4

Table 5: Occurrence of failure in cut piece heating

Occurrence of failure in pre-forging

OPN NO.	OPERATION DESCRIPTION	FAILURE MODE	CAUSES	OCCURENCE
160	Pre - forging	Not as per pre forging drawing	Variation in fullering of cut pieces	2

Table 6: Occurrence of failure in pre-forging

Occurrence of failure in die / tool setting (finisher)

OPN NO.	OPERATION DESCRIPTION	FAILURE MODE	CAUSES	OCCURENCE
180	Die / tool setting (finisher)	Misaligned dies	Improper die setting	4
			Dimension deviation in dovetail , cross key , sow block and ram	1

Table 7: Occurrence of failure in die / tool setting

Occurrence of failure in heating of pre-forging

OPN NO.	OPERATION DESCRIPTION	FAILURE MODE	CAUSES	OCCURENCE
200	Heating of pre-forging	Low heat	More number of pieces / charge	5
			Location of cut pieces in the furnace	5
			Furnace maintenance	4
			Operator skill	4
		High heat	Location of cut pieces in the furnace	5
			Furnace maintenance	4
			Operator skill	4

Table 8: Occurrence of failure in heating of pre-forging

Occurrence of failure in forging

OPN NO.	OPERATION DESCRIPTION	FAILURE MODE	CAUSES	OCCURENCE
210	Forging	Over size	Die over size	4
			Operator skill	4
			Low air pressure	4
		Under size	Die under size	2
		Un filling	Improper location of cut piece	6
			Low air pressure	2
		Mismatch	Machine accuracy , guide clearance	6
			Lock damage	
		Lap / crack	Material defect	2
		Scale pits	Improper scale removal	6

Table 9: Occurrence of failure in forging

Occurrence of failure in trimming

OPN NO.	OPERATION DESCRIPTION	FAILURE MODE	CAUSES	OCCURENCE
220	Trimming	Bend	Imperfect tooling	2
		Body cut	Improper placement of job on trim die	2
		Flash projection	Imperfect tooling	4

Table 10: Occurrence of failure in trimming

Occurrence of failure in heat treatment

OPN NO.	OPERATION DESCRIPTION	FAILURE MODE	CAUSES	OCCURENCE
250	Heat treatment (Normalising , Hardening , Tempering)	Desired characteristics not obtained	Furnace problem	3
			Operator skill	2

Table 11: Occurrence of failure in heat treatment

Occurrence of failure in shot blasting

OPN NO.	OPERATION DESCRIPTION	FAILURE MODE	CAUSES	OCCURENCE
270	Shot blasting	Poor finish	Low quality shots	2
			Duration of shooting	2

Table 12: Occurrence of failure in shot blasting

Occurrence of failure in fettling

OPN NO.	OPERATION DESCRIPTION	FAILURE MODE	CAUSES	OCCURENCE
290	Fettling	Product with burrs , tool marks and pits	Operator skill	4

Table 13: Occurrence of failure in fettling

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Application of FMEA in receipt of raw material

OPN NO.	OPERATION DESCRIPTION	DESIRED OUTCOME (PRODUCT CHARACTERISTICS)	FAILURE MODE	SEVERITY	CAUSES	OCCURRENCE	DETECTION	RPN	RECOMMENDED ACTIONS	RESPONSIBILITY	ACTION TAKEN
110	Receipt of Raw material	Specified Chemistry	Non Confirming Material	10	Raw material manufacturing defect	2	1	20	Reject Material	QA	Intimate Material Supplier
		Section/Size	Non Confirming Size	8	Raw material manufacturing defect	2	1	16	Rejection	QA	Intimate Material Supplier
		Surface Condition	Crack	10	Raw material manufacturing defect	2	2	40	Rejection	QA	Inform Material Supplier
		Physical Properties	Non Confirming to the Specification	10	Raw material manufacturing defect	2	2	40	Rejection	QA	Inform Material Supplier

Table 14: Application of FMEA in receipt of raw material

Application of FMEA in raw material cutting

OPN NO.	OPERATION DESCRIPTION	DESIRED OUTCOME (PRODUCT CHARACTERISTICS)	FAILURE MODE	SEVERITY	CAUSES	OCCURRENCE	DETECTION	RPN	RECOMMENDED ACTIONS	RESPONSIBILITY
120	Raw material cutting	Cut pieces of specified weight	Cut weight high	2	Section variation	2	2	8	Adjust the cut length	Production
					Cutting accuracy	2	1	8	Preventive Maintenance	Maintenance
			Cut weight low	10	section variation	2	2	40	Adjust the cut length	Production
					Cutting accuracy	2	2	140	Preventive Maintenance	Maintenance

Table 15: Application of FMEA in raw material cutting

Application of FMEA in die setting (pre forging)

OPN NO.	OPERATION DESCRIPTION	DESIRED OUTCOME (PRODUCT CHARACTERISTICS)	FAILURE MODE	SEVERITY	CAUSES	OCCURRENCE	DETECTION	RPN	RECOMMENDED ACTIONS	RESPONSIBILITY
130	Die Setting (Pre forging)	Properly set Dies	Misaligned Dies	8	Improper Die setting , Dimension deviation in dovetail ,cross key ,sow block and ram	4	2	64	Reset Dies	Production
						1	2	16	Correction& Repair of Ram & Sow Block	QA,D/S &MNT.

Table 16: Application of FMEA in die setting (pre forging)

Application of FMEA in cut piece heating

OPN NO.	OPERATION DESCRIPTION	DESIRED OUTCOME (PRODUCT CHARACTERISTICS)	FAILURE MODE	SEVERITY	CAUSES	OCCURRENCE	DETECTION	RPN	RECOMMENDED ACTIONS	RESPONSIBILITY
150	Cut Piece Heating	Uniformly Heated & Soaked Cut pieces to the specified Parameters	Low Heat	8	More number of pieces/ charge	5	2	80	Charge to conform with furnace capacity	Production
					Location of cut pieces in the furnace	5	2	80	Ensure position of cut pieces in the effective heating zone of furnace	Production
					Furnace Maintenance	4	3	96	Usage of specified quality refractory materials,thermocouples, bonding agents and proper furnace laying	Maintenance
					Operator Skill	4	2	64	Training	HRD
			High Heat	10	Location of cut pieces in the furnace	5	2	100	Super vision	Production
					Furnace Maintenance	3	3	90	Usage of specified quality refractory materials,thermocouples, bonding agent etc. and Supervsion	Maintenance
					Operator Skill	4	2	80	Training	HRD

Table 17: Application of FMEA in cut piece heating

Application of FMEA in die pre-heating

OPN NO.	OPERATION DESCRIPTION	DESIRED OUTCOME (PRODUCT CHARACTERISTICS)	FAILURE MODE	SEVERITY	CAUSES	OCCURRENCE	DETECTION	RPN	RECOMMENDED ACTIONS	RESPONSIBILITY
140	Die Pre-heating	Pre-heated Dies	Die crack/Damage	8	Improper Temperature	3	2	48	Heat to required temperature	Production

Table 18: Application of FMEA in die pre-heating

Application of FMEA in pre-forging

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OPN NO.	OPERATION DESCRIPTION	DESIRED OUTCOME (PRODUCT CHARACTERISTICS)	FAILURE MODE	SEVERITY	CAUSES	OCCURRENCE	DETECTION	RPN	RECOMMENDED ACTIONS	RESPONSIBILITY
160	Pre-forging	Pre-forging as per SIFL drawing	Not as per preforging drawing	7	Variation in fullering of cut pieces	2	2	28	Training	HRD/ Prodution

Table 19: Application of FMEA in pre-forging

Application of FMEA in die / tool setting (finisher)

OPN NO.	OPERATION DESCRIPTION	DESIRED OUTCOME (PRODUCT CHARACTERISTICS)	FAILURE MODE	SEVERITY	CAUSES	OCCURRENCE	DETECTION	RPN	RECOMMENDED ACTIONS	RESPONSIBILITY
180	Die/Tool Setting(Finisher)	Properly set Dies & Tools	Misaligned Dies	8	Improper Die setting , Dimension deviation in dovetail,cross key ,sow block and ram	4	2	64	Reset Dies,Repair Ram and Saw Block	Production/Maintenance
						1	2	16	Reinspection and correction	QA & D/S

Table 20: Application of FMEA in die / tool setting

Application of FMEA in heat treatment

OPN NO.	OPERATION DESCRIPTION	DESIRED OUTCOME (PRODUCT CHARACTERISTICS)	FAILURE MODE	SEVERITY	CAUSES	OCCURRENCE	DETECTION	RPN	RECOMMENDED ACTIONS	RESPONSIBILITY
250	Heat treatment(Normalising, Hardening, Tempering)	Specified structure and physical properties	Desired characteristics not obtained	8	Furnace problem	3	3	72	Furnace maintenance	Maintenance
					Operator Skill	2	3	48	Training	HRD

Table 21: Application of FMEA in heat treatment

Application of FMEA in heating of preforging

OPN NO.	OPERATION DESCRIPTION	DESIRED OUTCOME (PRODUCT CHARACTERISTICS)	FAILURE MODE	SEVERITY	CAUSES	OCCURRENCE	DETECTION	RPN	RECOMMENDED ACTIONS	RESPONSIBILITY
200	Heating of preforging	uniformly Heated & Soaked preforgings to the specified Parameters	Low heat	8	more number of pieces/ charge	5	2	80	Charge to conform with furnace capacity	Production
					Location of cut pieces in the furnace	5	2	80	Ensure position of cut pieces in the effective heating zone of furnace	Production
					Furnace Maintenance	4	3	96	Usage of specified quality refractory materials,thermocouples,bonding agent and proper furnace laying	Maintenance
					Operator Skill	4	2	64	Training	HRD
			High Heat	10	Location cut pieces	5	2	100	Charge to conform with furnace capacity	Production
					Furnace Maintenance	4	2	80	Usage of specified quality refractory materials,thermocouples,bonding agent and position of burners etc…	Maintenance
					Operator Skill	4	2	80	Training	HRD

Table 22: Application of FMEA in heating of preforging

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Application of FMEA in forging

OPN NO.	OPERATION DESCRIPTION	DESIRED OUTCOME (PRODUCT CHARACTERISTICS)	FAILURE MODE	SEVERITY	CAUSES	OCCURRENCE	DETECTION	RPN	RECOMMENDED ACTIONS	RESPONSIBILITY
210	Forging	Forging as per drawing with specified tolerances and without forging defects	Over size	3	Die over size	4	2	24	Die correction	Die shop
					Operator Skill	4	4	48	Training	HRD
					Low air pressure	4	2	24	Ensure air pressure	Production
			Under size	8	Die under size	2	2	32	Die correction	Die shop
			Unfilling	10	Improper location of cut piece	6	2	120	Training	HRD
					Low air pressure	2	2	40	Ensure air pressure	Production
			Mismatch	10	Machine accuracy,guide clearance	6	2	120	Preventive Maintenance	Production/Maintenance
					Lock damage				Lock correction Reject	Die shop QA
			Lap/crack	10	Material defect	2	2	40	Inform material supplier	MMD
			Scale pits	9	Improper scale removal	6	2	108	Proper scale removal	Production

Table 23: Application of FMEA in forging

Application of FMEA in trimming

OPN NO.	OPERATION DESCRIPTION	DESIRED OUTCOME (PRODUCT CHARACTERISTICS)	FAILURE MODE	SEVERITY	CAUSES	OCCURRENCE	DETECTION	RPN	RECOMMENDED ACTIONS	RESPONSIBILITY
220	Trimming	Bend free forgings with specified dimensions	Bend	10	Imperfect tooling	2	3	60	Tool to be plaster suited	Die shop
			Body cut	10	Improper placement of job on trim die	2	2	40	Operator training	HRD
			Flash projection	6	Imperfect tooling	4	2	48	Tool to be plaster suited	Die shop

Table 24: Appication of FMEA in trimming

Application of FMEA in shot blasting

OPN NO.	OPERATION DESCRIPTION	DESIRED OUTCOME (PRODUCT CHARACTERISTICS)	FAILURE MODE	SEVERITY	CAUSES	OCCURRENCE	DETECTION	RPN	RECOMMENDED ACTIONS	RESPONSIBILITY
270	Shot blasting	Scale free job	Poor finish	7	Low quality shots	2	2	28	Procure and use shots of specified grade	Stores
					Duration of shoting	2	2	28	Increase duration and rework	F&D

Table 25: Application of FMEA in shot blasting

Application of FMEA in fettling

OPN NO.	OPERATION DESCRIPTION	DESIRED OUTCOME (PRODUCT CHARACTERISTICS)	FAILURE MODE	SEVERITY	CAUSES	OCCURRENCE	DETECTION	RPN	RECOMMENDED ACTIONS	RESPONSIBILITY
290	Fettling	Finish product free from burrs and pits	Product with burrs,tool marks and pits	8	Operator Skill	4	2	64	Training	HRD/F&D

Table 26: Application of FMEA in fettling

VII. RESULT AND DISCUSSION

The maximum value of RPN is observed for UN filling and mismatch during forging operation. Proper training and preventive maintenance can reduce these problems. The high values of RPN are also noted for scale-pits in forging and for low and high heat during cut piece heating. Usage of specified quality refractory materials and proper supervision can avoid these failures.

VIII. FUTURE WORKS

After the implementation of the actions, new RPN can be calculated and the risk reduction can be understand. Conducting the cost oriented FMEA (CFMEA), the overall cost of production can be evaluated and further reduced.

REFERENCES

[1] Dr.D.R.Prajapati (July 2012) "Implementation of failure mode and effect analysis: a literature review" International journal of management, IT and Engineering, volume2, issue 7.

[2] Meril Baby, Subin George Mathew (Oct 2014) "cost oriented FMEA In mattress industry" International journal of emerging technology & research, volume 1, issue 6.

[3] H.Arabian-Hoseynabadi (Jun 2010) "Failure mode and effect analysis (FMEA) for wind turbines" Durham university.

[4] Swapnil B. Ambekar (Feb. 2013) "A Review: Implementation of Failure Mode and Effect Analysis" International Journal of Engineering and Innovative Technology (IJEIT) Volume 2, Issue 8.

[5] Piyush Kumar pareek, Praveen gowda (July 2012) "FMEA implementation in a foundry in Bangalore to improve quality and reliability" International journal of mechanical engineering and robotics research, volume1, No.2.

[6] JEDEC Publication (May 2005) "Potential failure mode and effect analysis" JEDEC Solid state technology association.

[7] A Wadhesh Kumar, M.P.Poonia (Jun 2011) "FMEA: Methodology, design and implementation" international journal of engineering science and technology, volume 3, no.6.

[8] Amrita Jhawar, and Purnima Bajpal (Nov 2014) "Applying FMEA and ISM technique to identify factors causing delay in road construction projects" International journal of applied engineering research, volume 9.

[9] "Failure mode and effect analysis (FMEA)", Total quality management- university of Michigan.

[10] "Failure mode and effect analysis", FMEA doc.

[11] Manufacturing technology committee (May 2008) "Failure mode and effect analysis guide", Risk management working group.

[12] Vladimir popvic, Branko vasic (Mar 2010) "The possibility for FMEA method improvement and its implementation in to bus life cycle" Journal of mechanical engineering.

[13] N.Sellappan, K.Palanikumar "Modified prioritization methodology for risk priority number in failure mode and effects analysis" International journal of applied science and technology.

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 4, Issue 7, January 2015

[14] Darina juhaszova (2013) "Failure analysis in development & manufacture for customer" quality innovation prosperity, volume 17, issue 2.

[15] Sibel Ozilgen (Mar 2012) "Failure mode and effect analysis for confectionery manufacturing in development countries: Turkish delight production as a case study" Department of food engineering.