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Review on Six Sigma DMAIC Methodology and Statistical Process Control Tools in Manufacturing Processes

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Abstract - In this review paper research and development work on Six Sigma DMAIC methodology and its use in various manufacturing processes and also in plastic injection molding is illustrated. Plastic injection molding is one of the very challenging processes to obtain output with a good quality and low cost. Injection molding is widely used to manufacture large and heterogeneous types of parts. It is considered as the most common technique for plastic production. Six Sigma methodologies is being largely implemented methodology to eliminate variations in process parameters. DMAIC (Define, Measure, Analyze, Improve, and Control) is utilized to clarify the work processes and how they fit within the specification. In addition, it creates work process enhancement to eliminate defects.

Keywords: DMAIC, DPMO, Process capability, Sigma level, SPC.

1. INTRODUCTION

Variation is the enemy of quality. The less variation in any manufacturing process, the greater the number of items that will be produced as designed. One must measure variation to reduce it. All processes are subject to a certain degree of variability. If you can measure how many “defects” you have in a process, you can systematically figure out how to eliminate them and get as close to “zero defects” as possible. Six Sigma is a statistical term that measures how far a given process deviates from perfection. Six Sigma is named after the process that has six standard deviations on each side of the specification window. It is a disciplined, data-driven approach and methodology for eliminating defects or variations.

Injection molding is an economical production process for producing complex plastic parts in large quantities. A hot melt of thermoplastic polymer is forced into a mould-cavity at a lower temperature, after that the hot melt solidifies. After solidification, the mould is opened and the product is removed from the mould cavity. In Plastic injection molding process there are number of process parameter which effect cost quality and productivity. Also there is variety of complexity in different large no of parts and its product design and different quality parameters. Therefore, the Six Sigma DMAIC is effective way of improving process capability and sigma level of a molding process. The fundamental objective of six sigma methodology is the implementation of a measurement based strategy that focuses on process improvement and variation reduction.

This research deals with review study of effective way of improving process capability and sigma level of a manufacturing process using Six Sigma DMAIC (Define, Measure, Analyse, Improve, Control) principles. Also there is an attempt to show different research strategies to plastic injections molding companies for implementation of Six Sigma and statistical process control tools.

Figure 1: DMAIC Approach of Six Sigma Methodology

Phase 1—Define
Define is the first phase of the DMAIC methodology of Six Sigma. The purpose of this phase is to define the problem, goal of the project and the process that needs to be improved to get higher sigma level. In this stage, the process which is needed to improve is identified by proper investigation. To understand the whole production process of, a flow chart is prepared including the different stages of production.

Phase II—Measure

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In this measurement stage, different variables are identified to measure. To improve the sigma level of the organization, initially measure the present sigma level using sigma calculator. To improve this level, different quality improvement tools have to be employed and the organization has to be set a milestone to achieve.

Phase III—Analyse
Analyse the process to determine the most likely causes of defects. The key variables most likely to be responsible for variation in the process are identified to find the reasons for generation of defects.

Phase IV—Improve
Improve the performance of the process and remove the causes of the defects. The specification limits of the key variables are fixed and the system established for measuring the deviations of the variables is validated. Improvisations in the process are undertaken to keep the variables within the specification limits.
Phase V—Control
Control phase is to ensure that the improvements are maintained over time. The modified process is subjected to vigil at regular intervals of time. Therefore ensure that the key variables do not show any unacceptable variations (beyond the specification limits).

Quality Improvement Tools: The following seven QC tools were identified by the Japanese Union of Scientists and Engineers (JUSE) are being used for continuous improvement:

Table 1: Application of QC tools in Six Sigma

Tool	DMAIC Application
Pareto chart	Analyse
Cause and effect diagram	Analyse
Stratification	Define
Check sheet	Measure, Analyse
Histogram	Measure, Analyse
Scatter diagram	Analyse, Improve
Control charts	Control

2. OVERVIEW OF RESEARCH PAPERS AND PUBLICATIONS:

Ilesanmi Daniyan ,Adefemi Adeodu, Khumbulani Mpofu, Rendani Maladzhi (2022) demonstrated the use of the Lean and Six Sigma DMAIC for improving the efficiency of the assembly operation of rail car bogie in terms of lead-time and process cycle efficiency. The problem of poor process cycle efficiency or productivity was solved. Process Cycle Efficiency is increased from 19.9% to 66.7 % by implementation of Kaizen and work standardization.

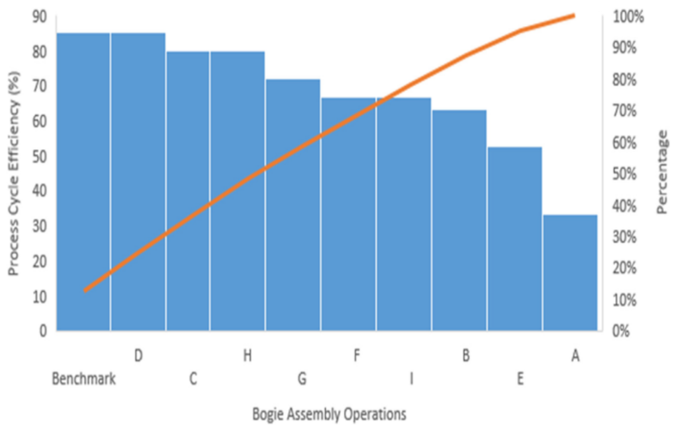

Figure 2: The Pareto analysis of the improved PCE for the assembly operations.

The study shows that integration of Lean and Six Sigma DMAIC tools can assist the manufacturing industries to achieve zero defects, optimum production performance, improved product's quality and fast delivery at optimum cost.
Karishma Raut 1, Niyati Raut (2021) uses the Six Sigma methodology to improve the qualitative rotomolded product in the "Pixel Polyplast" industry. The TL blue 500 models of the water tank were chosen to be a case study. This research aimed to apply DMAIC methodology in the Six Sigma concept to improve quality in the water tank. 37% total defect rate come from a black dot; dent, scratch, burn mark, etc. These defects were eliminated by performing appropriate remedial measures during the improvement stages. The key goal is to utilize Six Sigma to identify severe flaws and remove underlying causes using the DMAIC approach. Quality control tools such as statistical process control charts, pareto charts, histograms, run charts, are used.

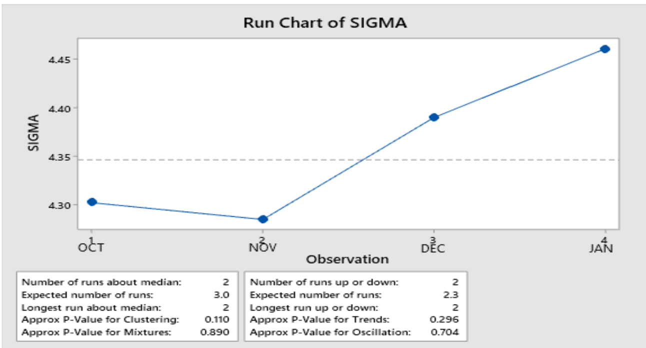

Figure 3: Improvement in Sigma level.

The study obtained a result in the form of a higher Sigma level after using the DMAIC technique. In January, the highest Sigma level was observed.
Prateek Guleria , Abhilash Pathania (2021) conducted a case study of an automobile filters manufacturing industry, facing the problem of rejection in the fuel filters about 12%. Value stream map (VSM) and DMAIC (Define, Measure, Analyze, Improve and Control) cycle were used to improve processes to reduce the rejection rate. Tools like process capability, control charts, Pareto chart, and fishbone diagram were used in this industry for

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improvement. As a result, the rejection rate was reduced drastically.

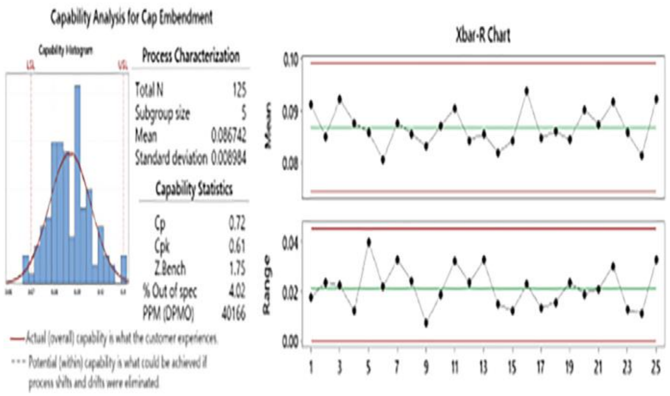

Figure 4: Histogram and process capability graph after the process improvement.

The rejection rate was drastically reduced from about 12% to 4%. The delivery cycle was also reduced from 12 days to 11 days. Now the industry is to supply the fuel filters to the customer every 11 days.

Jogender Singh Yadava, Dr. Prabhakar Kaushikb (2020) Six Sigma methodology was applied to a small injection molding unit manufacturing Latch. The DMAIC (Define, Measure, Analyze, Improve and Control) approach of Six Sigma was applied to reduce rejection rate of Latch (child part of automobile door lock system) by changing two parameters (injection molding pressure and pre-drying temperature) in the molding process. The statistical techniques such as process capability analysis and two sample t-test were done to found the process capability before and after the Six Sigma implementation. After implementing Six Sigma DMAIC approach it was found that the injection molding firm can increase its profit by controlling rejection rate of Latch.

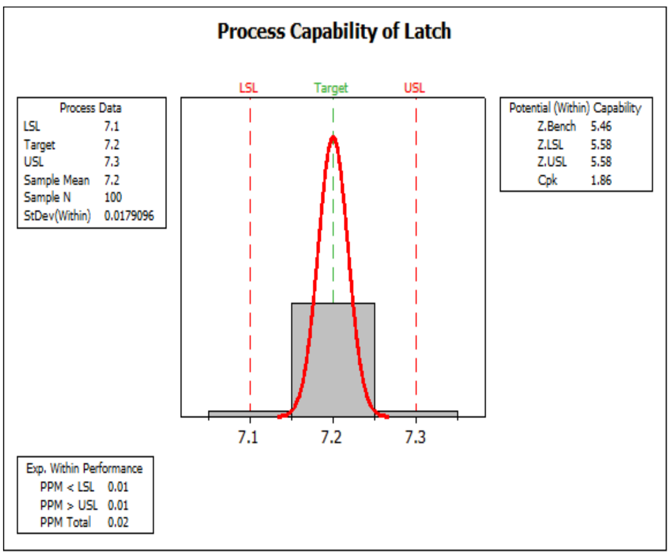

Figure 5 : Process Capability Analysis of Latch Rejection Data after Improvement

Six Sigma increase the process sigma level from 1.80 to 5.46 by reduction in Latch hole diameter variation. This increase in sigma level will give saving of Rs. 0.708 million per annum to the industry which is a good figure for such industry.

J.P. Costaa, I.S. Lopesb, J. P. Brito (2019) described the accomplishment of a six sigma project that consisted of reducing the number of defective units produced by the pin insertion process in an automotive industry through the application of Six Sigma methodology. Analysis was performed to determine the root cause, and it was concluded that it is the interaction of three factors that gives rise to the excessive insertion force: the PCBs physical characteristics, the pins contact zone and the wear of machine components.

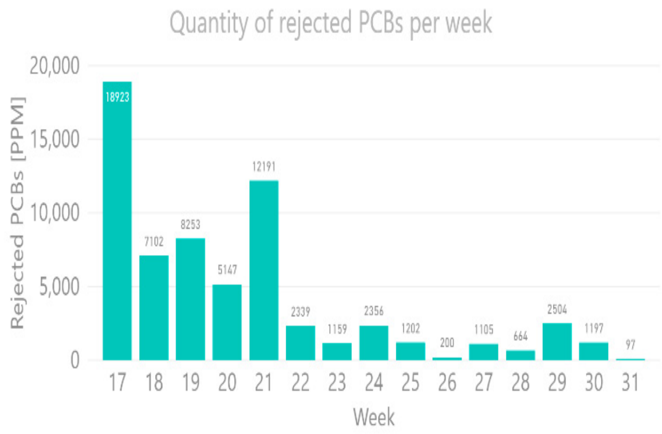

Figure 6: Improvements in weekly values of the DPMOs

The DMAIC structured approach is used that coupled with quality tools such as Pareto diagram, control charts, cause and effect diagram, flowcharts and some six sigma tools. The number of defective units from 3231 PPM to 312 PPM and the increase in the sigma level from 4.22 to 4.92.

Alaa Alshammari, Sahar Redha, Shahad Hussain, Tuleen Nazzal, Zahraa Kamal, and Walid Smew (2018) were applied Lean and Six Sigma to a Small and Medium-Sized Enterprise (SME) Company for plastic manufacturing in Kuwait, to reduce the variation in their injection molding process. Many of the plastic fittings were rejected as they were defective or having defects such as internal surface marks, flash, and bubbles. Floor Traps 6x4x2 fittings accounted for the highest rejection rate. Six Sigma DMAIC combined with the 5S were applied to tackle this problem. Company has achieved an improvement in its Sigma Level and Defects rate (DPMO) which lead to significant cost savings and increased its competitiveness.

Table 2 : Before and after values

Floor Trap Product	Before	After
Sigma Level	1.4	2.3
DPMO	516,500	190,000
Rejected quantity/ day	81	30
Rejected percentage (%)	18	7

B. Barbosaa, M. T. Pereira (2017) has been implemented Statistical process control (SPC) in Continental tyre manufacturing quality assurance system. This work presented

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the implementation of SPC to bead production. From an initial process analysis and a Pareto analysis, the tyre non-conformity with the highest rate was *retained air*. The cause-effect analysis performed, revealed that the cause of retained air originated from the beads production, mostly in the narrow beads. A DMAIC cycle and SPC was applied on that type of bead production, and on the APEX machine that produced it, during a six months period. Parameters to be controlled were defined as the bead dimensions and weight, as well as the variables to measure them. Twelve experiments were defined and carried out.

The number of non-conformities was reduced, and consequently the quality rate increased by 41%, as did the process control and capability.

R. Jayachitra, A. P. Senthil Kumar, U. Mohamed Faizel (2016) carried out research to study quality associated problems in an injection molded plastic product and to improve the quality of the product using Six Sigma methodology in a mid-size injection molding company. In this study, the DMAIC methodology implemented step by step, and different factors were tested for their effects on the amount of rejections/wastage. Based on the analysis, recommendations are provided to reduce the overall amount of rejections. The result proved that the quality of product in plastic industry can be improved by using Six Sigma.

3. CONCLUSION:

This study evaluates six sigma based framework to identify, quantify and eliminate sources of variations in various manufacturing processes and illustrates remarkable benefits of Six Sigma approach in various plastic injection molding companies. One can use different quality control tools like control charts, Pareto charts, cause and effect diagrams may be used for analysis and improvement of process. Existing sigma level can be calculated using SPSS/Minitab software. It is concluded that Six Sigma DMAIC is an innovative approach to detect and remove defects and improve business performance of manufacturing industries considerably.

REFERENCES

[1] [1] Ilesanmi Daniyan a, Adefemi Adeodu b, Khumbulani Mpofu a, Rendani Maladzhi (2022) , Aplication of Lean six sigma methodology using DMAIC approach for the improvement of bogie assembly process in rail car industry, Heliyon 8 (2022) e09043.

[2] [2] Karishma Raut 1, Niyati Raut, Applying Six Sigma DMAIC Approach on Plastic Rotomolding Process, International Conference on Emerging Trends in Engineering, Yukhti-2021, Government Engineering college Kozhikode, Sept2021

[3] [3] P. Guleria, A.Pathania, H.Bhatti , Leveraging Lean Six Sigma : Reducing defects and rejections in filter manufacturing industry, Materials Today proceeding 2021, 03.535.

[4] [4] Jogender Singh Yadava, Dr. Prabhakar Kaushik, Application of Six Sigma In Injection Molding Process, International Journal Of R&D In Engineering, Science And Management Vol.1, Issue I, AUG 2020 pp.:8-16, ISSN 2393-865X.

[5] [7] J.P. Costa, I.S.Lopes, J.P. Brito , Six Sigma application for quality improvement of the pin insertion process, Procedia Manufacturing 38 (2019) 1592-1599.

[6] [8] Alaa Alshammari, Sahar Redha, Shahad Hussain, Tuleen Nazzal, Zahraa Kamal, and Walid Smew, Quality Improvement in Plastic Injection Molding Industry: Applying Lean Six Sigma to SME in Kuwait, Proceedings of the International Conference on Industrial Engineering and Operations Management Bandung, Indonesia, March 6-8, 2018.

[7] [9] B. Barbosaa, M. T. Pereira (2017), Solving quality problems in tyre production preparation process : a practical approach, Procedia manufacturing 11 (2017), 1239-1246.

[8] [10] Jayachitra, A. P. Senthil Kumar, U. Mohamed Faizel, Quality Enhancement In Plastic Manufacturing Industry Using Six Sigma Methodology, International Journal of Engineering and Robot Technology. 3(1), 2016, 7-19.

[9] [11] Tarek Safwat, Aziz Ezzat, Applying Six Sigma Techniques in Plastic Injection Molding Industry , Proceedings of IEEM 2008,IEEE.