Reduce Rejection PPM of Slinger Height in Manufacturing component

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ROADMAP

- Overview
- Define
- Measure
- Analyse
- Improve
- Control

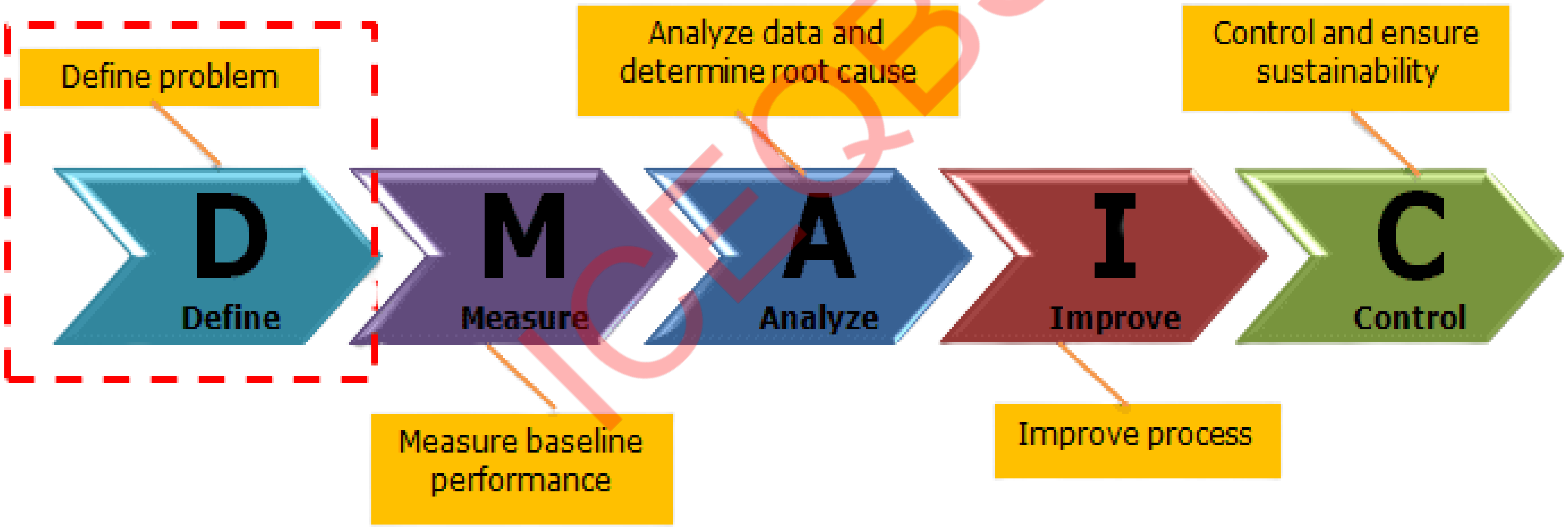
OVERVIEW

Background

The current in-process rejection level stands at 19,300 PPM, with slinger height variation contributing approximately 10,650 PPM, making it a major source of quality loss. These rejections result in significant material waste, rework, production delays, and increased operating costs, while also increasing the risk of customer complaints and reputational impact.

High rejection levels negatively affect process efficiency and equipment utilization, leading to reduced throughput and suboptimal Overall Equipment Effectiveness (OEE). Continued performance at this level will constrain capacity and limit the organization's ability to meet growing demand reliably.

DEFINE PHASE

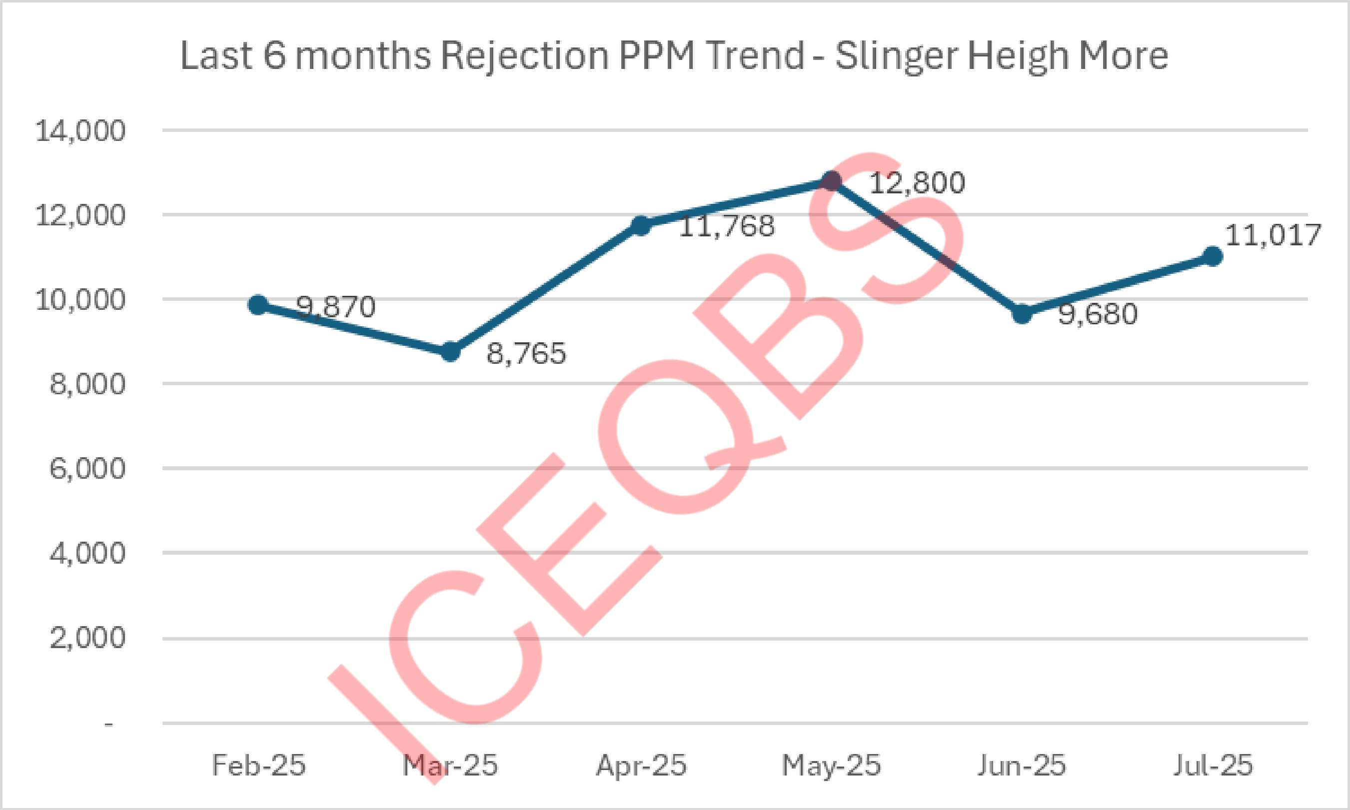


VOC & CTQ

CTQ Tree :

Voice of customer	Critical to X	Primary Metric for improvement
GM expects all slinger parts to meet height specifications for smooth assembly and zero rework; deviations have caused complaints.	CTQ – Slinger Height Rejection	**Primary Metric -** Y = % Rejection rate **Secondary Metric -** Productivity

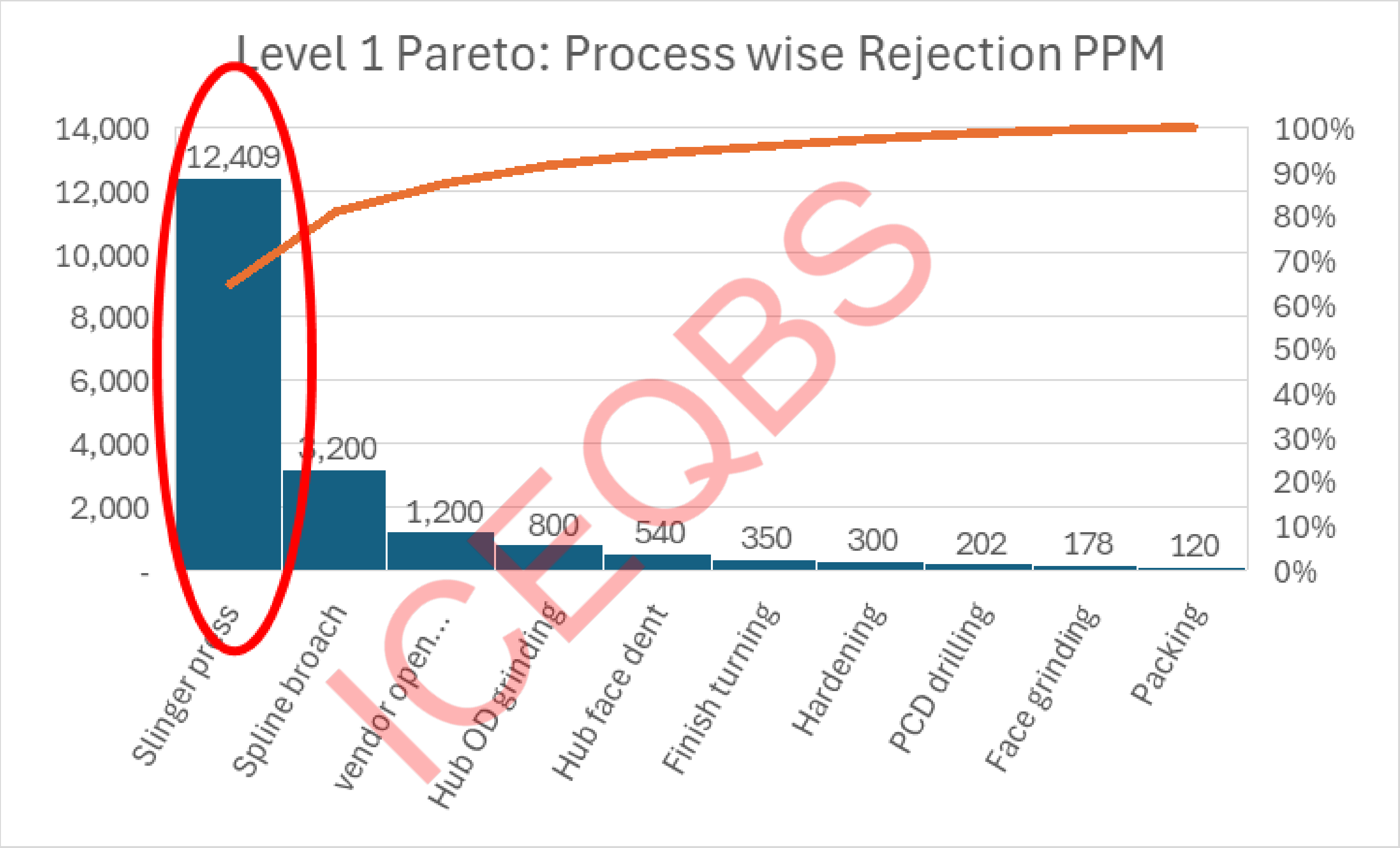
Baseline Performance of Primary Metric



Inference :

- Last 6 months data shows a significant variation and hence ideal problem to be taken up as a Six Sigma Project.

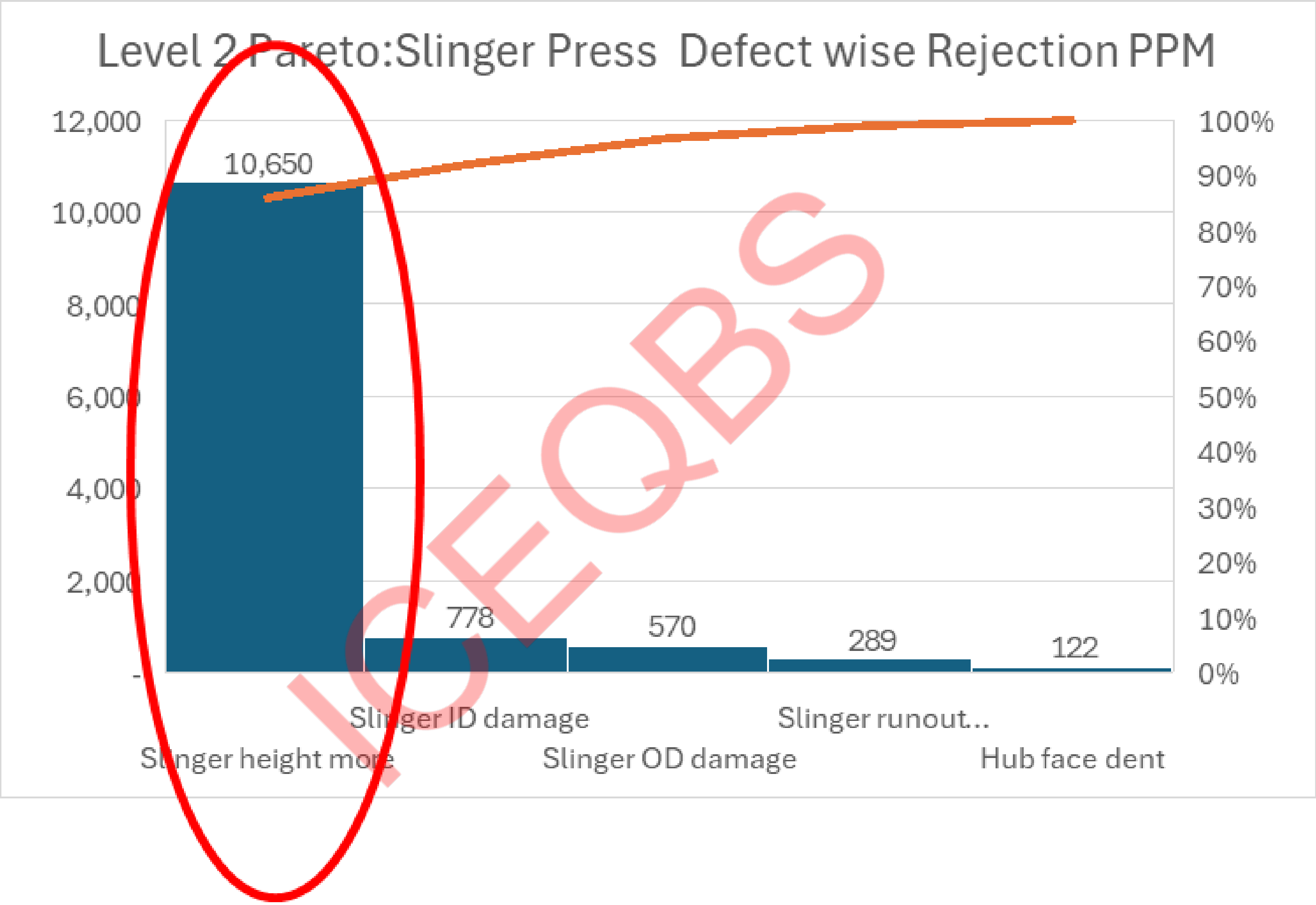
Pareto chart



Inference :

- Variation on slinger eight Process contributes substantially and included in the scope of the project

Pareto chart



Inference :

- Variation on slinger height Process contributes substantially and included in the scope of the project

Project Charter

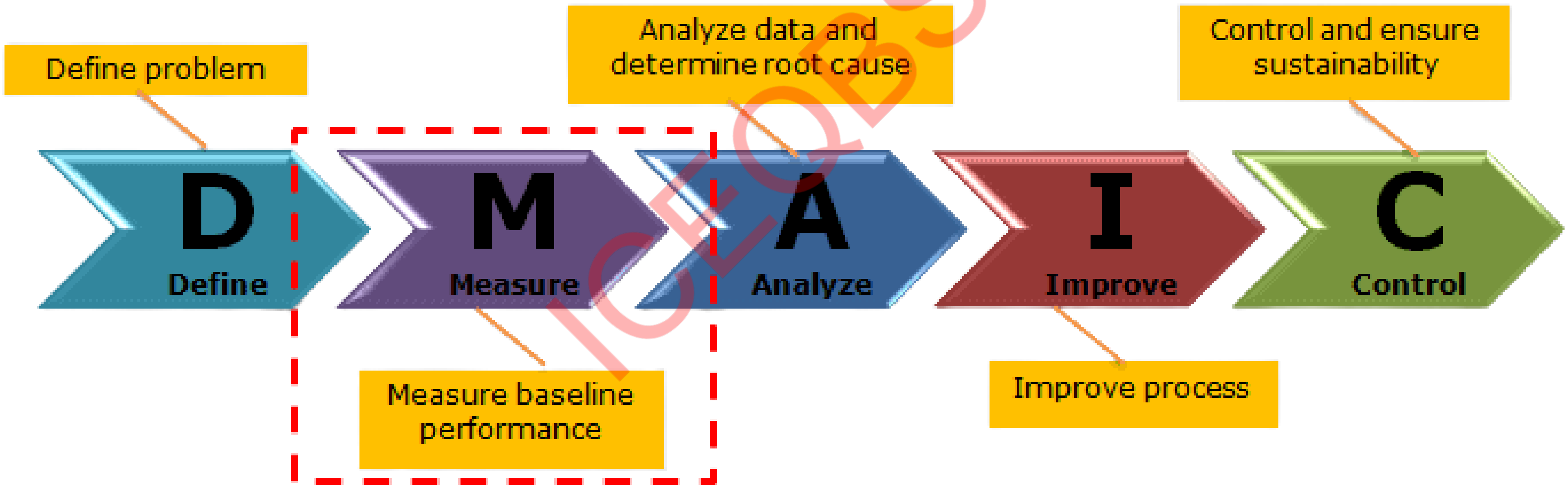
Project Title:	Reducing Slinger height Rejection PPM

Project Leader	Project Team Members:
Sonal	Anand Bhargav Charan Dritihi
Champion/Sponsors:	**Key Stakeholders**
Plant Head – Production	Plant Managers Production Quality team CNC operator
Problem Statement:	**Goal Statement:**
The current in-process rejection PPM is **19,300 PPM**, and **slinger height variation contributes 10,650 PPM**. This causes financial loss, production delays, and may lead to customer complaints. It also reduces process efficiency and can harm the company's reputation.	Reduce slinger height–related reject PPM from the current average of **29% to below 2% within 4 months**.
Secondary Metric	**Assumptions Made:**
Overall Equipment Effectiveness	Machine capability and press infrastructure remain stable during the project period. Required tooling, gauges, and inspection methods are available and calibrated.

Project Charter

Tangible and Intangible Benefits:	**Risk to Success:**
₹54 lakhs annual cost savings through reduction in scrap and rework. Improvement in **OEE from 72% to 76%** due to reduced downtime and rework.	Variation in operator adherence to new settings and standard work. Tool wear or machine condition changes affecting slinger height consistency.
In Scope:	**Out of Scope:**
press settings, tooling, grinding, operator skills, and inspection methods.	**Design changes to the slinger component or product specifications** are excluded from the scope of this project.
Signatories:	**Project Timeline:**
Process owner Sponsor	6 Months

MEASURE PHASE

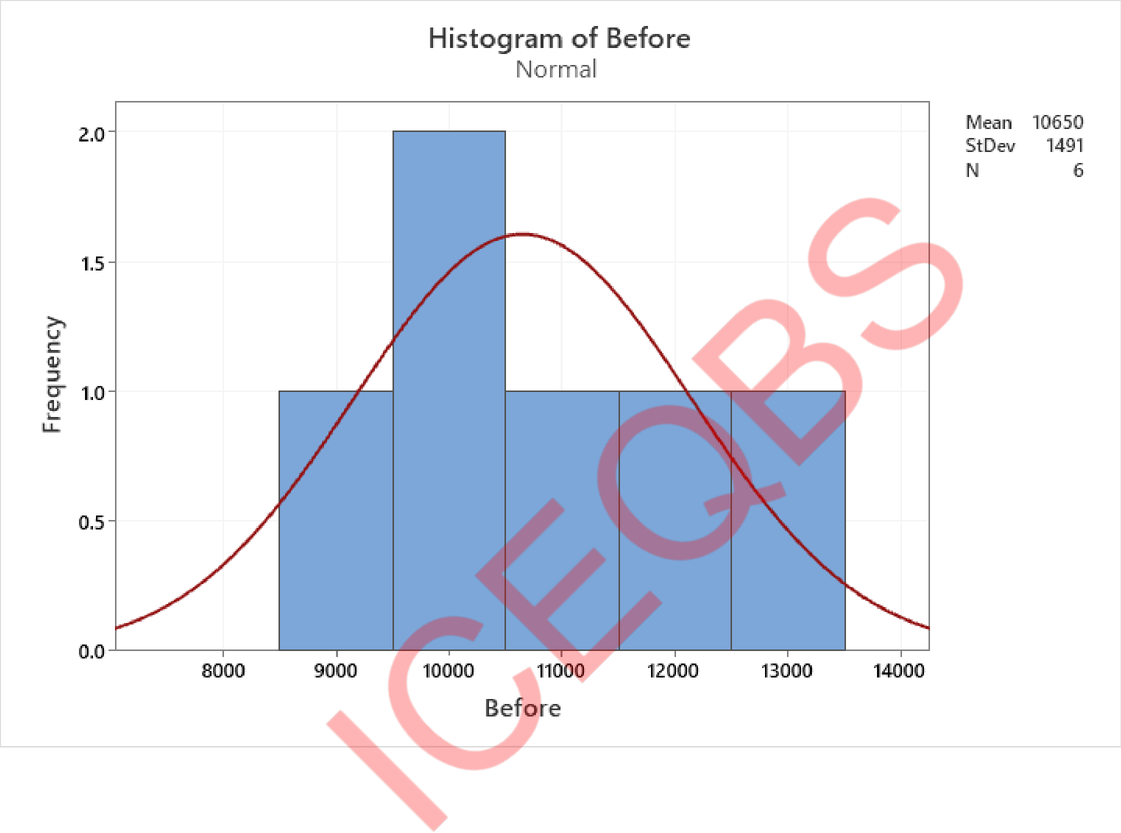


SIPOC

Suppliers	Inputs	Process Steps	Outputs	Customers
Raw material supplier	Slinger blank, GM CF part, hydraulic press setup	1.Load slinger and GM CF part 2. Press operation (apply pressure) 3. Grinding and finishing 4. Inspection of slinger height	Slinger part with correct height	Assembly team, End customer
Tooling supplier	Dies, Gauges, Hydraulic oil	Regular maintenance (AM/ PM)	Rejected/reworked parts if height exceeds spec	QC team, production supervisor
Training Department	Skilled operators, processed instructions	Skill matrix	High performance from operators	Customer and End-user

Process Mapping

Data collection – Histogram (Before improvement)



Inference :

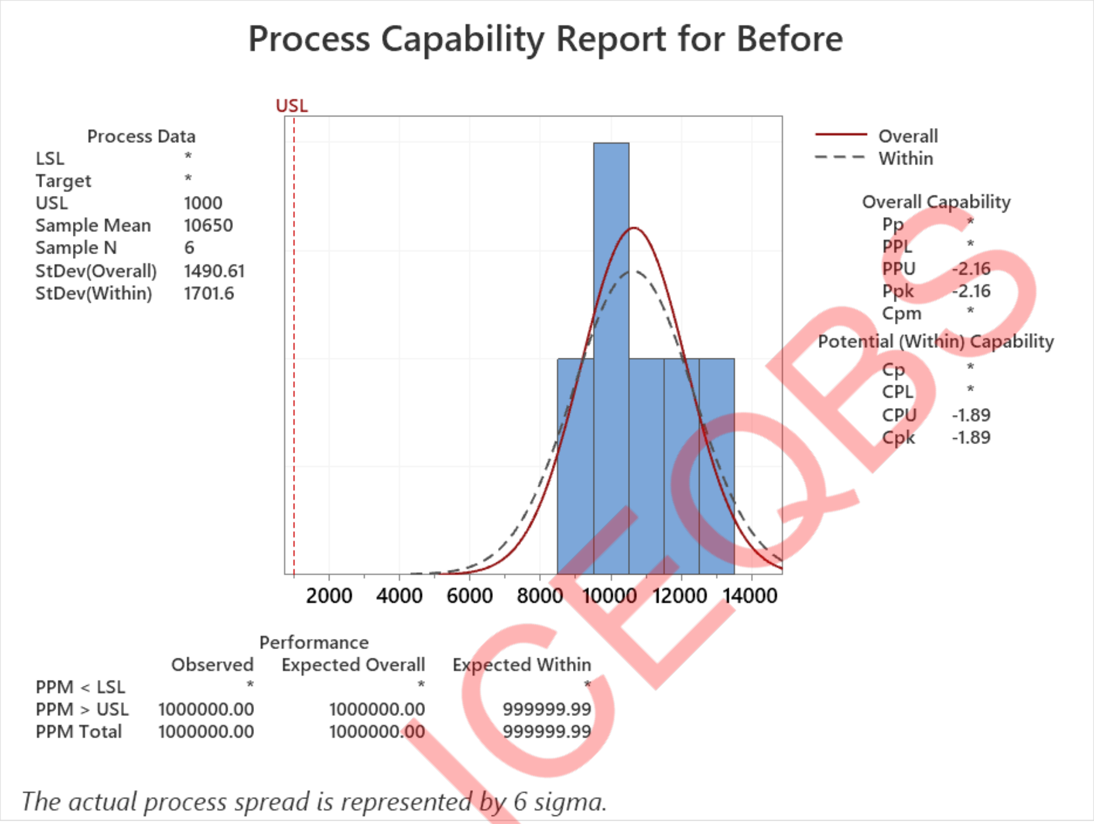
- Data is normally distributed over the mean

Data collection – Run Chart (Before improvement)

Inference :

Since all 4 p values >0.05, no special causes

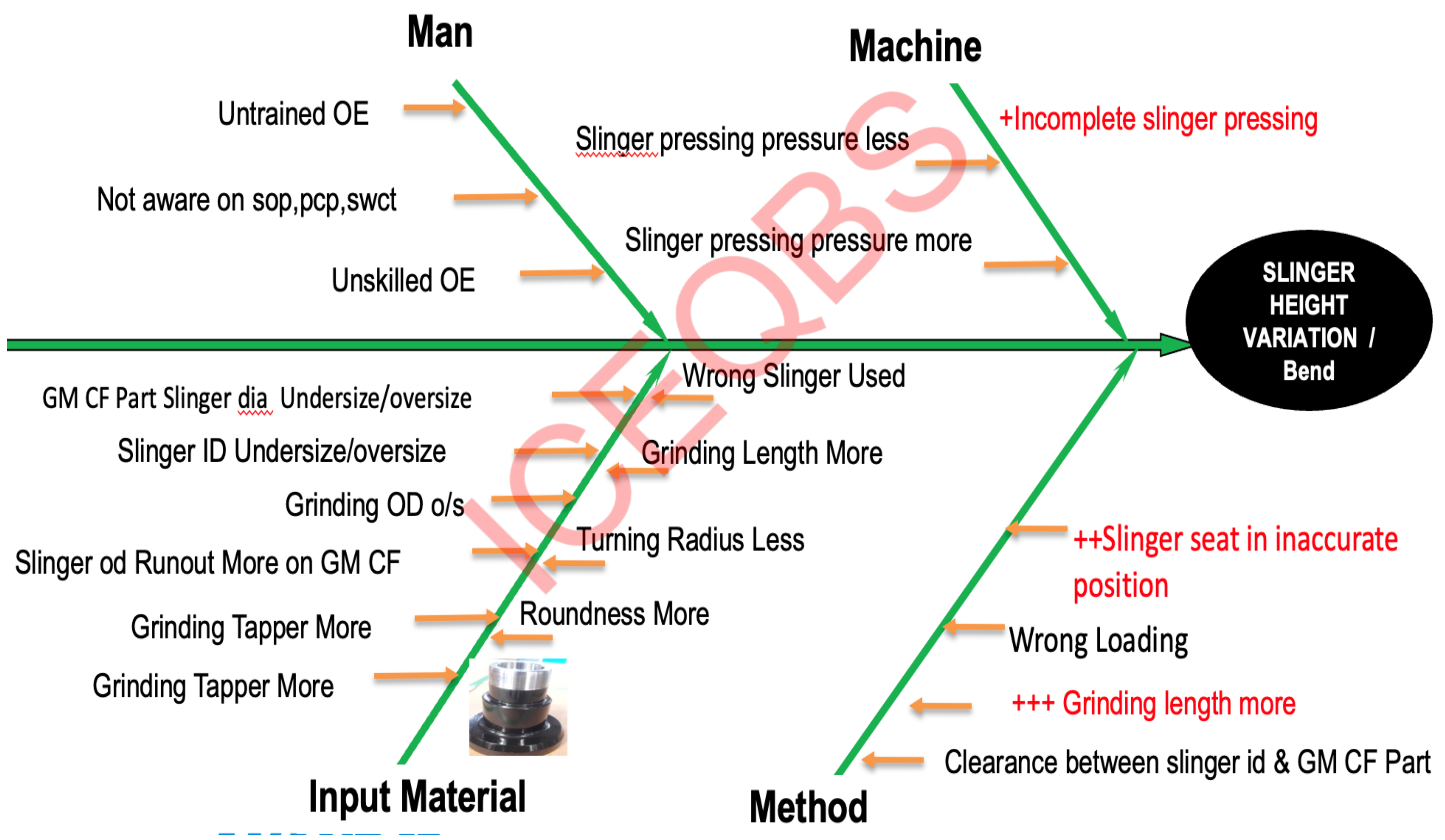
Process Capability



Inference :

- P > 0.05 in all scenarios, thus all the data is normally distributed

Fish Bone Diagram



Common and Special causes

Special Causes (Unusual, identifiable, or one-off issues)

- Slinger pressing pressure less than specification
- Slinger pressing pressure more than specification
- Slinger seat in inaccurate position
- Bending slinger to the wrong side
- Wrong slinger
- Grinding length more – part not detected
- Wrong loading

Common Causes (Systematic, recurring, related to process, equipment, or skill)

- GM CF Part slinger diameter undersize / oversize
- Slinger ID undersize / oversize
- Slinger OD runout more on GM CF
- Clearance between slinger ID & GM CF Part
- Grinding OD out of specification
- Grinding taper more than specification
- Grinding runout more
- Roundness more
- Grinding length more
- Slinger profile not ok
- Incomplete slinger pressing
- Unskilled operator (OE)
- Untrained operator (OE)

3M Analysis for Waste

Muda (Waste)	Non-value added activities	1. Reworking parts because height is too high 2. Running extra inspection cycles to measure height 3. Material/parts becoming scrap due to over-height
Mura (Inconsistency)	Variation / unevenness	1. Press pressure varies cycle-to-cycle causing different heights 2. Oil temperature changes leading to inconsistent cylinder movement 3. Variation in die/mould wear causing height
Muri (Overburden)	Overloading people or machine	1. Operator repeatedly adjusting pressure settings to correct height 2. Hydraulic press running at higher pressure than standard → machine stress 3. QC team overloaded with continuous height checks

8 Wastes Analysis

Type of Waste	Example 1	Example 2
1. Overproduction	Making slingers before confirming height	Producing extra parts "just in case"
2. Waiting	Operators waiting for inspection results	Machines idle until slinger height is verified
3. Transport	Moving slingers between departments for recheck	Shifting parts to storage before adjustment
4. Overprocessing	Multiple unnecessary machining passes	Re-measuring more than needed
5. Inventory	Stockpiling uninspected slingers	Keeping rejected parts before rework
6. Motion	Operators walking back and forth to measure	Reaching repeatedly for adjustment tools
7. Defects	Slinger height out of spec	Scrapped or reworked parts
8. Underutilized talent	Skilled staff doing repetitive checks	Employees not involved in process improvement

Action Plan for Low Hanging Fruits

Type of Waste (Special Cause)	Issue Identified	Lean Tool Used	Action	Owner	Timeline
1. Overproduction	Making slingers before confirming height	Pull System	Implement production based on customer demand	Production Lead	3 weeks
2. Waiting	Operators waiting for inspection results	Standard Work	Create standardized inspection process with in-line verification	Quality Head	4 weeks
3. Transport	Moving slingers between departments for recheck	Value Stream Mapping	Redesign layout to minimize movement	Layout Engineer	3 weeks
4. Overprocessing	Multiple unnecessary machining passes	Standard Work	Optimize machining parameters and standardize setup	Process Engineer	2 weeks
5. Inventory	Stockpiling uninspected slingers	Kanban	Implement two-bin system with clear flow	Stores Head	3 weeks
6. Motion	Operators walking back and forth to measure	5S	Implement point of use storage and tools	IE Head	2 weeks
7. Defects	Slinger height out of specification	Poka-Yoke	Install error proofing devices and monitoring system	Quality Engineer	4 weeks
8. Underutilized talent	Skilled staff doing repetitive checks	TWI	Develop multi-skill training program	Training Lead	3 weeks

Action Plan for Low Hanging Fruits

Special Cause	Issue Identified (Gemba Observation)	Lean Tool Used	Action	Owner	Timeline
Incomplete slinger pressing operation	Hydraulic oil leakage from hose pipe of slinger press machine due to hose pipe damage	1. 5S 2. TPM 3. Visual Controls	1. Hose pipe life re-defined 2. Create fixture maintenance schedule 3. Implement regular cleaning SOP	Tool Design/ Maintenance Engineer	4 weeks
Incomplete slinger seated position	Grinding wheel lock key was work out	1. 5S 2. TPM 3. Visual Controls	1. Hose pipe life re-defined 2. Create fixture maintenance schedule 3. Implement regular cleaning SOP	Tool Design/ Maintenance Engineer	3 weeks

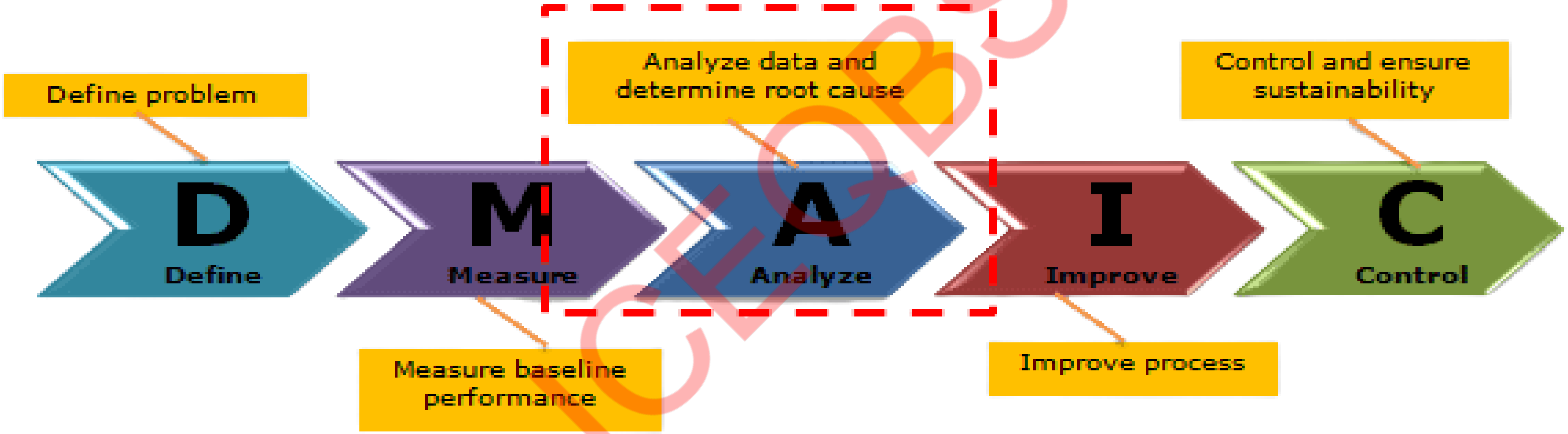
Top 12 Prioritized Root Causes (Based on Net Score)

Root Cause	Score
GM CF Part slinger diameter undersize / oversize	237
Slinger ID undersize / oversize	237
Slinger OD runout more on GM CF	175
Unskilled operator (OE)	161
Untrained operator (OE)	161
Grinding OD out of specification	159
Grinding taper more than specification	159
Incomplete slinger pressing	150
Roundness more	145
Grinding runout more	145
Slinger profile not OK	139
Clearance between slinger ID & GM CF	157

Data Collection Plan

Parameter	Sampling Frequency	Sample Size	Responsibility
Slinger Height Rejection PPM	Every shift (3 times/day)	100% inspection of produced parts	Quality Inspector
Rejection Downtime	Real-time monitoring	All downtime incidents	Production Supervisor
Grinding Length	Every 2 hours	5 pieces per batch	Machine Operator
Grinding Runout	Start of shift + every 4 hours	3 pieces per check	Quality Inspector
Pressing Pressure Variation	Every hour	10 pieces per check	Process Technician
Transport Movement Time	Twice per shift	Track 20 pieces per study	IE Coordinator

ANALYSE PHASE



Analyse – Hypothesis testing

Regression Equation

Rejection_PPM = 79.4 + 5406 OD_Runout_mm - 32.5 Training_Status - 93.58 Skill_Level + 13925 Grinding_Taper_mm

Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	79.4	27.9	2.85	0.009	
OD_Runout_mm	5406	1761	3.07	0.005	166.80
Training_Status	-32.5	11.0	-2.95	0.007	6.14
Skill_Level	-93.58	9.60	-9.74	0.000	5.05
Grinding_Taper_mm	13925	2958	4.71	0.000	159.78

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
11.4722	99.84%	99.81%	99.75%

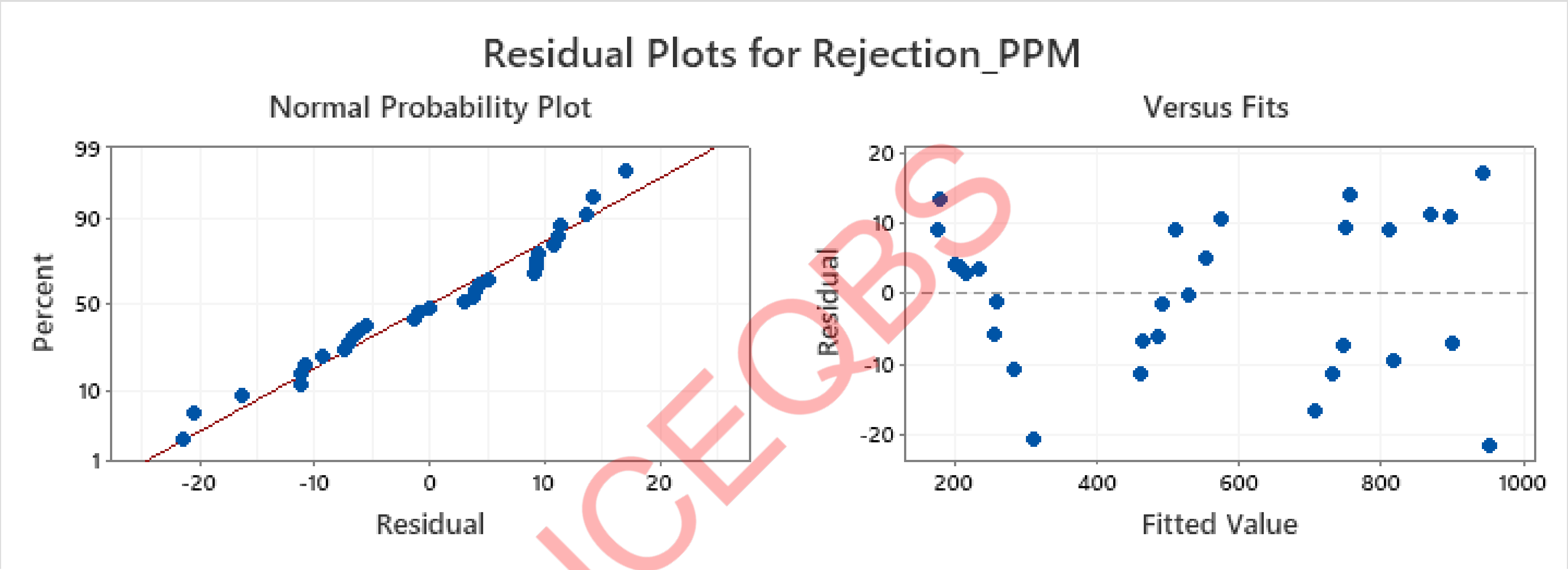
Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	4	2028290	507072	3852.81	0.000
OD_Runout_mm	1	1240	1240	9.43	0.005
Training_Status	1	1147	1147	8.72	0.007
Skill_Level	1	12495	12495	94.94	0.000
Grinding_Taper_mm	1	2916	2916	22.15	0.000
Error	25	3290	132		
Total	29	2031580			

Inference :

- OD runout and grinding taper significantly increase rejection PPM, while operator training and skill level significantly reduce it, making these the key root causes to address in the Improve phase.

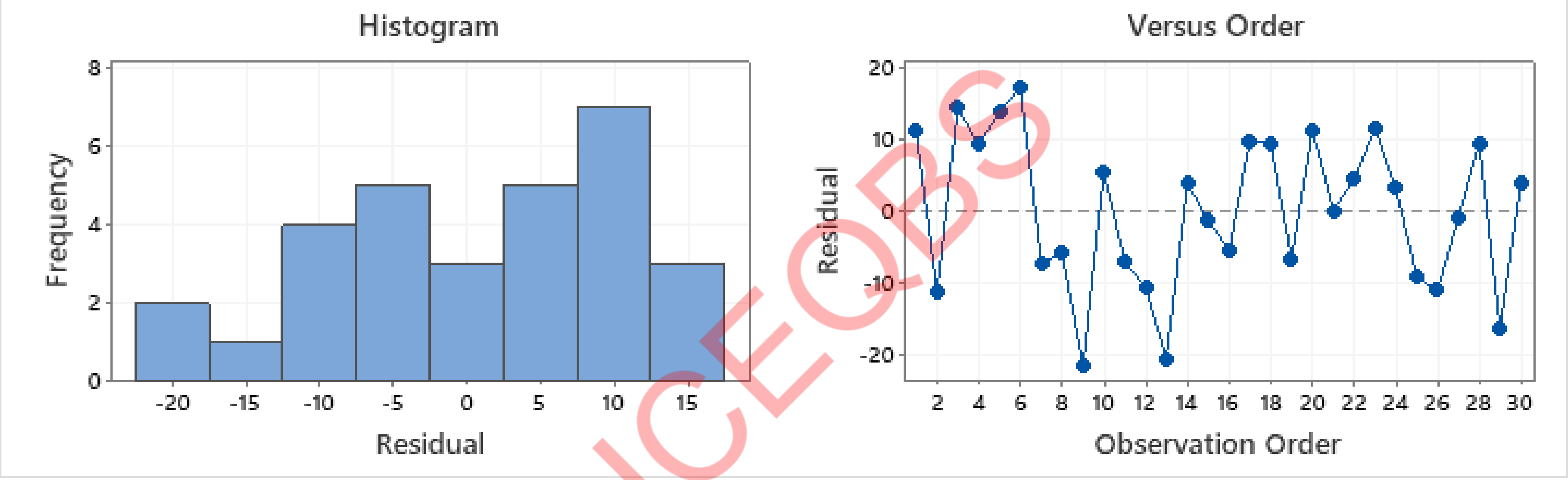
Analyse – Hypothesis testing



Inference :

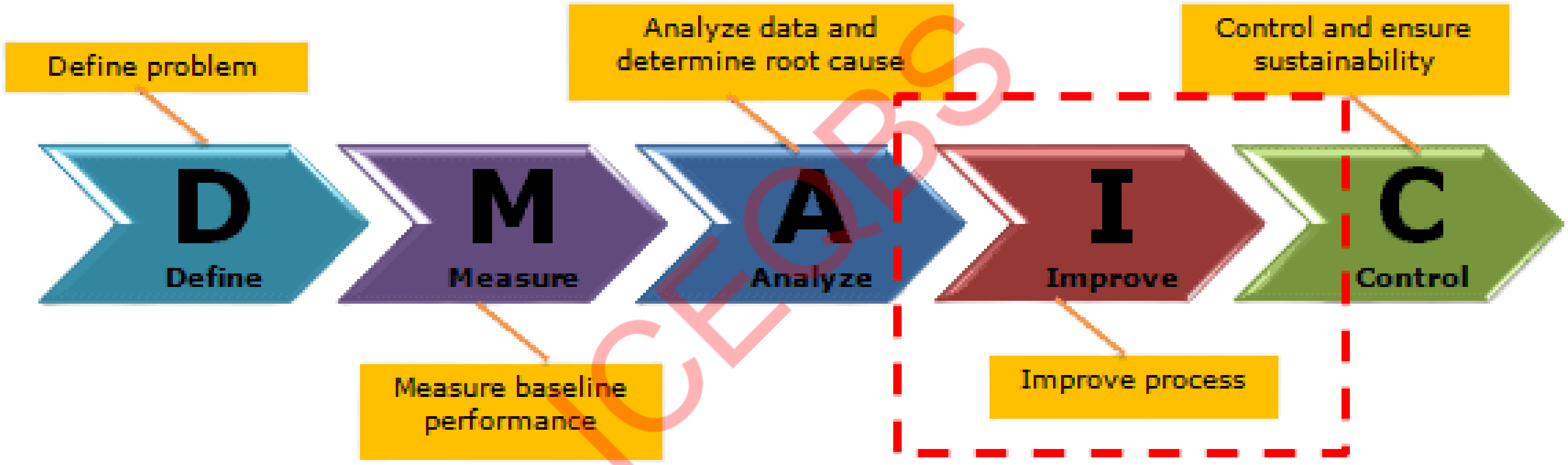
- The data show approximately normal and randomly distributed residuals with no clear pattern, confirming the regression model is valid and suitable for explaining rejection PPM in the Analyze phase.

Summary of Statistically validated Root causes



Data is randomly distributed over time and approximately symmetric, indicating no autocorrelation or bias and confirming the regression model assumptions are satisfied.

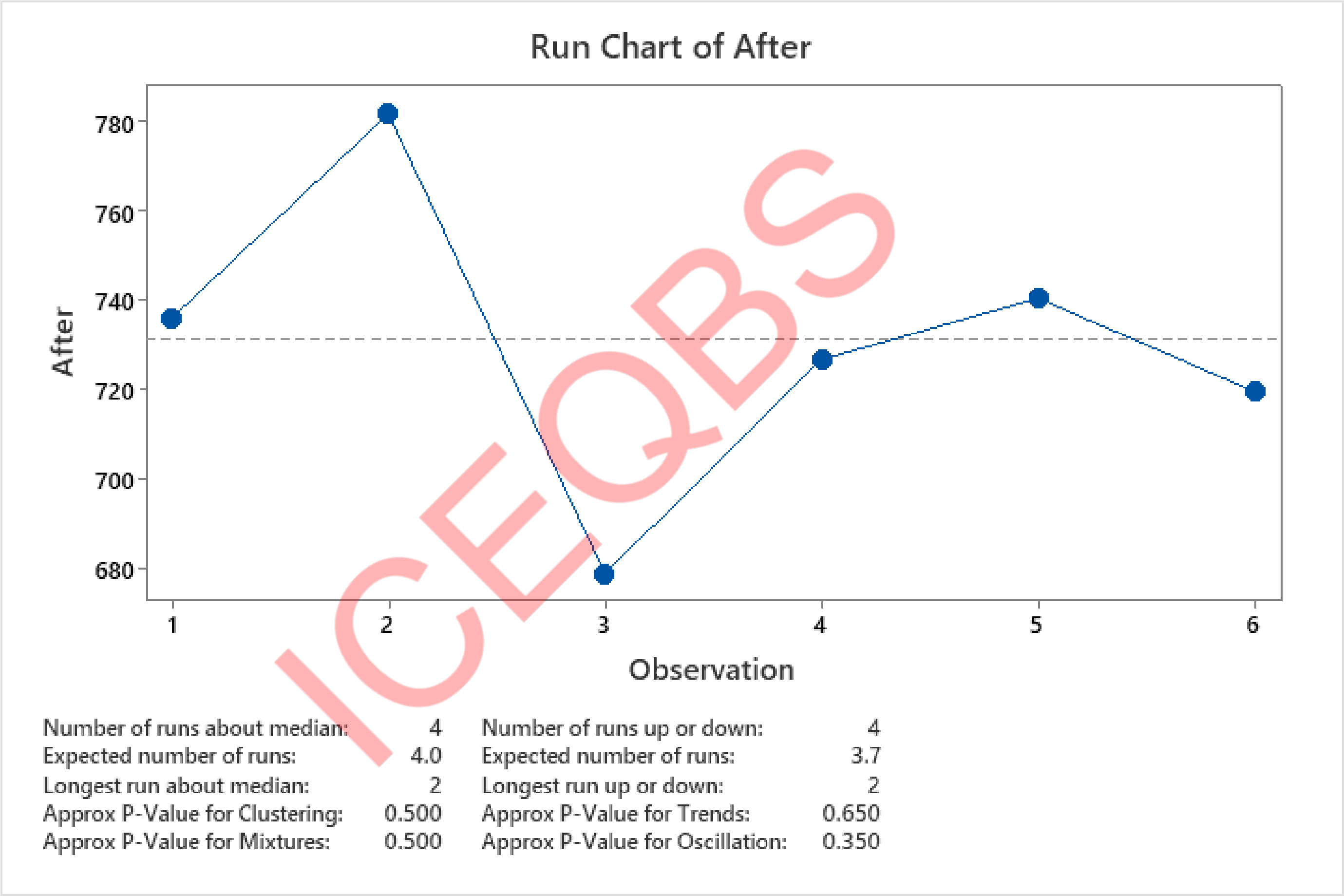
IMPROVE PHASE



Improve action plan for improvement to address the critical root causes

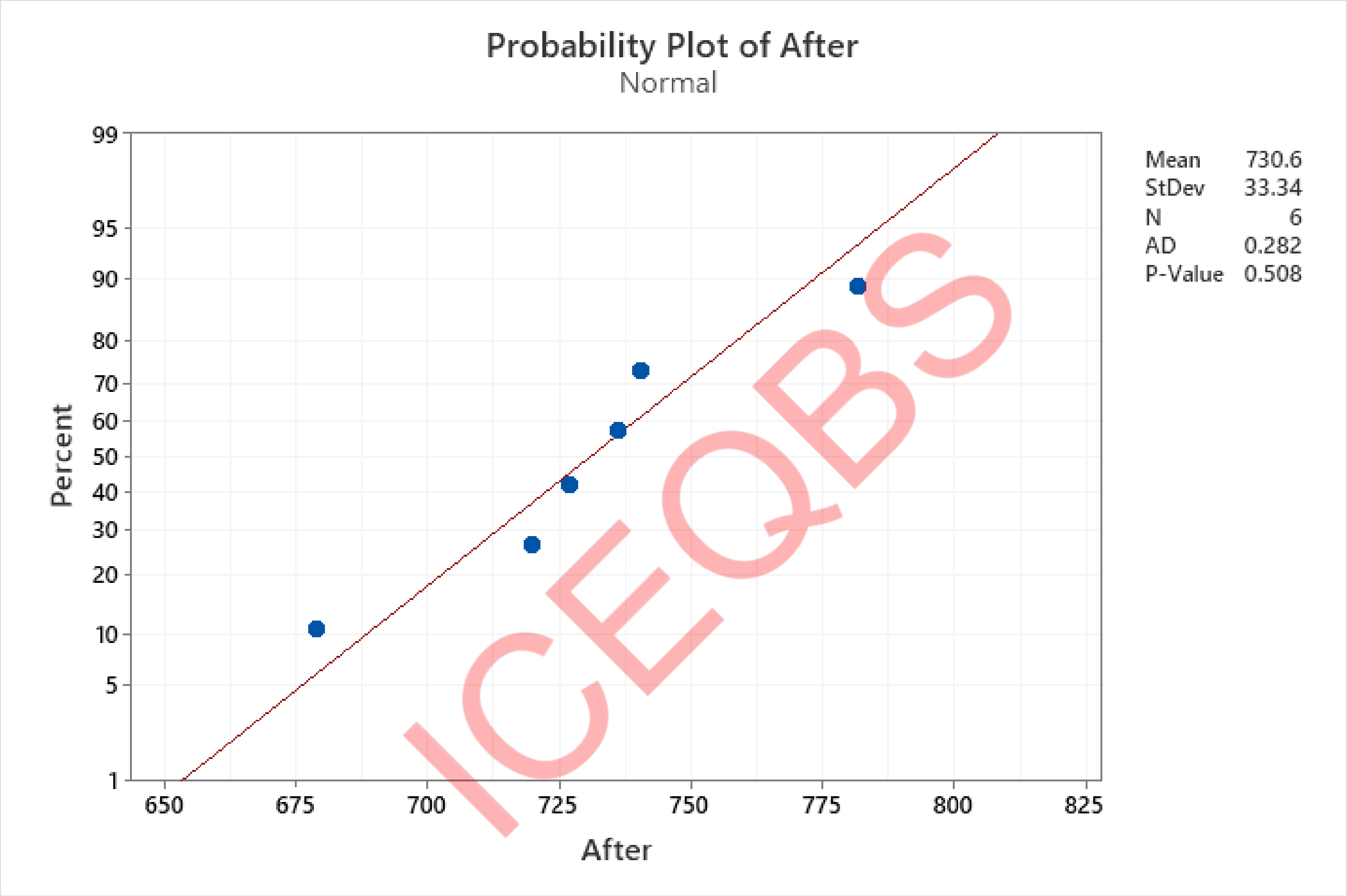
Sl. No	Critical Root Cause	Improvement Action	Tool / Method Used
1	Excessive Slinger OD Runout	Standardize chucking and clamping method for GM CF components; introduce soft jaws specific to GM CF	Fixture Standardization, Poka-Yoke
2	Excessive Slinger OD Runout	Introduce mandatory runout check after first-off and tool change	Control Chart ($\bar{X}$-R), First Article Inspection
3	Grinding taper more than specification	Optimize grinding wheel dressing frequency and dressing parameters	DOE (Wheel Dress Interval vs Taper)
4	Grinding taper more than specification	Introduce in-process taper measurement at mid-shift	In-Process Inspection
5	Untrained operator	Mandatory training module on GM CF critical dimensions and GD&T	Training Matrix, SOP
6	Untrained operator	Certification of operators before assignment to GM CF operations	Skill Certification
7	Low operator skill level	Restrict GM CF grinding operation to skilled operators only	Skill Matrix Enforcement
8	Grinding OD out of specification	Update grinding parameter window and lock settings	Process Capability Study
9	Measurement variation	Calibrate runout gauges and grinding OD measuring instruments	MSA, Gauge Calibration
10	Lack of control plan	Update Control Plan to include runout, taper, and training status	Control Plan Update

Improve



- **The after run chart shows stable performance with random variation around the median and no significant trends, indicating the improved process is under control.**

Improve



- **The probability plot confirms the post-improvement data is normally distributed (p > 0.05) with a stable mean, indicating consistent and predictable process performance after improvement.**

Improve

Two-Sample T-Test and CI: Before, After

Method

μ_1: population mean of Before
μ_2: population mean of After
Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
Before	6	10650	1491	609
After	6	730.6	33.3	14

Estimation for Difference

Difference	95% CI for Difference
9919	(8355, 11484)

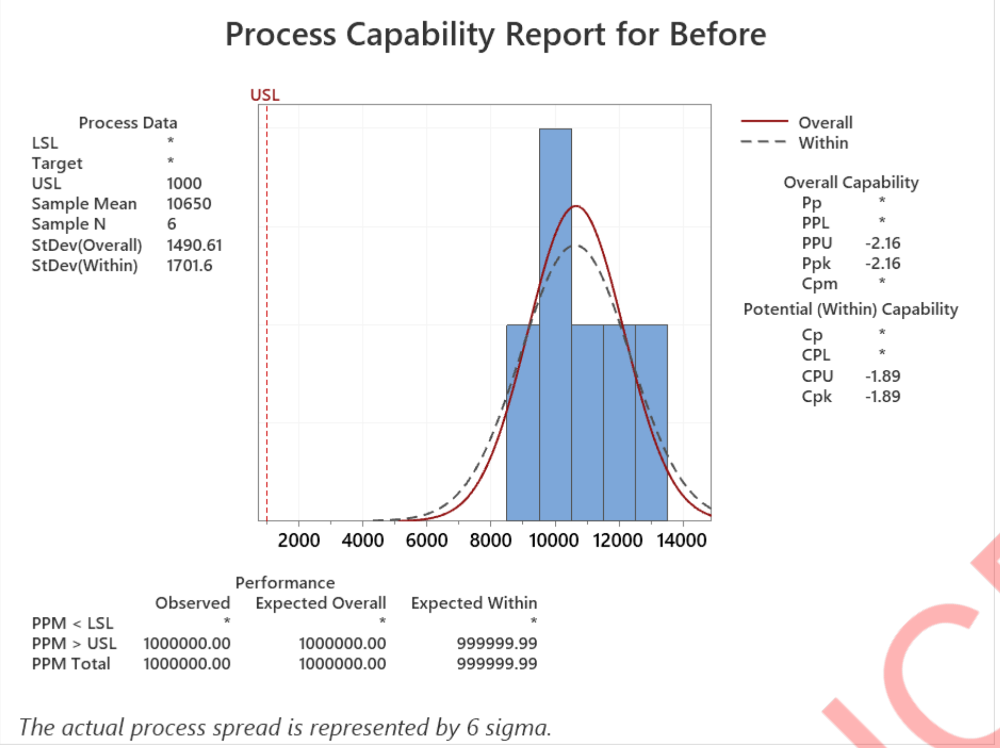
Test

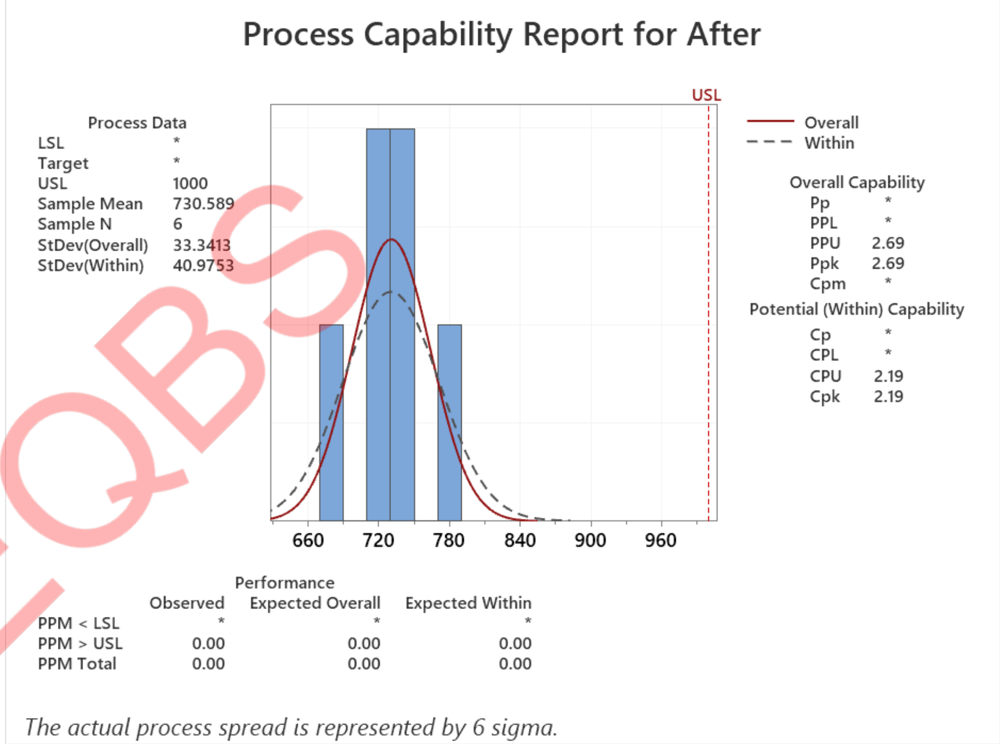
Null hypothesis	$H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis	$H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
16.30	5	0.000

The two-sample t-test confirms a statistically significant reduction after improvement, with rejection PPM dropping sharply from ~10,650 to ~731 ($p < 0.001$), demonstrating the effectiveness of the improvement actions.

Improve – Process capability – Before & After Improvement

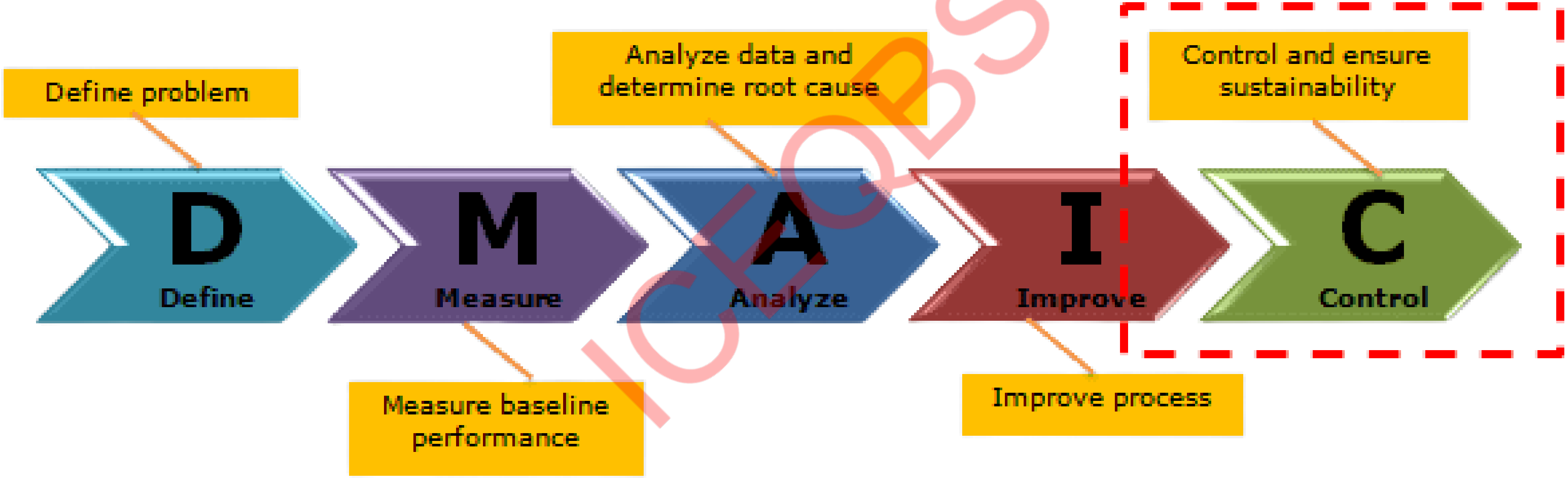




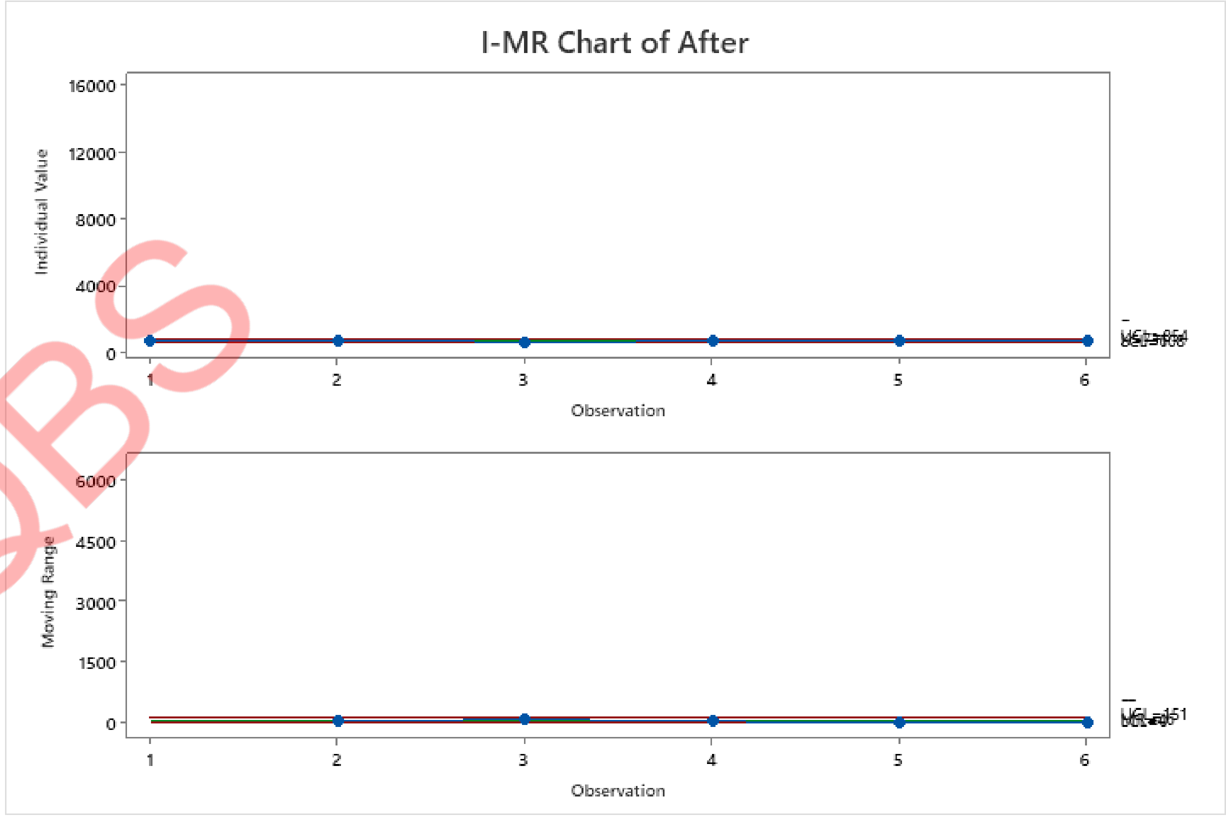
Inference :

- The before–after capability comparison shows the process improved from completely incapable (negative Cpk) to highly capable (Cpk > 2), with the mean well below the USL and near-zero defects after improvement.

CONTROL PHASE



Improve (Statistical validation for Improvement – I-MR Chart)



Inference:

- The I-MR charts show that after improvement the rejection PPM level dropped sharply with minimal variation, and the process is stable and well within control limits compared to the highly variable baseline.

Control Plan

5S Pillar	Mechanism	What Exactly to Implement	Sustaining Benefit
Sort	Red-tag non-GM fixtures	Separate GM CF fixtures, gauges, jaws from other family parts	Eliminates wrong fixture usage
Set in Order	Dedicated GM CF shadow board	Shadow outlines for soft jaws, runout gauge, taper gauge	Visual confirmation before start
Set in Order	GM CF green zone	Floor marking for GM CF WIP only	Prevents part mix-up
Shine	Wheel & chuck cleaning checklist	Mandatory cleaning at shift start	Reduces runout & taper drift
Standardize	GM CF grinding standard	One-page SOP with critical tolerances and photos	Reduces operator interpretation
Sustain	5S audit scorecard	Weekly audit with minimum 90% pass criteria	Management visibility & discipline

Control Plan

Root Cause Addressed	Poka-Yoke Mechanism	How It Works	Type
Excessive OD runout	Dedicated soft jaw with asymmetric key	GM CF part fits only in correct orientation	Prevention
Excessive OD runout	Runout OK/NOT-OK gauge	Machine cannot proceed unless runout is within limit	Detection
Grinding taper > spec	Mechanical stop on wheel slide	Prevents over-travel causing taper	Prevention
Grinding OD out of spec	Go/No-Go ring gauge	Operator cannot pass part without OK fit	Detection
Untrained operator	Training barcode lock	Machine enabled only after scanning trained operator ID	Prevention
Wrong part / wrong setup	Color-coded fixture and traveler	Fixture, traveler, and WIP color must match	Prevention
Missed inspection	Inspection checklist interlock	Operation sign-off required before next process	Detection

Control Plan

Process Step / Change	Potential Failure Mode	Potential Effect(s)	S	Potential Cause(s)	O	Current Controls (Prevention /Detection)	D	RPN	Recommended Proactive Action	Owner	Due	Post Action S/O/D (Expected)	Post RPN
1. Introduce GM CF dedicated soft jaws / fixture	Wrong jaw design or wrong orientation allowed	High runout, slinger height reject, customer spill	9	Design not validated; no orientation key	4	Trial fit by operator	7	252	Add asymmetric keying + design verification on CMM; first-off runout validation	Prod Engg	2 wks	9/2/3	54
2. Fixture installation on machine	Fixture not torqued / not seated properly	Runout variation and taper drift	8	No standard torque; rushed setup	5	Visual check	6	240	Create torque spec + torque wrench; setup checklist with sign-off	Production	1 wk	8/2/3	48
3. Runout gauge adoption (TIR)	Gauge out of calibration	False OK/NG decisions; escapes	9	Calibration missed; gauge damage	3	Annual calibration only	8	216	Add monthly verification using master; gauge handling standard + storage	Quality	1 wk	9/2/3	54
4. Runout check enforcement	Operator bypasses runout check	Drift not detected; spikes in PPM	8	No interlock; production pressure	6	Supervisor monitoring	7	336	Poka-yoke: traveler step must be filled; random audit 2/shift; optional digital entry	Production + Quality	2 wks	8/3/3	72
5. In-process taper measurement	Measurement method inconsistent	Wrong conclusions; over-adjustment	7	No standard points/locations	5	Informal method	6	210	Standardize measurement points + pictorial SOP; quick MSA (repeatability)	Quality	2 wks	7/2/3	42

Control Plan - to sustain improvements

Process Step	Product / Process Characteristic	Specification / Target	Measurement Method	Sample Size & Frequency	Control Method	Reaction Plan (If Out of Control)	Responsibility
Part loading on grinder	Correct GM CF part & fixture	Correct part + GM CF fixture only	Visual + color code	100%	Color coding, fixture keying	Stop job, segregate parts, re-verify setup	Operator
Clamping / chucking	Fixture seating & torque	As per standard torque	Torque wrench	Every setup	Setup checklist	Re-clamp, re-verify torque	Operator
Grinding – slinger OD	OD Runout (TIR)	≤ 0.025 mm	Runout gauge	First-off, then 1/hr	X̄-R chart	Stop process, adjust fixture, re-qualify	Operator / Quality
Grinding – slinger OD	Grinding OD	As per drawing	Micrometer / ring gauge	5 parts/hr	SPC	Adjust parameters, segregate lot	Operator
Grinding – taper	Grinding taper	≤ 0.010 mm	Two-point OD measurement	First-off + mid-shift	SPC	Redress wheel, adjust slide	Operator / Process Engg
Wheel dressing	Dressing frequency	As per standard	Checklist	Per shift	Standard work	Correct interval, verify first-off	Operator
In-process inspection	Inspection completion	100% compliance	Traveler sign-off	Every lot	Poka-Yoke (mandatory sign)	Hold lot, perform missed check	Quality

Conclusion

Results after improvement

- **This project successfully eliminated the major causes of rejection, stabilized the process, and achieved a sustained, statistically validated reduction in PPM, delivering significant cost savings and improved operational performance.**