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Quality Improvement by Application of DMAIC Technique: A Case Study in Small Scale Manufacturing Industry

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Abstract
The fundamental objective of the DMAIC methodology is that focuses on process improvement and variation reduction through the application of DMAIC improvement projects. This is accomplished through the use of DMAIC methodology. The concept described in DMAIC were applied to overcome the quality issues in small scale manufacturing Industry. In measure and analyze phase Multyvary analysis tool was applied and found that part to part variation is greater than that of time to time and stream to stream variation. In improve phase new tool was replaced by old one and new reading were taken out. In control phase process capability and process capability index were calculated and found that rejection percentage decreased from 6% to 2%.

Keywords
DMAIC (Define, Measure, Analysis, Improve, Control), Cp (Process Capability), Cpk (Process Capability Index)

I. Introduction
In competitive scenario, the markets are becoming global & economic conditions are changing fast. Customers are very quality conscious & demand for high quality product at competitive prices with product variety and reduced lead-time. organizations are facing tough challenge to respond to the needs of customer while keeping manufacturing related costs down. The companies are striving for their very survival. Companies can cut down their costs by reducing the production of defective parts. This is what DMAIC is all about DMAIC is scientific problem-solving technique, which uses statistical and non-statistical tools integrated with methodology to bring down number of defects to 3.4 defects per million opportunities in any process [1]. Developing an effective quality strategy is a factor in long-term business success. Statistical methods and statisticians have a fundamentally critical role to play in this process. DMAIC uses a set of quality management methods, including statistical and non-statistical methods. The term DMAIC originated from terminology associated with manufacturing, specifically terms associated with statistical modelling of manufacturing processes [2].

A. The Steps in DMAIC
1. **Define:** Identify, evaluate and select projects; prepare the mission; and select and launch the team.
2. **Measure:** Measure the size of the problem, document the process, identify key customer requirements, determine key product characteristics and process parameters, document potential failure modes and effects; theorize on the cause or determinants of performance.
3. **Analysis:** Plan for data collection; analyse the data and establish and confirm the "vital few" determinants of performance.
4. **Improve:** Design and carry out experiments to determine the mathematical cause, effect, relationships and optimize the process.
5. **Control:** Design controls; make improvements, implement and monitor [1].

B. Literature Review
A literature review of the recently published research work on DMAIC was carried out to understand the research issues involved and is presented here

Bhosle & G.R. Naik (2018) DMAIC refers to the minimization of variation through proper work flow maintenance and it leads to performance improvement. The critical objective of industries nowadays is to complete a project within a stipulated time, minimization of waste, organizational potential and efficient use of resources by using DMAIC technique. Most of the organizations face poor client satisfaction due to non-completion of the work as per the required standard and specifications. The main objective of this review is to offer a broad and extensive picture of the role of quality improvement technique in manufacturing, automobile and service industries [3].

Bhosle & G.R. Naik (2018) the concept described in DMAIC were applied to overcome the quality issues. The actual performance against the targeted level was measured and observed that quality was improved with considerable reduction in cost of poor quality. The define phase included the pareto analysis, study of process, calculating cost of poor quality and noting down the suspected sources of variation. In measure and analyze phase, paired comparison tool was used. In paired comparison Runout, Concentricity and surface roughness of product checked and count was calculated. Here, some DMAIC tools were applied for quality Improvement [4].

Chhikara et al. (2017) explained various methods and technique used for identification of DMAIC projects. While identifying projects one must know the input parameter such as as Kano Analysis, Value Stream Mapping, Theory of Constraints, Hoshin Planning, Cost of Poor Quality, Quality Function Deployment, Strategic Development plan and Voice of Customer etc. they have also explained Methods and Techniques used for Selection of DMAIC Projects such as Programming Methods, Scoring and Ranking, Real Option Analysis and Data Envelop Analysis along with they focused on value creation, improving the process capability making the process more reliable [5].

Vante & G.R. Naik (2016) in this paper dimensional variations in casting wall thickness in 3-cylinder metric block casting shows major defect contributing in rejection. From Pareto analysis it was clear that dimensional variation at water jacket wall i.e. wall-less has the maximum share responsible for the increased rejection percentage and it needs to be minimized. Different type of chaplets was tried and tested as remedies. The previously used 3-disc round chaplet was replaced by rectangular v-make chaplet. This change contributed in reduction in rejection as well as cost of poor quality. Rejection due to water jacket wall-less was reduced from 7% to 2.13%. Increased accuracy in dimensions and specifications according to standard indicates improvement in quality [6].

Gangai & G.R. Naik (2015) presents case study on DMAIC to reduce the rejection of EA16 engine cylinder head due to valve guide surface roughness out of specification in small scale industry. In define phase problem selection using pareto analysis and process mapping are carried out. Tool used for problem solving are paired comparison &multivary analysis. In multivary analysis they studied time to time variation, stream to stream variation and part to part variation and find out which parameter affects on critical to quality. In measure &analyse phase they studied Process capability before and after implementation of new tool using Minitab software. The cost saving achieved through successful implementation of this project is 6.26 lac/annum [7].

Sao & Sridhar (2015) presented DMAIC approach into a powerful business improvement methodology in many Global industries and its importance is growing. Authors describes some critical barrier while implementing DMAIC methodology in manufacturing industry such as internal resistance, lack of training and knowledge and lack of executive commitment etc. Explained implementation issues for the growing number of organizations and focus should be on improving overall management performance. Also presented statistical tools which give the basic idea of DMAIC, states that if process performance is improved then cycle time, inventory, capacity, reduction waste will also improve [8].

Youssouf et al. (2014) focused on the efficiency of maintenance of the industrial systems and Studied some major economic issues for their business concern. Identified some critical parameters for the quality, that is, those whose influence on the result is the largest. In define phase they understand the problem and its financial impact. In measure phase develops methods of data collection and find out the root cause of the problem. They try to optimize the number of personal maintenance and focused on preventive maintenance by using different methods of analysis of processes such as: the FMEA, design of experiments, Pareto analysis, cause and effect diagram and 5S tools etc. [9].

S. Soni et al (2013) explained reduction of welding defects using DMAIC Approach. They revealed that internal customer is affected by low SAW boom Machine welding process yield. By applying cause and effect diagram analysis improper removal of tab plates, improper weld groove and zurking of tractor machine. They prepared critical to quality tree, why-why Analysis to solve the problem as a result considerably reduction of possibility of failure, cost of poor quality and reduces labour expenses. They studied a real time monitoring system as a result reduced shear strength of the weld without destructive testing [10].

K. Ganguli (2012) provide the solution to the large aluminium company in developing hot rolling mill capabilities and reduction in down time due to strip slippage. Authors apply DMAIC principles and identified the current situation that the rolling mill worked out. While authors studying he observed that temperature loss was the major reason for slippage. To solve these issues author-initiated work in two directions one is to reduce the heat loss by installing monitoring coil rolling time, idle time and coil to coil time and second one raising the average rolling temperature from 510 to575C means keeping the slabs hot enough so that any heat loss from the rolling ingot may not have any effect on its roll ability. As a result, the company remains in competitive without any investment of new hot rolling mills [11].

A. Research Issues

1. There is great potential for research on DMAIC and its linkages with other initiative such as DMAIC in lean manufacturing.
2. Less work reported considering the effect of input and material related suspected sources of variation.
3. Work carried out using practical statistical tools and to find out the defects using Control Charts not explored yet with full potential.
4. There is a need to have more case studies clearly presenting the application of DMAIC within each domain in a proposed framework.

III. Problem Formulation

The case study is carried out and DMAIC is applied to quality improvement of Cover Bearing Front in small scale manufacturing industry. The project is focusing on a specific type of cover bearing front-330109 manufacturing for Eaton Company, Pune. The Outer diameter 56.900mm is going out of specification. (Observed: 56.939mm). Rejection percentage observed was 6% and Cost of poor quality is 12.6 lakh/Annum.

Tolerance range of OD: Ø56.900 – 56.935mm (Master piece: Ø56.919mm)

Process Start Point: Semi finished Cover Bearing Front from Casting Shop Department.

Process Stop Point: Well finished Cover Bearing is ready for inspection clearance.

External Customer: Eaton, Pune.

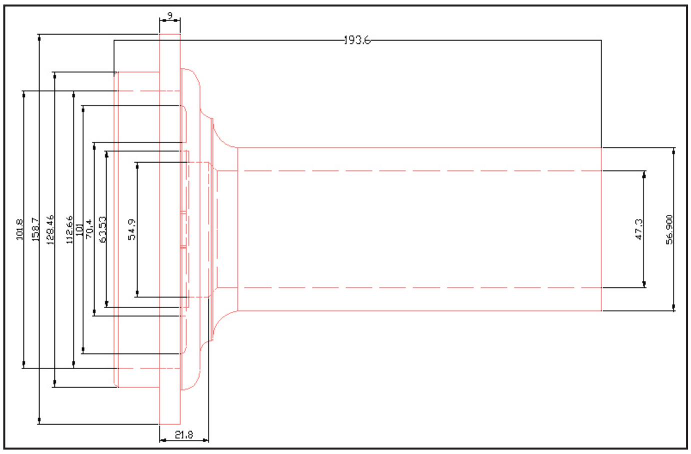

Fig. 1: Drawing of Cover Bearing Front

4. Multi-Vary Analysis

Next tool used in measure & analyse phase was multi vary analysis. Is used only when the problem is generated from a Manufacturing process.Response (Y) is analysed in this tool. Can be used only when the response is Variable. If the response is attributing, use Concentration chart.Used to find out what sources of variation is the highest in a process.Is applied only after the process creating the problem is established using the other tools.

A. Application

- Is used only when response is "variable".
- Is used only when the problem is generated from a manufacturing process.
- Used to identify what source of variation is the highest in a process.
- Response is analyzed in this tool.

B. Type of Variation

1. Part to Part Variation:
2. Time to Time
3. Stream to Stream

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1. Part to Part Variation

Variation between consecutive parts from the processes termed as Part to Part variation. Example Operator, Equipment, Tool etc.

2. Time to Time

Variation between time blocks from the process is termed as Time to Time variation. For Example: Shift hours, power failure, Tool offset, Adjustment, Dressing, breakdown, etc.

3. Stream to Stream Variation

Variation between streams from the process is termed as Stream to Stream variation. Example Process Design (Design of fixture, clamping method, spindle speed) etc. If Stream to Stream variation is greater than or equal to Part to Part variation, then the Reason is due to abnormality in streams.

C. Data Collection of Variations for Outer Diameter

In muti-vari analysis 10-time blocks were prepared and part to part, time to time & stream to stream variation were calculated.

Table 1: Data Collection of Variations for Outer Diameter

Tolerance range of OD: Ø56.900mm – 56.935mm **Cycle Time: 5 Min-5 Sec** **Speed: 900 rpm** **Feed: 0.16 mm/rev.** **All Dimensions are in mm**					
Sr. No.	**TIME**	**TIME BLOCK**	**OD(TOP)**	**OD(MIDDLE)**	**OD(BOTTOM)**
261	8AM-8.05AM		56.902	56.898	56.901
262	8.06AM-8.10AM		56.895	56.888	56.887
263	8.11AM-8.15AM		56.88	56.885	56.888
	RANGE-I	T-1	0.022	0.013	0.014
	RANGE -II		0.009		
	AVERAGE(X-BAR)		56.89233333	56.89033333	56.892
	AVERAGE(X=BAR)		56.89155556		
	RANGE-III		0.002		

Sr. No.	TIME	TIME BLOCK	OD(TOP)	OD(MIDDLE)	OD(BOTTOM)
264	8.16AM-8.20AM		56.912	56.918	56.922
265	8.21AM-8.25AM		56.903	56.901	56.906
266	8.26AM-8.30AM		56.891	56.895	56.896
	RANGE-I	T-2	0.021	0.023	0.026
	RANGE- II		0.005		
	AVERAGE(X-BAR)		56.902	56.90466667	56.908
	AVERAGE(X=BAR)		56.90488889		
	RANGE- III		0.006		

Sr. No.	TIME	TIME BLOCK	OD(TOP)	OD(MIDDLE)	OD(BOTTOM)
267	8.31AM-8.35AM		56.901	56.898	56.895
268	8.36AM-8.40AM		56.905	56.908	56.909
269	8.41AM-8.45PM		56.885	56.891	56.898
	RANGE- I	T-3	0.02	0.017	0.014
	RANGE- II		0.006		
	AVERAGE(X-BAR)		56.897	56.899	56.90066667
	AVERAGE(X=BAR)		56.89888889		
	RANGE- III		0.003666667		

Sr. No.	TIME	TIME BLOCK	OD(TOP)	OD(MIDDLE)	OD(BOTTOM)
270	8.46AM-8.50AM	T-4	56.889	56..894	56.896
271	8.51AM-8.55AM		56.895	56.898	56.898
272	8.56AM-9AM		56.905	56.901	56.904
	RANGE- I		0.016	0.003	0.008
	RANGE- II		0.013		
	AVERAGE(X-BAR)		56.89633333	56.8995	56.89933333
	AVERAGE(X=BAR)		56.89838889		
	RANGE- III		0.003166667		

Sr. No.	TIME	TIME BLOCK	OD(TOP)	OD(MIDDLE)	OD(BOTTOM)
273	9AM-9.05AM		56.91	56.912	56.908
274	9.06AM-9.10AM	T-5	56.898	56.895	56.9
275	9.11AM-9.15AM		56.91	56.916	56.92
	RANGE- I		0.012	0.021	0.02
	RANGE- II		0.009		
	AVERAGE(X-BAR)		56.906	56.90766667	56.90933333
	AVERAGE(X=BAR)		56.90766667		
	RANGE- III		0.003333333		

Sr. No.	TIME	TIME BLOCK	OD(TOP)	OD(MIDDLE)	OD(BOTTOM)
276	9.16AM-9.20AM	T-6	56.908	56.915	56.918
277	9.21AM-9.25AM		56.88	56.898	56.91
278	9.26AM-9.30AM		56.902	56.911	56.92
	RANGE- I		0.028	0.017	0.01
	RANGE- II		0.018		
	AVERAGE(X-BAR)		56.89666667	56.908	56.916
	AVERAGE(X=BAR)		56.90688889		
	RANGE- III		0.019333333		

Sr. No.	TIME	TIME BLOCK	OD(TOP)	OD(MIDDLE)	OD(BOTTOM)
279	9.31AM-9.35AM	T-7	56.887	56.895	56.88
280	9.36AM-9.40AM		56.905	56.92	56.918
281	9.41AM-9.45AM		56.911	56.922	56.925
	RANGE- I		0.024	0.027	0.045
	RANGE- II		0.021		
	AVERAGE(X-BAR)		56.901	56.91233333	56.90766667
	AVERAGE(X=BAR)		56.907		
	RANGE- III		0.011333333		

Sr. No.	TIME	TIME BLOCK	OD(TOP)	OD(MIDDLE)	OD(BOTTOM)
282	9.46AM-9.50AM	T-8	56.922	56.93	56.936
283	9.51AM-9.56AM		56.925	56.935	56.938
284	9.56AM-10AM		56.889	56.902	56.898
	RANGE-I		0.036	0.033	0.04
	RANGE-II		0.007		
	AVERAGE(X-BAR)		56.912	56.92233333	56.924
	AVERAGE(X=BAR)		56.91944444		
	RANGE- III		0.012		

Sr. No.	TIME	TIME BLOCK	OD(TOP)	OD(MIDDLE)	OD(BOTTOM)
285	10AM-10.05AM		56.905	56.915	56.921
286	10.06AM-10.10AM		56.909	56.898	56.88
287	10.11AM-10.15AM		56.891	56.9	56.906
	RANGE- I	T-9	0.018	0.017	0.041
	RANGE- II		0.024		
	AVERAGE(X-BAR)		56.90166667	56.90433333	56.90233333
	AVERAGE(X=BAR)		56.90277778		
	RANGE- III		0.002666667		

Sr. No.	TIME	TIME BLOCK	OD(TOP)	OD(MIDDLE)	OD(BOTTOM)
288	10.16AM-10.20AM		56.891	56.905	56.897
289	10.21AM-10.25AM		56.881	56.89	56.902
290	10.26AM-10.30AM		56.904	56.915	56.916
	RANGE- I	T-10	0.023	0.025	0.019
	RANGE- II		0.006		
	AVERAGE(X-BAR)		56.892	56.90333333	56.905
	AVERAGE(X=BAR)		56.90011111		
	RANGE- III		0.013		

From above measure and analysis phase we concluded that

- **Part to Part Variation:** Highest Value of Range-I In All Entries = 0.045mm= **45 Micron**
- **Time to Time Variation:** (Highest X=Bar)- (Lowest X=Bar) = 56.920-56.892= **0.028= 28 Micron**
- **Stream to Stream Variation =** Highest Value of Range-Iii= **0.019333333= 19 Micron**

Out of the three-variation part to part variation was found to be more exceeding time to time & stream to stream variation.

5.Improve Phase: Is used to validate the root cause of the problem identified using others DOE tools.If the cause is validated, then we can calculate how much the improvement has taken place. Tool is applied only when Better and Current condition can be created alternately.Results on Product Specification after implementation of new Insert tool: The new tool used was ACHTECK TNMG 160408E-KC4 TNMG 332A-KC4 ACK 15A CAST IRON K10-K30.The product specification was checked for Outer Diameterand found to be within specification. readings show the product Dimensions after implementation of new tool.The process parameters were checked and Found within specification. The tool life was calculated and was found to be for 75 jobs.

V. Control Phase-Study of Process Variation

Process capability compares the output of an in-control process to the specification limits by using capability indices. The comparison is made by forming the ratio of the spread between the process specifications (the specification "width") to the spread of the process values, as measured by 6 process standard deviation units (the process "width").

A. Process Capability

Process capability is the ability of the process to meet the design specifications for a service or product. Nominal value is a target for design specifications. Tolerance is an allowance above or below the nominal value.

1. Study of Variation Results

As part to part variation was highest the equipment used was creating the defect.While analysing the process the tool and process parameter were studied.The tool used was WINTECH INSPECTED CVD C1115 TNMA160408 Coated Carbides for Cast Iron TNMG160408PH.

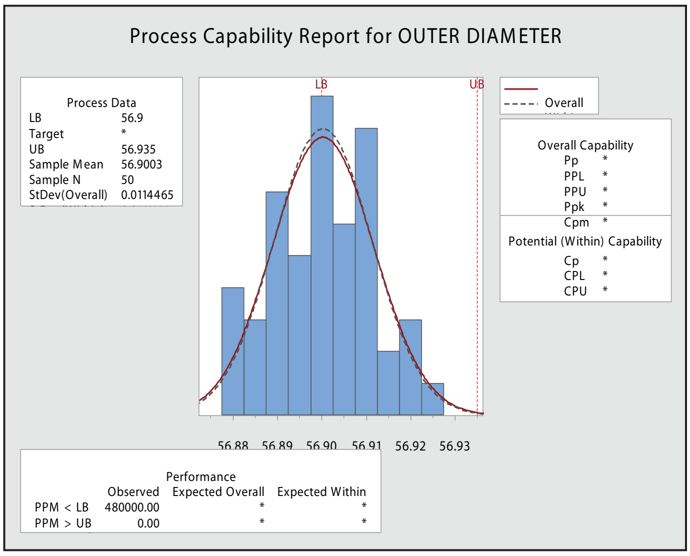

Fig. 2: Process Capability Report for Outer Diameter Before Implementing Tool

From above chart the process is not stable & Bell-shaped curve shifted towards Left hand side of the specification limit that leads to rejection of Cover Bearing Front. The process is not set to mean position.

2. Process Capability (After) Study and Analysis using Minitab

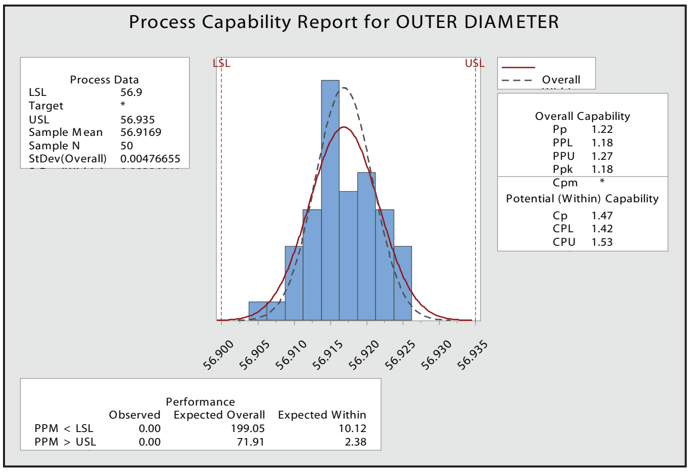

Fig. 3: Process Capability Report for Outer Diameter

From above chart we can concluded that the process is stable & set to mean position. the value of Cp and Cpk is 1.47 and 1.42 respectively.

VI. Conclusion

In the above Case Studyfunneling approach was used. DMAIC technique was implemented to find the root cause.In Measure & Analyze Phase input related SSV's were eliminated and multyvary analysis tool was applied. In Multi-vary analysis part to part variation was found high and process was studied.Trials were taken by implementation of the new tool ACHTECK TNMG160408E-KC4 TNMG 332A-KC4 ACK 15A CAST IRON K10-K30 and no rejection was observed for first 75 jobs.In control phase process capability & process capability index calculated and found that process was stable & set to mean position. This implementation eliminated Cost of Poor Quality which was 6.2 Lakhs& rejection Percentage decreased from 6% to 2%.

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