SHRIRAM PISTONS & RINGS LTD.

A SIX SIGMA PROJECT ON REJECTION REDUCTION

SHRIRAM PISTONS AND RINGS LTD

Prepared by Kashvi Agrawal

15th May 2025

IIT Guwahati

CONTENTS

Tip: Use links to go to a different page inside your presentation. Links work best for pages like this one!

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Kindly delete this note after editing this page. Thank you!

Phase 1 Problem Definition

Phase 2 Measure and Analyse

Phase 3 Improve

Phase 4 Control

WORKFLOW

DMAIC Methodology

Define

Measure

Analyse

Improve

Control

PHASE 1

PROBLEM DEFINITION

Go Back to Contents Page

Topics Covered

- Project Charter
- Project Planning
- Process Mapping
- Pareto Analysis
- COPQ Calculation
- SSV Identification

Project Number	01
Plant	Shriram Pistons & Rings Ltd
Mentor	Mr. Ompal Singh
Team Members	Kashvi Agrawal
	Sradha Shivangi
Internship Period	15th May- 20th June 2025

Problem Statement - Rejection in Piston Diameter (Dia. Dn) due to over size

Process stages where the Problem is detected – Finish Oval turning

Part number selected for study – A
Other similar part numbers having the problem –xyz
Number of lines/presses/machines used for processing – One

Current average rejection for last 6 months –1.2%

Maximum and Minimum rejection in last 6 months

-Maximum rejection in a month - 1.76%
-Minimum rejection in a month - 1.14%

Objective of the Project

Rejection reduction from 1.2% to 0.3% on Dn diameter

Response Y

Nominal Diameter (Variable)

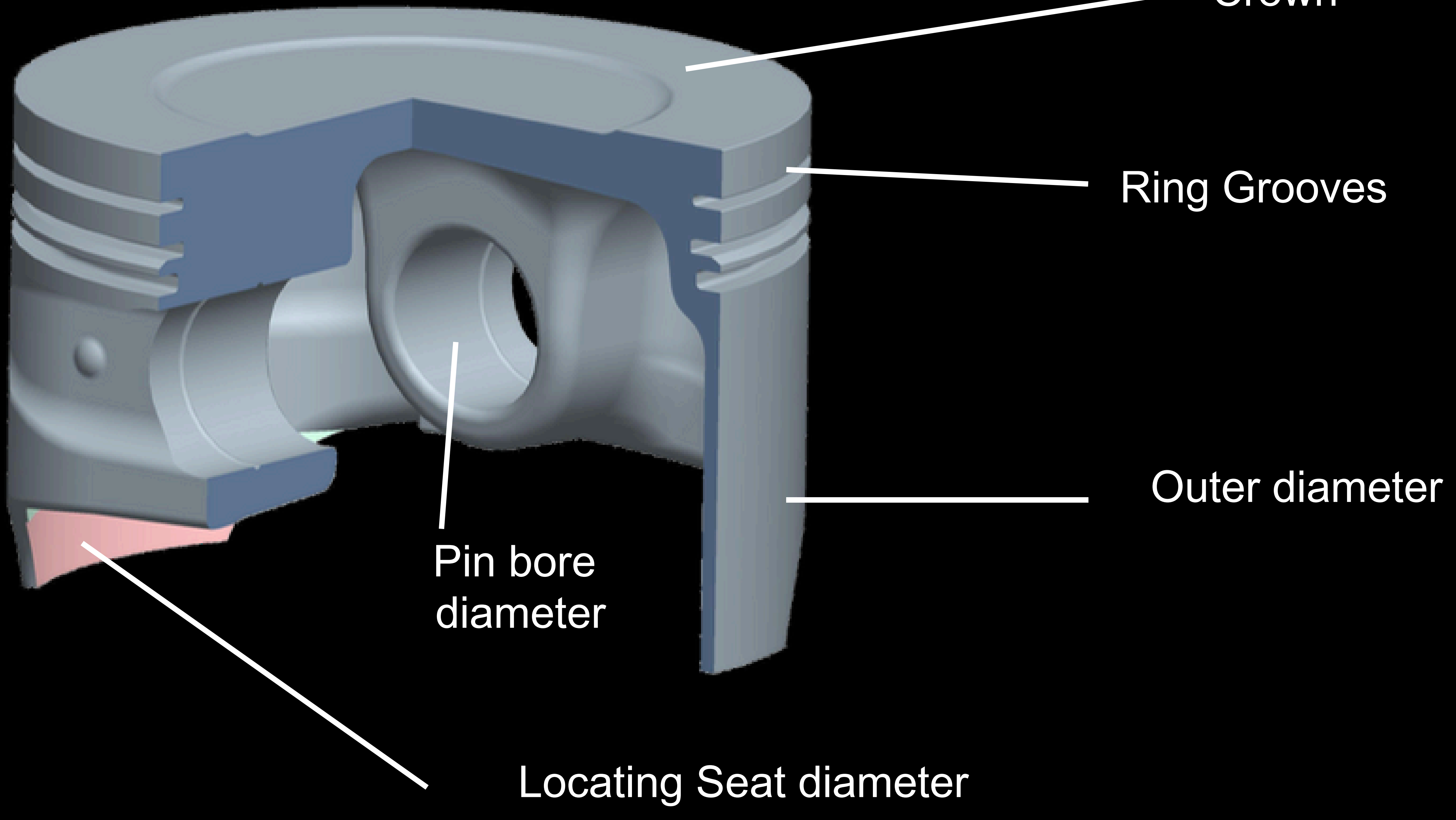
Specification

78.977mm to 78.992mm

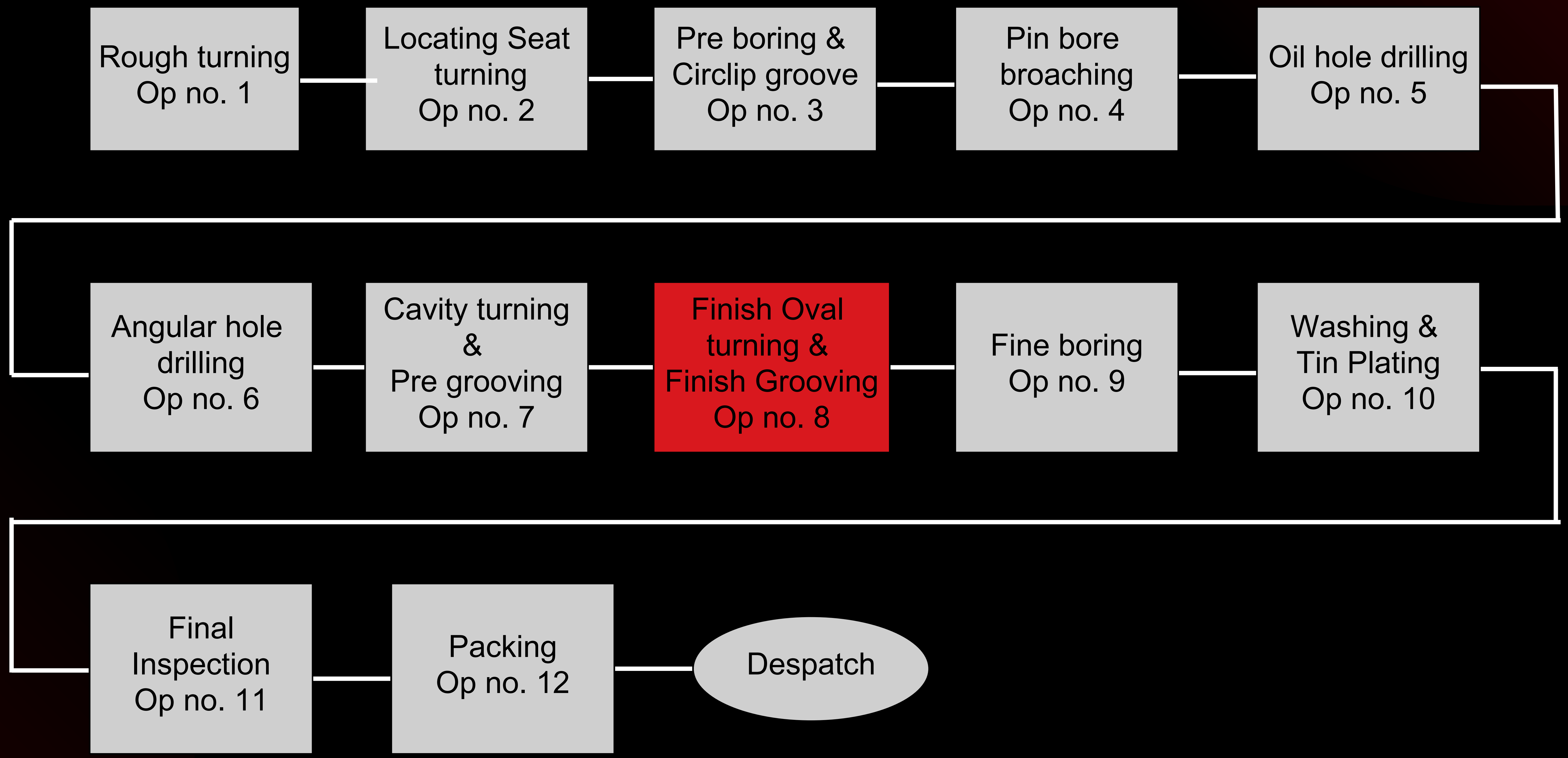
PROJECT PLANNING

Phase	Month-May’25				Month-June’25			
	W1	W2	W3	W4	W1	W2	W3	W4
Define								
Measure & Analyze								
Improve								
Control								

CUT SECTION OF A PISTON

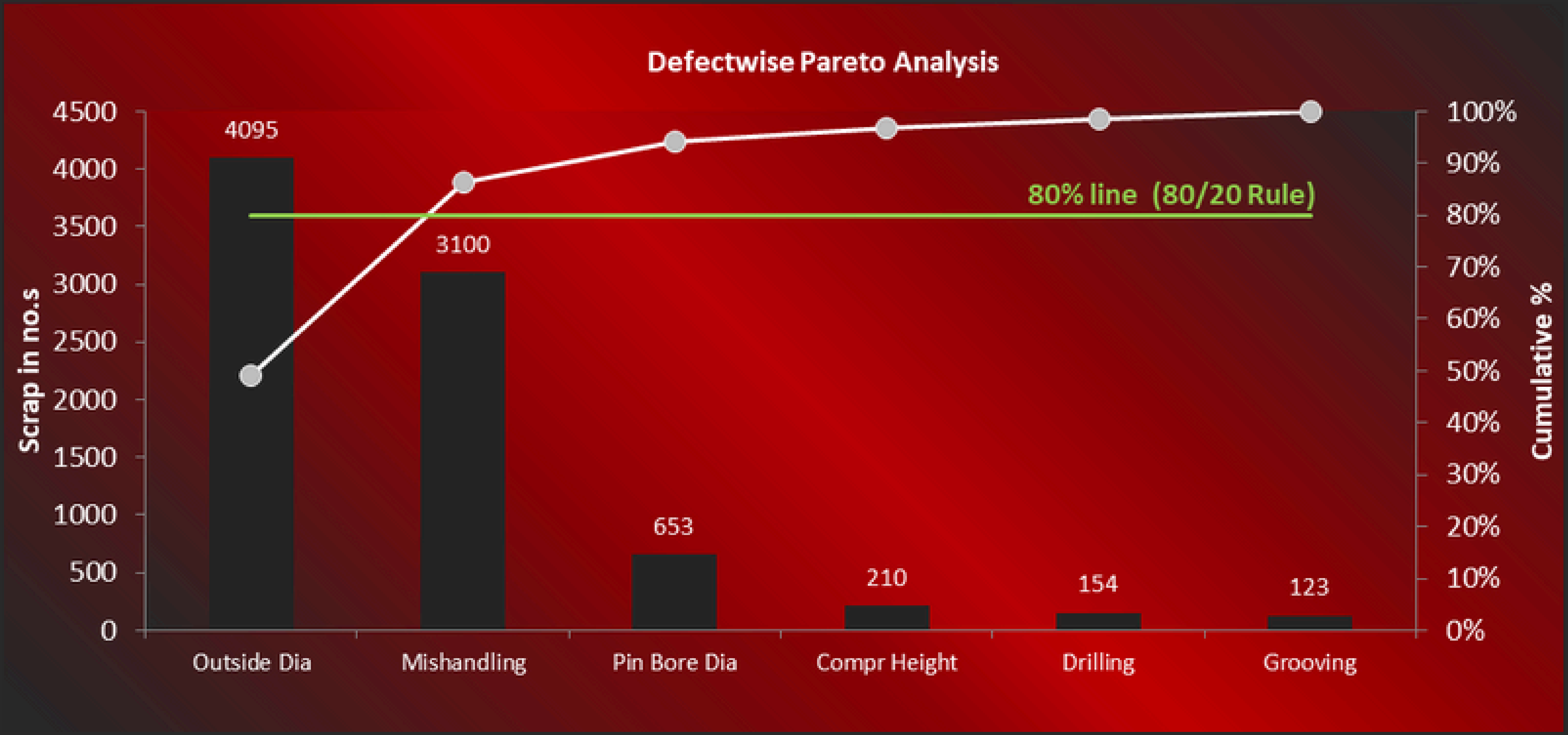


PROCESS MAPPING



PARETO CHART

49% of the rejection is due to OD oversize



COST OF POOR QUALITY

COPQ Calculation

Number of pieces rejected last month	912
Number of pieces scrapped last month	912
Number of pieces reworked last month	0
Scrap cost/piece	Rs90
Rework cost/piece	-
Total scrap cost (Rs. Lakhs) for last month	Rs0.82 lac
Total rework cost(Rs. Lakhs) for last month	-

Total Rejection cost (Rs. Lakhs) for last month	Rs0.82 lac
Extrapolated Total rejection cost (Rs. Lakhs) for one year	Rs9.8 lac

Qty produced: 325576 nos.
Qty scrap: 8565 nos.
Scrap % - 2.6
OD scrap- 4095nos.
OD scrap %- 1.2

SSV IDENTIFICATION

Suspected Sources of Variation

Locating Seat Diameter

Pre OD Dimension

Crown Runout wrt Locating Seat

Hardness

Finish Oval Turning Process

RPM

Tailstock Pressure

Seat Sharpness

PHASE 2

MEASURE AND ANALYSE

Go Back to Contents Page

Topics Covered

Analysis 1 Ishikawa Diagram

Analysis 2 Paired Comparision

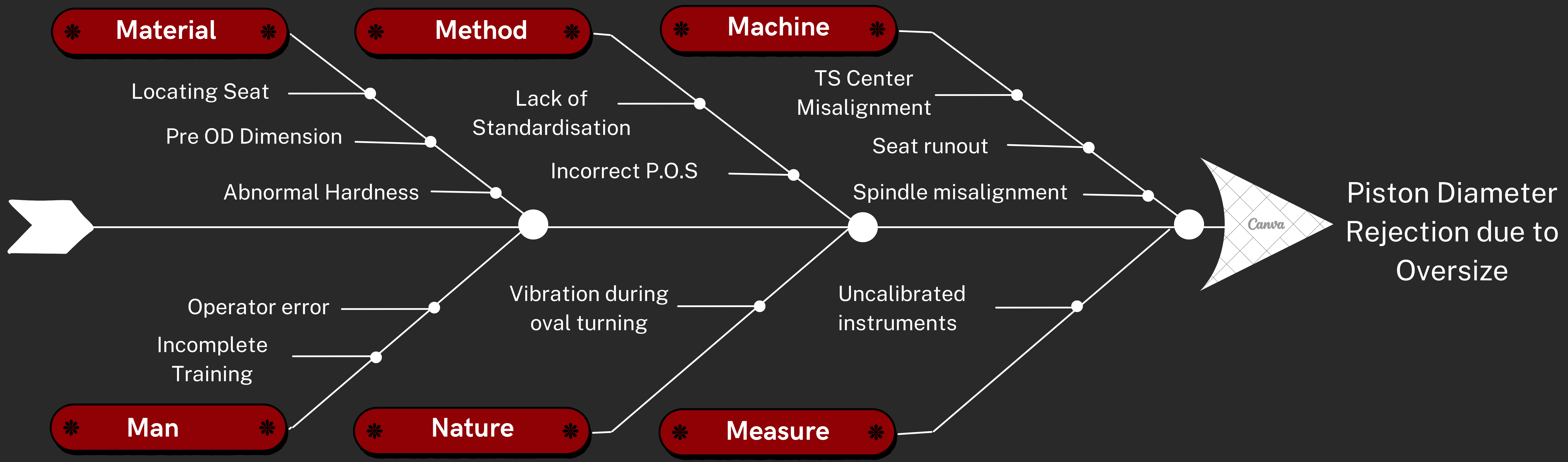
Analysis 3 MVA

Analysis 4 Variable Search

Root Cause

TOOL #1 ISHIKAWA DIAGRAM

Fishbone / Cause and Effect



TOOL #2
PAIRED COMPARISION

Why?

Paired Comparison was an essential tool to begin this project. This technique is a simple but powerful one to lower down a high number of SSVs when the product (here, piston) cannot be disassembled into components.
By focusing on the best and worst, it helps to quickly isolate the most significant factors contributing to quality issues.

Specification	Response Dn diameter 78.977-78.992	SSV#1 Locating seat dia. 75.03-75.05	SSV#2 Crown runout 20 micron max	SSV#3 Hardness 110-130
Unit	mm	mm	micron	BHN
BOB1	78.985	75.038	6	119
BOB2	78.984	75.018	9	118
BOB3	78.985	75.012	8	119
BOB4	78.986	75.022	13	119
BOB5	78.986	75.028	7	118
BOB6	78.984	75.028	7	118
BOB7	78.987	75.032	8	118
BOB8	78.985	75.032	12	118
WOW1	78.997	75.024	12	119
WOW2	78.994	75.026	15	119
WOW3	78.994	75.024	12	118
WOW4	78.998	75.026	4	119
WOW5	78.996	75.044	13	119
WOW6	78.994	75.03	10	120
WOW7	78.994	75.032	15	119
WOW8	78.996	75.038	14	119

Response Category	SSV#1 Locating seat dia. 75.03-75.05 mm
BOB3	75.012
BOB2	75.018
BOB4	75.022
WOW1	75.024
WOW3	75.024
WOW2	75.026
WOW4	75.026
BOB5	75.028
BOB6	75.028
WOW6	75.03
BOB7	75.032
BOB8	75.032
WOW7	75.032
BOB1	75.038
WOW8	75.038
WOW5	75.044

Top Count=3
Bottom Count=1.5
End Count=4.5 < 6

Response Category	SSV#2 Crown runout 20 micron max micron
WOW4	4
BOB1	6
BOB5	7
BOB6	7
BOB3	8
BOB7	8
BOB2	9
WOW6	10
BOB8	12
WOW1	12
WOW3	12
BOB4	13
WOW5	13
WOW8	14
WOW2	15
WOW7	15

The Minimum and Maximum readings are from same category.

Response Category	SSV#3 Hardness 110-130 BHN
BOB2	118
BOB5	118
BOB6	118
BOB7	118
BOB8	118
WOW3	118
BOB1	119
BOB3	119
BOB4	119
WOW1	119
WOW2	119
WOW4	119
WOW5	119
WOW7	119
WOW8	119
WOW6	120

Two Minimum readings are of different category.

Specification	Response	SSV#4
	Dn diameter	Pre Outside dia
	78.977-78.992	78.28-78.38
Unit	mm	mm
BOB1	78.984	78.29
BOB2	78.985	78.29
BOB3	78.985	78.3
BOB4	78.985	78.29
BOB5	78.986	78.305
BOB6	78.984	78.305
BOB7	78.986	78.3
BOB8	78.985	78.3
WOW1	78.997	78.295
WOW2	78.995	78.29
WOW3	78.996	78.305
WOW4	78.997	78.3
WOW5	78.996	78.305
WOW6	78.998	78.3
WOW7	78.995	78.3
WOW8	78.996	78.3

Response Category	SSV#4
	Pre Outside dia
	78.28-78.38
	mm
BOB1	78.29
BOB2	78.29
BOB4	78.29
WOW2	78.29
WOW1	78.295
BOB3	78.3
BOB7	78.3
BOB8	78.3
WOW4	78.3
WOW6	78.3
WOW7	78.3
WOW8	78.3
BOB5	78.305
BOB6	78.305
WOW3	78.305
WOW5	78.305

Two Minimum reading are of different categories.

SSV'S

Interpretation

By sequentially comparing each measured parameter with the response data, little variation was observed between max and min values. Hence, we are able to conclude that input material dimensions do not have a significant effect on the nominal diameter of the piston. Therefore, the first 4 possible SSV's are eliminated.

Suspected Sources of Variation

~~Locating Seat Diameter~~

~~Pre OD Dimension~~

~~Crown Runout wrt Locating Seat~~

~~Hardness~~

Finish Oval Turning Process

RPM

Tailstock Pressure

Seat Sharpness

TOOL #3
MULTI VARIABLE ANALYSIS

Why?

As Analysis #2 helped us conclude that input material is not a possible root cause of the problem, we now inspect the method i.e the operation “Finish Oval Turning” for potential variables X. This is a complex process, with multiple inputs which are not necessarily independent of each other. Moreover, the quality of our product is determined by the joint interaction of these numerous attributes.

Multi-vari analysis is used to reduce a large number of suspected sources of variation to a smaller family of variables containing the dominant source of variation. A multi-vari analysis is based on the assumption that any process variation can occur as a result of three factors, viz.,

- Positional or Part-to-Part Variation
- Temporal or Time-to-Time Variation
- Cyclical or Stream-to-Stream variation

Each type of variation is individually measured using a run of approximately 3 to 5 units produced consecutively at any given time. After a time lapse, another run of 3 to 5 units are produced. This process is repeated until 80 per cent of the out-of-control variation in the process is captured. A plot of these results indicates which one of the three variations is maximum.

Data Collection for Response Y (MVA)

Number of Streams = 1

Time block	Part 1	Part 2	Part 3	Event	Range	Average (time block)	Cummulative Variation
2:20 PM	78.995	78.992	78.989	No	0.006	78.992	0.006
2:25 PM	78.992	78.985	78.993	No	0.008	78.990	0.01
2:31 PM	78.991	78.986	78.992	No	0.006	78.990	0.01
2:46 PM	78.995	78.993	78.987	No	0.008	78.992	0.01
2:49 PM	78.989	78.99	78.995	No	0.006	78.991	0.01
3:10 PM	78.99	78.989	78.989	No	0.001	78.989	0.01
3:20 PM	78.986	78.987	78.991	No	0.005	78.988	0.01
3:25 PM	78.984	78.99	78.988	No	0.006	78.987	0.011
3:31 PM	78.985	78.982	78.99	No	0.008	78.986	0.013
						0.006	

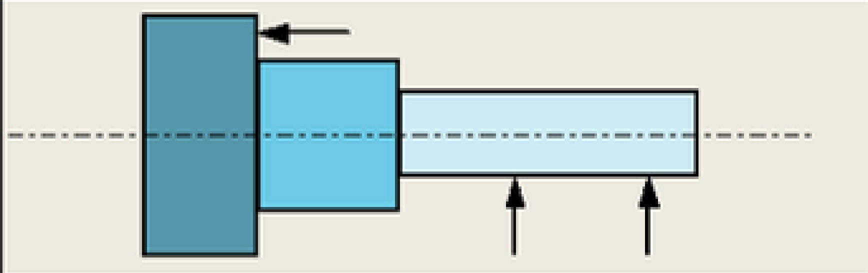
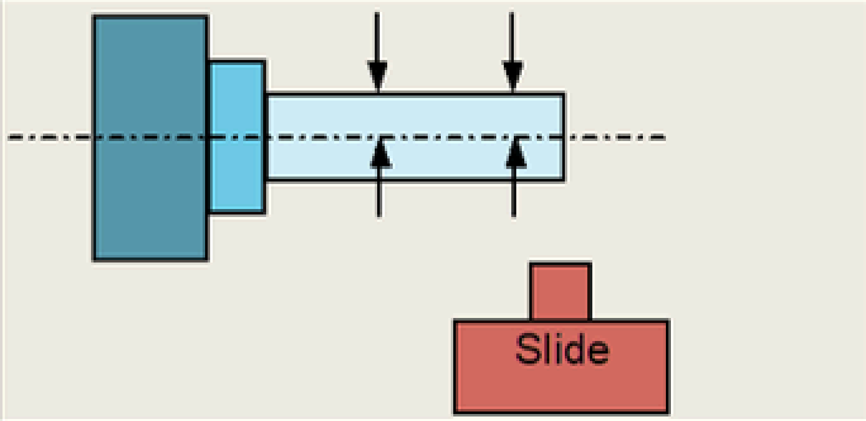
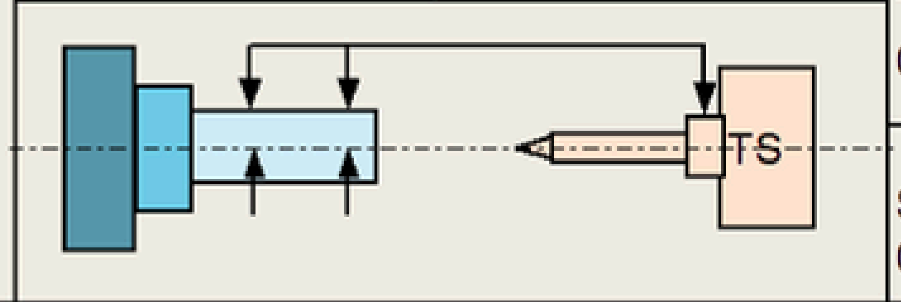
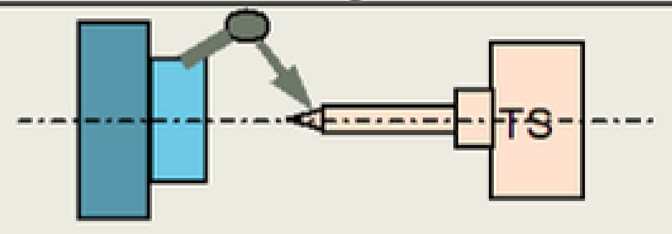
Part to Part Variation

Time to Time Variation

Cumulative Variation

ANALYSIS : Since Part to Part variation is highest we have to check for Equipment/Process dominance

Equipment Accuracy Check

S.No	Equipment Condition	Standard	Actual value	Status
1	Spindle & face runout 	0.01mm/max	Spindle : 0.005 mm Face : 0.002 mm	OK OK
2	Parallelism of Main Spindle w.r.t slide 	Top Surface : 0.01/100mm	Top Surface : 0.006/100mm	OK
		Side Surface : 0.01/100mm	Side Surface : 0.005/100mm	OK
3	Parallelism of Main Spindle w.r.t Tail Stock 	Top Surface : 0.01/100mm	Top Surface : 0.007/100mm	OK
		Side Surface : 0.01/100mm	Side Surface : 0.008/100mm	OK
4	Tail Stock Center alignment 	0.01 Max	0.008 mm	OK
5	Seat Runout	0.01 Max	0.008 mm	OK

ANALYSIS : Machine setup is correct. The problem is not equipment dominant. Hence, we have to optimise the machine settings.

TOOL #4
VARIABLE SEARCH

Why?

Variables Search is a very effective troubleshooting technique developed by Dorian Shainin. It is an experimental design technique, which is much easier to learn and use as compared to classic six sigma tools such as taguchi orthogonal arrays or fractional factorials. Using VS we can quickly find out whether key parameters have been accounted for or overlooked. It is also inexpensive, as relatively few experiments are required to pinpoint the critical variables.

5 Stages

Critical Parameters

Significant Parameters

Interaction of Parameters

Regression Equation

Optimal Setting

(-) & (+) SETTINGS FOR CRITICAL PARAMETERS

STAGE 1

	Parameter	- setting	+ setting
A	RPM	3300 rpm	3000 rpm
B	TS Pressure	70 Kgf	50 Kgf
C	Seat sharpness	No	Yes
D	LS diameter	75.039mm	75.02mm

selecting variables

It's better to include seemingly irrelevant variables on the list, rather than omitting them, in case those variables turn out to be significant.

choosing settings

Each (+) value should be chosen with the belief that it will lead to the desired outcome, while each (-) value should be selected with the thought it will lead to an unwanted result.

data collection

Based on the (-) and (+) settings data was collected for 10 parts for the response for 1st , 2nd & 3rd run alternatively.

ANALYSIS AND VERIFICATION

STAGE 1

Test	- Setting	+ Setting
1st run	15	9
2nd run	13	7
3rd run	14	8
Median	14	8
Range	2	2
D (diff of Median)	6	
d (avg. of range)	2	
D/d	3	

Response Y : Dn diameter variation (in microns)

Since the D/d ratio is >= 3 means that the parameters identified are correct and we can **PROCEED TO STAGE 2**

Signal and Noise

In data analysis, the signal is the true underlying pattern, and noise is the random fluctuation that obscures that pattern. So, when signal > noise, we know, the improvement is real, not just statistical fluctuation.

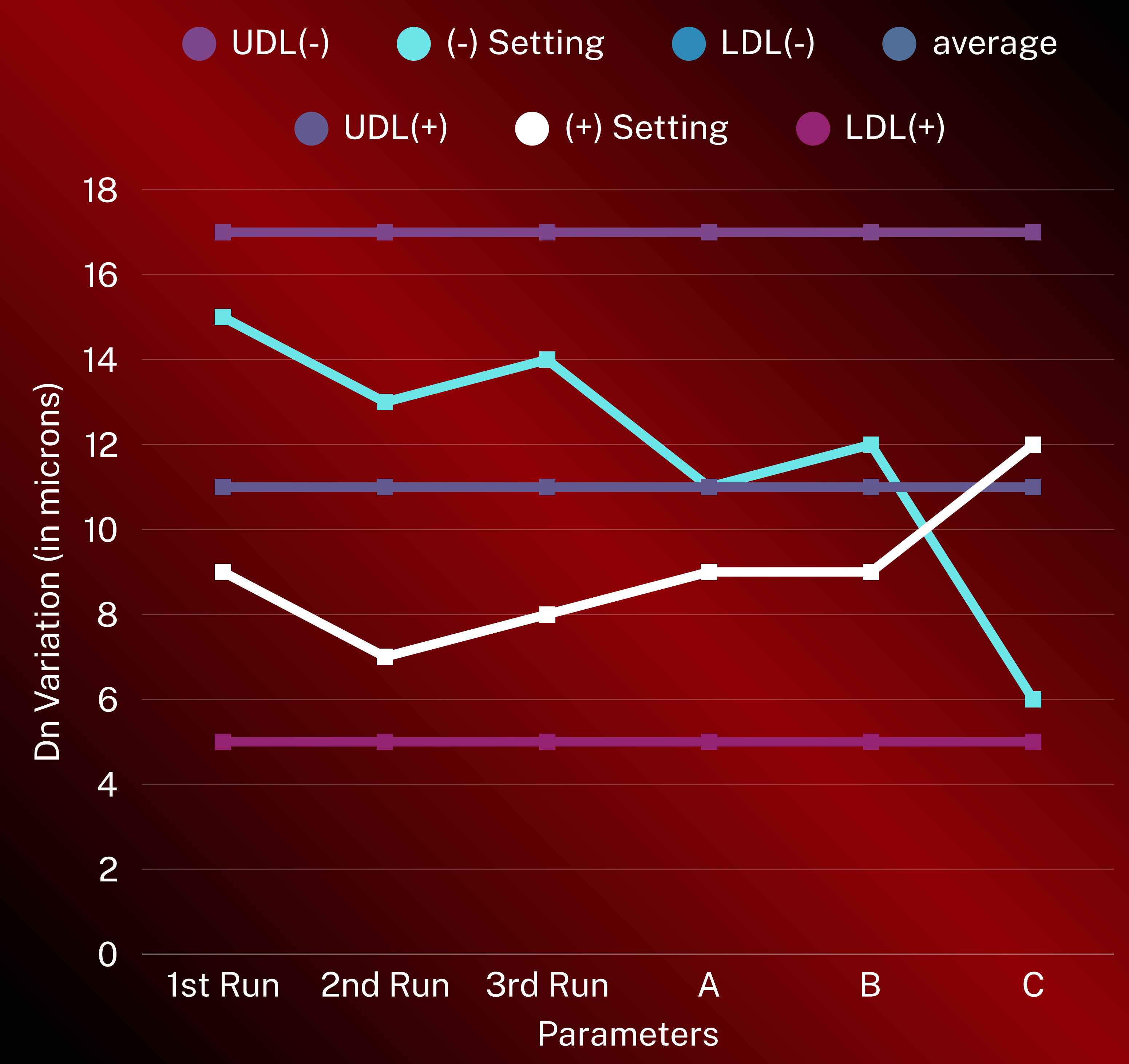
The D/d ratio serves as a simplified signal-to-noise metric, quantifying whether the observed improvement is distinguishable from inherent process variation.

D/d >= 3	statistically significant
1.25<D/d<3	valid if no data overlap
D/d<1.25	invalid conclusion

STAGE 2 GRAPHING

Median	8
Median	14
Avg of Median	11
1.45*d	3

UDL (+) = M(+) + 1.45*d	11
UDL (-) = M(-) + 1.45*d	17
LDL (+) = M(+) - 1.45*d	5
LDL (-) = M(-) - 1.45*d	11



IDENTIFICATION OF SIGNIFICANT PARAMETERS

STAGE 2

	-Setting	+Setting	Average	UDL(+)	LDL(+)	UDL(-)	LDL(-)	Conclusion	Contribution
1st Run	15	9	11	11	5	17	11		
2nd Run	13	7	11	11	5	17	11		
3rd Run	14	8	11	11	5	17	11		
A	11	9	11	11	5	17	11	Imp.	Not Zero
B	12	9	11	11	5	17	11	Not Imp.	Zero
C	6	12	11	11	5	17	11	Imp.	Not Zero
			11	11	5	17	11		
			11	11	5	17	11		
			11	11	5	17	11		

Phase 2 consists of a series of paired experiments to screen variables for their significance. This is done by swapping the (+) and (-) values of one variable at a time. By keeping all other variables at the conditions established during the Phase 1 experiments, the effect of the changed variable is highlighted.

These paired experiments have three possible outcomes:

- The response variable is not affected at all when the variable under study is switched. This indicates that particular variable is insignificant within the range of conditions tested.
- The outputs change somewhat. This means the variable being studied is significant and it is interacting with other variables.
- There is a complete reversal of outputs. This means the switched variable is the one and only critical variable.

FACTORIAL TABLE

STAGE 3

A	C	Response	Median	Interaction (A*C)
-	-	15,13,14	14	-
+	-	11,12	12	-
-	+	9,6	8	-
+	+	9,7,8	8	+
1(-)	5(-)			3(-)

A(-) = Average of all A(-) reading = (14+8)/2 = 11
A(+) = Average of all A(+) reading = (12+8)/2 = 10
C(-) = Average of all C(-) reading = (14+12)/2 =13
C(+) = Average of all C(+) reading = (8+8)/2 = 8

Contribution of A = A(-) – A(+) = 11-10 = 1(-)
Contribution of C = C(-) – C(+) = 13-8 = 5(-)

Interaction (A*C) (-) setting = (14+12+8)/3 = 11
Interaction (A*C) (+) setting = 8

Influence of A on C = 3 (-)

REGRESSION EQUATION

STAGE 4

Characterisitic	Value	Sign
Mean of all responses	11	
Contribution of RPM (A)	1	(-)
Contribution of Seat Sharpness (C)	5	(-)
Contribution of RPM & Seat Sharpness together (A*C)	3	(-)

$Y = f(X_i)$

Y= Mean of all resp. + ½ (Cont. Of A)*A+ ½ (Cont. Of C)*C + ½ (Cont. Of (A*C)) * A*C

$Y = 11 - \frac{1}{2}(1)A - \frac{1}{2}(5)C - \frac{1}{2}(3)A*C$

$\boxed{Y = 11 - 0.5A - 2.5C - 1.5A*C}$

OPTIMAL SETTING

STAGE 5

Parameter			
RPM (A)	3300	3150	3000
Seat Sharpness (C)	No Sharp		Sharp
Coded Value	-1	0	+1

Optimal setting	
RPM	3075 RPM
TS pressure	70 Kgf
Seat	Sharp

Since Y is the Dn diameter variation , for optimal solution it should be 50% of the tolerance. Assuming Seat is sharp (C=+1) , let us see what the optimal RPM would be :-

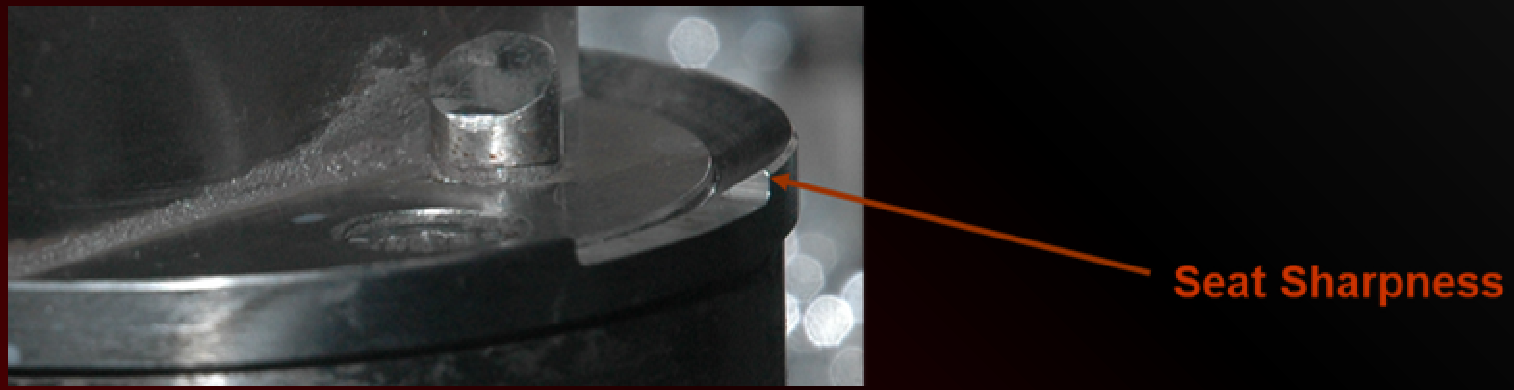
$$Y = 11 - 0.5\,A - 2.5\,C - 1.5\,A * C$$

$$7.5 = 11 - 0.5\,A - 2.5 * (+1) - 1.5\,A * (+1)$$

$$A = 0.5$$

$$\boxed{A = 3150 - 0.5 * 150 = 3075 \text{ RPM}}$$

ROOT CAUSE X



Analysis Conclusion

Sharpness of the adaptor seat is the major contributing factor for variation in the Dn Diameter.

Upon analysing the Finish Oval Turning Process, we concluded that the Optimal Setting of the finish oval turning machine is at 3000 RPM , Tail Stock Pressure – 70 Kgf and Sharp Seat.

Suspected Sources of Variation

~~Locating Seat Diameter~~

~~Pre OD Dimension~~

~~Crown Runout wrt Locating Seat~~

~~Hardness~~

Finish Oval Turning Process

~~RPM~~

~~Tailstock Pressure~~

Seat Sharpness

PHASE 3

IMPROVE

Go Back to Contents Page

Topics Covered

Project Charter

Project Planning

Process Mapping

Pareto Analysis

COPQ Calculation

SSV Identification

PHASE 4

CONTROL

Go Back to Agenda Page

Topics Covered

Project Charter

Project Planning

Process Mapping

Pareto Analysis

COPQ Calculation

SSV Identification