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Failure Mode Effect Analysis-Case Study for Bush Manufacturing process

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Abstract— Manufacturing performances tend to produce defects due to various reasons, which can be improved by identifying and eliminating them using six sigma. In the present work, DMAIC (Define, Measure, Analyze, Improve and Control) has been used to reduce the number of bush rejection. In define phase problem was defined by selecting the core issues concerned. In the measure phase data was collected to determine the current performance and the process capability. During Analyzing phase root causes of bush rejection were identified. In the improvement phase solutions were arrived at and finally in the control phase various tools were implemented for process to keep under control.

This paper makes use of Failure Mode Effect Analysis (FMEA) to adopt the innovative technologies integrated with the operational aspects in order to enhance the process capability. The main objective of the study is to improve machinery system reliability and its performance.

Keywords—**Failure Mode Effect Analysis (FMEA), Risk Priority Number (RPN),System development and analysis**

1. INTRODUCTION

In order to evaluate &optimize thebush manufacturing process rejection analysismust focus on the entire machining process. A grinding machine is much more difficult to control than facing machine and pressing other machining process.

The case study was undertaken at a bush and bearing manufacturing company. The product taken under consideration wasengine bush i.e. bush-j and total bush manufacturing process.The Pareto analyses were done to select the type of bush and its machine as it contributing more percentage of the total scrap quantity. In the manufacturing process bush J contributing 34% rejection of total quantity and we have done also percentage wise rejection analysis is performed and quantity analysis, then it was found bush-j contributing more quantity of total percentage rejection. Hence the initial data were collected on the all the stages of manufacturing and it was found that grinding machine, pressing machine and facing machine contribute more rejection of the bush.

Hence from the process map study various permanent parameters were identified. After that cause-effect matrix study were done. From the cause-effect matrix according to the importance to the customer some input steps required for operation were selected. Since the critically important steps for the capability enhancement for total bush manufacturing process machines and precautions are extremely vital. Therefore this paper utilized the Failure Mode Effect Analysis (FMEA) approach to formulate satisfactory solutions to reduce rejection quantity and improve quality of bush. The potential risk associated to the manufacturing process of bush J and all machine process involved in manufacturing process clarified based on FMEA. Hence the significance of the proposed idea lay to the transforming of operational feedback and evidences to prevention action against machine performance.

The organization of this paper given as this section begins with motivating information on the paper. In section 2, a brief introduction to FMEA is given. In section 3, the application of the FMEA on to the process capability index enhancement machining process. In section 4 the conclusion remarks are expressed.

2. Failure Mode Effect Analysis (FMEA)

FMEA is a proactive analysis tool allowing engineers to define, identify and eliminate known /or potential failure, problems, errors and so on from the system, design, process /or service,[Omdahl, 1988, Stamatis 2003]

FMEA is an inductive approach to support risk management studies and the principles of FMEA is to identify potential hazards along with the focused system and to prioritize the required corrective actions or strategies. In 1949 the FMEA methodology was developed and implemented for the first time by the United States army and then in the 1970 with its strength and robust characteristics its application extended to aerospace and automobile industry, to the general manufacturing.[3]

Now a day's FMEA mainly applied in industrial production of machinery, motors cars, mechanical and electronic component. FMEA is a procedure in product development and operation management for analysis of potential failure modes within a system for classification by the severity and likelihood of failures. A successful FMEA activity helps a team to identify potential failure modes based on the past experience with similar product or process or problem, enabling the team to design those failures out of the system with the minimum of efforts and resource expenditure thereby reducing development time and cost. It is widely used in manufacturing industries in various phases of product life cycle. Applying FMEA involves number of steps starting from analysis of product, process system in every single part, list of process steps, process inputs, then list of identified potential failures, evaluation of their frequency of occurrence, severity (Its effect on process/product/system and to its surroundings in case of failure) and their detection

FMEA should be initiated by the design engineering for the hardware approach and the system engineering for the functional approach. Once the initial FMEA has been completed, the entire engineering team should participate in review process. FMEA cannot be accomplished on an individual basis because FMEA is team function. The FMEA team reviews for identifying high risk areas that must be addressed to ensure completeness. A various expertise people from different areas can participate in FMEA activity, for instance project manager, design engineer, test engineering, maintenance and safety engineering, operator etc. The expertise team can vary according to the scope and complexity of the focused failure problems. The group leader/coordinator, preferably FMEA experts organizes the expert team activities in accordance with FMEA theory and data can be collected during work. The most important aspect of FMEA is the evaluation of the risk level of potential failure identified for every sub-process. The value of damage caused on system by every failure indicated with the Risk Priority Number (RPN). A FMEA uses the RPN to assess the risk in three categories: Occurrence (O) is the assessment for how frequently the problem occurs within system, Severity(S) is an assessment of seriousness of the effect of potential failure to the process or system or surrounding and Detection (D) is the assessment of the probability of detection of occurred problem with available monitoring system before component/system is damaged and stopped. The RPN is generated by taking the product of three index (occurrence, severity, detection) on the scale from 1-10 for each one. Hence RPN number will decide the seriousness of potential risks critical to safety of system or productivity of process.

RPN=S*O*D

FMEA document shows a list of items that identified:- (i)Process steps (ii) Process inputs (iii) potential failure mode(iv) potential effect of failure(v)potential causes/mechanisms of failure(vi)Severity index (vii)Occurrence index (viii) Detection index (ix) Risk Priority Number. Table 1-3 shows quantitative scales commonly used for the occurrence, severity and delectability index.

TABLE NO. 1 OCCURRENCE RANKING

Likelihood	Criteria : Severity of Effect on Product (Customer Effect)	Rank
Very high	≥ 100 per thousand	10
	≥ 1 in 10	
High	50 per thousand	9
	1 in 20	
	20 per thousand	8
	1 in 50	
	10 per thousand	7
	1 in 100	
Moderate	2 per thousand	6
	1 in 500	
	0.5 per thousand	5
	1 in 2,000	
	0.1 in thousand	4
	1 in 10,000	
Low	0.01 per thousand	3
	1 in 1,00,000	
	≤ 0.001 per thousand	2
	1 in 1,000,000	
Very Low	Failure is eliminated through preventive control.	1

TABLE NO: 2 SEVERITY RANKING

Effect	Criteria: Severity of effect on Process (Manufacturing/Assembly Effect)	Rank
Failure to meet safety and/or Regulatory Requirements	May endanger operator(machine or assembly) without warning	10
	May endanger operator(machine or assembly) without warning	9
Major Disruption	100% of product may have to be scrapped. **Line shutdown** or stop ship.	8
Significant Disruption	A portion of the production run may have to be scrapped. **Deviation from primary process** including decreased line speed or added manpower.	7
Moderate Disruption	**100% of production** run may have to be **reworked off line** and accepted.	6
	A portion of the production run may have to be reworked off line and accepted.	5
Moderate Disruption	**100% of production** run may have to be **reworked in-station** before it is processed.	4
	A portion of the production run may have to be reworked in-station before it is processed.	3
Minor Disruption	Slight inconvenience to process, operation, or operator.	2
No effect	No discernible effect	1

TABLE NO: 3 DETECTION RANKING

Opportunity for Detection	Criteria : Severity of Effect on Product (Customer Effect)	Rank
No detection opportunity	No current process control; Cannot detect or is not analyzed.	10
Not likely to detect at any stage.	Failure Mode and/or Error (Cause) is not easily detected (e.g. random audits).	9
Problem Detection Post Processing	Failure Mode detection post-processing by operator through visual/tactile/audible means.	8

Problem Detection at Source	Failure Mode detection in-station by operator visual/tactile/audible means or post-processing through use of attribute gauging (go/no-go, manual torque check/clicker wrench, etc.).	7
Problem Detection Post Processing	Failure Mode detection post-processing by operator through use of variable gauging or in-station by operator through use of attribute gauging (go/no-go, manual torque check/clicker wrench, etc.).	6
Problem Detection at Source	Failure Mode or Error (Cause) detection in-station by operator through use of variable gauging or by automated controls in-station that will detect discrepant part and notify operator (light, buzzer, etc.) Gauging performed on setup and**first-piece** check (for set-up causes only).	5
Problem Detection Post Processing	Failure Mode detection post-processing by **automated controls** that will detect discrepant part and lock part to prevent further processing.	4
Problem Detection at Source	Failure Mode detection in-station by **automated controls** that will detect discrepant part and automatically lock part in station to prevent further processing.	3
Error Detection and/or Problem Prevention.	Error (Cause) detection in-station by **automated controls**that will detect error and prevent discrepant part from being made.	2
Detection not applicable; Error Prevention.	Error (Cause) prevention as a result of fixture design, machine design or part design. Discrepant parts cannot be made because item has been error proofed by process/product design.	1

3. APPLICATION

3.1 Introduction to case study

The case study has been taken for the process capability enhancement of BUSH manufacturing process. The particular case study carried out at one of bush manufacturing company. There are several stages of bush manufacturing i.e. material preparation and selection, pressing (separate piercing, piercing, pre knuckling, final knuckle), grinding (surface finish), both side facing (width control) and inspection. The Paretoanalysis was done for all bushes & **bush-J** selected for further improvement/ enhancement because it contributes 38% total rejection.By observing all the process steps it founds that grinding and facing machine creates more bush rejection so these two machines are selected for further improvement. Fig 1.1 shows percentage wise Parato analysis for all bushes and Fig1.2 shows quantity wise Paratoanalysis.

Initial data were collected and its process capability index has been calculated.

The process capability is an important concept for industrial people to understand how well a process can produce acceptable product. As a result, a manager or engineering can prioritize needed process improvements and identify those processes that do not need immediate process improvement. The process capability study indicates if a process is capable of producing virtually all conforming product. If the process is capable then statistical process control can be used to monitor the process and conventional acceptance efforts can be reduce or eliminated entirely. This not only yields great cost savings in eliminating non-value added inspection but also eliminate scrape, rework and increase the customer satisfaction.

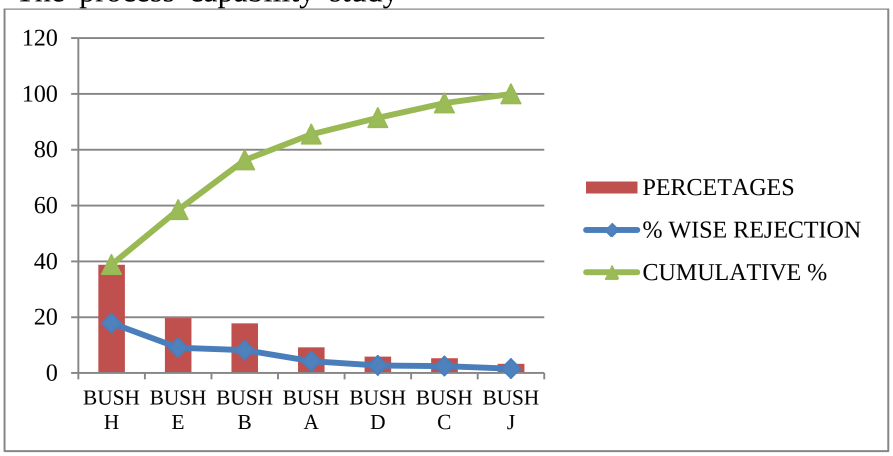

Fig.1.1 Percentage wise rejection Parato analysis

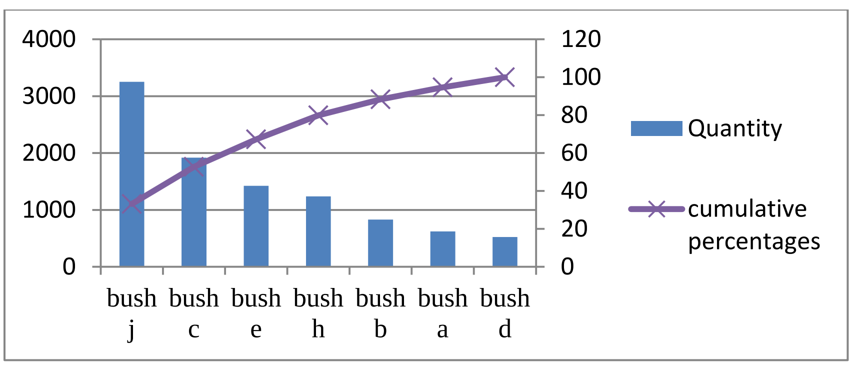

Fig.1.2 Quantity wise rejection Parato analysis

Grinding machine grinds the Bush-J. From the process map analysis different input parameters required for the grinding which affects the outputis selected. The selected various inputs from process map carried further for the cause –effect matrix. In this analysis according to the rating of importance to the customer few critical inputs were selected.i.e. Work head rpm, cutting speed ratio, grinding compensation, dressing interval and dressing play, ,diamond height, dent marks on bush, OD variation, scratches on bush. These inputs are further selected for FMEA. Although great efforts have been made to maintain & improve the performance of grinding machine, it cannot be entirely controlled. It can be minimized by implementing new maintenance regimes, integrating advance technologies in to system comply with company rules and regulation and other safeguards. The causality nature should be identified via using evidence & past experience. Recalling historical development background of capability enhancement of similar type of machine will help to a great extent. The operational survey conducted hereby guides this study in order to structure the methodological procedure based on FMEA.

Both sides facing machine controls the width of BUSH JFrom the process map analysis different input parameters required for facing which affects the output is selected. Selected various inputs from process map carried further for cause-effect matrix. In this analysis according to the rating of importance to the customer few critical inputs were selected i.e. facing machine setting, tool setting, tool wear and lapping of cutting tool, chucks cross slide movements, clamping unit and its vertical movement. It can be minimized by implementing new maintenance regimes, integrating advance technologies in to system comply with company rules and regulation and other safeguards. The causality nature should be identified via using evidence & past experience. Recalling historical development background of capability enhancement of similar type of machine will help to a great extent. The operational survey conducted hereby guides this study in order to structure the methodological procedure based on FMEA.

3.2 The methodological approach

Conducting an initial survey to gather feedback/evidences from different capability enhancement projects in the company itself. A required level of knowledge to apply FMEA was enabled. The main goal of methodological approach to capability enhancement is to identify all aspects of failure & to suggest precautions that combine operational duties & technological means. Complying with FMEA application principles, the investigation team which contributes a FMEA fractioned and couple of 6-sigma expertise were guided the following six main steps

Step 1: Brainstorm potential failure mode

In this first step potential failure mode based on functional requirement are determined through brainstorming. They are enlisted in to the FMEA worksheet which is illustrated in Table

Step 2: list potential effects of each failure mode.

This step begin with ascertain potential effects for each failure mode by gathering feedback from experts.i.e. Starting from operator to manager. A cause effect analysis is carrying out during for identification of potential effect of each failure mode.

Step 3: Assign on occurrence ranking for each failure mode

A team identified the potential cause of failure associated with each failure mode. This information not only helps likelihood of failure occurring but also helps target their improvement efforts.

Step 4: Assign severity ranking

Failure can have various efforts and each effect can have their different levels of severity. Parato analysis can be done at this step.

Step 5: Assign Detection ranking

In this step all controls currently in place for each of potential cause of failure or effects of failure are listed and assign detection ranking.

Step 6: Calculate Risk Priority Number

RPN number calculated for each failure mode by multiplying severity, occurrence, and detection numbers.

3.3 Analysis and discussion:

To clarify the required precautions, the quantitative results derived from FMEA application to process capability enhancement should be emphasis in this section. According to this assumption, a level of preventive actions for process inputs of process steps To express the utilization of FMEA application results on process capability of BUSH process results explain below in table.

PROCESS FUNCTION	POTENTIALFAILURE MODE	POTENTIAL EFFECT OF FAILURES 1.END USERS/CUSTOMERS 2.ASSEMBLY 3.SAFETY	POTENTIAL CAUSE MECHANISM OF FAILURE	CURRENT PROCESS CONTROL DETECTION	RECOMMENDED ACTION	RESPONSIBLE PERSON	ACTION RESULTS ACTION TAKEN
Grinding process	Size Variation OD Plus/ Minus	1.Displacement During Operation	1.Depth Of Cut/ Grinding Pass Not Defined & Followed	Checking Bush OD On Sampling	Define Depth Of Cut/Pass In Control Plan Currently They Are Passing 1000 Bush In Three Passes In Each Batch	Mech. Dept.	By DOE Defined Each Bush Required Depth Of Cut And Mentioned On Control Plan. And Reduced Bush Quantity 600-700 In Each Batch.
			2. Improper Dressing	Visual Check Of Bush OD	Prepare Work Instruction & Train Operator To Dress Regulating & Grinding Wheel At Same Angle. (In Order To Prevent Dent Caused By Uneven Grinding Force).	Mech. Dept.	By DOE Prepared All Work Instruction About Awareness For How To Dress Wheels
			3.Incorrect Work Head Rpm Setting	Tachometer	Check Surface Speed Of Cutting & Finalize	Mech. Dept.	Value Obtained By Trial And Error

			4.Improper Material Feed Rate	Checked No Of Jobs/Min. & Roughness Of OD	Feed Rate Of Each Bush Type To Be Defined In Control Plan And Operators Are Trained	Mech. Dept.	Value Obtained By Trial And Error
	Marks On OD	1. Rejection Of Lot 3. No Effect	Faulty Machine Setting	First Piece Approves	Follow setting instruction properly	Operator	Use Control Plan
			Improper Dressing	Visual Check Of Bush OD	1. Prepare Work Instruction & Train Operator To Dress Regulating & Grinding Wheel At Same Angle. 2. Change Diamond To Get Sharper Dressing 3.Wash Wheel Thoroughly With Coolant After Dressing.	Mech. Dept.	1. Awareness About Dressing Method Improved By Showing Proper Dressing Method 2.Diamond Changed .
			Loose Wheel Mount	First Piece Approves By Checking It	Tighten Spindle Nut Or Clamping Screws Through Collets.	Mech. Dept.	Maintenance Of Spindle Nut And Clamping Screw To Be Done
			Coolant Condition	Refracrtometer	Check Coolant Condition & Finalize	Operator	Coolant Changed
			Vibration In Machine	Operator Check Visually Lines Or Marks On Bush Surface	Check Motor Bearing Condition And Finalize	Mech. Dept.	Motor Bearing To Be Changed
			Problem In Regulating Wheel Spindle	Operator Check Visually Lines Or Marks On Bush Surface	Require To Check Maintenance Of Machine Spindle	Mech. Dept.	Maintenance Of Spindle To Be Done
Pre-Knuckle	Clinch Damage	Misalignment Of Edges At The Time Of Final Knuckle	1.Twist In Bending Tool	Visual Checking Of Bush	Wear Out Of Bending Tool	Mech. Dept.	Bending Tool Changed
			2.Improper Setting Of Tool	First Piece Approves	Follow setting instruction properly	Operator	Use Control Plan

Final Knuckle	OD Variation	1.Shifting Of Axial Hole Position 2.Slot/Hole Deformation	Deformed Die (Variation In Bending Angle)	Visual Check Of Bush OD	Check Die Angle And Prepare Work Instruction And Train Operator For Proper Maintenance. Mention Proper Angle And Proper Die On Control Plan	Mech. Dept.	Given Instruction To Check Die Angle And Set Proper Die Angle
			Incorrect Die Pressure	First Piece Approval 5nos.(Use X Bar And R-Bar Chart)	For Pressure Setting Digital Display Unit Synchronizing With Die And Punch Should Be Mount And Mention Proper Pressure For Each Type Of Bush On Control Plan.	Mech. Dept.	Ongoing Process To Synchronize Die Pressure To Digital Display Unit
			Incorrect Die	First Piece Approval 5nos.(Use X Bar And R Bar Chart)	Mention Proper Die Type On Control Plan	Operator	Given Instruction To Operator To Use Control Plan
	Wrong Bending And Twisting	Variation In Bend Radius	Incorrect Punch	First Piece Approval 5nos.(Use X Bar And R Bar Chart)	Mention Proper Punch Type On Control Plan	Operator	Given Instruction To Operator To Use Control Plan
			Twist In Bending Tool	Visual Checking Of Parts By Operator	Change Or Do Maintenance Of Bending Tool	Mech. Dept.	Bending Tool Changed
		Possibility Of Taper Bending	Burr At Edges	Visual Checking By Operator	Clean Die-Punch Set And Give Instruction To Operator for Proper Attention On Burrs	Operator	Given Instruction To Operator
	Scratches And Dents (Bending Marks)		Improper Handling And Cleaning Of Bush	Visual Checking By Operator	Give Instruction To Operator To Clean Bush And Give Proper Care Of Bush Placing In Buckets. Wash Bushes By Using Oils Before It Placing And Packing.	Operator	Awareness For Finish And Marks To Be Increases By Operator In Rejection Quantity By Displaying Current Rejection Status

Facing process	Width Variation	1.Axial Hole Distance Variation 2.Grove Axial Distance Variation	Improper Of Setting Of Tool	First Piece Approval 5nos.	Mention Proper Setting Procedure On Control Plans (Use X-Bar And R-Bar Charts)	Operator	Proper Setting Procedure Mentioned In Control Plan
			Play In Cross Slide Moment Of Chucks	Visual Checking Of Bush When Chatter Marks Observed	Check Play In Of Moments Of Chucks And Finalize	Operator	Maintenance Of Chuck Run Out To Be Done
			Wear Out Clamping Unit Screw	Visual Checking By Operator	Check Clamping Unit Play In Movement And Change Screw If Found Faulty.	Mech. Dept.	Clamping Unit Maintenance To Be Done.
	Face Uncut		Improper Of Setting Of Machine	Visual Checking By Operator	Follow setting instruction properly	Operator	Use Control Plan
	Chamfer Not Ok		1.Tool Wear Out 2.Improper Setting Of Chamfer Tool	First Piece Approval 5nos.	Follow setting instruction properly	Operator	Use Control Plan

4. Conclusion:

Failure Mode Effect Analysis (FMEA) for capability enhancement requires great level of knowhow and competency. In addition methodological approach for this kind of technical problems should be considered to find satisfactory solution for different failure cases. This paper applied FMEA approach to capability enhancement. FMEA tend to give the importance to the prevention efforts, at point combined technical solution and operational precautions are proposed to prevent or decrease the probability of affecting machine performance.

Besides specific attempts to analysis capability improvement, the main task behind this paper is to express integrity of operational precautions and process technology in order to produce optimal solutions for process capability enhancement for whole BUSH manufacturing process.. Therefore improving the process system reliability and enhancing operational safety concept and for pressing, facing and grinding machine. In addition to this, in this paper it is seen that FMEA is an adequate risk management tool in order to prevent the problems. As in the study ram speed, pre-knuckle bending pressure, bending punch and die selection, bending method, grinding compensation, grinding compensation interval, dressing interval, cutting speed ratio, clamping pressure, work head rpm ,facing machine setting , lapping of tool and tool wear measurement are the crucial inputs to improve the process capability index of BUSH manufacturing process.

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