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Reduction of Defect and Variation using Six Sigma Methodology in an Instrument Manufacturing Company

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Abstract:- Our Project centres around the implementation of the Six Sigma DMAIC methodology, a structured approach utilized by organizations to effectively address challenges and achieve their objectives. The project's objective is to decrease the rejection rate of valves and variation in the Instrument Manufacturing Company process in Gujarat, India. Following the systematic steps of Define, Measure, Analysis, Improve, and Control (DMAIC) within the Six Sigma framework, the project study aims to identify the root cause(s) of defects and provide a reliable solution to reduce or eliminate them thereby enhancing operational capabilitiesmaking it a valuable tool for the organization.

I. INTRODUCTION

➢ *Company Overview*

The instrument manufacturing industry is a diverse and dynamic industry that plays an important role in providing precision instruments, equipment and instruments in various fields including scientific research, medical, etc. healthcare, engineering, electronics, aerospace, etc. This industry designs, manufactures and distributes a wide range of tools to support process measurement, analysis, control, and monitoring.

Valve manifolds are noted for their durability, dependability, and precision, making them excellent for use in harsh settings. To satisfy the individual demands of the customers, they provide a wide choice of conventional and custom-designed valve manifold alternatives.

In addition to high-quality valve manifolds, the company offers customer service and technical assistance. The team of professionals is available to assist you in selecting the best valve manifoldfor your application as well as with installation and maintenance.

II. LITERATURE REVIEW

➢ *Six Sigma and its Methodology*

Since its inception in the manufacturing sector, Six Sigma is a highly effective method of process improvement and quality management that has been adopted by several industries. A process's flaws, variances, and errors must be kept to a minimum to attain near-perfect levels of performance and customer satisfaction. The methodology makes use of the DMAIC (Define, Measure, Analyze, Improve, Control) structured approach to identify the root causes of problems, measure process performance, examine data for opportunities for improvement, implement changes, and establish control measures to maintain the improvements.

➢ *DMAIC*

DMAIC is a data-driven approach used for optimizing and improving existing business designs and processes. It is an effective method of controlled change management. The five phases of DMAIC are listed below, and each phase involves tools and tasks to help find the final solution.

- *Define the problem and the goals of the project.*
- *Measure the different aspects of the existing process in detail.*
- *Analyze data to find the main flaw in a process.*
- *Improve the given process.*
- *Control the way the process is implemented in the future.*

Six Sigma's guiding principles include a relentless focus on customer needs, making decisions based on data and facts rather than preconceptions, and allowing cross-functional teams to collaborate in the quest for process improvement. Organizations can improve productivity, cut costs, improve product quality, and develop a culture of continuous improvement by implementing Six Sigma, making it a powerful tool for attaining operational excellence and providing superior value to consumers.

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III. DEFINE PHASE

The purpose of this phase is to clearly state the problem and to establish measurable goals for reducing defects and improving overall quality.

This information is usually documented to write down what you currently know to determine the critical quality characteristics of the valve that are most important to customers and the business.

➢ *Project Charter*

A project charter is a concise, formal document that outlines the project's goals, scope, schedule, resources, and key stakeholders, providing a clear roadmap for successful project implementation labour.

Table 1 Project Charter

<table>
<tr><td colspan="15">PROJECT CHARTER</td></tr>
<tr><td colspan="15">Project Name: Reduction of Defect and Variation Using Six Sigma Methodology in an Instrument Manufacturing Company</td></tr>
<tr><td colspan="15">Problem Statement:
1. Reduce defects and rework during valve manifold production.
2. Decrease process variation, leading to a more consistent and reliable product.</td></tr>
<tr><td colspan="15">Project Scope:
Critical parameters that are impacting the creation of defects and process variation shall beidentified and improved using the DMAIC methodology.</td></tr>
<tr><td colspan="15">Project Objective / Goal Statement:
Our main goal focuses on optimizing the manufacturing process of valve manifolds, aimingto streamline production, minimize defects, and reduce variation in the final output. We will analyze the key stages of the manufacturing process, identify bottlenecks, and implement data-driven solutions to enhance efficiency and quality.</td></tr>
<tr><td colspan="5">Metrics
Defects Per Million Opportunities (DPMO)
• Process Sigma (σ)</td><td colspan="5">Baseline
DPMO = (181/2500) *1000000 =72400</td><td colspan="5">Goal
Reduce DPMO by25%.</td></tr>
<tr><td colspan="3">Define
Tools used: -Process MapCTQ Tree</td><td colspan="3">Measure Tools used: - Check Sheets
Data CollectionP Chart
R&R Analysis</td><td colspan="3">Analysis
Tools used: -
Pareto Analysis Fishbone DiagramANOVA</td><td colspan="3">Improve Tools used: -DOE</td><td colspan="3">Control Tools used: - SOP</td></tr>
<tr><td colspan="15">Team Members:
Dhananjay Mrutunjay Nayak, Harsha Nagadasanahalli Suresh, Devanshu Rathore, DarpanKumar, Karishma Raghu Shetty</td></tr>
</table>

➢ *Process Map*

A process map is a visual representation of a workflow, illustrating the sequence of activities, decision points, and interactions within a process, allowing for better understanding, analysis, and process improvement.

- *High-Level Manufacturing Process Map*

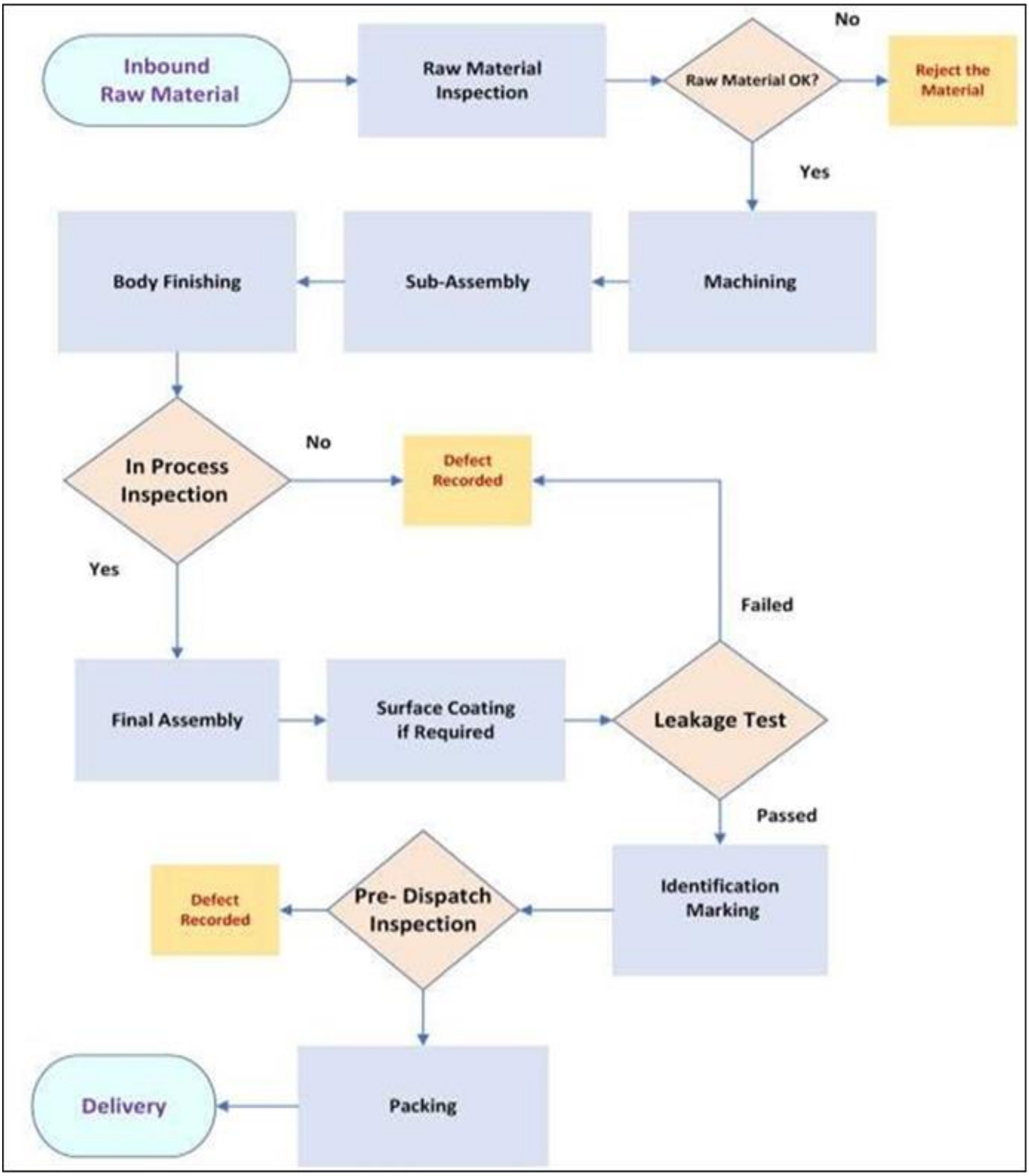

Fig 1 High-Level Manufacturing Process Map

➢ *CTQ Tree*

The CTQ (Critical-to-Quality) tree is a powerful tool in the Six Sigma methodology that helps identify andprioritize the most important quality characteristics (CTQs) of a product or process, tailoring them to the requirements customers to drive targeted improvement efforts.

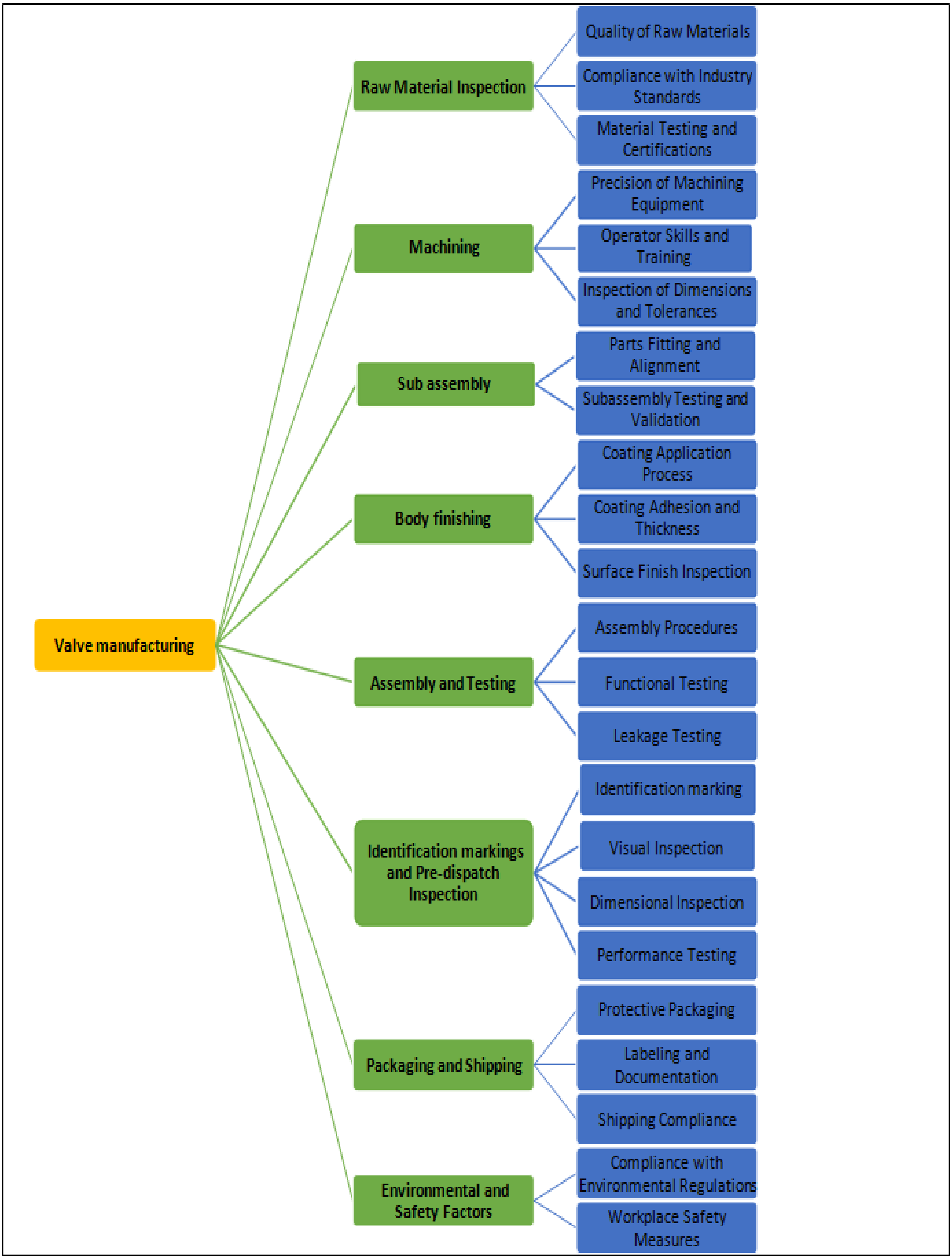

Fig 2 CTQ Tree

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IV. MEASURE PHASE

The measure phase is about the baseline of the current process, data collection, validating the measurement system, and determining the process capability

➢ *Check Sheet*

Table 2 Check Sheet

Company													
Inspection Checklist													
Client Name	ABC Company	Report Date	Jan-23		PO QTY		250		Verified By		Team 3		
Item Description	Needle Valve	PO Number	56002356										
SR No.	Parameters To be Checked	Specification	Instrument	1	2	3	4	5	6	7	8	9	10
1	Process Connection Thread	3/8 BSP (M)	Thread Ring Gauge	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok
2	Process Connection Thread Length	15MM	Digital Vernier Calliper	15.02	15.08	15.1	15.02	15.04	15.09	15.06	15.12	15.14	15.16
3	Instrument Connection	3/8 BSP (F)	Thread Plug Gauge	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok
4	Instrument Connection Thread Length	15MM	Digital Vernier Calliper	14.6	14.92	15.12	15.14	15.12	15.14	15.16	15.18	15.12	15.14
5	Total Length	120MM	Digital Vernier Calliper	12.06	120.19	120.12	120.15	120.16	120.22	120.16	120.22	12.26	12.28
6	Square Body	32MM	Digital Vernier Calliper	32.08	32.12	32.1	32.02	32.14	31.9	31.92	31.95	32.08	32.18
7	Bonnet	M16 X 1.25(F)	Thread Plug Gauge	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok
8	Vent	3/8 BSP (F)	Thread Plug Gauge	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok
9	Vent Connection Thread Length	15MM	Digital Vernier Calliper	15.1	15.02	15.06	15.12	15.14	15.16	15.12	15.16	15.18	15.19
10	Body Finish	Dent, Crack, burr etc	Visual	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok
3.3	Finish Product	Identification / Marking		ok	ok	ok	ok	ok	ok	ok	ok	ok	ok
3.4	Finish Product	Pressure Testing		ok	ok	ok	ok	ok	ok	ok	ok	ok	ok
4	Packing	Visual Check		ok	ok	ok	ok	ok	ok	ok	ok	ok	ok

Inspection Check Sheet

➢ *Data Collection*

Data collection is the systematic process of collecting and recording relevant information and observations from a variety of sources, providing the basis for analysis, decision-making, and information generation, research, business, and other fields.

We have collected data in the month of April 2023 where there were 10 lots each of 250 valves manufactured. From the check sheets from the In Process Inspection and Final Dispatch Inspection, we collected the.

Table 3 Data on defects

Sr. No	Lot Size	No of defects	Machining Error	Dimension Error	Body Finish	Alignment	Marking	Leakage test
1	250	11	8	2	1	0	0	0
2	250	23	16	4	1	1	1	0
3	250	15	9	3	3	0	0	0
4	250	18	12	4	1	1	0	0
5	250	7	2	1	2	1	0	1
6	250	23	15	4	2	0	2	0
7	250	28	21	5	1	0	0	1
8	250	19	11	5	3	0	0	0
9	250	16	7	3	3	0	3	0
10	250	21	14	5	2	0	0	0
Total	**2500**	**181**	**115**	**36**	**19**	**3**	**6**	**2**

➢ *KPI Identification*

From the above we have identified the following two KPIs: -

- *Defects Per Million Opportunities*

Our current Defects Per Million Opportunities, DPMO = (181/2500) *1000000 = 72400

- *Process Sigma*

Our current process sigma level is shown below.

➢ *P Chart*

A p-chart is a statistical control chart used in quality management to track the percentage or percentage of nonconforming items in a sample or process, allowing organizations to identify variations and take corrective action to maintain process stability and quality.

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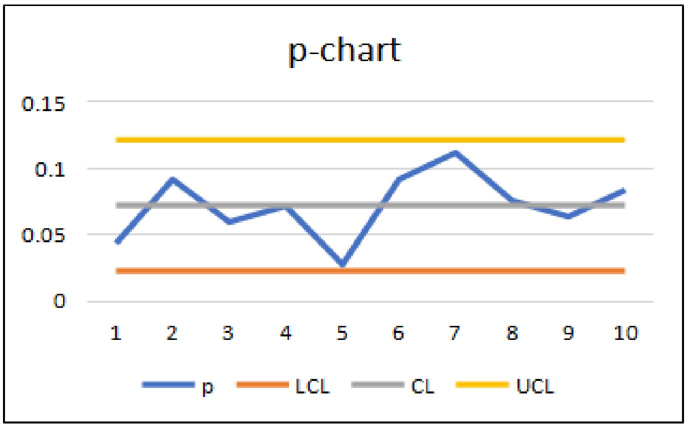

Sr. No	Lot Size	No of defects	p	LCL	UCL
1	250	11	0.044	0.023	0.122
2	250	23	0.092	0.023	0.122
3	250	15	0.06	0.023	0.122
4	250	18	0.072	0.023	0.122
5	250	7	0.028	0.023	0.122
6	250	23	0.092	0.023	0.122
7	250	28	0.112	0.023	0.122
8	250	19	0.076	0.023	0.122
9	250	16	0.064	0.023	0.122
10	250	21	0.084	0.023	0.122
Total	**2500**	**181**			

p-bar	0.072
UCL	0.122
LCL	0.023

Process Sigma	**2.958**

with 1.5 shift

Fig 3 P-Chart

- *R&R Analysis*

R&R analysis, also known as instrument repeatability and reproducibility analysis, is a statistical methodused to evaluate the variability and reliability of a measurement system, allowing the organization to determine whether a measurement tool or process can produce the consistent and accurate results required for quality, process assurance and improvement.

Table 4 Operator Readings of Five Valves - Valve Body Length Dimension

Part	Reading-01	Reading-02	Mean	Range
		Operator-01		
1	119.98	119.97	119.975	0.01
2	120.12	120.15	120.135	0.03
3	120.26	120.29	120.275	0.03
4	119.91	119.93	119.92	0.02
5	120.28	120.29	120.285	0.01
		Operator-02		
1	119.91	119.98	119.945	0.07
2	120.11	120.12	120.115	0.01
3	120.21	120.26	120.235	0.05
4	119.91	119.88	119.895	0.03
5	120.26	120.29	120.275	0.03
		Operator-03		
1	119.99	120.01	120	0.02
2	120.13	120.18	120.155	0.05
3	120.11	120.19	120.15	0.08
4	119.92	119.88	119.9	0.04
5	120.32	120.31	120.315	0.01
	Average		120.105	0.033
	LCL	**Mean**	**UCL**	
Range	0.000	0.033	0.107	
Average	120.044	120.105	120.166	
Sigma (e)	0.028			

Constants				
D3	0			
D4	3.267			
A2	1.88			
D2*	1.15			

Table 5 Operator-01 Operator-02 Operator-03

Part	**Reading-01**	**Reading-02**	**Reading-01**	**Reading-02**	**Reading-01**	**Reading-02**	**Mean**	**Range**
1	119.98	119.97	119.91	119.98	119.99	120.01	119.973	0.1
2	120.12	120.15	120.11	120.12	120.13	120.18	120.135	0.07
3	120.26	120.29	120.21	120.26	120.11	120.19	120.220	0.18
4	119.91	119.93	119.91	119.88	119.92	119.88	119.905	0.05
5	120.28	120.29	120.26	120.29	120.32	120.31	120.292	0.06
Average							120.105	0.092
	LCL	**Mean**	**UCL**		**Constants**			
Range	0	0.092	0.184368		**D3**	0		
Average	120.061	120.105	120.149		**D4**	2.004		
					A2	0.483		
					D2*	2.56		
Sigma (m)	0.0359							
Sigma(repr)	0.0220							
Part-to-part variation								
R(p)	0.387				**D2***	2.67		
Sigma(p)	0.145							
Sigma(t)	0.149							
%EV	19.04%							
%AV	14.75%							
%R&R	24.08%							

Table 6 Go and No-go Thread Plug Readings

Part	**Standard**	**A**	**B**	**C**	**Date**	**Time**	**Reproducibility**	**Accuracy**	
1	1	1	1	1		Morning	1	1	
1	1	0	1	1		Evening	0	0	
2	0	0	0	0		Morning	1	1	
2	0	0	0	0		Evening	1	1	
3	1	1	1	1		Morning	1	1	
3	1	1	1	0		Evening	0	0	
1	1	1	1	1		Morning	1	1	
1	1	1	1	1		Evening	1	1	
2	0	0	0	0		Morning	1	1	
2	0	1	1	1		Evening	1	0	
3	1	1	1	1		Morning	1	1	
3	1	1	1	1		Evening	1	1	
							83.33%	75%	
	Overall			**Week-01**			**Week-02**		
	A	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**
A	66.66	74.995	74.995	66.66	83.33	66.66	66.66	66.66	66.66
B		83.33	83.33		100	83.33		66.66	66.66
C			83.33			66.66			66.66

Inspector	**A**	**B**	**C**						
Accuracy	83.33	83.33	75						

- *Repeatability - 66.66+83.33+83.33/3=77.75*
- *Reproducibility-83.33*
- *Accuracy-74.99Bias-19.44*

➢ *Remarks*

With the above calculation of Part-to-Part Variation, Repeatability and Reproducibility analysis, we conclude that the Company has a healthy measurement system.

V. ANALYZE PHASE

In the Analyze phase, data is collected so that hypotheses about the root causes of variations in the process measurements can be generated and validated. It is at this stage that issues are analyzed using statistical methods and further inquiry.

➢ *Pareto Analysis*

Pareto analysis, based on the Pareto principle (80/20 rule), is a problem-solving technique that helps identify and prioritize the most important factors that contribute to a problem or outcomeorganizations focus their efforts on some of the most important areas with significant impact.

➢ *Error Analysis*

Table 7 Error Analysis

Machining Error	**Dimension Error**	**Body Finish**	**Alignment**	**Marking**	**Leakage test**
115	36	19	3	6	2

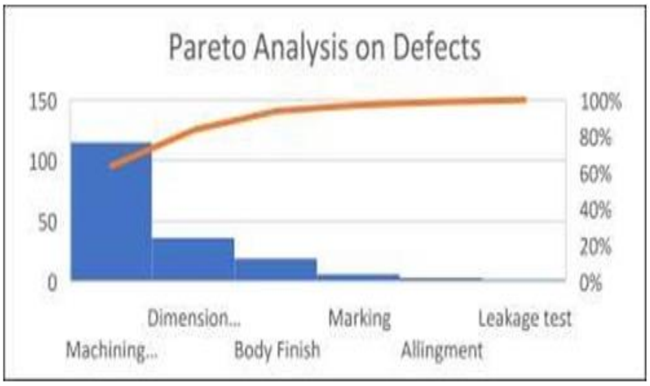

Fig 4 Pareto Chart on Machining Error

Fig 5 Pareto Chart on Machining Error

Further, we will analyse what are the different types of machining errors and which machining error is the most significant.

➢ *Fishbone Diagram*

With fishbone analysis, we investigate the possible cause and effect of the errors.

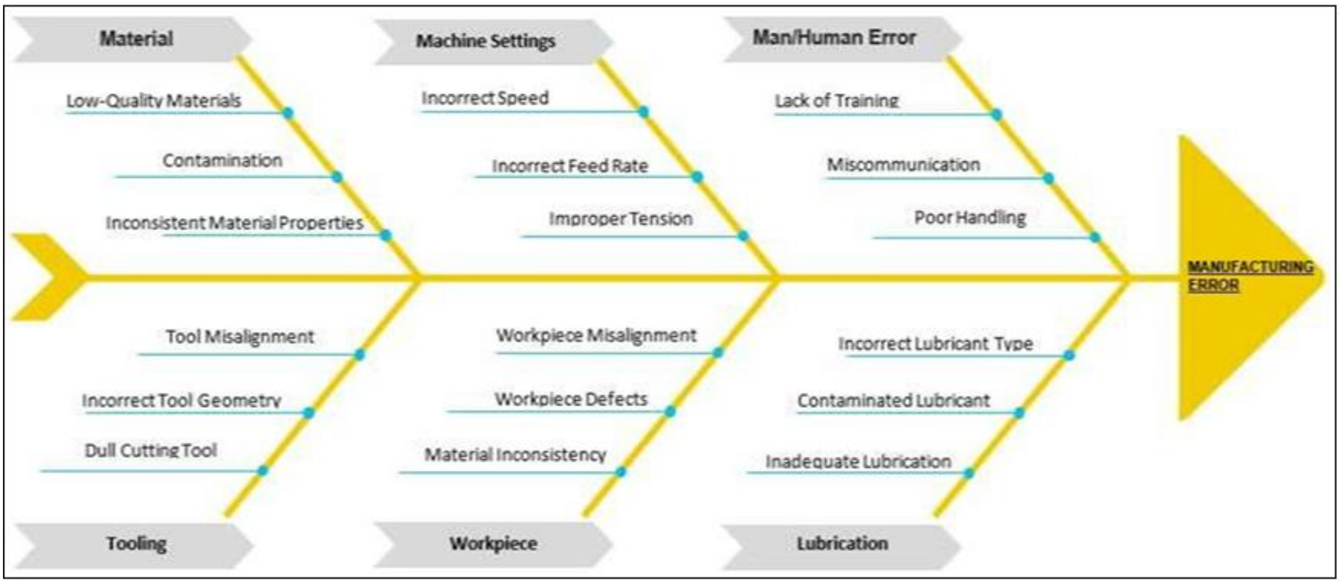

Fig 6 Fishbone Diagram

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➢ *Analyze Phase Analysis*

From the above Analysis, we identified that the following factors are responsible for Threading Errors.

- *Speed of the Machines*
- *Feed Rate*
- *Tool Material*
- *Coolant Type*
- *Coolant Pressure*

After further investigation, causal factors like tool material, coolant type and coolant pressure are either customer-specified or fixed during product development.

Thus, our focus will be on two main factors, the Speed of the Machines and Feed Rate as they areoperator controlled and we can see variability in these factors during Production.

➢ *ANOVA*

Using ANOVA, we see that there is a relationship between the Feed Rate and Speed of themachines on the defects.

For the ANOVA, the following is the Null Hypothesis Hypotheses Formulation:

- *Null Hypothesis (H0):*

✓ H01: The feed rate does not have a significant effect on the pitch diameter. H02: The speed does not have a significant effect on the pitch diameter.
✓ H03: There is no interaction effect between feed rate and speed on the pitch diameter.

- *Alternative Hypotheses (Ha):*

✓ Ha1: The feed rate has a significant effect on the pitch diameter. Ha2: The speed has a significant effect on the pitch diameter.
✓ Ha3: There is an interaction effect between feed rate and speed on the pitch diameter. Following are the results of ANOVA from Minitab: -

Factor Information

Factor	Type	Levels	Values
feed rate(mm/sec)	Fixed	3	0.5, 0.8, 1.0
Speed	Fixed	2	1000, 1200

Fig 7 Factor Information

Analysis of Variance for Pitch Diameter

Source	DF	SS	MS	F	P
feed rate(mm/sec)	2	0.004571	0.002286	5.55	0.010
Speed	1	0.006690	0.006690	16.26	0.000
feed rate(mm/sec)*Speed	2	0.026112	0.013056	31.72	0.000
Error	24	0.009878	0.000412		
Total	29	0.047251			

Model Summary

S	R-sq	R-sq(adj)
0.0202871	79.10%	74.74%

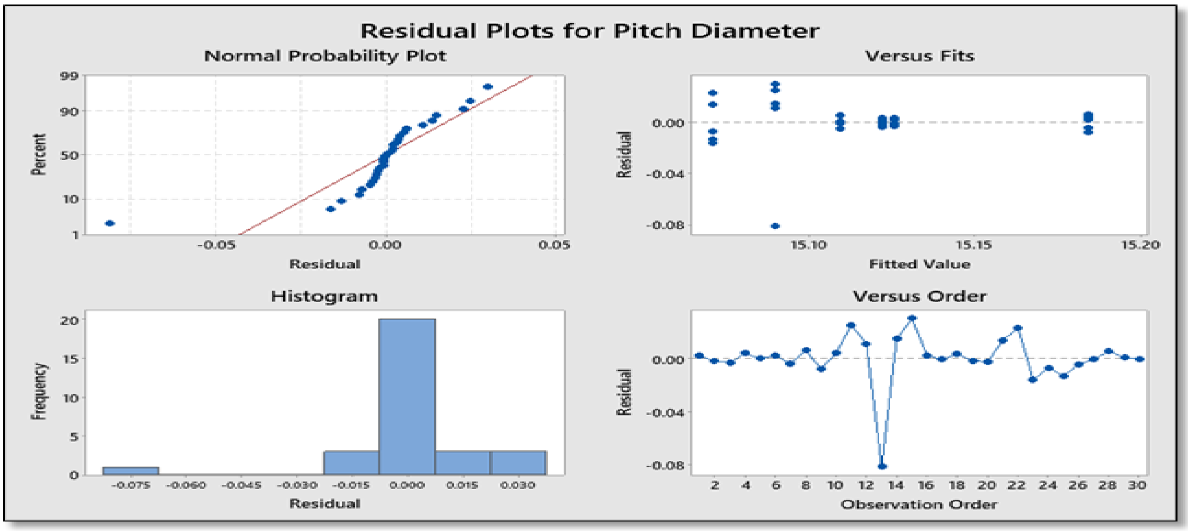

Fig 8 Anova Analysis

In conclusion, based on the analysis results and interpretation, you can reject the null hypotheses for feed rate and speed, suggesting that both factors have a significant effect on pitch diameter. Additionally, the interaction effect between feed rate and speed is also significant. The model appears to be a good fit for the data, explaining a substantial portion of the variability in pitch diameter

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VI. IMPROVE PHASE

➢ *Design of Experiments*

DOE is a statistical technique used in quality control for designing, controlling, evaluating, and interpreting groups of experiments to make sound decisions at a low cost and in a short amountof time.

DOE is concerned with understanding the impacts of certain variables on other variables. The goal is to create a cause-and-effect link between a variety of independent factors and relevant dependent variables. In the DOE competition, the dependent variable is known as the response, while the independent variables are known as factors. Experiments are carried out at various factor values known as levels. Each experiment run involves a different level of the researched factors.

Table 8 Doe Parameters M16 X 1.5

Experiment	X1 (RPM)	X2 (Feed Rate)	Observation (Y)
1	1000	0.5	15.061
2	1000	0.5	15.059
3	1000	0.5	15.069
4	1000	0.5	15.058
5	1000	0.8	15.205
6	1000	0.8	15.189
7	1000	0.8	15.2
8	1000	0.8	15.07
9	1000	1	15.01
10	1000	1	15.034
11	1000	1	15.11
12	1000	1	15.143
13	1000	1.2	15.15
14	1000	1.2	15.123
15	1000	1.2	15.045
16	1000	1.2	15.118
17	1100	0.5	15.11
18	1100	0.5	15.132
19	1100	0.5	15.128
20	1100	0.5	15.121
21	1100	0.8	15.085
22	1100	0.8	15.092
23	1100	0.8	15.098
24	1100	0.8	15.079
25	1100	1	15.156
26	1100	1	15.168
27	1100	1	15.148
28	1100	1	15.152
29	1100	1.2	15.103
30	1100	1.2	15.118
31	1100	1.2	15.109
32	1100	1.2	15.099
33	1200	0.5	15.063
34	1200	0.5	15.078
35	1200	0.5	15.1
36	1200	0.5	15.088
37	1200	0.8	15.182
38	1200	0.8	15.191
39	1200	0.8	15.209
40	1200	0.8	15.179
41	1200	1	15.036
42	1200	1	15.001
43	1200	1	15.044
44	1200	1	15.034
45	1200	1.2	15.126
46	1200	1.2	15.117

47	1200	1.2	15.134
48	1200	1.2	15.129
49	1250	0.5	15.204
50	1250	0.5	15.228
51	1250	0.5	15.213
52	1250	0.5	15.195
53	1250	0.8	15.077
54	1250	0.8	15.065
55	1250	0.8	15.08
56	1250	0.8	15.063
57	1250	1	15.157
58	1250	1	15.139
59	1250	1	15.161
60	1250	1	15.169
61	1250	1.2	15.024
62	1250	1.2	15.048
63	1250	1.2	15.037
64	1250	1.2	15.03

The above table shows the variations in the RPM and Feed Rate with respect to the variation in Pitch Diameter. We carried out four trials for each with four levels of variation in the attributes. Each trial gave us a different pitch dimension, all the obtained data are to be evaluated so that we can conclude which among the variation is suitable to obtain good dimension stability in future work also.

➢ *ANOVA ON DOE*

Factor Information

Factor	Type	Levels	Values
X1 (RPM)	Fixed	4	1000, 1100, 1200, 1250
X2(Feed Rate)	Fixed	4	0.5, 0.8, 1.0, 1.2

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
X1 (RPM)	3	0.003072	0.001024	1.39	0.257
X2(Feed Rate)	3	0.011467	0.003822	5.19	0.003
X1 (RPM)*X2(Feed Rate)	9	0.156902	0.017434	23.67	0.000
Error	48	0.035348	0.000736		
Total	63	0.206789			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.0271369	82.91%	77.56%	69.61%

Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	15.1116	0.0034	4454.93	0.000	
X1 (RPM)					
1000	-0.00886	0.00588	-1.51	0.138	1.50
1100	0.00702	0.00588	1.19	0.238	1.50
1200	-0.00467	0.00588	-0.80	0.430	1.50
X2(Feed Rate)					
0.5	0.00758	0.00588	1.29	0.203	1.50
0.8	0.01739	0.00588	2.96	0.005	1.50
1.0	-0.00773	0.00588	-1.32	0.194	1.50
X1 (RPM)*X2(Feed Rate)					
1000 0.5	-0.0486	0.0102	-4.77	0.000	2.25
1000 0.8	0.0459	0.0102	4.51	0.000	2.25
1000 1.0	-0.0208	0.0102	-2.04	0.047	2.25
1100 0.5	-0.0035	0.0102	-0.34	0.736	2.25
1100 0.8	-0.0475	0.0102	-4.67	0.000	2.25
1100 1.0	0.0451	0.0102	4.43	0.000	2.25
1200 0.5	-0.0323	0.0102	-3.17	0.003	2.25
1200 0.8	0.0[illegible]59	0.0102	6.48	0.000	2.25
1200 1.0	-0.0705	0.0102	-[illegible].92	0.000	2.25

Fig 9 ANOVA ON DOE

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Fisher Pairwise Comparisons: X1 (RPM)

Grouping Information Using Fisher LSD Method and 95% Confidence

X1 (RPM)	N	Mean	Grouping
1100	16	15.1186	A
1250	16	15.1181	A
1200	16	15.1069	A
1000	16	15.1027	A

Means that do not share a letter are significantly different.

Fisher Pairwise Comparisons: X2(Feed Rate)

Grouping Information Using Fisher LSD Method and 95% Confidence

X2(Feed Rate)	N	Mean	Grouping
0.8	16	15.1290	A
0.5	16	15.1192	A B
1.0	16	15.1039	B C
1.2	16	15.0944	C

Means that do not share a letter are significantly different.

Fisher Pairwise Comparisons: X1 (RPM)*X2(Feed Rate)

Grouping Information Using Fisher LSD Method and 95% Confidence

X1 (RPM)*X2(Feed Rate)	N	Mean	Grouping
1250 0.5	4	15.2100	A
1200 0.8	4	15.1902	A B
1000 0.8	4	15.1660	B
1250 1.0	4	15.1565	B C
1100 1.0	4	15.1560	B C
1200 1.2	4	15.1265	C D
1100 0.5	4	15.1227	C D
1000 1.2	4	15.1090	D E
1100 1.2	4	15.1072	D E
1100 0.8	4	15.0885	D E F
1200 0.5	4	15.0822	E F
1000 1.0	4	15.0742	E F
1250 0.8	4	15.0712	E F G
1000 0.5	4	15.0617	F G H
1250 1.2	4	15.0347	G H
1200 1.0	4	15.0287	H

Means that do not share a letter are significantly different.

Fig 10 Fisher Pairwise Comparison

The Fisher Pairwise Comparisons analysis for the interaction between RPM and Feed Rate reveals significant differences in pitch diameter among different combinations. Specifically, the Pitch Diameter at 1250 RPM with a Feed Rate of 0.5 and Pitch Diameter at 1200 RPM with a Feed Rate of 0.8 is significantly better than other combinations. These findings emphasize the intricate interplay between RPM and Feed Rate on the pitch diameter outcomes in the needle valve manufacturing process.

- *Control Phase*

The Control Phase of the "Reduction of Defect and Variation Using Six Sigma Methodology" endeavour focuses on sustaining the advancements made in minimizing defects and process variation. Through the deployment of a range of tools, the initiative ensures the optimization, efficiency, and uniformity of the valve manifold manufacturing process. Precise process controlsare methodically introduced, guiding operators in adhering to standardized procedures and pivotal parameters. Statistical Process Control methods provide real-time surveillance, enabling swift actions to counter potential deviations. Ongoing training initiatives continually enhance the workforce's skills, ensuring precise execution of the enhanced process. Consistent monitoring and audits ascertain alignment with established standards. Key performance indicators are vigilantly monitored and communicated, providing valuable insights into the effectiveness of control measures and overall project triumph. By leveraging these Control Phase tools, the overarching objective of streamlining production, reducing defects, and lessening process variation is accomplished, culminating in heightened efficiency and product quality.

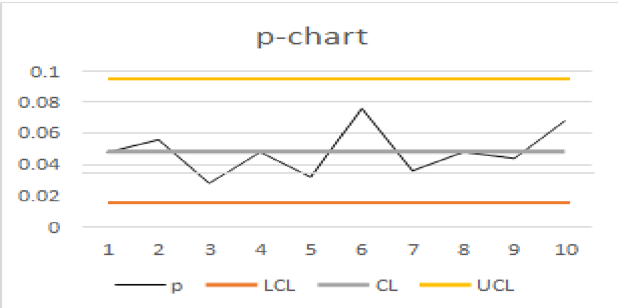
- *Control Phase Report:*

- Implementation of Process Controls and Standardization: During the Control Phase of the "Reduction of Defect and Variation Using Six Sigma Methodology" initiative, strong emphasis should be placed on introducing process controls and standardization measures. Crucial parameters identified in earlier DMAIC phases should be closely monitored to ensure they remain within specified limits. Standardized work instructions, visual aids, and comprehensive process documentation should be put in place to guide operators and uphold consistency.
- Utilization of Statistical Process Control (SPC): To maintain the achieved reductions in defects and process variation, Statistical Process Control techniques should be harnessed. Continuous monitoring of control charts should be conducted to swiftly detect any shifts or trends in process performance. This proactive approach facilitates prompt corrective actions, safeguarding stable production.
- Continual Training and Skill Enhancement: Ongoing training initiatives should be executed to elevate the competencies and understanding of operators and pertinent staff members. The periodic training should ensure that the workforce is well-equipped to adhere to established protocols, effectively manage unforeseen situations, and proficiently sustain the improved manufacturing process.
- Regular Monitoring and Auditing: Consistent audits and process evaluations should be performed to assess adherence to established process controls and standards. This continuous monitoring mechanism shall aid in the early detection of potential issues or deviations, enabling timely interventions and corrective measures.
- Measurement of Performance and Reporting: Essential performance indicators (KPIs) should be diligently tracked to gauge the effectiveness of process controls and enhancements. Progress and accomplishments should be communicated through periodic performance reports, offering stakeholders valuable insights into project success.

VII. CONCLUSION

To measure the above-chosen improvement decision, we have initiated the data of possible defects with the same volume and number of lots of valves manufactured. Using the P Chart, wemeasure the.

Sr. No	Lot Size	No of defects	p	LCL	CL	UCL
1	250	12	0.048	0.008	0.048	0.089
2	250	14	0.056	0.008	0.048	0.089
3	250	7	0.028	0.008	0.048	0.089
4	250	12	0.048	0.008	0.048	0.089
5	250	8	0.032	0.008	0.048	0.089
6	250	19	0.076	0.008	0.048	0.089
7	250	9	0.036	0.008	0.048	0.089
8	250	12	0.048	0.008	0.048	0.089
9	250	11	0.044	0.008	0.048	0.089
10	250	17	0.068	0.008	0.048	0.089
Total	2500	121				



p-bar	0.048
UCL	0.089
LCL	0.008

Process Sigma	3.161

with 1.5 shift

Fig 11 Possible Process Sigma Level

➢ *From the Identified two KPIs: -*

- *Defects Per Million Opportunities*

Our New Defects Per Million Opportunities = (121/2500) *1000000 = 48400 Improvement on DPMO = (Initial DPMO - Final DPMO) / Initial DPMO

Improvement on DPMO = (72400 - 48400) / 72400 Improvement on DPMO = 33.15%

- *Process Sigma Level*

Our new process sigma level is 3.161

Improvement on Process Sigma Level = (Updated Process sigma level - Initial process sigma level) / Initial process sigma level

Improvement on Process Sigma Level = (3.161 – 2.958) / 2.958 Improvement on Process Sigma Level = 6.86%

We have reached our aim of the six-sigma project to reduce the defects by atleast25%.

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