Improving HN Fuse Link Process & Product Quality using Six Sigma Methodology

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Abstract--- This paper deals with manufacturing of five different types of fuses namely HN-000, HN-0, HN-1, HN-2, HN-3. Company had found that rejection of fuses of all types was more than 7%. This research paper is based on implementing Six Sigma methodologies at one of the suppliers of company to improve the process of manufacturing HN Fuse link. This paper also discusses the additional benefits achieved post implementation of Six sigma methodology like minimizing lead time, defects, rejections to name a few. Overall improvement in quality and raised the sigma level from 4.31 to 4.56.

Keywords--- Six Sigma, DMAIC Method, RPN, Pareto Charts, Poka Yoke

I. INTRODUCTION

1.1 Six Sigma

Six sigma is -“A comprehensive & flexible system for achieving, sustaining & maximizing business success is six sigma.”[5] Six sigma deals with strategies of continuous improvement & defect reduction to achieve a quality standard of not more than 3.4 defects per million opportunities (DPMO). In today's business environment, the six sigma standard is synonymous with excellence.

Six sigma is uniquely driven by a close understanding of customer needs, disciplined use of facts, data, and statistical analysis & diligent attention to managing, improving, & reinventing business processes [3] [4]. Dr. Genichi Taguchi, a quality management expert, defines quality of a product as “the loss incurred by the society when a substandard product is sent to the market.” This loss is due to the deviation in the functional characteristics of the product/ process from the target value. The deviation of the performance from the target is due to some controllable & non-controllable factors. Hence, to achieve good & consistent quality not only the target response but also the variation should be taken into consideration.

Six sigma is a holistic approach to business improvement that includes philosophy, performance measurement, improvement frameworks & a tool kit, all of which is intended to complement & enhance existing engineering, service and manufacturing processes & can serve as both, an enterprise governance model & a tactical improvement engine. It is a disciplined, data-driven approach & a methodology for

eliminating defects in any process & thus is a product of that process.

1.2 Evolution of Six Sigma

Six sigma was started at Motorola in 1987 by Mr. Bill Smith to improve the quality of their products. However, this concept gained popularity only after GE implemented it under the guidance of Mr. Jack Welch in 1995 [6]. Philosophy of Six sigma includes constant focus on customer, Data driven management, focus on business process, proactive management, think team, continuous improvement, Rigor based approach. Six sigma is excellent at what it does-driving bottom-line improvements in short period of time [2].

1.3 Six Sigma Methodologies

Six sigma can be implemented through two methodologies namely;

1. DMAIC (Define, Measure, Analysis, Improve, Control)
2. DMADV (Define, Measure, Analysis, Verify, Control)

Project deals with existing product so that DMAIC methodology is useful for this implementation.

Table 1: Phases in Six Sigma Methodology

Phase	Step	Tools
Define phase	Project charter	Problem statement, Goal statement, Current sigma, Target sigma, cost saving
	High level	SIPOC
	Specify responsibilities & authority for the project	Roles of the team members- Who will give inputs Who will give review Who will be accountable Who will sign off
Measure phase	Define defect, opportunities, unit	Based on CTQ's, process knowledge& benchmarking
	Develop data collection plan	Sampling plan
	Collect the data & tabulate	Dataset & check-sheet
	Calculate sigma baseline	DPMO, Sigma level calculation
Analysis phase	Determine root causes	Cause & Effect Diagram, Pareto
	Prepare Action Plan to explore various	Brainstorming & SWOT analysis
Improve phase	Assess Failure Modes of	FMEA

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	Reduce risks associated with potential	Mistake proofing
	Plan & Execute	Verification
	Fine-tune the potential	Brainstorming
	Check performance	DPMO, Sigma levels.
Control phase	Develop & Implement the	SOP's
	Developing & implementing the Control	Control charts

II. STUDY OF PROCESS

Table 2: Study of Suppliers & Process

Supplier	Input	Process	Output	Customer
1.Siddhi Industries	Man-Workers	HN Fuse Assembly	HN Fuse	External Customer
2.Amod Industries	Material- Fuse Body, End Plate,		-HN 000	
3.Jyoti Ceramic	Inner plate, Fuse Element, Gasket, Indicator Wire, Sand		-HN 1	
4.Shriniws Metals	Machine- Spot welding, Solder Gun, mV Tester		-HN 2 -HN 3	

III. NEED FOR THE STUDY

In today's business scenario improve process, use of automation, improve quality, reduce lead time are main keys to grow business. This helps to increase productivity & ultimately profit will increase. Fuse production of company is 40,000 per month. So this shows there market importance & customers demand for fuse. For the month of March & April, it was found that rejection of fuse was more than 6% at assembly line which affect their production schedule & profit. This rejection was affecting the company's marketing strategy & it was difficult to fulfill the requirement of customers with desired quality & on time. So, company has started this project to reduce defects, improve process & reduce lead time. This project will also help to save the cost.

IV. PROBLEM STATEMENT

1. Rejection of fuse was up to 7% during assembly.
2. Quality was affected for which company is known to whole market.
3. Productivity was reduced which affects the profit of company.

V. OBJECTIVES OF STUDY

The objectives behind carrying out the project are as follows,

1. To improve Rolled Throughput Yield (RTY) of HN fuses link.
2. To improve sigma level of the process.
3. To reduce defects occurring during process

4. To achieve Cost saving by reducing rejections
5. To improve Quality of HN fuse

Figure 1: Assembly Procedure Chart (Suggested)

VI. RESEARCH METHODOLOGY

This paper is based on primary data which is collected during actual working on the job & observations made. It includes collecting daily rejections, dimension measurements before & after improvements, take down voltage readings for different fuses.

The secondary data is only used for understanding six sigma methodologies which consists of magazines, research papers, case studies. SOP's, machine & fixture manual, rejection sheet for previous months were referred & studied during project as secondary data.

6.1 Sampling Methodology

1. Random Sampling:- Sample size = 10 products

Population = 100 Purpose - Inspection & check mV readings

2. Systematic Sampling:- Sample size = 1 i.e. every 30th unit of welding machine & Population = 75 pieces per machine per hour

Purpose -

3. Check strength of element after applying 5 kg weight.
4. Check continuity & repeatability of welding machine.

6.2 Data Collection

Output data is divided into Discrete Data & Continuous Data. Discrete data is countable. Eg. No of defects, no of errors; whereas continuous data is measurable. Eg. Voltage, Temperature etc

Rejection data is collected & tabulated in table no. 3

Table 3: Rejection Data Collection from May to July

Sr. No	Process	Type of Defect	May	June	July
1	Fuse body visual defects	Fuse body chip off	156	171	52
2		Poor quality printing	0	10	0
3		Printing damaged	0	15	0
4	Plug piercing	Damaged plug	57	71	0
5		Plug not flushed end while piercing	0	0	0
6		Damaged end plate	43	58	0
7	Indicator clip assembly	Damaged gasket	0	0	0
8		Indicator red paint missing	0	0	0
9		Damaged indicator	0	0	0
10		Damaged indicator clip	0	0	0
11	Solder deposition	Damaged element	0	73	0
12		Element poor Ag plating	0	28	0
13		Solder material on neck	491	258	132
14		Inadequate soldering	477	234	97
15	Spot welding	Inner plate poor Ag plating	0	0	0
16		Inner plate damaged	0	12	0
17		Missed spot	0	0	0
18	Fuse link assembly	Damaged end plate	44	59	0
19		Indicator wire broken	295	129	45
20		Screw thread in fuse body slipped off	0	0	0
21	Sand filling	Printing rubbed	0	0	0
22		Plug damaged	65	71	0
23	Weight measurement	Under weight	0	0	0

24	Visual inspection	Scratch marks on fuse body	0	0	0
25		Plating & printing rejection	0	0	0
26		Other rejections	411	150	174
27	mV drop testing	Not within band	613	287	299
		Total	2652	1626	799

Major reductions in rejections are highlighted in the above table. Using this rejection data, RTY & Sigma level is calculated.

Table 4: RTY & Sigma Level Calculations from April to July

	APRIL	MAY	JUNE	JULY
Total Rejection	2944	2652	1626	799
Quantity supplied	39172	43875	31481	25775
Total Quantity Produced	42116	46527	33107	26574
Percentage of Rejection	7	5.7	4.91	3.01
RTY	93	94.3	95.09	96.99
Sigma Level	4.3	4.36	4.41	4.56

Rejection details for each type of HN fuse (HN000 to HN3) are collected to study the improvements in reducing rejections & improving sigma level.

Table 5: Rejection Details of Each Fuse Type

Fuse Type	May		
	TP	TR	%R
HN 000	14915	689	4.62
HN 0	7802	378	4.84
HN 1	11218	631	5.62
HN 2	8974	594	6.62
HN 3	3618	360	9.95
Total	46527	2652	5.70

Fuse Type	June		
	TP	TR	%R
HN 000	7094	257	3.62
HN 0	7306	306	4.18
HN 1	11007	540	4.90
HN 2	5151	283	5.49
HN 3	2549	240	9.42
Total	33107	1626	4.91

Fuse Type	July		
	TP	TR	%R
HN 000	4544	137	3.01
HN 0	2472	86	3.48
HN 1	11753	382	3.25
HN 2	5504	137	2.49
HN 3	2301	57	2.48
Total	26574	799	3.01

*where, TP = Total Production, TR = Total Rejections & % R = Percentage Rejections

6.3 Data Analysis & Interpretation

Data analysis can be done with the help of following three tools namely;

1. Cause & Effect Diagram

2. Failure Mode & Effect Analysis (FMEA)
3. Pareto Analysis

6.3.1 FMEA

Six sigma works on basis of calculated risk i.e. Assessment of risk & Reduction of risk.

This paper is related to process FMEA used to uncover problems related to an existing process.

FMEA quantifies risk in terms of three categories namely Severity, Occurrence & Detection [1]. Each category is rated on a scale from 1 to 10, with lower rating representing a lower risk. After the severity, occurrence & detection ratings are developed, the scores are multiplied together to provide a Risk Priority Number [7]. RPN represents the risk associated with each failure mode [8]. Ref: Table: 6 FMEA Chart

FMEA chart analysis:

1. Major risk is associated with 4 types of defects namely solder material on neck, inadequate soldering, broken indicator wire & Not within band defect.
2. Not within band defect is having highest RPN with 126 value
3. Recommended actions are decided & implemented to reduce RPN value.
4. Responsibilities are allocated to respective person to initiate these activities.

6.3.2 Pareto Analysis

The basic principle of PARETO is “Around 80% of overall effect is contributed by 20% of causes & vice versa.” This analysis helps to find out few important factors & trivial many.

Figure 2: PARETO Diagram for May

Figure 3: PARETO Diagram for June

Figure 4: PARETO Diagram for July

6.3.3 Analysis from Pareto Diagrams

Table 7: 80-20 % analysis of Pareto diagrams

Factors	Month			Result
	May	June	July	
Few Important Factors	Not within band, Solder material on neck, Inadequate soldering, Other rejections, Indicator wire broken	Not within band, Solder material on neck, inadequate soldering, Body cheep off, Other rejections	Not within band, Other rejection s, Solder material on neck	Important factors are reduced
Trivial Many Factors	Body cheep off, Damaged plug, others	Damaging plug, Indicator wire broke, Damaged end plate, others	Inadequa te soldering , Body cheep off, Indicator wire broken, Others	Trivial factors are remained same

For statistical analysis from Pareto diagram please refer to Table 8 Annexure 2.

VII. IMPROVEMENTS

1. Making Full Proof Fixtures (Poka Yoke)

Figure 5: Soldering Fixture

Problem identification:

1. Solder material gets spread on the element neck even after fixing it in the fixture.
2. Element was getting disturbed during soldering.
3. Length of resting part is not enough to hold element.
4. Distance between two fixing part is more than required.

Technical improvements in the fixture are:

- a. Length of resting part is equal to length of element i.e. 5 cm, leading to eliminate the chances of element disturbance during soldering. This is also called as RCO (Reduce Chances of Occurrence).
- b. Distance between two fixing parts is reduced from 8 mm to 7mm by increasing the width of fixing part from 4mm to 5mm which helps to reduce the chances of spreading soldering material on element neck.

2. Making Changes in Assembly Fixtures

Figure 6: Before Improvements

Figure 7: After Improvements

Figure 8: End Plate

Problem Identification:

1. Less tension in the indicator wire causes breakage of wire during screw fitting.
2. Front end was not completely rested on the assembly fixture leading to create less tension in the wire.

A slot is created in assembly fixture for front end of end plate so as to create tension in indicator wire during assembly.

3. *Kaizen Activity (2S- Seiton)*

“Place for everything & everything at its place”

Figure 9: Improper Storage Leads to Damage of Element

Figure 10: Proper Storage of Elements in Bins

4. *Selection of stopper combination:*

Stoppers are used at welding machines to locate the elements within inner plates. Stoppers are selected randomly by the workers leading to dislocation of the elements. Correct stopper combinations are chosen by trial n error method such that it helps to weld elements within two inner plates.

Figure 11: Stopper Combinations are shown Visually for 2 Welding Machines

Figure 12: Stopper Combinations are shown visually for 2 Welding Machines
Effect of selecting stopper combination;

Figure 13: Dislocation of Elements

Figure 14: Right allocation of Elements

5. *Purchase of New Temperature Controller*

Temperature controllers are used along with soldering fixtures so as to melt soldering material to spread properly on the plate of element.

VIII. RESULTS

1. Improved RTY from 93% to 97%

2. Improved Sigma Level from 4.31 to 4.56

3. Rejections are Reduced from 7% to 3.01%

4. Productivity is Improved as DPMO Reduced from 2111 to 1113

Figure 15: Screen Shot of Sigma Calculator

5. Approx. Cost Saving of 1 Lac Per Annum

It is estimated that approximately the improvement in the process will save Rs. 1, 00,000/- per annum. The saving will increase with more production.

IX. SUGGESTIONS

1. Continuous use of soldering fixture is must to reduce soldering related defects.
2. Disassembling of rejected fuses should be done within two days after rejection of that particular defect. It leads to reduce inventory & storage problem.
3. Maintenance should be provided to welding machine & printing machine which leads to occur improper welding & printing defect respectively.
4. Continuous use of bins for the storage of material leads to reduce breakage of element.
5. Morale of the workers must be improved to realize them that what the importance of quality is.
6. SOP's (Standard Operating Procedure) for assembly should be followed by the workers.

X. CONCLUSIONS

1. Linking Six sigma program to employees will help in getting better co-operation, improved work culture & morale.
2. Linking Six sigma to suppliers will help in improving collaboration, which shall result in the effective implementation of six sigma.
3. Six sigma methods help to improve process, quality, and productivity through different phases. It also helps to save the cost leads to improve profit.
4. Workers, operator & management involvement should be there to improve quality, productivity. Morale plays vital role in improving quality & productivity.
5. The deviation of the performance from the target is due to some controllable & non-controllable factors. Hence, to achieve good & consistent quality not only the target response but also the variation should be taken into consideration.

XI. ABBREVIATIONS

DMADV – Define Measure Analysis Design Verify

DMAIC – Define Measure Analysis Improve Control

DPMO – Defects per Million Opportunities

FMEA- Failure Mode Effect Analysis

RPN- Risk Priority Number

RTY- Rolled Throughput Yield

SIPOC – Suppliers Inputs Process Output Customers

SOP – Standard Operating Procedure

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Annexure – I Table no.: 6 FMEA Chart

Process function require ment	Potential failure mode	Potential effect of failure	Sever	Potential causes of failure	Occur	Detect	RPN	Recommended Action	Action Result
Functional Parameter	Solder material on neck	Rejection of element	7	No use of full proof fixture	5	3	105	Use of fixture & use of 2 solder bit per day	Defect is reduced
	Inadequate soldering	Rejection of element	7	1.Quantity of solder material	5	3	105	Use of soldering fixture	Defect is reduced
	Broken Indicator Wire	Rejection of fuse	6	1.Wire Strength 2.Operator skill	4	2	48	Changes in assembly fixture	Defect is reduced
	Not Within Band	Rejection of fuse	7	1.Damaged element 2.Improper spot welding	6	3	126	1.Use of bins to keep the material 2.Stopper combination for spot welding	Defect is reduced
Aesthetic Parameter	Fuse body chip off	Rejection of fuse	4	1.Transportation 2.Screw fitting process	3	2	24	1.Initial inspection 2.use of bins to avoid breakage	Chip off defect identified at initial stage
	Printing Defect	Rework problem	4	Poor maintenance of printing machine	4	2	32	1.Initial inspection 2.Use of bins to keep fuse body	Printing defect is identified at initial stages, Rework is reduced
	Damaged plug	Rework problem	2	No piercing, Size of plug	2	2	8	Plug should be checked	Defect is reduced
	Damaged end plate	Rework problem	3	Fixture at screw fitting, Dimensions of end plate	2	2	12	Check end plate during screw fitting,	Rework is reduced

Annexure 2: Table 8: Statistical Analysis from Pareto Diagrams

Type of Defect	% Defect (May)	Status	% Defect (June)	Status	% Defect (July)	Status
Not within band	23.11	Major	17.65	Reduced	37.55	Major
Solder on neck	18.51	Major	15.87	Reduced	16.52	Minor
Inadequate soldering	18	Major	14.39	Reduced	12.14	Reduced
Other rejections	15.5	Major	9.23	Reduced	21.78	Major
Indicator wire broken	11.13	Major	8.73	Reduced	5.63	Minor
Fuse Body chip off	5.88	Minor	10.52	Major	6.51	Minor