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Unleashing the Challenges before PVC Pipe Extrusion SMEs through D-Phase of Six Sigma

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Abstract : *This paper divulges the role of Define phase in effective implementation of six sigma. A notional idea behind six sigma embarks with defining the problem, to recognise the correct problem. If this is ignored, rest of the activities are almost futile. The Define in the DMAIC process focuses on understanding which underlying metric(s) will reflect project success & to identify the right issue that need to be addressed. Define phase insinuate researcher with the existing environment of the process thereby command the research in a direction to improve the process by attacking the critical parameters. So far the studies conducted in PVC pipe manufacturing field are broad brush, Japanese techniques provides unsustainable improvement. Well defined lucid research problem enable the researcher be on track in conducting research in a holistic manner. Successfully implemented six sigma technique begins with clearly defined problems using powerful qualitative tools such as process mapping, C_{pk} studies, process metrics, Cost of Poor Quality to lay the foundation of research, i.e. Defining the problem. This paper demonstrates the define phase tools in to formulate the research problem that will help the researchers, students, academicians to define the problem with relevant tools.*
Keywords *- Critical process metrics, COPQ, Define phase, project charter PVC pipe extrusion, Six Sigma*

I. INTRODUCTION

Six Sigma is a structured methodology that focuses on reducing variation of the process by measuring defects resulting in improvement of the quality of products, processes and services. Six Sigma methodology was originally developed by Motorola in 1980s and it targeted a difficult goal of 3.4 parts per million defects [1]. Motorola University Design for manufacturing training program defined Six Sigma initially by six steps [2]. Six Sigma has evolved to become an extension to total quality management [3]. As a project-driven management approach, the range of Six Sigma applications is also growing from reduction of defects in an organization's processes, products and services to become a business strategy [4]. A fancied idea behind Six Sigma embarks with defining the problem and to recognise the root cause of the problem. Ignoring this activity will make rest of activities in vein. The very first step of applying Six Sigma using DMAIC is Define phase. Define phase is the start up of the six sigma project that defines the overall project, including scope, objective and goals. It also selects the project leader, team members, sponsor, stakeholders, and schedule. There are various tools to depict all the credentials during this phase. During this phase, the process is also defined [5]. This phase employs tools like brainstorming, affinity diagrams, voice of the customer, surveys, focus groups, market research, interviews, and the business case. It is essential to select and scope a Six Sigma project to deliver high impact results [6] Understand customer needs and metrics taking care of CTQ.

II. LITERATURE REVIEW

This paper covers the hidden aspects of define phase of six sigma DMAIC methodology. Besides being given guidelines for establishing an improvement opportunity, this paper focuses on specific methods for capturing the voice of the customer and how to use Six Sigma improvement opportunities from a financial perspective: what to consider before launching a project, the financial metrics that will be involved and how to calculate the cost of poor quality. D is the first phase in the DMAIC model. During the D-phase, the project's definition is developed. The project's definition includes the overall scope, objectives, and goals of the project. It also determines the project leader, team members, sponsor, stakeholders, and schedule. During the D-phase, the process is also defined [9]. Define phase employs various tools such as flow charts, process mapping, and supplier, input, process, output and customer diagrams. Team formation is an important part of this phase [16]. The team leader has a significant role in a Six Sigma project and it is the leader's job to keep the team focused on the stated objective, scope and goal [10]. But by skipping Define phase, hidden aspect of define phase remains undiscovered. A well-defined, well-scoped Six Sigma project is more likely to be completed successfully and results in huge savings. A project that starts directly at the measure phase has the potential to be ditched as investigation of the current problem may open a can of worms that diverts attention from the original goal [11]. Usually, a significant amount of head scratching is done before practitioners can unveil the right x's and have a clear understanding of their impacts on the *Y* [12]. This is why the Define-stage in the DMAIC model of Six Sigma is so important. Define consists of qualitative tools, such as project charters, problem statements, process maps and critical-to (CT) trees [15]. Because team members are human and miscommunication can happen, so it is important to answer all of the questions regarding current situation and constraints and record the answers in a 'go-to' document. This can serve as a source of backup information when anyone asks "Why are we doing or what we are doing?" This also helps to build consensus about the current state, desired future state and any other goals [13]. In Define, teams may discover things they never knew existed. This typically occurs during the use of process flow and value stream mapping tools. Why do these discoveries happen? Because in the daily running of operations, process owners are focused on getting the job done and do not necessarily stop and analyze that why they are doing something a certain way. The discoveries explain some of the drivers of variation and non-value-added work. In the multiple roles an employee plays at work, it is hard to remember every detail. Define also acts as a refresher to the team members about the process and sometimes this review causes team members to look at the process with a fresh pair of eyes [14].

III. PROBLEM FORMULATION

Define phase is a critical part of Six Sigma methodology. It defines the existing problem in the process that needs to be solved and conversion of the problem into opportunity to improve the process. A preliminary research is often required to define any problem. Quality is regarded as a technical issue managed by the quality department. Because of poor management commitment on quality, most of the industries don't have a culture to monitor and maintain process capabilities and capacities. Profitability of any production unit majorly depends upon its tendency to produce not 'products' but 'quality products'. Because of poor process design the company may face huge production losses. This would infact down-fires to more rework, scrap, poor quality, long cycle times and high production losses that ended up with poor customer satisfaction. During literature review, scarcity of some standard procedure for enhancing process capability has strongly been felt, particularly in pipe extrusion SMEs. Mainly some industrial tools like, Scrap analysis, Control charts, Pareto charts, Tree diagrams and Root cause analysis by Fish bone diagrams etc. have been applied for controlling and improving the industrial processes. The purpose of this paper is to redefine the define phase of a comprehensive approach of Six Sigma and to answer the following critical to quality questions:

- What are the various quality problems that are faced during defining a problem?
- Which are the different critical process design parameters that effect the process?
- How the given SME try to set these process parameters in define phase?
- What quality tools they are already used in define phase?

IV. CASE STUDY

Most of the Indian PVC pipe industries have a short-term view on business which focuses on quantity and profit rather than quality. Quality is regarded as a technical issue managed by the quality department. Because of poor management commitment on quality, most of the industries don't have a culture to monitor the process. During define phase a critical process metrics was developed to focus on the area of improvement. In define phase various tools were also executed. A case study has been carried out at Patiala Polymers Ltd, B 23 Focal point Patiala, Punjab. It is a Small scale enterprise that manufactures PVC pipes. It has production capacity of 25-90 ton per month employing manpower of 25. The Extrusion process is used to manufacture PVC pipes. Extrusion is a continuous in line process wherein several processes are simultaneously performed. In PVC pipe manufacturing, stearic acid, PVC resin, Wax, Calcium stearic, titanium & calcium carbonate are the raw materials that are mixed in right proportions to form PVC pipes of different diameters, length, weight & bursting pressure

4.1 Defining critical Process Metrics

In the very first step of define phase critical process metrics was developed. A comprehensive metrics was found. The raw material in fixed volume is extruded is converted into pipe. So the final volume of pipe was:

$$Volume\ of\ pipe = \frac{do2 - di2}{4} \times \pi \times length$$

Weight is the product of mass & gravity and mass is the product of density, volume & gravity (refer to Figure 1), value of gravity is constant.

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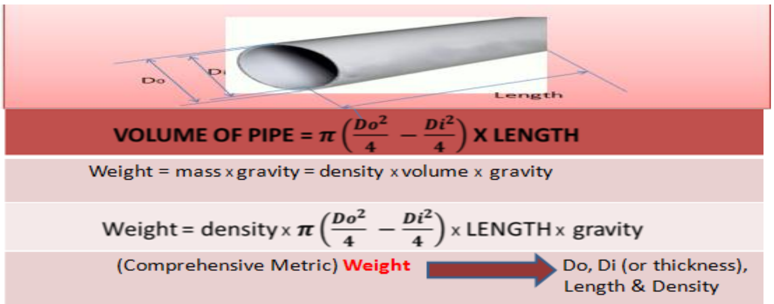

Fig.1. Critical Process Metrics

From comprehensive metrics it was found that weight of pipe is directly proportional to thickness, length & density. Weight is the property that is related to thickness, length & density of the pipe. Thickness of pipe is a significant attribute for a PVC pipe. It indicates strength of the pipe, increase in thickness also increases the weight of the pipe. Weight is the derived parameter which contains the effect of all the parameters. If weight is in control it implies that all the parameters are well within control limits. Sources of variation include variability in thickness, length & density of the pipe that will directly affect the weight of the pipe. So it was decided that weight was the parameters that need to be governed in order to reduce the process variation. Next step was to find out the process capability of the weight of pipes. Following data for the weight of the pipe was collected from production sheets (refer to Table 1).

Table.1. calculation of weight

Pipe Weight in Kgs (Recorded from Production Sheets)
11.950
11.090
12.500
11.095
11.850
12.000
11.700
12.000
11.750
11.750
11.800
11.600
11.650
11.700
13.750
12.800
12.750
12.400
12.150
12.100
12.800
12.550
12.200
11.550
10.900
11.000

Data was collected from production of two shifts at regular interval of 20 minutes. This data was analyzed using Minitab 14 to calculate the process capability analysis.

4.2 Cpk Analysis

Figure 2 depicts the C_{pk} analysis of the weights of the pipe using Minitab 14. In this first output is moving range chart for 25 observations that shows the moving range of the observations over time to monitor process variation for individual observations. Moving average chart shows range between subgroup averages. All the points in the moving range chart are within control limits, since all the points are well in control limits so the process is stable. Capability histogram shows the process capability overall (firm line) & within (dotted line), the dotted black line represents the normal distribution of the data using the overall standard deviation of 0.020, while the red line represents the normal distribution of the data using the within standard deviation of 0.01. The capability of the process has potential to go from 0.21 to 0.31. Next figure is showing normality test on the data, it creates an estimated cumulative distribution function from sample by plotting the value of each observation against the observation's estimated cumulative probability. As clear from the figure all the data points follow the fitted distribution line, the distribution is in almost straight line showing that data is normal data thereby passing normality test having p value 0.393. X chart is plotted showing 26 observations, only one observation is falling outside the limit. Total no. of readings taken were 26 with subgroup size 1. Mean came out to be 11.976, overall standard deviation was 0.64460 and standard deviation within 0.43191.

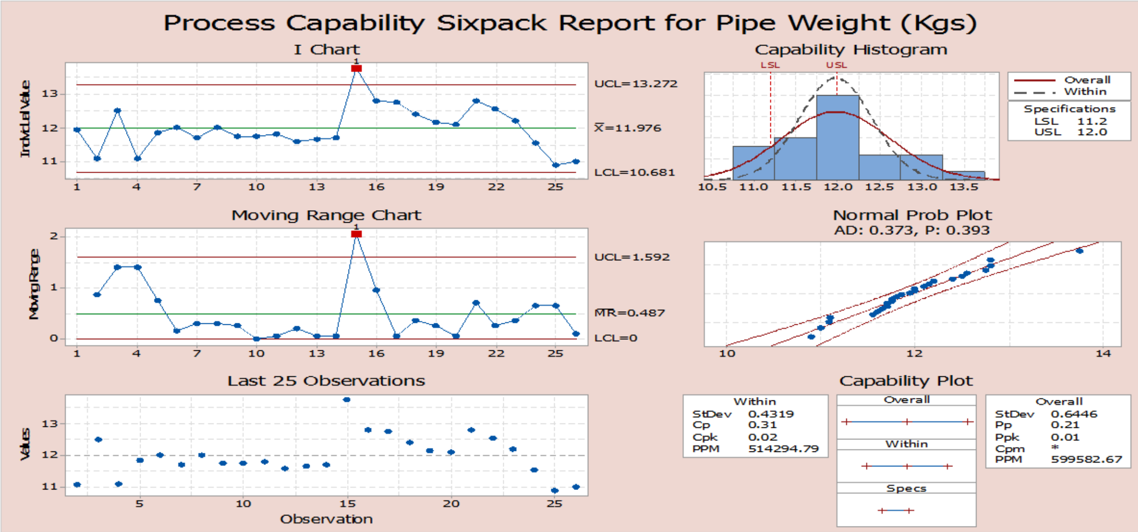

Figure-2: Process Capability

Figure 2 depicts that the process mean differs significantly from the target as $p < 0.05$. The defect rate is 59.96%, which estimates the percentage of parts from the process that are outside the specification limits. Actual (overall) capability is what the customer experiences. Potential (within) capability is what could be achieved if process shifts and drifts were eliminated. Percent out of specification (estimated) is 51.43 %, which means 51.43 % of pipes are rejected. C_p tells about the centeredness of the process, C_p of the process came out to be 0.31. C_{pk} tells about the smartness of the curve & C_{pk} value was 0.02. From standard table corresponding to $C_{pk} = 0.02$, it was found that process is running at 1.5 Sigma level. As process was running with very poor process capability so there was a huge scope of improvement in the PVC pipe extrusion process.

4.3 Cost of poor quality (COPQ) Matrix: Cost of poor quality matrix was made from production sheets and reports of the company. It takes into account the cost encountered by the company as cost of poor quality. Different types of defects that were prevalent included unbalanced wall thickness, diameter variation, surface defects, pipe out of round, discolored material, circumferential waviness and melt fracture. When the process was analyzed, Loss per month in number of pieces was calculated that was due to rework. Corresponding loss per month for all the shifts was calculated. COPQ due to pipe defects was Rs. 2,88,360 (refer to Table 2).

Table-2: Cost of poor quality

S.No.	Defects	Loss (Nos.) Per month	Total Loss (Rs) Per month
1	Unbalanced wall thickness	218	141264/-
2	Diameter variation	48	31104/-
3	Surface defects appearing at the die	64	41472/-
4	Pipe out of round	32	20736/-
5	Discolored material	32	20736/-
6	Circumferential waviness	44	28512/-
7	Melt fracture	3	1944/-
8	Miscellaneous Defects	4	2592/-

COPQ is very high in the present case study. It was observed that due to unbalanced wall thickness company encountered a loss of Rs 1,41,264 (218 pieces per month).

4.4 Project Charter

Project Charter carries information about title of project, project team, project plan, project scope, opportunity statement and goal statement (refer to Fig 3). Business case is a broader statement depicting the reasons for undertaking the project. Opportunity statement is a secondary objective of the project that is associated with the business case. Goal statement is the specific aim of the project for which research has been conducted to focus in a narrow direction. Project scope describes the expected outcome of the Six Sigma project. Project plan lays down a road map for the project within specific time limits. Team selection is a critical part of the project charter that defines team members who are responsible for the successful project completion.

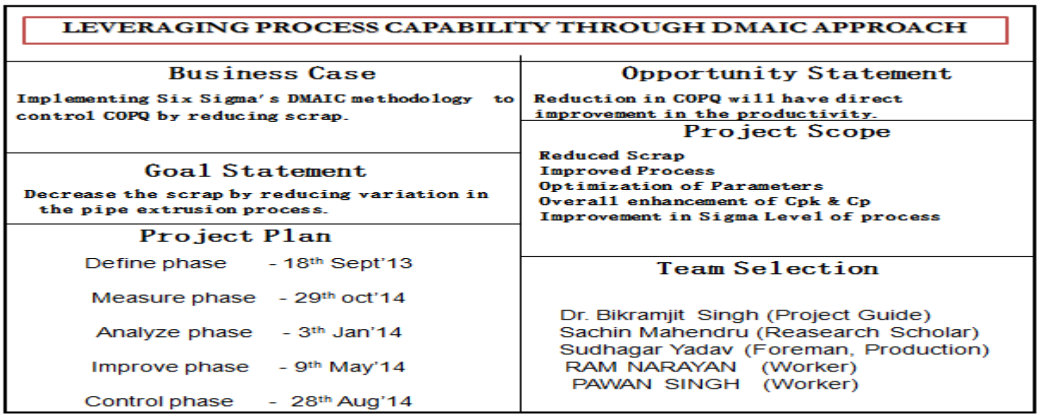

Figure-3: Project Charter

The span of this project was planned for the duration of 11 months. It was found in the opportunity statement that reduction in COPQ will have direct improvement in the productivity as well as the defect rate can be reduced by reducing the process variation.

V. CONCLUSION

Define phase is an important phase of DMAIC methodology. It tells about Company's profile including product capacity of the plant, product range was studied. Critical process metrics was found thereby focusing the study on variation of the weight. To study the weight variation process capability analysis was performed. It was found that standard deviation of the process was 0.64460 that means that process mean differ significantly from target values. Value of C_{pk} was 0.02 which is a very low capability. Corresponding sigma level was around 1.5. COPQ matrix unveiled that company was suffering for huge losses and the COPQ per month was around Rs 2,88,360. Project charter was formed, defining reasons for undertaking the project, target benefits and baseline for the project.

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