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INSE 6210

Total Quality Methodologies in Engineering

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Final Project Report:

Improving the fuel tank manufacturing process Cycle time of Kautex India

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Executive Summary:

Kautex - A Textron Company is one of the largest automotive suppliers. It has more than 30 plants in 14 countries, and this six-sigma project is implemented in the Kautex India, Viramgam Plant. This Plant manufactures BS6 Regular and BS6MCA Petrol/Diesel fuel tanks for Ford and Mahindra companies. It is a semi-automated plant with advanced machines. From the last three months the Fuel tank manufacturing time has been increased to 15 minutes from 13 minutes.

We have applied Six Sigma DMAIC methodology to reduce this cycle time to 13 minutes. We have defined the project charter and created a SIPOC diagram to get a high-level understanding of the process.

We developed the data collection plan after performing Gauge R&R study. From the Process Capability Study, it is inferred that Process is running outside of customer specification. The IMR Control charts have been analyzed to find the specific process in which cycle time has been increased.

From the Analyze stage, we concluded that two processes; Blow molding process and Ultrasonic Leak Testing Process, are taking more time than the standard cycle time. We have used FMEA and 5Why methods to identify root causes and actions to eliminate these root causes.

The improvement plan has been developed using Kaizen and Poka-Yoke. The improvement has been recorded though the IMR control charts. The Control Plan has been created for effective operation and monitoring. Finally, Project is handed over to the Operating team.

Introduction:

Six Sigma is an approach with a set of management tools and techniques intended to improve product, process or service by significantly reducing the probability of defect occurrence. The Six Sigma is derived from a Bell curve (Normal Curve) used in statistics where one Sigma signifies the one standard deviation away from the mean. The defect rate decreases as the sigma level increases and defect rate for the six-sigma process is 3.4. There are several frameworks used in Six Sigma and we are using the DMAIC framework.

Cycle time is an important process parameter for every industry. The growth and profit of industry is directly or indirectly dependent on the cycle time. The cycle time is defined as the time required to manufacture per unit product. If the cycle time increases than the standard, the process consumes more resources including raw material and electricity, which results in the increased production cost. The increased cycle time reduces the production capacity and results in the delayed delivery to the customers.

In this project, we focus on the cycle time and implement DMAIC methodology to reduce the cycle time of a Fuel Manufacturing Company.

DMAIC:

Fig. 1 DMAIC Phases

DMAIC refers to Define, Measure, Analyze, Improve and Control. DMAIC is a data-driven quality strategy that emphasizes the development of existing systems. Using various statistical tools and techniques the customer needs, product defects and root cause are identified. Several initiatives are taken to eliminate the root causes for the improvement of the process. The control plan is developed for easeful controlling and monitoring of the process.

Project Objective

Problem Statement:

The manufacturing time per unit is increased to 15 minutes from 13 minutes. This surge in cycle time leads to delayed fuel tank delivery to the customers.

- Customers have complained about this issue and two main customers; Mahindra Sanand Plant and Ford Sanand Plant have reduced their orders by 35%. Due to this increased cycle time, the company reputation, profit and customer satisfaction has been jeopardized.

Project Goal:

To reduce the manufacturing time per unit back to 13 minutes from 15 minutes on dated 1st May 2021.

1. Define:

1.1. VOB and VOC:

We have captured the Voice of Business from Kautex India, Viramgam and Voice of Customer from Mahindra Sanand Plant and Ford Sanand Plant. The Critical to Quality and Critical to Process align with each other so after the accomplishment of this project, there will be a win-win situation from Business as well as customer.

Critical to Quality (CTQ) and Critical to Process (CTP) for this project is to reduce the average cycle time to 13 minutes from 15 minutes.

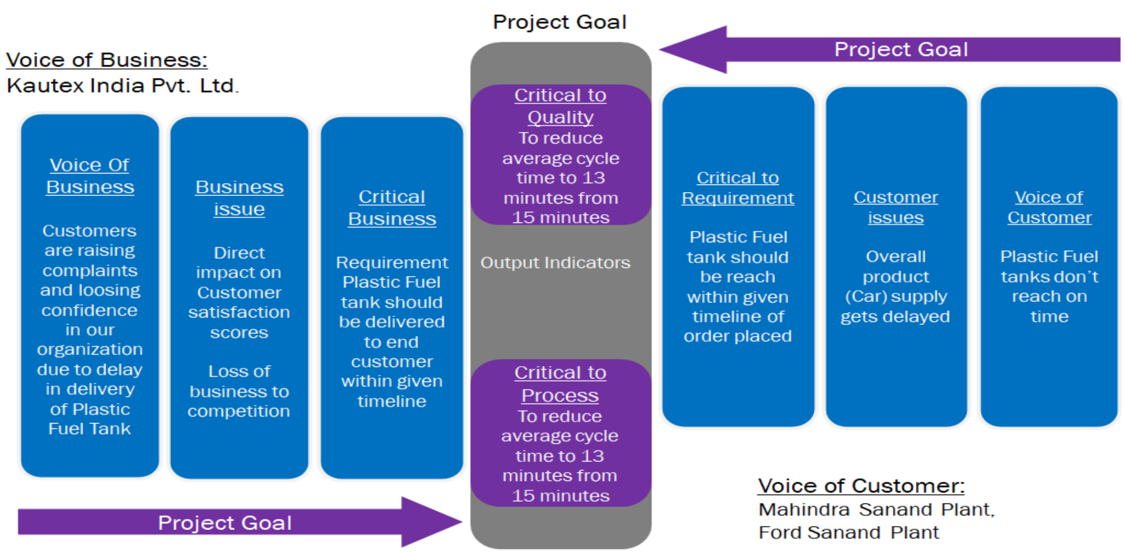

Fig. 2 VOB and VOC

1.2 Project Charter:

GENERAL PROJECT INFORMATION	
Project Name:	Improving the Fuel tank Manufacturing Process Cycle time of Kautex India, Viramgam with DMAIC framework
Organizational Unit:	Production Unit
Process Impacted:	Fuel tank production
Expected Start Date:	January 2021
Expected Completion Date:	April 2021
Expected Savings:	$130,000
Estimated Costs:	$25000
Green Belts Assigned:	02
Black Belts Assigned:	01

PROBLEM, ISSUE, GOALS, OBJECTIVES, DELIVERABLES	
Problem or Issue:	Delayed Fuel Tank delivery to customer
Purpose of Project:	Make Fuel tank manufacturing process fast to meet the deadline of delivery to customers and reduce the waste of raw materials
Goals/Metrics:	To reduce the manufacturing time per unit back to 13 minutes from 15 minutes on dated 1st May 2021.
Expected Deliverables:	Fast and timely product delivery, Increased production, cost-effective process

PROJECT RESOURCES & COST	
Project Team	Amit Kumar Shivam Pandya
Resources	Human Resources: Electrical and Instrumentation engineers, Operators, Six sigma Green belts team Components: Electrical and electronic tools, AutoCAD software, PLC, HMI WorkPlace: WorkStation for operation Cost: $25000
Special Needs	Personnel with Experience in PLC Integration

PROJECT BENEFITS & CUSTOMERS	
Process Owner	Increased Profit and loyal customers
Key Stakeholders	Process become more efficient
Final Customers	On time delivery of high-quality fuel tanks
Expected Benefits	Efficient and fast production of fuel tanks

PROJECT RISKS, CONSTRAINTS, ASSUMPTIONS	
Risks:	Potential System Failure due to lack of training
Constraints:	Principles of PMBOK, ISO 9001:2008

Team Charter	
Champion	VP Operations – Kautex India
Sponsor	General Manager
Mentor	Dr. Nizar Bouguila
Process Owner	Kautex India

Milestones		
Define	Start Date: 5th Jan'21	End Date: 20th Jan'21
Measure	21th Jan'21	25th Feb'21
Analyze	26th Feb'21	26th Mar'21
Improve	27th Mar'21	17th Apr'21
Control	18th Apr'21	1st May'21

1.3 ARMI & Communication Plan

ARMI & Communication Plan is defined to make communication effective and transparent. This plan helps to avoid any confusion or misunderstanding between teams. As Six sigma projects require a multidisciplinary approach, this plan helps to maintain the communication between several teams.

Here ARMI stands for;

- A = Approver of team Decisions
- R = Resource or subject matter expert
- M = Member of team
- I = Interested party who will need to be kept informed

ARMI Worksheet

Key Stakeholders	Define	Measure	Analyze	Improve	Control
Stakeholders – General Manager	I	I	I	I	I
Sponsor – VP	A	A	I	A	A
Hod of Production	I	I	I	I	I
Quality head	I	R	I	I	I
Black Belt	I	A	M/A	M	M
Team Members	I	R	R	I	I

Communication Plan

Message	Audience	Media	Who	When
Project Status	Leaders	Email	Black belt	Weekly
Project activities & Deliverables	Team members	Email, conference calls, meeting	Black Belt/Members	Weekly

1.4. SIPOC Diagram:

SIPOC refers to Suppliers, Inputs, Process, Outputs and Customers. SIPOC diagrams provide a high-level understanding of the process and help to identify the scope of the project. Here the Six steps of the Fuel tank manufacturing process are the scope; whereas, suppliers and storage process are out of the scope of this project.

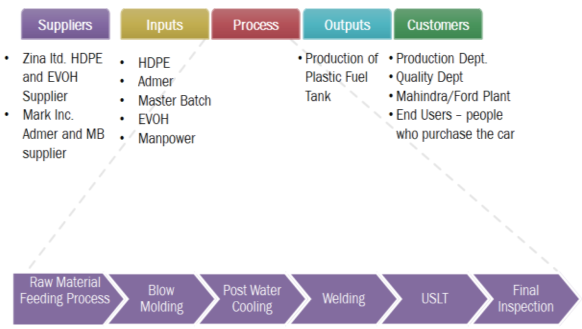

Fig. 3 SIPOC Diagram

Process Map:

This is the process map of Kautex India. The fuel manufacturing process starts from the Raw material feeding system and then the raw material fed to the blow molding machine, where the fuel tank cast is prepared. There are several testing performed on the fuel tank i.e. post water cooling test, and ultrasonic leak test. There are three inspection stations between these stages and the fuel tank has to pass from all of these inspections before reaching customers.

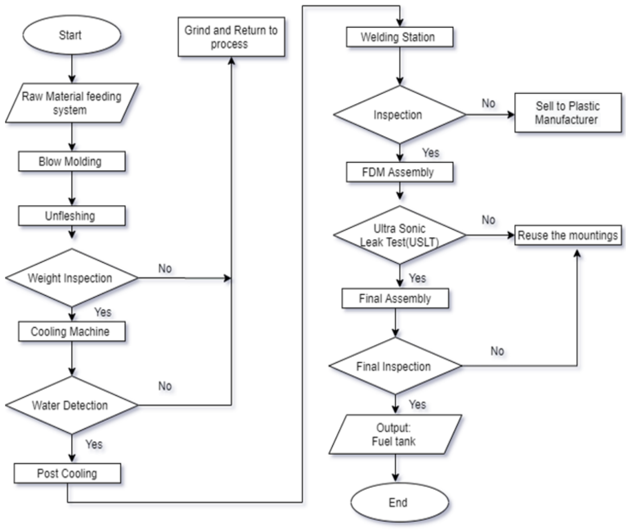

Fig. 4 Process Map

2. MEASURE PHASE:

2.1. Gauge R&R Study

We have performed Gauge R & R study to check the Accuracy, reproducibility and repeatability of Measurement system analysis. Here the Parts*Operator variation is 0.650, which is greater than 0.05.

Two-Way ANOVA Table With Interaction

Source	DF	SS	MS	F	P
Parts	9	168.430	18.7145	142.556	0.000
Operator	2	0.116	0.0580	0.442	0.650
Parts * Operator	18	2.363	0.1313	1.554	0.103
Repeatability	60	5.069	0.0845		
Total	89	175.978			

α to remove interaction term = 0.05

Fig. 5 Two-Way ANOVA Table

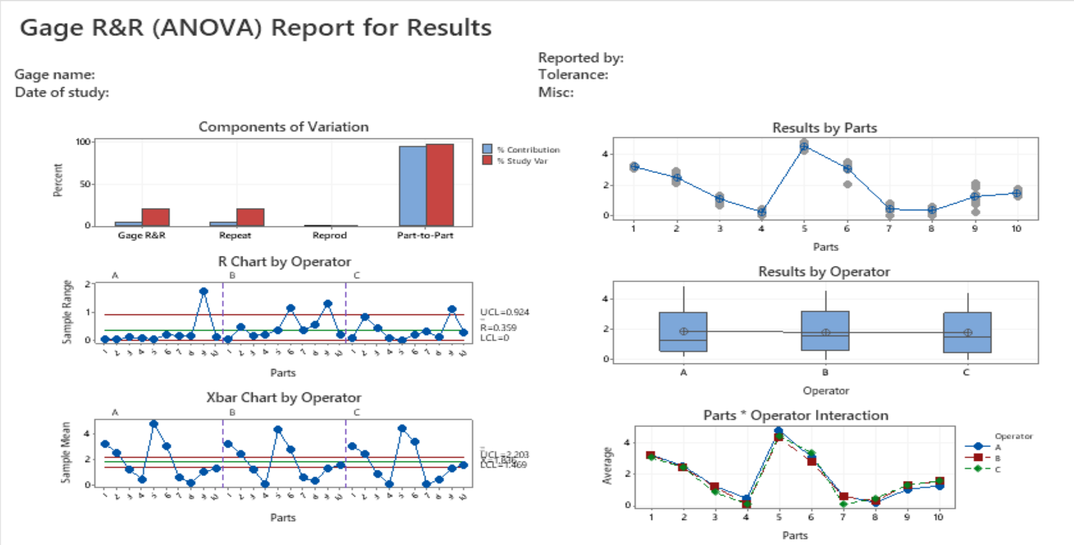

Fig. 6 Gauge R & R Reports for Results

From Components of variation graph, part to part variation is higher than all three that is Gauge R&R, Repeatability and Reproducibility. The R Chart by Operator shows that Operator B measures parts inconsistently. In the X Bar Chart by Operator, most of the points are outside the control limits. Thus, much of the variation is due to differences between parts.

Parts to operator P value is 0.103, which is greater than 0.005 so that instrument accuracy, Repeatability and Reproducibility is acceptable.

Gage Evaluation

Source	StdDev (SD)	Study Var (6 × SD)	%Study Var (%SV)
Total Gage R&R	0.30867	1.85203	20.98
Repeatability	0.30867	1.85203	20.98
Reproducibility	0.00000	0.00000	0.00
Operator	0.00000	0.00000	0.00
Part-To-Part	1.43833	8.63000	97.77
Total Variation	1.47108	8.82648	100.00

Number of Distinct Categories = 6

Fig. 7 Gauge Evaluation

The number of Distinct Categories is 6, which is greater than 5, & the total Gage R&R variance is 20.98, which is acceptable under certain condition so we can work this measurement system.

2.2. Data Collection Plan

It is essential to develop a data collection plan before collecting data, it helps to make data collection process transparent and organization. We are going to collect the 30 readings of cycle time to perform analysis.

Y	Operational Definition	Defect Definition	Performance Standard	Specification Limit	Opportunity
To reduce Cycle Time	Fuel tank cycle time should not be more than 13 minutes	More then 13 minutes cycle time per unit production of Fuel tank	13 minutes	12.5 minutes-13.5 minutes	Weekly
Mode of Collecting Data					
Y	**Data Type**	**Unit**	**Decimal Used**	**Data base Container**	**Existing or new data base**
To reduce cycle time	Continuous	minutes	3	Excel	New 1 month data
Formula to be used	**Data item required**	**Equipment used for measurement**	**Equipment calibration information**	**Responsibility**	**Any Training Required**
Total Production/total time	Cycle time	Timer	Weekly	Black Belt	Yes

2.3. Process Capability Study

We have performed Anderson-Darling Normality test to check whether the process data is normally distributed or not. If the data is normally distributed and stable, then and only then we can find Process Capability.

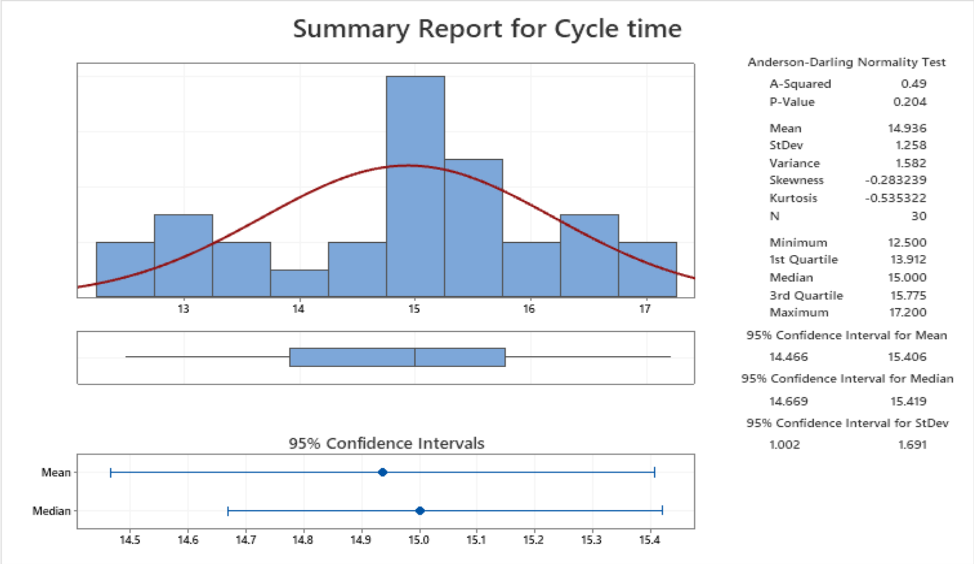

Fig. 8 Normality Test

- This report for cycle time the threshold value is 0.05 and the P-value of report is 0.204. It means the p-value of report is greater than threshold value. So, the data is normally distributed and we can perform Process Capability study.

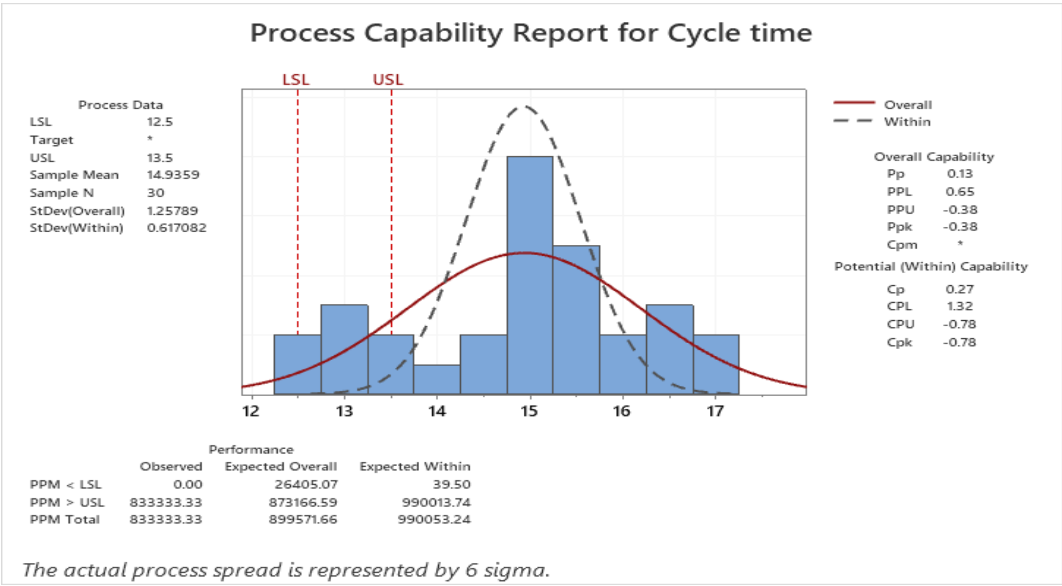

Fig. 9 Process Capability Report

- The value of Cpk is -0.78 of process capability report for cycle time which is less than 1.3, it means the process is incapable to perform as per customer specification and the system is running outside of the LSL and USL. The previous mean is 13 but now due to slow process the mean is 15.

- Here, PPM (Parts per million) is 833333.3.

- We have taken total 30 readings of cycle time, and among them 25 reading are out of the USL and LSL. There are 6 stages in the process, so there will be 6 opportunity.

DPMO (Defects per million opportunities) = 25/(30*6) * 1000000 = **138889**

Sigma level of this process is 2.58σ with 1.5σ shift.

3. Analyze Phase

Analyze is the third phase of the DMAIC process, where the problems are studied. We have analyzed the various IMR (individual and moving range) control chart of each manufacturing stages and we found two stages where the processing time has been increased by one minute each and these are Blow moulding and USLT (ultrasonic Leisure testing).

Cycle time is Continuous data type and the group size is less and 2, so we have analyzed the IMR Control Charts.

IMR charts of Blow Molding Process

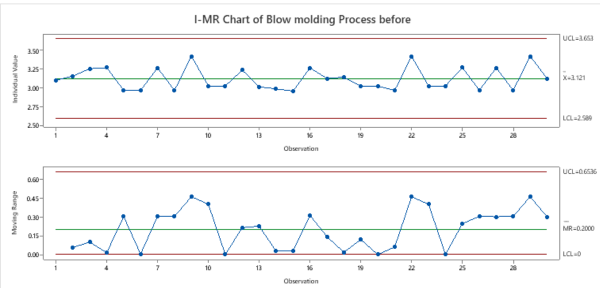

Fig. 10 IMR Chart of Blow Molding Process BEFORE

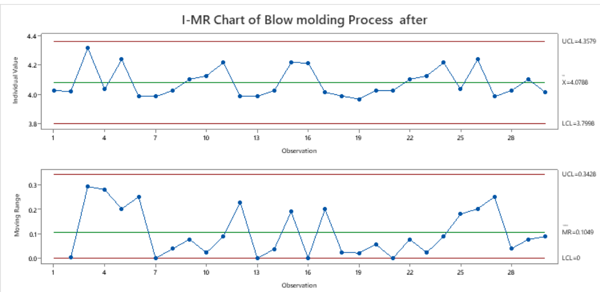

Fig. 11 IMR Chart of Blow Molding Process AFTER

- From the control chart shown above of the Blow Molding Process the average process time has increased to 4.0 minutes from 3.12 minutes.

IMR Charts of USLT Process

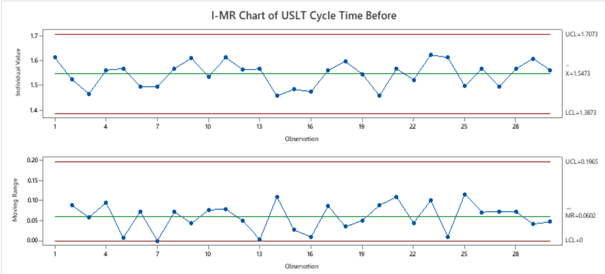

Fig. 12 IMR Chart of USLT BEFORE

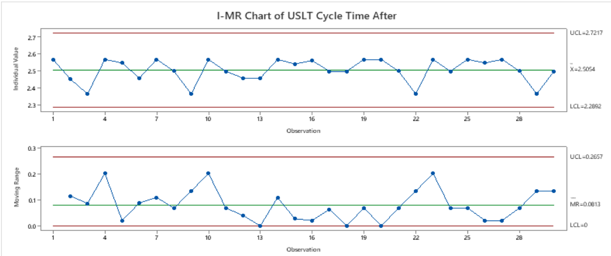

Fig. 13 IMR Chart of USLT AFTER

- From IMR control chart of USLT station the average process time has been increased 2.50 minutes from 1.54 minutes

3.1 Fishbone Diagram:

(For Blow Molding Process)

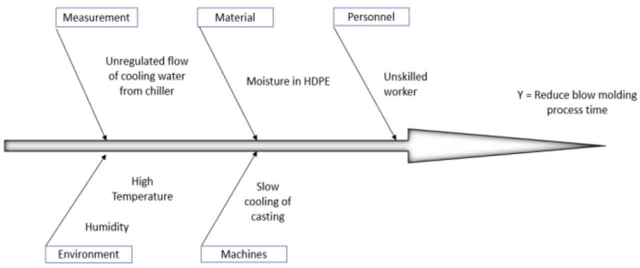

Fig. 14 Fishbone Diagram for Blow Molding Process

We have brainstormed potential causes for Blow Molding machine that contributes in the increased cycle time.

In the measure cause due to unregulated flow of cooling water from chiller

In the material the cause is due to moisture in HDPE (high density polyethylene)

In the personnel, due to unskilled work or untrained workers make the system slow.

Environment is one the cause and which happened due to humidity and high temperature around the blow molding. Last is machines due to the slow rate of cooling newly formed casting in the blow molding. All this causes reduced blow molding process time due which the overall process gets slow.

3.2. Pareto Chart

(For Blow Molding Process)

- Pareto chart state that the unregulated flow of chilled water, High temperature of blow molding and some contribution of slow cooling of fuel tank casting are the major root cause of blow moulding which is 80% of the total delay in blow molding process that why their cycle time is increased by actual time.

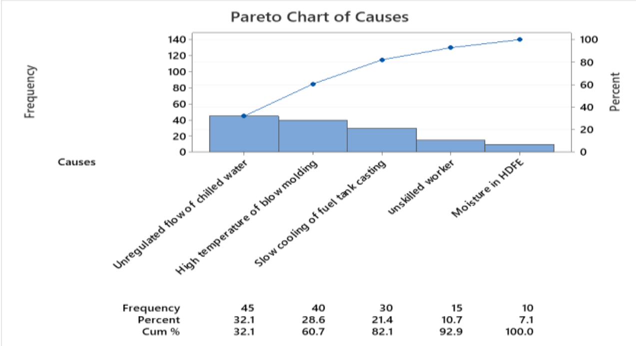

Fig. 15 Pareto Diagram for Blow Molding Process

3.3. Failure Modes and Effects Analysis (FMEA)

(For Blow Molding Process)

To identify the root causes which increase the Blow Molding Process Cycle time, we have used FMEA method. Here, various failure modes of Blow molding machines are brainstormed and the possible effects on the

FMEA

Process Name: Blow Molding Process
Process Number: SBT 445
Date: 1/10/2020

FAILURE MODE	Possible effects	A) SEVERITY Rate 1-10 Severe	Possible Root Cause	B) OCCURRENCE Probability Rate 1-10 10=Highest Probability	Process Control detection	C) DETECTION Probability Rate 1-10 10=Lowest Probability	RISK PRIORITY NUMBER RPN AxBxC
Slow Cooling Mechenism	Long time in cooling cast	8	Unragulated chilled water flow	7	Temperature sensor reading for chiller	3	**168**
Watermark on the Part	Poor appearance	7	Water leakage/Chiller temp too low	2	Operator awareness and training	8	112
Part Weight less/more	Fitment issue	7	Wrong Core & Punch size	3	Operator awareness and training	6	126
Very high tempeature of Part	Part become brittle	8	low pressure of chilled water	6	Temperature sensor at Post water cooling	3	**144**

FMEA

Process Name: Blow Molding Process
Process Number: SBT 445
Date: 1/10/2020

FAILURE MODE	Possible effects	A) SEVERITY Rate 1-10 10=Most Severe	Possible Root Cause	B) OCCURREN CE Probability Rate 1-10 10=Highest Probability	Process Control	C) DETECTION Probability Rate 1-10 10=Lowest Probability	PRIORITY NUMBER RPN AxBxC	ACTION TO IMPROVE	REVISED VALUES A	B	C	RPN
Slow Cooling Mechnism	Long time in cooling cast	8	Unragulated chilled water flow	7	Temperature sensor reading	3	168	Change the Chilled water Control valve and use a high-quality valve for reliability.	8	3	5	120
Very high tempeature of Part	Part become brittle	8	low pressure of chilled water	6	Temperature sensor at Post water cooling	3	144	Detailed inspection of chilled water and repair of faulty fixtures.	8	4	3	96

Fig. 16 FMEA for Blow Molding Process

customers are identified. These effects on customers are rated using Severity ranking. Then, the potential root causes are depicted and rated them by Probability of Occurrence. Lastly, the current process control detection is considered and given Detection Probability. The Risk Priority Number (RPN) is the multiplication of Severity rate, Occurrence probability rate and detection rating. And it is high for two failure modes.

1. Slow Cooling Mechanism
2. Very high temperature of the part (cast)

Hence, the root causes are identified. Now the action to improve is brainstormed and implemented to mitigate these two failure modes and root causes.

Reassessment after implementing the action is crucial because after reassessing the FMEA, we know that the action to improve is effective and reduced the Risk Priority number.

3.4. 5-Why Analysis:

(For USLT Process)

To identify the root cause of the USLT process, we are using 5 Why analysis, in which the why question is being asked to the problem to find out the root cause of the problem.

Problem Statement:

USLT process time is increased to 2.5 minutes from 1.54 minutes.

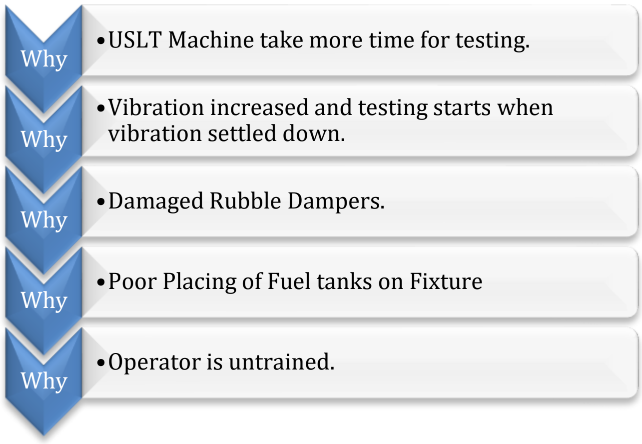

Fig. 17 5-Why Analysis for USLT Process

Root Cause: Operator is Untrained.

Untrained Operator Forcefully Fix Fuel Tank in the Fixture, and this damages the rubber dampers that absorbs the excess machine vibration. So, we need to take action to eliminate this root cause.

4. Improve:

In the Improve phase, the action is taken to eliminate the root causes that increased the cycle time for USLT and Blow molding processes. These are the actions taken to mitigate the one root cause for the USLT process and two root causes for the Blow Molding Process.

4.1. Improver Plan

The Actions for Improvement have been taken by brainstorming with experts and team members.

Root Cause	Action to Improve
For USLT Process:	
Operator is untrained	**Training Of USLT Machine Operators:** Supervisor will be responsible to provide training to all USLT Machine Operator where Operators learn; • How to Pick fuel tank from Conveyer belt. • Appropriate steps to fix fuel tank in fixture. • How to do Ultrasonic Leak Testing. • How to pull out fuel tank from the fixture. • How to put fuel tank on Conveyer belt.
	Displaying "How To" Diagram at USLT Station: Step-by-step guide for USLT testing including fixture placing will be displayed on the poster with Photos. This Poster will be placed beside USLT machine.
For Blow Molding Process:	
Unregulated Chilled Water flow	Change the Chilled water Control valve and use a high-quality valve for reliability.
Low Pressure of Chilled Water Flow	Detailed inspection of chilled water and repair of faulty fixtures.

Fig. 18 Improve Plan

4.2. Poka-yoke:

Mistake-proofing devices are used to prevent human error at the USLT station.

Type of Human Error: Lack of Skills

Mistake Proofing device: Photoelectric Switch

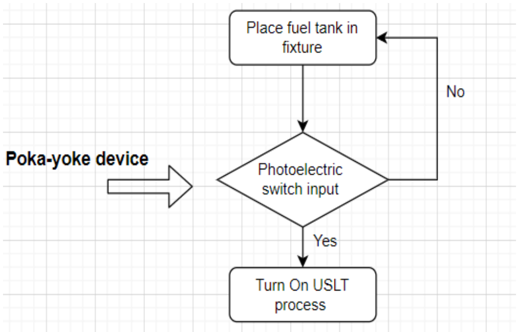

Fig. 19 USLT Poka-yoke

The photoelectric switch is placed on the fixture. This switch will give input only if Fuel tank is properly placed on the Fixture and when the photoelectric switch gets input, then and only then the USLT machine will start. So, if the Photoelectric switch doesn't get input, it means the operator needs to place the fuel tank properly.

5. Control:

The IMR chart is monitored to identify whether the project is successfully accomplished or not. The average cycle time has been reduced to 12.96 minutes. So, the implemented actions have successfully reduced the cycle time of the fuel tank manufacturing process.

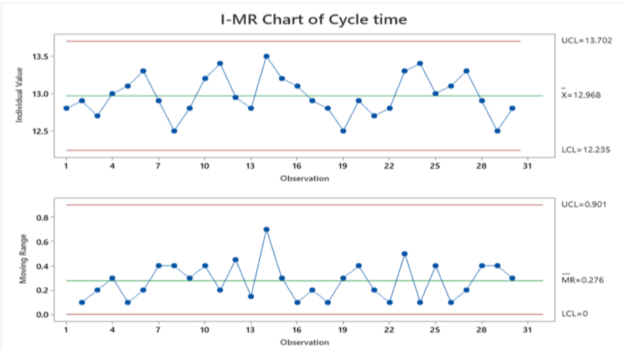

Fig. 20 IMR Chart of Cycle time After Six Sigma

It is crucial to create a Control plan. In the control phase, the responsibility of the Operating team is more than the Six sigma team. This Control plan guides the operating team and also suggests the reaction plan if any of these defects appear in the future.

Process	Metric Process Specification	Measurement tool	Responsibility	Frequency of check	Checked by	Reaction Plan
Blow Molding Process	LSL = 2.5 min USL = 3.5 min	Timer	Process Team Leader	15 days	Process Manager	1. Measuring the pressure and temperature of Cooling water 2. Check Cooling water Control valve
USLT Process	LSL = 1.4 min USL = 1.6 min	Timer	Process Team Leader	15 days	Process Manager	1. Check the Skill of Operator 2. Inspect rubber dumper

Fig. 21 Control Plan

Conclusion:

After successfully implementing the Six Sigma methodology, the fuel tank manufacturing process time (Cycle time) has been reduced to 12.96 minutes from 15 minutes, which is in fact 0.04 minute less than the standard, which is appreciable. Now Kautex India is able to manufacture the fuel tank as per the customer deadline. This helps them to get more orders from their customers and improves the company's reputation.

References:

- The Six Sigma Handbook – Thomas Pyzdek
- INSE 6210 Lecture Notes – Dr. Nizar Bouguila
- https://www.researchgate.net/publication/328849863_Fuel_Tank_Design_Optimization_in_Extrusion_Blow_Moulding
- http://ieomsociety.org/toronto2019/papers/405.pdf
- https://www.isixsigma.com/implementation/case-studies/case-study-reducing-purchase-order-cycle-time-part-1/
- https://www.plasticsnews.com/news/automotive-fuel-tank-blow-molder-kautex-may-be-selling-block
- https://asq.org/quality-resources/dmaic
- https://goleansixsigma.com/

Worklog:

Task Performed	**Start Date**	**End Date**	**Responsibilities**
Defining of Project	21/09/2020	01/10/2020	All the team members
Defining Phase	02/10/2020	14/10/2020	Shivam Pandya
Measure Phase 1.Gauge R & R Study 2.Data Collection Plan	15/10/2020	26/10/2020	Amit Kumar
Measure Phase 3.Process Capability Study	15/10/2020	26/10/2020	Shivam Pandya
Analyzing the data 1.Fishbone Diagram 2.Pareto Chart	27/10/2020	05/11/2020	Amit Kumar
Analyzing the data 3. 5-Why Analysis 4. FMEA	27/10/2020	05/11/2020	Shivam Pandya
Improvement phase	05/11/2020	10/11/2020	Shivam Pandya
Control Phase	11/11/2020	16/11/2020	Amit Kumar
Preparation of presentation slides	16/11/2020	21/11/2020	All the team members
Project documentation	22/11/2020	02/12/2020	All the team members