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SIX SIGMA APPROACHES FOR PROCESS DEVELOPMENT IN A MEDIUM SCALE INDUSTRY THROUGH VALUE ENGINEERING

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Abstract

In current scenario, production sector is the back bone of economy of any country and it is mandatory for the manufacturing organizations to control the cost as they do not have the control over the price. To minimize the cost, it is required to reduce the defect rate. Six sigma quality management systems is a customer-focused and data-driven quality strategy that provides a clear roadmap for organizations to deliver nearly perfect products and services. On the other hand, value engineering has for its purpose the efficient identification of unnecessary cost. It focuses the objective of equivalent performance at lower cost. This paper presents the application of six sigma approach combined with value engineering methodology to reduce process variability in a medium scale manufacturing industry with cost-effective manner.

Keywords: Six Sigma, Value Engineering, Production, Horn Assembly Pro-E, FAST Diagram

1. Introduction

Quality is typically defined in terms of fitness for use or conformance with specifications. However, the ultimate measure of quality is whether the product or service lives up to customer expectations. Quality is thus the foundation on which the customer satisfaction is built. Every type of industrial production is based on production processes. To survive in a demanding market, it is necessary to achieve the high level quality of the products. Product quality results from the quality of manufacturing process. The main cause of quality problems is basically variation. To improve quality, variation must be measured, reduced, and prevented. Statistically, six sigma refers to a process in which the range between the mean of a process quality measurement and the nearest specification limit is at least six times the standard deviation of the process. The statistical objectives of the six sigma are to center the process on the target and reduce process variations. A six sigma process will approach zero defects with only 3.4 Defects per Million Opportunities (DPMO) to occur.

In the other hand, Value Engineering is a customer focused technique. The functional analysis technique is so powerful that is questions everything we do in order to meet the expectations of the customers at the lowest cost. The reason for the preference of this tool by the management is that, this technique tries to identify and eliminate the unnecessary costs. But while reducing or eliminating the cost, it takes into account that there is no deterioration of quality parameters. It is not a cheapening technique. This paper focus on minimizing the defects in a horn manufacturing industry using six sigma methodology and integrating value engineering technique to achieve a cost-effective solution.

The tested horn assemblies coming out of the horn tuning stage is found to have defects at random times causing horn failures there by impacts a huge revenue loss to the company.

2. Literature Review

The possibilities of using seven basic quality tools such as flow chart, Pareto diagram, check sheet, control chart, histogram, scatter plot and C&E diagram in some phases of PDCA cycle, Six sigma approach, and design for six sigma methodologies were reviewed [1-4]. Six sigma has been widely used project-driven management approach to produce high quality products with the lowest possible cost were identified. The author mainly focuses on the DMAIC methodology of Six Sigma which has been successfully adopted by various SME. The author also discusses the various tools and techniques used in each phase of DMAIC approach, its impact on bottom line through benefits gained and critical success factors to show the roadmap for other SMEs to initiate Six Sigma in their industries [5-7]. The implementation of Six sigma methodology in manufacturing industries were discussed. The strengths and challenges of lean six sigma implementation in manufacturing industries and proposed the important tools that can be used in each phase of lean six sigma methodology in implementing it in the manufacturing industries were explored. Various process methodologies that are used to reduce the defects in the manufacturing process in order to improve the productivity of the manufacturing systems were investigated [8-11].

Lean six sigma approaches in a food processing industry and reduced the defects in food packages were implemented. Lean six sigma can be applied easily in any kind of business areas like service, production, marketing, sales and procurements etc. The major outcomes of this approach are to reduce cost, reduce time, maximize profits, quality of the products and increase customer satisfaction [12-14]. Wenny Chandra, discussed key success factors for six sigma implementation .There are several factors that make six sigma an increasingly popular quality imitative, even more so than the past TQM, ISO, Zero defect and so on. These factors are also determinants as to whether a six sigma program will lead to significant improvements. The importance of using six sigma methodology and discussed about the development of the six sigma methodology in manufacturing industry and others were studied [15, 16]. Six sigma is a long term commitment and it changes the way a company thinks by teaching fact-based decision making to all levels.

3. Methodology

The methodology flow chart is shown in Figure 1.

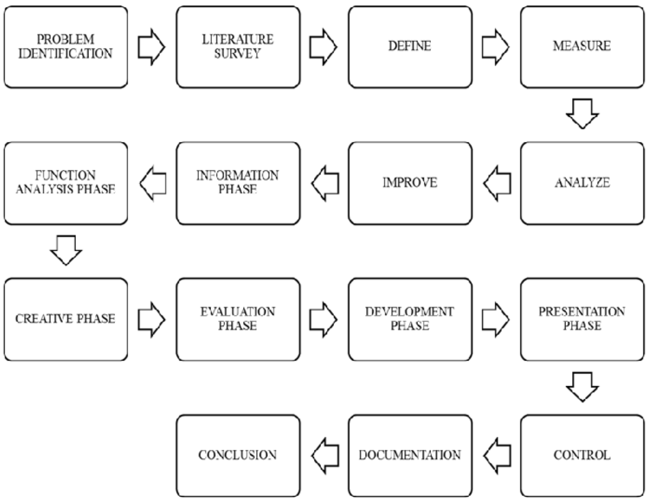

Figure 1. Backward Event Privacy Level Vs M and S

4. Define Phase

The DMAIC methodology starts with define phase in which two important tools are used- project charter and SIPOC diagram.

4.1 Project Charter

The key elements of a Six Sigma project charter are the business case, problem statement, goal statement, roles and responsibilities, scope of the project, preliminary project plan, and communication plan which is shown in Table 1.

Table 1 Project Charter

Six Sigma Project Charter	
Project Information:	Resource Information:
Project Name: Reducing Inline rejections	Master Black belt: NA
Project Start date : 01-09-2018	Black belt: NA
Project End date : 30-04-2019	Green belt: NA
Team Members: A. Babu, K. Saravanan	
Business case: The average number of Inline rejections from September 2017 to August 2018 is 5478 PPM. The number of rejected assemblies was 3982. Because of this, the company loses its sale around Rs.11, 94,600. **Problem statement:** In this project, we have analysed the manufacturing of electric horn through assembly process. Data has been collected for a period of twelve months from September 2017 to August 2018, where the production and rejection statistics of the horn production line are noted. The electric horn assembly line experiences a large rejection rate. It is difficult to control the inline rejections in the assembly line. The rejection rate in the assembly line is 8126.256 PPM There is no apparent reason for the inline rejections. Hence, the horn production line is considered for this work. **Goal statement:** The goal of the project is to reduce the defective horn assemblies from 8126.256 PPM to 5000 PPM within April 2019. **Project scope:** The scope of the project includes all the processes in the assembly line and the processes required to manufacture child part for the horn assemblies **Preliminary project plan:** *Refer Methodology* **Communication plan:** Weekly meeting	

4.2 SIPOC Diagram

A useful tool in developing the process map is a S-I-P-O-C diagram detailing the suppliers, inputs, process steps, outputs, and customers promotes a common understanding of the project scope, the inputs and outputs of the process, and the customers who receive the outputs as shown in Figure 2.

5. Measure Phase

Measure Phase involves identifying appropriate measurement data, followed by collecting the data and using it to measure baseline performance.

5.1 Data Collection

The data about the list of defects have been collected for the months from September 2016 to August 2017 and Pareto diagram was drawn to identify the major defects in the assembly line. Pareto Analysis was done for the collected data as shown in Figure 3.

The Major defects affecting the assembly line were found to be

- Pointer Holder Assembly Bend – 33.90%
- Tuning Screw Height Variation – 30.90%

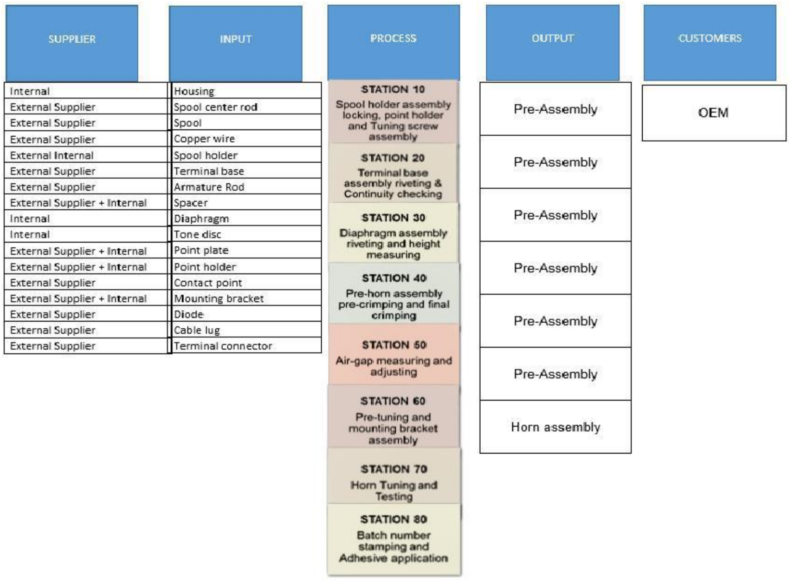

Figure 2. SIPOC Diagram

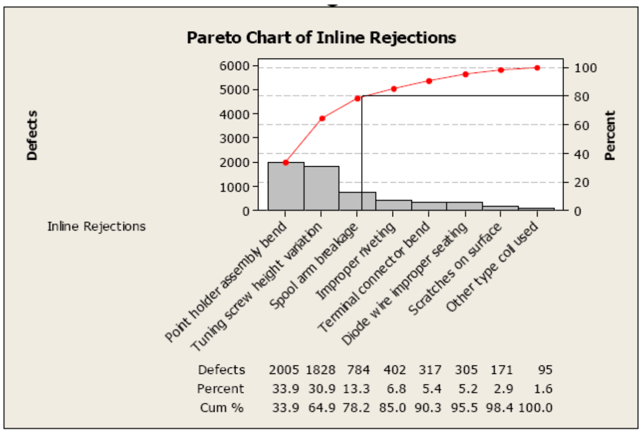

Figure 3. Pareto Analysis

5.2 Six Sigma Measurement

Defects per opportunity	= 5907 / 726903 = 0.008126256
Defects per million opportunity	= DPO * 1000000
	= 0.008126256*1000000 = 8126.256 PPM

From sigma conversion table, the sigma level is found to be 3.9

5.3 Measurement System Analysis

Measurement system analysis is done for identifying and separating out the variation due to the measurement system with 3 operators, 10 components and 3 trials.

Gage R&R	= 23.22% which is less than 30%
Number of distinct categories	= 5

The Measurement system can be accepted.

5.4 Root Cause Analysis

Cause and Effect diagram also known as fishbone diagram along with five why analysis drawn as shown in Figures 4, 5, 6 and 7 to identify the root cause of the defects-point holder assembly bend and tuning screw height variation.

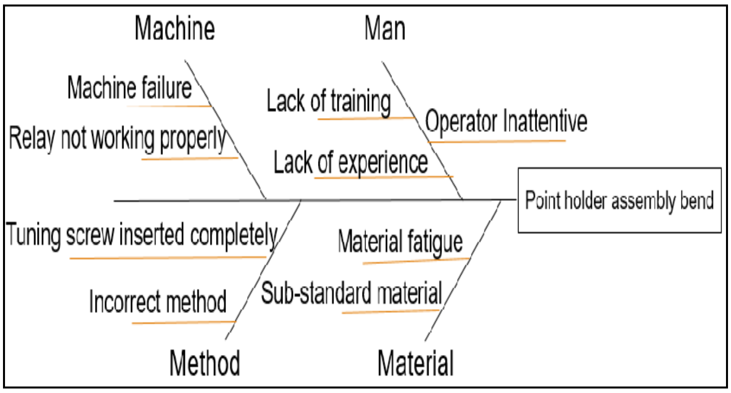

Figure 4. Fishbone Diagram - Point Holder Assembly Bend

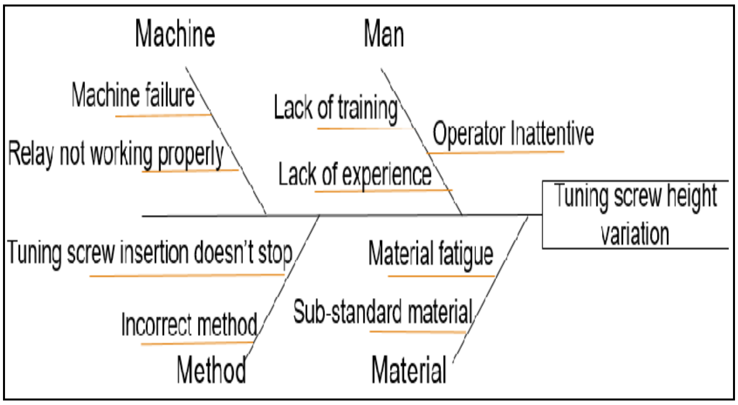

Figure 5. Fishbone Diagram - Tuning Screw Height Variation

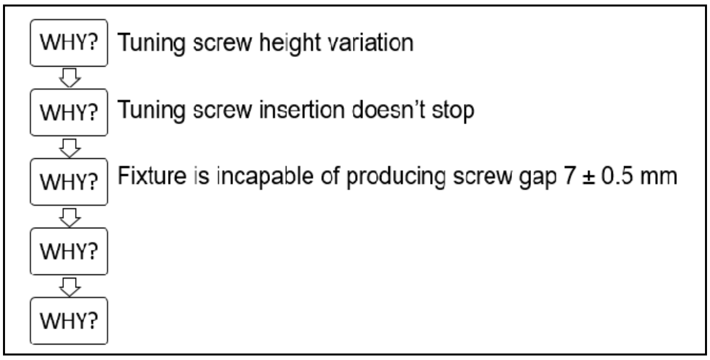

Figure 6. 5 WHY Analysis – Tuning Screw Height Variation

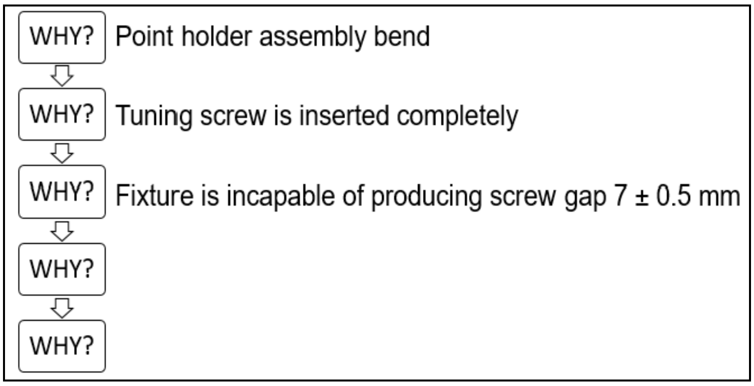

Figure 7. 5 WHY Analysis – Point Holder Assembly Bend

5.5 Process Capability Analysis

The ability of a process to meet customer specifications is called process capability and is measured through the process capability index, Cp. Cp is a measure of the allowed variation or tolerance spread compared to actual data spread. The actual process output is compared to the customer specifications and judgments are made as to whether the process is capable of meeting those specifications. The process capability Cp is determined to be 1.96 and Cpk is determined to be 0.95. The variation is too large and the process mean is not on target.

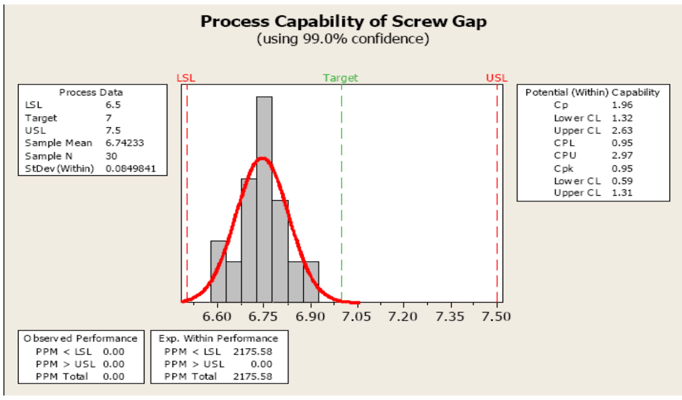

Figure 8. Process Capability Analysis

6. Analysis Phase

The analyze phase involves statistical analysis of collected data.

6.1 Hypothesis testing

Hypothesis testing is stated in the form of a null hypothesis and an alternative hypothesis. Hypothesis testing is made to test whether the defect is caused by the identified root cause. Hypothesis testing is used to help make a judgment about a claim. Screw gap must be 7 ± 0.5mm.

H0: Mean μ	= 7 mm
H1: Mean μ	≠ 7mm
Confidence interval α	= 0.01
Degrees of freedom	= n-1 = 30-1 = 29
T	= $(X - \mu H_0)$
	= (6.742333 – 7) / 0.071424 = -18.13
T table value	= -2.462
Null Hypothesis H_0: μ	=7 is rejected

This proves the tuning screw insertion process does not meet the standard screw gap value of 7 mm.

7. Improve Phase

The Six sigma team should start the improve phase with a clear understanding of the root causes of the problems. The Improve Phase focuses on improving the processes. There should be clear evidence that solutions generated and integrated into redesigned processes are capable of closing the gaps between the current process and the customer's CTQ requirements.

7.1 Brainstorming

Brainstorming is a technique designed to produce a lot of ideas quickly. The generated ideas were

- Insert Tuning screw before Spool Holder riveting
- Insert Tuning screw before Terminal Base riveting
- Use Pneumatic screw driver to insert Tuning screw
- Use screw driver and insert manually
- Use removable cork to maintain gap of 7mm
- Use thermocol lining

- Hammer it
- Use eye screw
- Use sensors to control insertion
- Use knife and insert manually
- Use Magnetic strip screw drivers
- Use electric motor to insert Tuning screw
- Remove screw mechanism and replace with spring mechanism
- Replace the metal detector with Physical contact sensor
- Replace the metal detector with Physical contact breaker
- Detect the insertion of the screw directly using sensor
- Modify the existing fixture
- Design an alternate fixture

The feasible ideas were filtered using Feasibility ranking matrix and the best ideas were combined to form alternatives

7.2 Alternatives Generation

Table 2 Alternatives

Alternatives	Ideas
Alternative 1	Use screw driver and insert manually Use removable cork to maintain gap of 7mm
Alternative 2	Use eye screw and drive manually Use removable cork to maintain gap of 7mm
Alternative 3	Use electric motor to insert Tuning screw Use removable cork to maintain gap of 7mm
Alternative 4	Design an alternate fixture Use electric motor to insert Tuning screw Replace the metal detector with Physical contact breaker
Alternative 5	Design an alternate fixture Use electric motor to insert Tuning screw Replace the metal detector with Physical contact sensor

7.3 Criteria Selection

To evaluate the alternatives, four parameters are selected and their importance was determined using Paired comparison method as shown in Table 3.

- A - Accuracy
- B - Productivity
- C - Maintenance
- D – Reliability

Table 3 Paired Comparison Matrix

	B	C	D	Total	Normalized	%wt
A	2A/B	A	A	4	5	41.67
	B	B	B	3	4	33.3
		C	D	0	1	8.33
			D	1	2	16.67

7.4 Decision Matrix

The decision matrix is used to select best alternative as shown in Table 4. From the decision matrix, Alternative 4 is selected as the best feasible solution for implementation.

Table 4 Decision Matrix

	Accuracy		Productivity		Maintenance		Reliability		Total	Rank
Weight	41.67		33.33		8.33		16.67			
Existing Fixture	3	125	5	166.67	3	25	3	50	366.67	4
Alternative 1	4	166.67	3	100	4	33.33	4	66.67	366.67	4
Alternative 2	5	208.35	2	66.66	4	33.33	4	66.67	375.01	3
Alternative 3	4	166.67	2	66.66	4	33.33	4	66.67	333.33	5
Alternative 4	5	208.35	5	166.65	4	33.33	4	66.67	**475**	**1**
Alternative 5	5	208.35	5	166.65	3	25	3	50	450	2

7.5 Conceptual Diagram

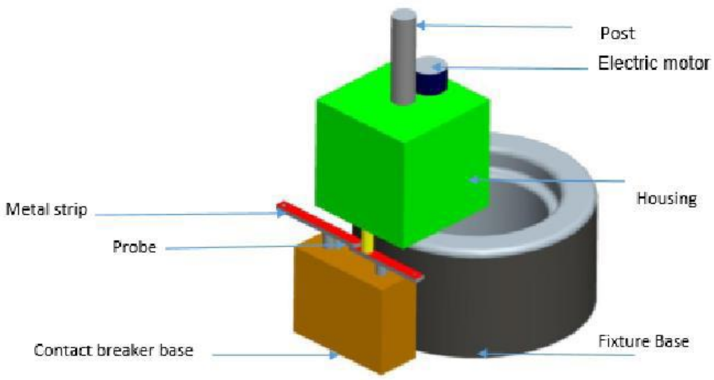

Figure 9. Conceptual Design

The Conceptual design is shown in Figure 9. The Horn assembly is placed in the fixture base. The post is attached with the fixture base. The electric motor is placed in the housing which slides vertically along the post. Two metal strips are placed one above the other in the contact breaker base as shown in above figure. The electric power supply is given to the electric motor through the electric strips. When the power is supplied, the screw gets inserted and housing slides down along the post. The probe is fixed at particular height such that when particular screw gap is reached, the probe bends one of the metal strips thus the circuit becomes open and the screw insertion stops. Now, the voltage supply is switched off and the horn assembly can be removed from the Fixture. The developed design is shown in Figure10.

7.6 Developed Design

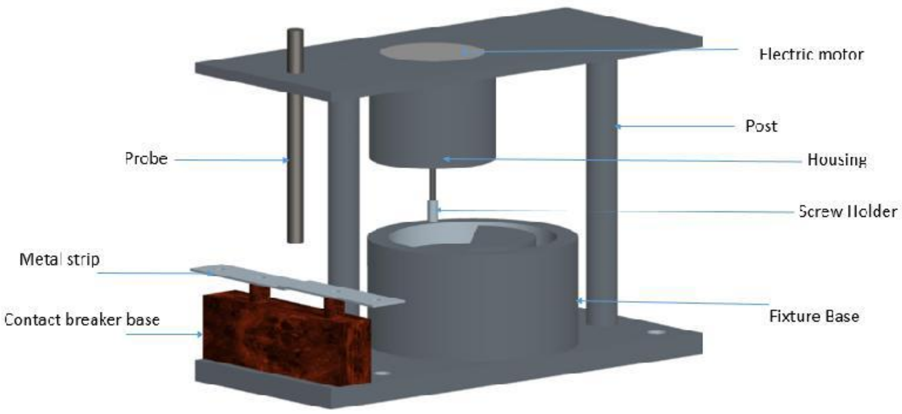

Figure10. Developed Design

8. Information Phase

The information about the value engineering project is the backbone of the whole process. The general information that is obvious are part description, part number, manufactured or bought out, standard or nonstandard, materials specification, process of manufacture, etc. The estimated cost of the components consists of

- Material Cost
- Labor Cost
- Overheads – Assumed to be 20 % of Material and labor cost

The labor cost is derived based on the machine hour rate and the time required for machining each component is estimated from Pro-E manufacturing simulation as shown in Figure11.

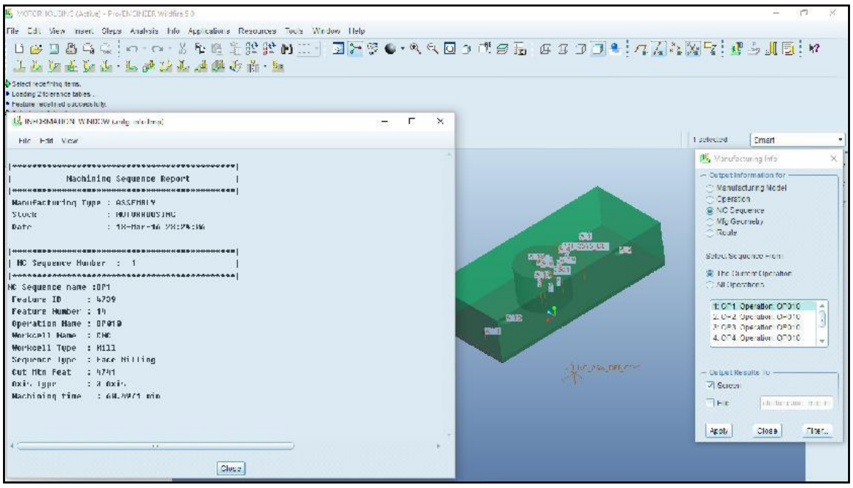

Figure 11. Pro-E Manufacturing Simulation

The Components of the fixture and its cost details are given Table 5.

Table 5 Estimated Cost

Components	Estimated Cost (INR)
Fixture Base	3305.88
Motor Housing	2129.76
Contact Breaker Base	252.30
Post	194.322
Probe	113.384
Metal strips	1242
Electric motor	200

Screw Holder	43.29
M3 screw	3
M8 Hexagonal nut	3
M5 screws	8
Total Cost	7494.936

9. Function Analysis Phase

During this phase, the function of each component is defined in two words – an active verb and measurable noun. The Function Analysis System Technique (FAST) diagram is drawn using the derived functions.

9.1 Function Analysis System Technique

The function analysis system technique diagram is one of the versatile and unique communication tools. It is used to identify the missing function. It helps redefine the functions that would be more meaningful for the project as well as indicates the functions that are most important to the VE project. The unnecessary functions are also visible. The FAST diagram for the designed fixture is shown in Figure12.

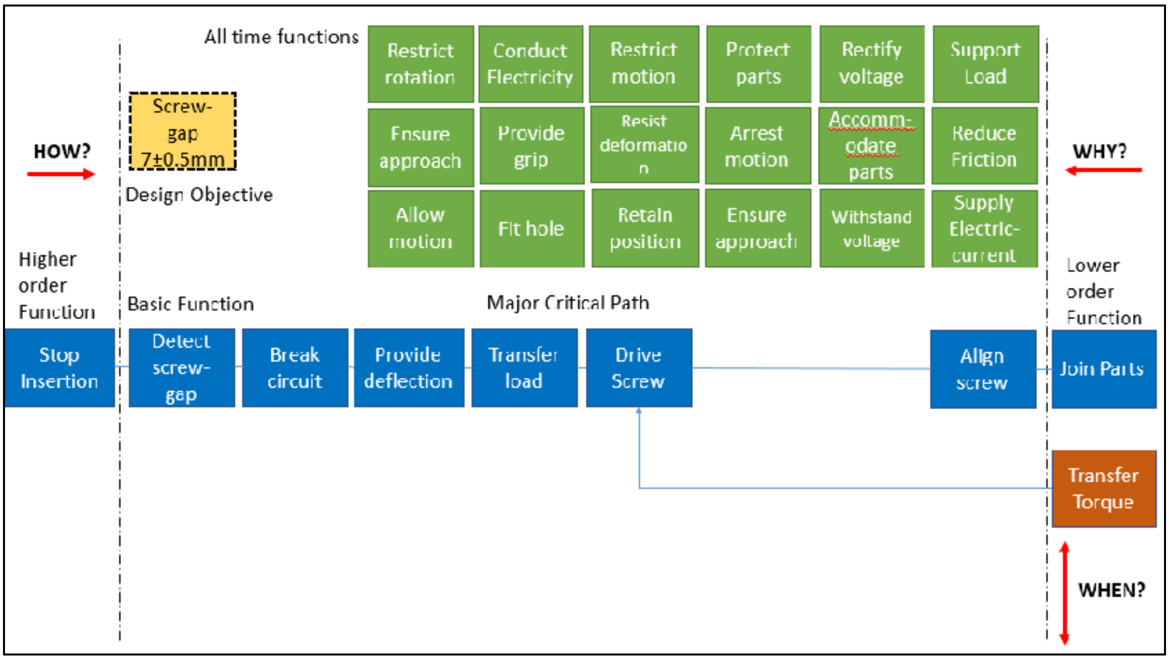

Figure12. FAST Diagram

9.2 Pareto Analysis

Pareto Analysis is done for the cost of the components and it is found that 27.27 % components constitutes to 89.20 % of the total cost. So, value engineering is done to reduce the unnecessary cost of fixture base, motor housing, and metal strips.

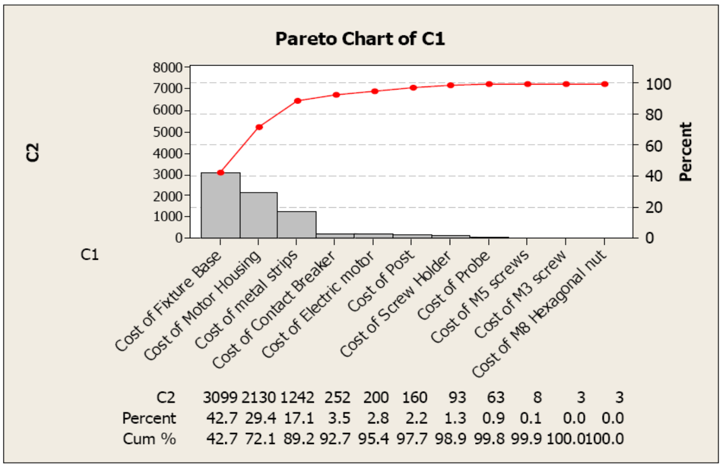

Figure13. Pareto Analysis for Cost Elements

9.3 Function Cost worth Analysis Matrix

Function Cost worth Analysis (FCWA) is used to determine the value gap of each function. In this project, allocation of costs was done based on First School of thought i.e. all the costs were allocated to the basic function of the component as shown in Table 6.

Table 6 FCWA Matrix

Component	Function		Cost	Alternate	Worth (INR)	Value Gap	Rank
	Active verb	Measurable noun					
Metal strips	Provide	Deflection	1242	Use of point plate	30	1212	3
Fixture Base	Accommodate	Parts	3098.52	Use wood fixture	150	2948.52	1
Motor Housing	Transfer	load	2129.76	Weighing stone	50	2079.76	2

10. Creative Phase

The creative Phase divides the existing concept from the proposed concepts. The creative phase consists of divergent and convergent thinking. While creative approaches are required during the divergent stage, analytical approaches are necessary at the convergent stage. The ideas were generated using brainstorming technique for the selected functions.

10.1 Provide Deflection

- Change material to plastic
- Use steel material
- Reduce the dimensions
- Eliminate metal strips and replace with contact sensors
- Eliminate contact breaker and fix metal strips with the post
- Replace with Point plate of the horn
- Change dimension of contact breaker base

10.2 Transfer Load

- Manufacture Motor cover separately and join with the top plate
- Don’t machine the unwanted volume
- Weld motor cover with the housing
- Use fasteners for joining motor cover with the plate

- Use thread cuts to join parts
- Change material to wood
- Change material to plastic
- Replace another cheapest metal
- Eliminate drilling holes
- Use welds
- Use Transition fits

10.3 Accommodate Parts

- Manufacture Fixture Base separately and join with the plate
- Don't machine the unwanted volume
- Weld work piece locator with the housing
- Use fasteners for joining work piece locator with the plate
- Use thread cuts to join parts
- Change material to wood
- Change material to plastic
- Replace another cheapest metal
- Eliminate locator profile
- Use two point locator
- Eliminate drilling holes
- Use welds
- Use Transition fits
- Eliminate contour milling and use location profile
- Reduce the work piece locator height

11. Evaluation Phase

This phase of the job plan deals with the process which helps to find out the best alternative. The feasible ideas were filtered out using Feasibility Ranking matrix. The feasible ideas are combined to form alternatives. The alternatives for selected functions were evaluated and the criteria for evaluation and their weightages were determined by paired comparison method.

Table 7 Alternatives – Provide Deflection

Function	Provide Deflection
Alternate 1	Use steel material
Alternate 2	Eliminate contact breaker and fix metal strips with the post
Alternate 3	Replace with Point plate of the horn Change dimension of contact breaker base

Table 8 Alternatives – Transfer Load

Function	Transfer Load
Alternative 1	Manufacture Motor cover separately and join with the top plate
	Use welding to join components
Alternative 2	Don't machine the unwanted volume
Alternative 3	Eliminate drilling holes

Table 9 Alternatives - Accommodate Parts

Function	Accommodate Parts
Alternative 1	Manufacture Fixture base separately and join with the plate
Alternative 2	Don't machine the unwanted volume Reduce the workpiece locator height
Alternative 3	Eliminate locator profile Use two point locator

Table 10 Decision Matrix – Provide Deflection

Function		Provide Deflection									
		Accuracy		Performance		Maintenance		Reliability		Total	Rank
	Weight	33.33		41.67		8.33		16.67			
Existing Fixture		5	166.65	3	125.01	3	24.99	4	66.68	383.33	3
Alternative 1		5	166.65	4	166.68	3	24.99	4	66.68	425	2
Alternative 2		4	133.32	3	125.01	2	16.66	4	66.68	341.67	4
Alternative 3		5	166.65	4	166.68	4	33.32	5	83.35	450	1

Table 11 Decision Matrix – Accommodate Parts

Function		Accommodate Parts									
		Accuracy		Stability		Maintenance		Reliability		Total	Rank
	Weight	50		20		10		20			
Existing Fixture		5	250	4	80	3	30	5	100	460	2
Alternative 1		4	200	4	80	5	50	4	80	410	4
Alternative 2		5	250	5	100	4	40	5	100	490	1
Alternative 3		4	200	5	100	3	30	5	100	430	3

Table 12 Decision Matrix – Accommodate Parts

Function		Accommodate Parts									
		Accuracy		Stability		Maintenance		Reliability		Total	Rank
	Weight	50		20		10		20			
Existing Fixture		5	250	4	80	3	30	5	100	460	2
Alternative 1		4	200	4	80	5	50	4	80	410	4
Alternative 2		5	250	5	100	4	40	5	100	490	1
Alternative 3		4	200	5	100	3	30	5	100	430	3

Table 13 Best Alternatives

Component	Function	Alternative
Metal Strips	Provide Deflection	Replace with point plate of the horn Change the dimension of the contact breaker
Motor Housing	Transfer Load	Manufacture Motor cover separately and join with the top plate. Use welding to join components
Fixture Base	Accommodate Parts	Reduce the workpiece locator height Don't remove the unwanted volume

12. Development Phase

The purpose of the Development Phase is to determine the best alternatives for presentation to the decision maker. The Technical drawings are developed based on the alternatives selected for each function and their corresponding cost was estimated.

12.1 Metal Strips

The metal strips are replaced by Point Plate of the Horn Assembly which provides the same function in the Horn. The dimensions of contact breaker are changed in order to accommodate the Point Plate.

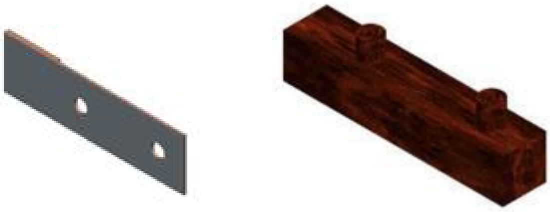

Figure14. (a) Point Plate (b) Contact Breaker

12.2 Motor Housing

The Motor Housing is changed into an integrated assembly of Motor Cover and Top Plate.

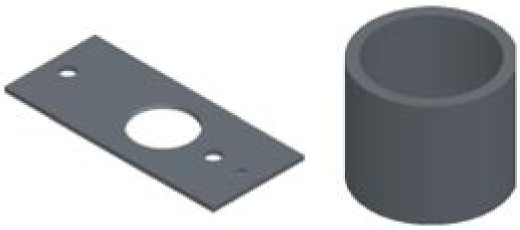

Figure15. (a) Top Plate (b) Motor cover

12.3 Fixture Base

The Height of the locator is reduced and the unwanted volume is left not machined.

Figure16. Fixture Base

13. Presentation Phase

The purpose of the Presentation Phase is to obtain a commitment to follow a course of action and initiate an alternative. In this Phase, the alternatives are presented to the management with their cost analysis and approval for implementation is obtained. The Assembled view of updated fixture is shown in Figure17. The estimate cost to manufacture the updated fixture is given in Table 14.

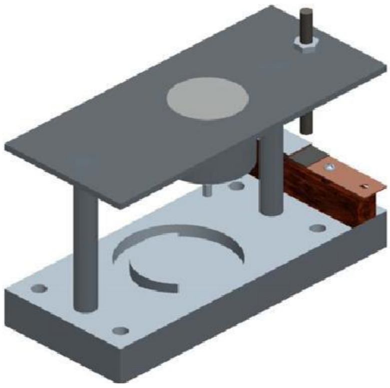

Figure17. Fixture Assembly

Table 14 Estimated Cost

Components	**Estimated Cost (INR)**
Fixture Base	2153.09
Motor cover	1235.836
Top plate	397.85
Contact Breaker Base	252.30
Post	160.4095
Probe	113.384
Point holder	30
Electric motor	200
Screw Holder	43.29
M3 screw	3
M8 Hexagonal nut	3
M5 screws	8
Total Cost	4600.1595

14. Control Phase

The objective of the Control Phase is to determine whether the expected improvements actually occur. A process scorecard is used to monitor the performance of the new fixture.

15. Conclusion

The proposed fixture is implemented to reduce the number of defective horn assemblies in the horn assembly line. Some of the important conclusions are:

- The proposed fixture can reduce the number of defective horns in the assembly line, thus increasing the productivity and profitability.
- Value Engineering can be integrated with Six Sigma methodology to solve a problem in a cost effective manner.
- It is found that Value Engineering applied in the design stage reduced 38.62% of the total cost, thus improving the value of the product.

16. References

[1]. Kunal Ganguly, "Improvement process for rolling mill through the DMAIC six sigma approach", International Journal for Quality research, 6(3), 2012, 21-26

[2]. G. Muthukumaran, V.S.K. Venkatachalapathy and K. Pajaniradja, “Impact on integration of lean manufacturing and six sigma in various applications - A review”, IOSR Journal of Mechanical and Civil Engineering, 6(1), 2013, 98-101
[3]. V. Bharathi and R. Paranthaman, “Application of value engineering in construction building”, Indian Journal of Applied Research, 4(4), 2014, 2249-2455
[4]. Chakraborty Abhijit and Pawani Reyya, “Performance improvement by value engineering in SMEs”, International Journal of Engineering and Management Sciences, 5(4), 2014, 263-265
[5]. Hongping Wang and Xuwei Li, “The application of value engineering in project decision-making”, Journal of Chemical and Pharmaceutical Research, 5(12), 2013, 714-720
[6]. Nayana Tom and V. Gowrisankar, “Value engineering in residential house construction”, International Journal of Civil Engineering and Technology, 6(6), 2015, 46-52
[7]. Transactional Six sigma and Lean Servicing, Betsi Harris Ehrlich, CRC Press LLC, Florida, 2002
[8]. The lean six sigma Blackbelt handbook, Frank Voehl, H. James Harrington, Chuck Mignosa and Rich Charron, CRC Press, NY, 2014
[9]. C. Elanchezhian, T. Sunder Selwyn and B. Vijaya Ramanath, “Design of jigs, fixtures and press tools”, Eswar Press, Chennai, 2004
[10]. Faculty of Mechanical Engineering, PSG college of Technology, Coimbatore, “PSG Design Data Book”, Kalaikathir Achchagam, Coimbatore, 2013
[11]. Akbar Alem Tabriz, Hessam Zandhessami, Behzad Ghasemi and Reza Keshavarzi, “A study of the effect of using value engineering on improving the performance of manufacturing systems with focus on six-sigma: A case of khosh khorak sina food industrial company apjem arth prabandh”, A Journal of Economics and Management, 3(2), 2014, 2278-2789
[12]. Chougule Mahadeo Annappa and Kallurkar Shrikant Panditrao, “Application of value engineering for cost reduction - A case study of universal testing machine”, International Journal of Advances in Engineering & Technology, 6, 2012, 36-42.
[13]. Anilkumar Mukhopadhyaya, “Value Engineering: Concepts, Techniques and Applications”
[14]. Mohit Taneja and Arpan Manchanda, “Six sigma an approach to improve productivity in manufacturing industry”, International Journal of Engineering Trends and Technology, 5(6), 2013, 236-241
[15]. Nabeel Mandahawia, Rami H. Fouad and Suleiman Obeidat, “An application of customized lean six sigma to enhance productivity at a paper manufacturing company”, Jordan Journal of Mechanical and Industrial Engineering, 6(1), 2012, 103-109
[16]. Surasit Rawangwong, Jaknarin Chatthong, Julaluk Rodjananugoon, Romadorn Burapa and Worapong Boonchouytan, “An investigation of optimum cutting conditions in face milling nodular cast iron FCD 400 using carbide tool”, International Journal of Materials, Mechanics and Manufacturing, 1(4), 2013, 56-62.