ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 6, Issue 4, October 2016

Improving an Assembly Process in a Manufacturing Company using Six Sigma Methodologies

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Abstract: ***As the world market is always evolving it requires continuous improvement of the quality and environment management, which therefore is in turn able to satisfy the needs and expectations of all parties (customers, staff and other stakeholders) and also helps in maintaining competitive advantage in the market. In this paper, I present a solution for improving an assembly process in a Manufacturing Company in India with the help Six Sigma Process using DMAIC Methodology.***

Index Terms--**Six Sigma; DMAIC; Xbar & R charts; PARETO; Ishikawa.**

I. INTRODUCTION

Having the desire to achieve business excellence in the Industry, numerous companies have embraced Six Sigma projects for improving competitiveness and to promote efficient production.Six Sigma is a structured approach to problem solving that entailsplacing emphasis on improving or optimizing existing products or processes (Chowdhury, 2003; He &Goh, 2015; Montgomery &Woodall, 2008).

Usually, for a Manufacturing Company, the primary objective is to conduct mainly along the following lines: improve the quality, steady decrease in costs, better customer service and to optimizeresource consumption and better waste management.Each Six Sigma project which is carried out within an organization functions along a defined sequence of steps and has specific value targets. In this context Pyzdek and Keller (2010) considered that Six Sigma methodology is the best way for improving quality / reducingwaste by helping organizations produce products and services better, faster, and cheaper.

I present a case study to demonstrate how the DMAIC framework is used to improve assembly line process in a Manufacturing Industry. Six Sigma can be further classified into two approaches: DMAIC (D-Define, M-Measure, A-Analyze, I-Improve, C-Control).),which is applied to an existing product or process to be improved, and DMADV (D-Define, M-Measure,A-Analyze, D-Design, V-Verify) which is used to develop new products or processes.

II. IMPLEMENTATION OF DMAIC

When applied for performance improvement of an existing product, process, or service, the Define-Measure-Analyze-Improve-Control, or DMAIC model is used. The product is manufactured for a ship building client requiring 1250 scroll turbo parts from the Flash Forge LTD.

A. Define Phase

The first step in the Define Phase was to develop a Project Charter. The official plan and authorization for the project is condensed in the Six Sigma Project Charter.The charter was used to determine the respective roles and responsibilities ofeach member within the design team as well as the objective of the project.Sufficiently defined customer requirements translating intoengineering requirements are created in the define phase. On the production line, for this product, are performed the following operations:

1. Forming
2. Pressing
3. Spinning
4. Bending
5. Welding
6. Post Weld Heat Treatment
7. Assembly and Painting

A Pareto analysis was performed on 1,250 semi-finished products from which 101 were defective, revealing that incorrect height of therivet (30 defects) as the major defect (Fig. 1.) which was calculated using the CMM machine.

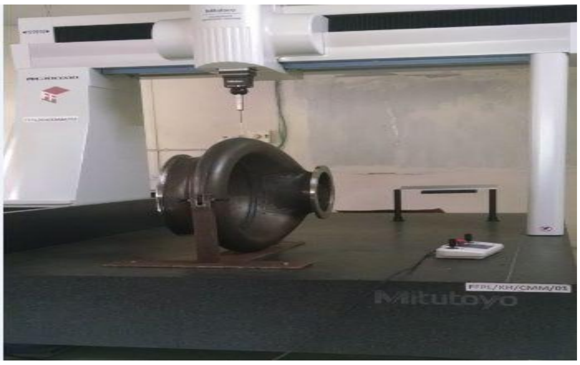

Fig. 1 Co-ordinate Measurement using CMM machine

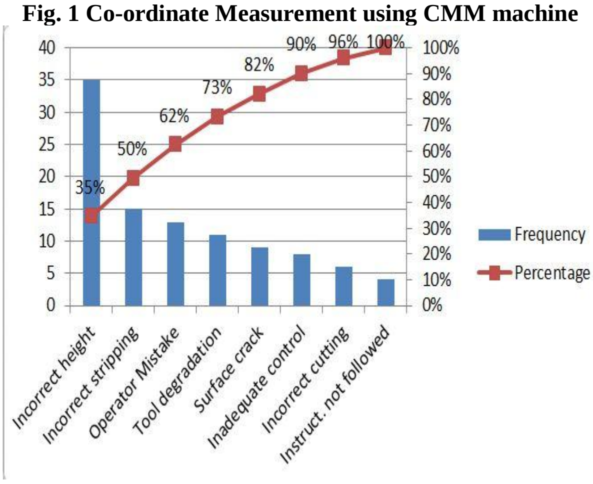

Fig. 2 Pareto Analysis for scroll turbo assembly

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ISO 9001:2008 Certified
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B. *Measure Phase*

The team decided to concentrate improvement efforts on bending process which caused the highest number ofdefects in the manufacturing process. This process is done manually by inserting the upper plate in a holding device thanapplying a force using a special hand operated tool.The characteristic CriticaltoQuality (CTQ) is measured as heightH1 is very critical for thenext operation in the final assembly of the finished product. According to the technical drawingdrawn according to the customer requirements by our engineers, the height (assembled) dimension is 150.3 ± 0.041 mm. It has been decided to measure 10 samples of 5finished products each, during a10 hour shift.

After performing tests to detect the random character of the sample data, tests to detect and remove outliers,have been assessed to confirm whether the data obtained through measurement came from a normal distribution (Table 1) andalso were assessed indicators of process capability (Fig. 3.).

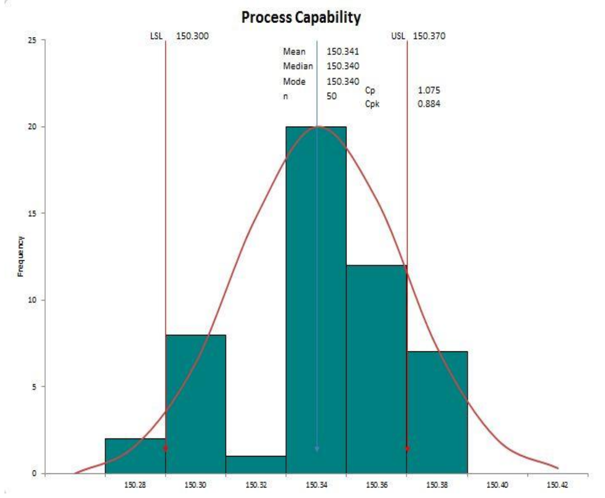

Fig.3. Process Capability chart

In table 1 we can see the results of chi-square test, which divides the amplitude data 14 and is used to compare the number ofequi-probable cases of each class of the expected number, Shapiro-Wilk test which is based on a comparison of a normal distribution quintiles of the data and Kolmogorov-Smirnov test, which calculates themaximum distance between data probability function and probability function of a normal distribution, to determinewhether the data can be modeled by a normal distribution. Since p-value of the three tests is ≥ 0.05, we can notreject the idea that the data come from a normal distribution with a probability of 95%.

Table 1. Statistical tests for normality

Test for normality	Test statistics	P - value	Distribution
Kolmogorov-Smirnov	20.075	0.093356	Normal (p ≥ 0.05)
Chi-square	0.0542148	0.9203922	Normal (p ≥ 0.05)
Shapiro-Wilk	0.95721	0.3	Normal (p ≥ 0.05)

To verify if the process is under control or not, the 50 measurements were projected on an Xbar& R charts, and we can see that regarding R chart the process was under control (Fig. 5.) but regarding the Xbar chart the process was not in control(Fig. 6.).

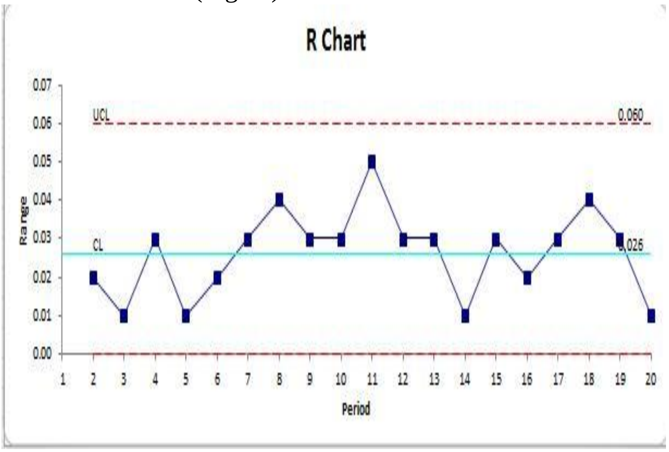

Fig. 4. R Chart

One can see that there are not only points which exceed the control limits, but also there is a clear tendency of increasing the rivet height as the time passes, definitely showing that there is a systematic problem which causes thissituation. For Cpk= 0.88 resulting in Sigma Level short-term ≈ 2.9 respectively Sigma Level long-term ≈ 1.4.

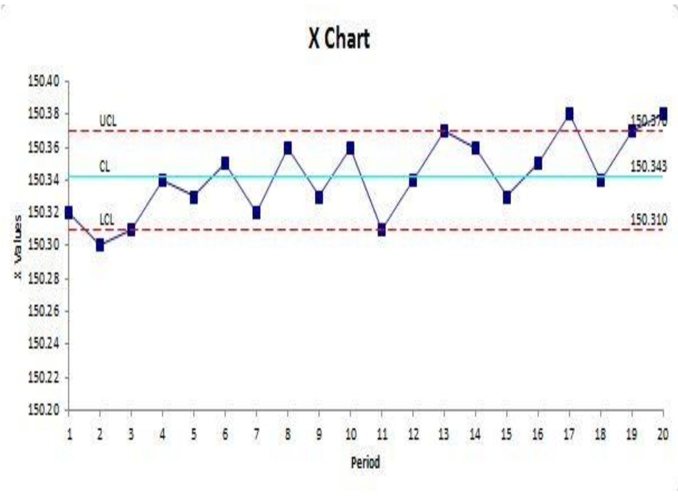

Fig. 5. R Chart

After Measure Phase the following conclusions were drawn:

- Amplitude values are within control limits and therefore riveting process is stable as precision.
- Average values exceed control limits and therefore riveting process is unstable as adjustment (usually, adjustmentinstability may have as sources, failure to periodically check machine-tools, tool wear, improper machineadjustment to work dimension and inhomogeneous semi-finished products).
- There is an abnormality in the riveting process meaning there is a constant tendency of

displacement toincreasingly higher values of rivet height.
- The riveting process is not capable on short and long term.

C. Analyze Phase

In the Analyze phase, after taking into account the conclusions drawn from Measure Phase it was decided to address the following issues:

- Constant displacement of rivet height to increasingly higher values must be thoroughly analyzed.
- The riveting process should be more in control.
- Riveting process capability must be substantially improved in long term.

In the first step, to analyze these issues, the team decided to utilize an Ishikawa diagram has been utilized. Ishikawa diagram or "Cause -Effect" diagram is a tool for analyzing and plotting the relationship between a given effect and its possible causes. We performedthis analysis in conjunction with a “5 Whys – RCFA”analysis and it was determined that the root cause off rivet height noncompliance is the use of improper rivetingforce during work deployment due to the operator`s fatigue, as the ten-hour shift takes place (Fig. 7.).

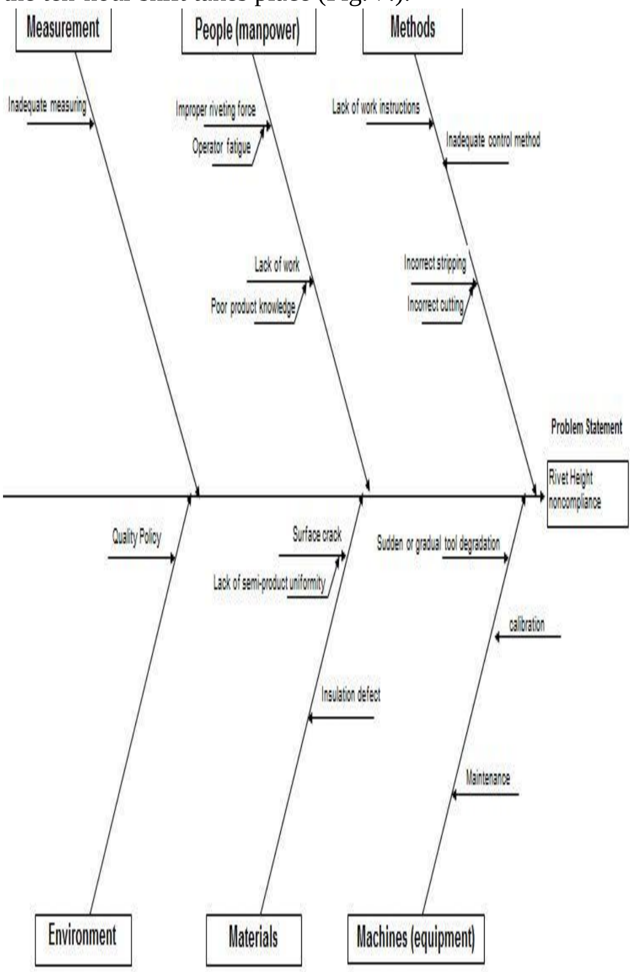

Fig. 6. Ishikawa Diagram

In the analyze phase it was determined that at the beginning of the ten-hour shift the operator`s tendency is to apply a greater down force than needed and as the time deploys the down force diminishes due to operator fatigue, which explains the tendency of increasingly higher values of rivet height.Also a FMEA analysis was performed. It has been determined (Fig. 8.) that the function affected wasthe contact betweenthe turbo scroll assembly and the rest of car electrical system. The potential failure mode was detected as the inadequate riveting force using the Ishikawa analysis.

By taking into account the severity, occurrence and detection, a RPN of 105 was calculated. The recommendedaction by Six Sigma FMEA team was to install a device to properly control the riveting force. Also it has beenrecommended that the riveting hand-tool design to be improved, even if the necessary down force is not high. The team decided to tackle this issue regarding the lack of semi-finished products inconsistency(generating 30.29% of total defects) andit was decided to use AHP (Analytic Hierarchy Process) to choose from 5different suppliers of sensors based on some important criteria.

D. Improve Phase

Based on the recommendations from Analyze Phase, there were implemented the following changes:

- The tool design was improved allowing to be handled smoothly.
- An acoustic measuring device was installed.
- A supplier of cables was selected using AHP.

FMEA Template for AIAG and Six Sigma																	MEADinfo Product
Prepared By:									FMEA No/Rev: 0000/01								
Date: 12-08-16									Process/Component:								
												Action Results					
Item	Function	Potential Failure Mode	Potential Effects or Failure	Svrty	Potential Causes of Failure	Occrnc	Current Controls for Prevention/ Detection	Dtctn	RPN	Recommended Action	Responsibility and Target Completion Date	Action Taken	Svrty	Ocrnc	Dtctn	RPN	
1	Contact between the die and the electric system car	Inadequate bending force	Unable to couple to other subsequent subassemblies	7	One cannot control downforce	5	Operator training	3	105	Installing a device to control the bending downforce	Process Engineering					0	

Fig. 7. FMEA Template

To improve the riveting process it has been decided to use a, an acoustic measuring device with warning. When the operator applies the down force, thelimiter gives visual and acoustic signals when the necessary force has been reached, meaning that the proper rivetheight is attained.

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There were selected 5 potential sensor suppliers (denoted from A to E), using 6 decision criteria, namely Experience (EXP), Financial Stability (FS), Quality Performance (QP), Human Resources (HR), Technological Resources (TR) and Current Workload (CW). Priorities matrix, Criteria weights and Priority vector for the 5 Potential sensor suppliers are presented in Table 2. Therefore, according to Priority vector, supplier B was chosen.

Table 2. AHP

	EXP (0.186)	FS (0.120)	QP (0.308)	HR (0.270)	TR (0.082)	CW (0.085)	Priority vector
A	0.161	0.26	0.32	0.24	0.34	0.118	0.22
B	0.205	0.10	0.10	0.19	0.17	0.401	0.36
C	0.171	0.21	0.39	0.40	0.76	0.160	0.31
D	0.364	0.36	0.13	0.12	0.08	0.226	0.17
E	0.082	0.09	0.05	0.07	0.06	0.150	0.07

E. Control Phase

In control phase the improvements presented in Improve Phase were performed, there were measured 10 samples of 5 semi-finished products each, during a10 hour shift. These tests were performed to detect the random character of thesample data, and also used to assess whether the data obtained through measurementcame from a normal distribution and also were assessed indicators of process capability (Fig. 9.).To asses if theimproved process is in control or not, the 50 measurements were plotted on an Xbar & R charts, revealing that regarding both Xbar & R charts the process was in control (Fig. 10 and Fig. 11.). For Cpk= 1.78 resulting in SigmaLevel short-term ≈ 5.2 respectively Sigma Level long-term ≈ 3.8.

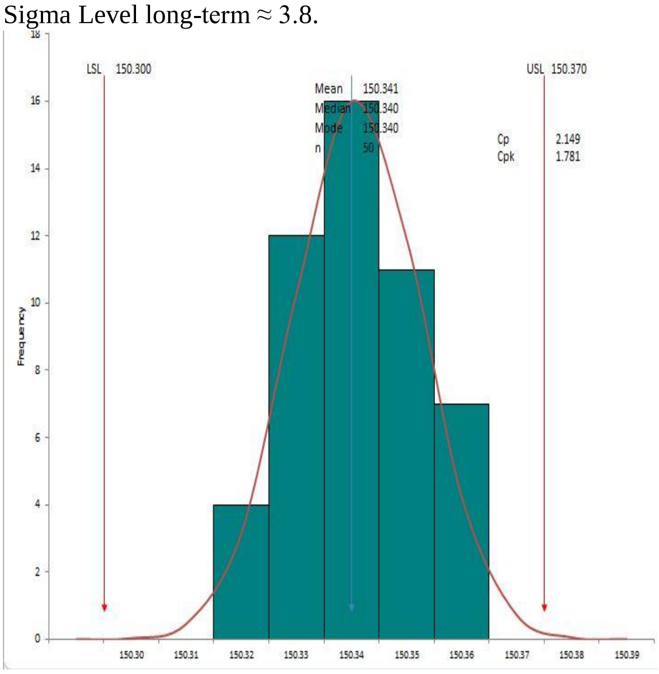

Fig. 8. Process Capability chart (improved process)

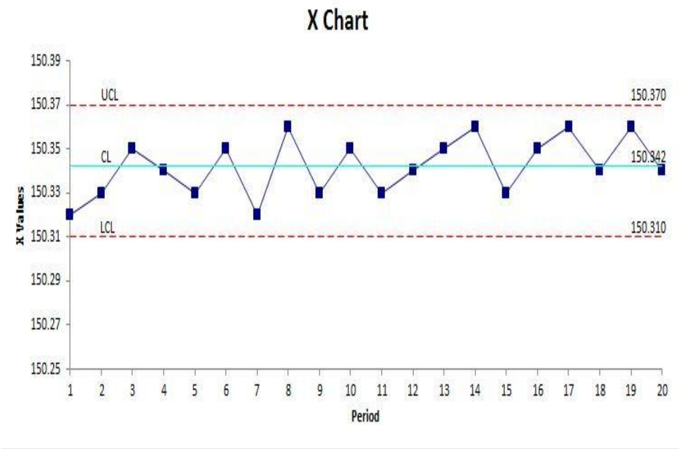

Fig. 9. X chart(improved process)

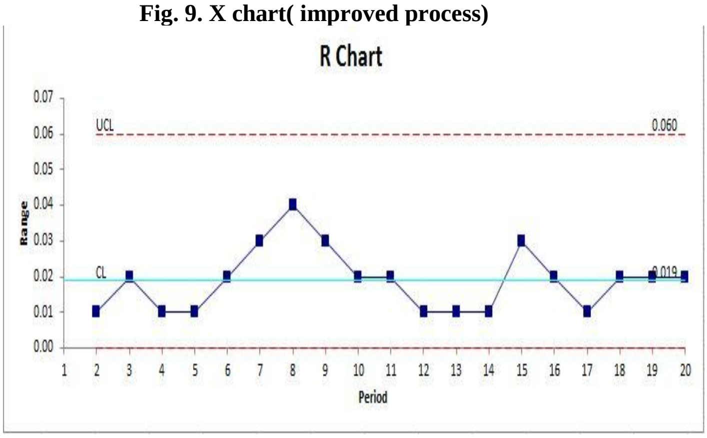

Fig. 10. R chart(improved process)

After the implementation of the recommended action by Six Sigma FMEA was to install a device that can properly control theriveting force, the updated FMEA is presented in figure 11, showing a much lower RPN of 14.

FMEA Template for AIAG and Six Sigma *MEADinfo Product*																	
Prepared By:								FMEA No/Rev: 0000/01									
Date: 00/00/00								Process/Component:									
												Action Results					
Item	Function	Potential Failure Mode	Potential Effects or Failure	Svrty	Potential Causes of Failure	Ocrnc	Current Controls for Prevention/ Detection	Dtctn	RPN	Recommended Action	Responsibility and Target Completion Date	Action Taken	Svrty	Ocrnc	Dtctn	RPN
1	Contact between the die and the electric system car	Inadequate bending force	Unable to couple to other subsequent subassemblies	7	One cannot control downforce	5	Operator training	3	105	Installing a device to control the bending downforce	Process Engineering	Device installed on 20.08.2016	7	1	2	14

Fig. 11. Updated FMEA

III. CONCLUSION

As we all know the revenue and growth of a company depends on how efficiently they launch new product. Therefore, by the application of Six Sigma Methodology using DMAIC to the riveting process the results were obtained: the tool design was improved allowing to be handled smoothly, anacoustic measuringdevice was installed signaling visually when the necessary down

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ISO 9001:2008 Certified
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force was attained, the rivetingprocess was brought in-control, the process capability was substantially improved on short and long term,Cpk increased from 0.88 to 1.78, Sigma Level short-term increased from 2.8 to 5.2, Sigma Level long-term increased from 1.4 to 3.8. To ensure the effectiveness of a Six Sigma project, the commitment of managers in investing resources to support the program is essential.

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Ashish Kumar Atri has completed B.tech Mechanical engineering from Vellore Institute of Technology. His research interests are Operations research, Supply Chain Management and Industrial Engineering.