Quality Improvement of Turbo-Charger Manufacturing Process through Process Failure Mode Effect Analysis (PFMEA)

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***Abstract*:** In current scenario, quality of product is playing an important role in customer expectation and satisfaction. So it is important for an organization to select various strategies to improve the manufacturing processes. Process Failure Mode Effect and Analysis (PFMEA) tool is the most effective in identifying the failure mode with its effect and proposes the solution for the cause of failure. This Paper aims to identify the various potential problems from the manufacturing process of turbo charger in the industry with the approach of PFMEA.
After the Complete study of manufacturing process of turbo charger, PFMEA identified some critical process indicating higher R.P.N (Risk Priority Number) which required mitigating steps to improve the quality as well as save money and time**.**
Keywords – Turbocharger, impeller wheel, PFMEA, Quality Improvement.

I INTRODUCTION

PFMEA methodology works on the principle of defect prevention which analyze and monitors each process and each sub process at each stage of the process and safeguards the product or process against appearance of a problem. As per PFMEA, collecting information on upcoming failures and prevent them is a much more efficient way of improving quality than the standard quality control [1].

To minimize the defect in the manufacturing process, PFMEA (Process Failure Mode Effect and Analysis) can be implemented. PFMEA is used to identify potential failure mode of parts, its effect on other parts or customers and propose solution for the potential failure. PFMEA is the sub part of FMEA (Failure mode effect and Analysis) and the other one is DFMEA (Design Failure Mode Effect and Analysis) which related to design phase. PFMEA is more complicated and time consuming then DFMEA [2].

PFMEA is methodology which should be applied in industries for finding defects of the process as well as searching and solving the best solution for the cause of defects.

II LITERATURE REVIEW

The FMEA was first developed and implemented in the year 1949 by U.S. Army and later in Apollo Space program to minimize the risk [10].In 1977, FMEA was introduced in Automotive industries by Ford Company to minimize the problems in production. Later it publish the Potential Failure Mode and Effect Analysis Hand Book in 1984 [10]. FMEA methodology involves various steps from Failure identification, its effects, its criticality by RPN value and its mitigation to minimize the failure [13]. During the course of study, PFMEA can be useful to identify and eliminate potential problems in a manufacturing process of cylinder head [3]. PFMEA is an important tool to improve Product Quality of Air-Duct Manufacturing Industry [1]. PFMEA applied in Sheet Metal Industry to reduce the waste and improve the quality of product resulted in gaining both profit and time [8]. Implementation of PFMEA in the manufacturing process of hollow core slab to identify the risk associated and analyze the risk as well as determine the priority of the processes [4].An implementation Paper on Welding process showed that how successfully PFMEA could be used to improve the quality of product [5]. The FMEA has the potential reduce the risk associated in transportation and Distribution of Pharmaceutical Industries [6].

Applied FMEA technique on life care product Manufacturing Industry to reduce the Breakdown in the subsystem of industry [7].PFMEA Methodology by analyzing the mode and risk associated with the operation and integrated approach with minimizing un-necessary processes and reducing the wastage of material [11]. The Fuel consumption by agricultural machinery also reduced by using FMEA technique. The Technique is applied to Tillage operation which accounts 80% of fuel consumption and by various steps it can be reduced [12].

III DEFINITION OF FMEA

Failure mode and effect analysis (FMEA) is a tool which combines technology and experience of people to identify the probable failure mode and effect of product or process and planning for its mitigation. FMEA is a series of precautious action that requires the team effort to implement various mitigating actions which enhance the quality as well cost effective. [3].

The objective of FMEA is

- Identify and evaluate the potential failure of a product or process and its effects.
- Determine actions that could eliminate or reduce the chance of potential failures.
- Documentation of the whole process for future use.

Terms used in PFMEA

1. **Part and process Functions** : it includes all parts and process associated with parts.
2. **Potential Failure Mode** : It is the method through which potential failure may cause in higher or next operation.
3. **Potential Effect of Failure** : It May be defined as the result of Failure. It may be Noise, poor Appearance, instability etc.
4. **Severity** : It is the assessment of the seriousness of the potential failure mode.Severity should be rated on 1-10 scale, with one being none and 10 being the most severe

Table 1 : Table of Severity

Effect	Criteria	Ranking
Hazardous without warning	Potential failure mode affects the safety norms without warning	10
Hazardous with warning	Failure mode affects with warning	9
Very high	Loss of primary function of parts or parts get rejected	8
High	Performance reduction and 25% chances of rejection	7
Moderate	Item is operable and part need more rework	6
Low	Item is operable but part needs some rework	5
Very low	Item is operable but part needs little rework	4
Minor	Defect is acceptable up to certain tolerance	3
Very minor	Defect is acceptable	2
None	No noticeable defect	1

5. **Potential Cause of Failure *:*** It means reason behind the failure. It may be inadequate instruction, poor environment or Human error
6. **Occurrence *:*** It is the Chance of failure cause that will occur. In this step, we have to identify how many time the failure occur.

Table 2 : Table Of Occurrence

Frequency	Ranking
10 and 9	Very high failure rate
8 and 7	Frequent failure
6 and 5	Moderate failure
4 and 3	Low failure
2 and 1	Failure unlikely

7. **Current Design Control** : It includes prevention measures for the failure like Design validation, Design verification etc.
8. **Detection** : It is the ranking of the ability of design control to detect the failure mode.

Table 3: Table of Detection

Detection	Criteria	Ranking
Absolutely uncertain	Process control is unable to detect problem	10
Very remote	Very rare chance of detection	9
Remote	Remote chance of detection	8
Very low	Very low chance of detection	7
Low	Low chance of detection	6
Moderate	Moderate chance of detection	5
Moderately high	Chances of detection of failure mode is moderately high	4
High	High chance of detection	3
Very high	Very high chance of detection	2
Almost possible	Detection is always there	1

9. **Risk Priority Number (RPN) :** It indicates whether the failure mode is critical or not. It is obtained from product of Severity (S), Occurrence (O), and Detection (D).
   RPN = Severity X Occurrence X Detection.

IV PARTS DESCRIPTION

Turbocharger is the mechanical device which is used to increase the density of inlet air entering into the combustion chamber of IC engine with the help of compressor which gets its power from a turbine runs by exhaust gas of same IC engine. Turbo charging increases quantity of air entering into the combustion chamber which promotes lean combustion, this further result into better performance and lower exhaust emissions [9].

Main Parts of Turbo Charger

The Essential part of Turbo Charger is Turbine, Compressor, Connecting Shaft, Intercooler, radiator, Bearing and Housings

- Turbine – It consist of impeller in turbine housing converting exhaust energy into mechanical energy
- Compressor- It Consist of Compressor Wheel in Compressor Housing which direct the inlet air at high pressure (compressed air) to engine. This part gets energy from turbine rotating shaft.
- Centre housing**-** It is the core of Turbo Charger it support the shaft and Bearing Assembly and provide lubrication to shaft.

V RESEARCH OBJECTIVES AND PFMEA ANALYSIS

The initial research on manufacturing company shows those 10-12 % parts gets rejected in various stations. It also shows an increase of 16 % in rework of the parts from last few months. The Organization wants to minimize these rejection and rework of parts as it consumes both time and money. To minimize the rejection and improving quality it is necessary to implement PFMEA. The PFMEA tool is applied on the following manufacturing and assembly station of the company:

- Impeller wheel and Shaft Manufacturing Process
- Centre Housing Assembly
- Compressor housing assembly
- Turbine Housing Assembly

PFMEA procedure

First the manufacturing process of Turbo Charger is studied and the failure mode is estimated. After identifying the effect and cause of failure mode, assign ranking of severity occurrence and detection. The assessment of Occurrence Severity and Detection are on the basis of last month rejection and rework of parts. From the severity, occurrence and detection ranking, RPN value is calculated. The manufacturing process showing high Risk Priority will be considered as critical and prompt mitigating action is applied on that process.

Table 4: Implementation of PFMEA in Turbo Charger Manufacturing

Sr .No.	Process / Product Function	Potential Failure Mode	Potential Effect Of Failure	Sev	Potential Cause	Occ	Current Process Control	Current Process Control Detection	Det	RPN
1	Raw Material Received	Casting Defect in impellor wheel	Rejection of parts during operation	8	Wrong material supply	3	Raw material Inspection	Inspection By appropriate sampling method.	2	48
		Impeller Wheel Broken	Rejection of parts during operation	7	Wrong material supply/ Inappropriate material handling	3	Raw material Inspection	Inspection By appropriate sampling method.	2	42
		Housing Data Plate Damage	Difficult for operation/ Tracebility Issue	3	Improper material loading /Damaged during transit	4	Raw material Inspection	Inspection By appropriate sampling method.	3	36
		Wrong Raw Material	Increases the cycle time and testing	5	Material Supply grade not as per specification	4	Raw material Specification sheet	Inspection By appropriate sampling method.	6	120
2	Mass Centering Operation	wrong centering	Rejection of part	8	Fixture is not used according to wheel	3	Standard Operating procedure, First Piece inspection	Inspection Frequency 1 out of 10	5	120
3	Friction Welding	Overall distance of wheel & Shaft	Rejection of assembly	8	Shaft may be Rusted or Burr inside the wheel	3	Standard Operating procedure, First Piece inspection	Inspection Frequency 1 out of 5	6	144
4	Shaft End Centering	Drilling tool broken	Wheel and shaft assembly gets damaged	6	Wrong Command given to machine for the different shaft	2	----	Standard Operating Procedure	5	60
		Centering Location Wrong	Parts get rejected	7	Fixture is not used according to shaft dia	2	Standard Operating Procedure,	Inspection Frequency 1 out of 30	6	84
5	Shaft Turning	Diameter Not as per specification	cycle time increases/ Part goes for Rework/ Part get rejected	6	Wrong Command given to machine for the different shaft	5	Standard Operating procedure, First Piece inspection	Inspection Frequency 1 out of 10	5	150
		Tool Failure	poor surface finish/part get damaged	4	tool wear out	1	Tool Checking after 600 parts	----	3	12

6	Induction Hardening	Melting Of Shaft	Rejection of part	8	Wrong Command given to machine for the different shaft	1	Standard Operating procedure	Operator Training and Attention	1	8
		Over hardening	difficult for further operation/ parts goes for rework	7	Temperature is high	3	Standard process Parameter Sheet	Operator Training and Attention	4	84
7	Broaching Operation	Broach Distance Undersized	Part goes for rework	5	Wrong Command given to machine for the different shaft	3	Standard operating Procedure	Operator Training and Attention	7	105
		Wrong Broach location	Rejection of part	7	Shaft position is not appropriate	2	Standard process Parameter Sheet	First piece inspection of every lot	7	98
8	Groove Grinding	Over grinding	Rejection of part/assembl y	5	Unskilled operator	3	Standard process Parameter Sheet	Operator Training and Attention	6	90
9	Groove Turning	Groove Turning location	Rejection of part	7	Shaft Position is not appropriate	4	Standard Operating procedure	First piece inspection of every lot	7	196
		Over turning	Rejection of part	7	Wrong Command given to machine for the different shaft	4	----		6	168
10	Wheel Profile grinding	In appropriate Grinding	Part goes for Rework/part s get rejected/fitm ent problem	6	Unskilled operator	5	Standard Operating procedure, First Piece inspection	1. Operator Training, 2. Inspection Frequency 1 out of 5	7	210
11	Thread rolling	Poor Thread Finish	Difficult in further operation	7	Shaft position is not appropriate	4	Standard process Parameter Sheet	Inspection of every part	6	168
		Thread Position Dislocate	Part get rejected	8	Shaft position is not appropriate	3	Standard process Parameter Sheet		6	144
12	Wheel And Shaft Balancing Correction	Un Balanced assembly	cycle time increases/par t goes for rework	8	Unskilled operator	3	Standard process Parameter Sheet,, Inspection frequency 1 out of 10	Operator Training And Inspection Frequency 1 out of 5	8	192

13	Laser Mark Operation	Wrong Laser Mark Punch	difficult to identify part/Traceability issue	2	Unskilled operator	3	Standard process Parameter Sheet	Operator Training	6	36
14	Compressor Housing	Inlet and Assembly Face Finish	Leakage of compressed air pressure issue	6	Improper Material Removal	2	Standard process Parameter Sheet, Inspection Frequency 1 out of 20	Inspection Frequency 1 out of 10	3	36
		Bolting Thread Damaged	Difficulty in assembly	5	Improper Tapping/tool setting	4	---	Standard Process Parameter Sheet	4	80
		Dowel pin Throughout	Rejection of part	6	Improper Drill Depth specification	3	Standard process Parameter Sheet	Inprocess inspection	2	36
15	Turbine Housing	Inappropriate Exhaust Face finish	Leakage of smoke & fitment problem	6	Improper Material Removal	2	Standard process Parameter Sheet,Inspection Frequency 1 out of 20	Inspection Frequency 1 out of 10	3	36
16	Air Testing	Air Pressure and Leakage Test	Reduce efficiency of turbo charger at customer end	8	Improper Leakage Testing	3	Standard Operating procedure	Complete Inspection	1	24
		Leakage from Actuator Bolt Hole	Air pressure issue	7	Improper Material	3	Standard Operating procedure	Complete Inspection	1	21
17	Core Assembly and testing	Poor cir clip Groove	Difficulty in assembly	5	Defective material supply	4	----	Inspection By appropriate sampling method.	3	60
		Journal Bearing Tear Down	cycle time increases	5	Defective material supply	5	----		3	75
		Impeller Run Out	casing get damaged	7	Improper wheel Grinding	4	Standard process Parameter Sheet	In process Inspection	7	196
		Impeller diameter Over Size/ undersize	fitment issue/Efficiency reduced	7	Improper wheel Grinding	5	Standard process Parameter Sheet		3	105
		Thrust Bearing Tear down	cycle time increases	5	Defective material supply	5	----	Inspection By appropriate sampling method.	3	75

		Shaft Thread Damage	Difficulty in assembly/ Shaft get rejected	4	Improper storage/ Handling	4	----	In process Inspection/ Thread cover should be applied	2	32
		Heavy unbalance of shaft and wheel	core and housing get damaged	7	Improper balancing	3	End of Line Inspection	Inspection Of every part	4	84
18	Cleaning And Packing	Dust and Rust Inside the turbo charger	Customer may face Functional problem	4	Improper Cleaning	3	Standard Operating Procedure	Inspection before dispatching	3	36

VI RESULTS

After applying the tool of PFMEA in the manufacturing and assembly process of Turbo Charger various processes in manufacturing are identified which have high Risk Priority (RPN greater than 150) which should be minimized by appropriate mitigating action. Following are the processes which require prompt corrective action-

Table 5 : Table for Recommended action

S.No.	**Process Function**	**Failure Mode**	**RPN**	**Recommended Action**
1	Groove Turning	Groove Turning location	196	Holding fixture should be Re-design
2	Wheel Profile grinding	In appropriate Grinding	210	Go/No-Go fixture should be implemented
3	Thread rolling	Poor Thread Finish	168	Operator Training and standard operating procedure
4	Wheel And Shaft Balancing Correction	Un Balanced assembly	192	Auto correction followed by manual correction process should be applied
5	Core Assembly	Impeller Run out	196	Inspection Fixture should be implemented

VII CONCLUSION

PFMEA methodology provide us sharp eye on the process/function which required immediate mitigating step for improvement of certain processes. The above document analyzes all the defects making issue in the manufacturing process and will guide for future use and ensure continues improvement of process. Following standard operating procedure, first piece inspection will reduce chances of defects and improve efficiency of manufacturing process. Some manufacturing processes are interlinked and failure in one process will be devastating at the end of the process. By increasing the frequency of inspection in some critical process will minimize risk of rejection and rework. PFMEA also provide certain mitigating steps for raw material inspection and material handling which reduces the wastage of raw material and time.

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