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A Case Study of Defects Reduction in a Valve Guides of cylinder heads for large engines Manufacturing Process by Applying Six Sigma Principles and DMAIC Problem Solving Methodology

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Abstract— The Six Sigma's problem solving methodology DMAIC has been one of several techniques used to improve quality. This paper demonstrates the empirical application of Six Sigma and DMAIC to reduce product defects within a valve guides manufacturing organization. The paper follows the DMAIC methodology to investigate defects, root causes and provide a solution to reduce/eliminate these defects. The analysis from employing Six Sigma and DMAIC indicated that the oven's temperature and conveyor's speed influenced the amount of defective gloves produced. In particular, the design of experiments (DOE) and two-way analysis of variance (ANOVA) techniques were combined to statistically determine the correlation of the oven's temperature and conveyor's speed with defects as well as to define their optimum values needed to reduce/eliminate the defects. As a result, a reduction of about 50% in the "leaking" gloves defect was achieved, which helped the organization studied to reduce its defects per million opportunities (DPMO) from 195,095 to 83,750 and thus improve its Sigma level from 2.4 to 2.9.

Keywords— Cylinder heads, Defects reduction, DMAIC, Six Sigma, Valve Guides.

I. INTRODUCTION

In today's world, business has become more and more competitive. All industries and organisations have to perform well in order to survive and be profitable. As well as the engine manufacturing industry, the organisation studied in this paper itself has to maintain the quality of its products so as to be able to delight customers and thus effectively compete in the market. In general, one of the most vital concerns for the valve guides manufacturing industry is the reduction of common quality defects such as size of internal diameter after honing operation. From this point, not only does an organisation waste its resources and time to re-manufacture the products, but it also contributes to the loss of customers' satisfaction and trust. As a result, this has driven a particular valve guides manufacturing organisation to improve the quality of its products in order to create a competitive strategic advantage for its business and introduce itself to become a global organisation for further prospects. This paper investigates quality issues at a valve guides manufacturing company and provides a solution to reduce/eliminate the most common defects. In order to accomplish this, the paper evocates the principles and tools of one of the most effective quality management and improvement methodologies, Six Sigma. In particular, the DMAIC (Define-Measure-Analyse-Improve-Control) problem-solving and improvement model of Six Sigma is followed. Under the umbrella of this model, several statistical and quality improvement tools such as fishbone diagram, Pareto chart, Design of Experiments (DOE) and two-way analysis of variance have been used. As an initial step, the paper briefly reviews some of the relevant theory of Six Sigma and DMAIC, paying particular attention to the benefits and the positive impact on performance that these approaches bring to organisations, and the manufacturing process studied.

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II. METHODOLOGY

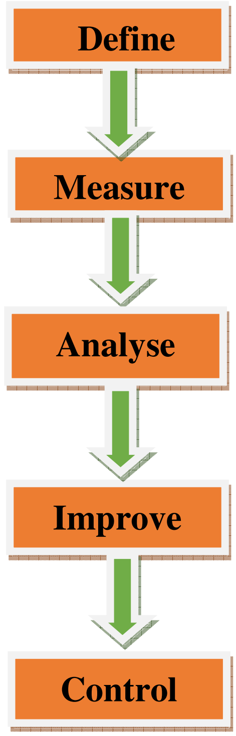

Fig.1 Flowchart diagram of methodology

2.1 Define

This stage within the DMAIC process involves defining the team's role; project scope and boundary; customer requirements and expectations and the goals of selected projects.

2.2 Measure

This stage includes selecting the measurement factors to be improved and providing a structure to evaluate current performance as well as assessing, comparing and monitoring subsequent improvements and their capability.

2.3 Analyse

This stage centres in determining the root cause of problems (defects), understanding why defects have taken place as well as comparing and prioritising opportunities for advance betterment.

2.4 Improve

This step focuses on the use of experimentation and statistical techniques to generate possible improvements to reduce the amount of quality problems and/or defects.

2.5 Control

Finally, this last stage within the DMAIC process ensures that the improvements are sustained and that ongoing performance is monitored. Process improvements are also documented and institutionalized.

III. PROBLEM DEFINITION

Problem Statement - Valve Guide bore undersize after fitment in to Cylinder Head.

3.1 Horizontal Valve Guide Study

a) Part number selected for study - 27.023.22.0.01 – Cylinder Head Valve Guide
b) Other similar part numbers having the problem - Nil
c) Other similar part numbers not having the problem - Nil
d) Last manufacturing process stage where the Problem is generated- Valve Guide fitment

e) Process stages where the problem is inspected currently-- Final Inspection at Sub Assembly
f) Current average rejection in % for last 1 Year - 8 %
g) Maximum and Minimum rejection in % for the last 8 months
h) Suspected physical phenomenon's that can lead to the problem
i) Valve Guide ID not coming back to its original shape after fitment.
j) Contraction of valve guide ID.
k) Actual physical phenomenon observed in the shop that is leading to the problem
l) Valve Guide ID not coming back to its original shape after fitment.
m) Number of lines/presses/machines used in the suspected last manufacturing stage creating the problem-- One Line (Sub Assembly)
n) Number of moulds in each equipment/machine-- Nil
o) Objective of the project- To reduce the rejection from 8 % to 0 %
p) Annual Savings in Rs. Lakhs if the defect is made zero in the part number selected for doing the study - Rs.0.78277 Lakhs
q) Response - Variable
r) Specification (if the response is variable) - 18.000 to 18.027

3.2 Process mapping clearly indicating the generating stage and inspection stages

a) Finished Valve guides from stores (from Supplier) &Finished Cylinder head from Machine shop.
b) Snap Ring fitment on the valve guide groove (At Sub-Assembly
c) Valve guide Dipping into liquid nitrogen (At Sub-Assembly)
d) Valve guide fitment into Cylinder head (At Sub-Assembly)

Fig.2 Photograph of Valve Guide

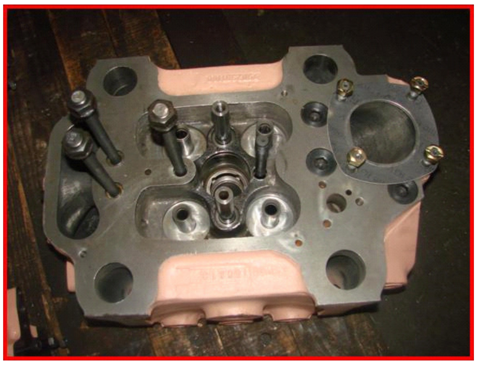

Fig.3 Valve Guide fitted into Cylinder Head

IV. MEASURE AND ANALYSIS

4.1 Objectives of Measure

To identify the parameter which causes the valve guide ID Undersize.

4.1.1 List of parameters (SSV's):

1. Valve Guide OD.
2. Valve Guide ID.
3. Valve Guide Hardness

4.1.2 Technique / Tool used:

- Product / Process search
- Paired Comparison

4.1.3 Product / Process search for SSV# 1 & 2 i.e. Valve Guide ID & OD

- We have collected the data of 54 nos valve guides.
- We have checked these valve guides before fitment for OD & ID.
- The same 54 nos were checked after fitment in to the cylinder head for the ID.

Table 1. Paired Comparison SSV -1

Sr No	OD Before Fitment Bottom	Sr No	OD Before Fitment Middle	Sr No	OD Before Fitment Top
B3	28.028	B3	28.027	B3	28.029
B1	28.029	B4	28.028	B4	28.029
B4	28.029	B1	28.031	B1	28.031
G6	28.033	B7	28.033	G8	28.031
B5	28.034	B8	28.033	B7	28.033
B7	28.034	G4	28.033	G2	28.033
B6	28.035	G8	28.033	G4	28.033
G3	28.035	B2	28.034	G3	28.034
G7	28.035	G7	28.034	G7	28.034
B2	28.036	G2	28.035	G1	28.035
G1	28.036	G6	28.035	G6	28.036
B8	28.036	B5	28.036	B2	28.037
G4	28.036	B6	28.036	B5	28.038
G8	28.036	G3	28.036	B8	28.038
G2	28.037	G1	28.037	B6	28.039
G5	28.040	G5	28.039	G5	28.042
Top Count	3	Top Count	3	Top Count	8
Bottom Count	2	Bottom Count	2	Bottom Count	8
Total Count	5	Total Count	5	Total Count	16

Since TC < 6
This SSV is not the Cause

Since TC < 6
This SSV is not the Cause

Since TC < 6
This SSV is not the Cause

Table 2. Paired Comparison SSV -2

Sr No	ID Before fitment Bottom Avg
B7	17.997
B2	18.002
B5	18.002
B8	18.003
B6	18.004
B1	18.005
B4	18.005
B3	18.006
G7	18.008
G3	18.009
G8	18.012
G5	18.015
G4	18.016
G2	18.019
G1	18.02
G6	18.021

Sr No	ID Before fitment Middle Avg
B8	17.999
B6	18.001
B7	18.001
B4	18.003
B1	18.004
B2	18.004
B5	18.004
G7	18.007
B3	18.009
G8	18.011
G3	18.015
G5	18.017
G4	18.019
G2	18.020
G6	18.022
G1	18.023

Sr No	ID Before fitment Top Avg
B6	18.001
B5	18.002
B2	18.004
B1	18.006
B4	18.008
G7	18.008
B8	18.010
G8	18.011
B3	18.012
B7	18.015
G5	18.016
G3	18.019
G2	18.022
G6	18.022
G4	18.023
G1	18.031

Top Count	8
Bottom Count	8
Total Count	16

Top Count	7
Bottom Count	7
Total Count	14

Top Count	4.5
Bottom Count	6
Total Count	10.5

Since TC > 6
THIS SSV IS CONFIRMED CAUSES

Since TC > 6
THIS SSV IS CONFIRMED CAUSES

Since TC > 6
THIS SSV IS CONFIRMED CAUSES

Table 3. Paired Comparison SSV -3

Valve Guide hardness

Specification	740 Min.
G6	637
B5	652
G1	657
G2	670
B4	684
B2	692
B3	695
B7	700
G7	705
B1	710
G3	730
B6	737
G4	744
G8	757
B8	765
G5	785

Top Count	1
Bottom Count	1
Total Count	2

Since TC < 6
This SSV is not the Cause

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4.2 Analysis

a) Valve guide ID total count at Bottom, Middle and Top is more than 6. This is the cause for the Valve Guide ID Undersize problem.
b) To validate the Valve Guide ID Before fitment is one of the cause for valve guide ID Undersize after fitment.
c) Better Condition Vs Current Condition.

Parameter	Better Condition	Current Condition
Valve Guide ID Specification	18.008 / 18.035	17.997 / 18.006

Sample Size: 6B, 6C

Table 4. Better Vs Current

Top Count	6
Bottom Count	6
Total Count	12

Sr No	ID After fitment
	Bottom
B2	17.898
B1	17.990
B3	17.991
B6	17.992
B5	17.995
B4	17.996
G5	18.015
G3	18.018
G4	18.021
G2	18.023
G6	18.029
G1	18.032

Since TC > 6 and there is no Overlap hence the cause is validated

4.2.1 Root Cause Analysis

Summary

Table 5. Root Cause Analysis

No	Root causes identified for the problem	Technique/Tool used for pinpointing	Department responsible for controlling	Process owner responsible for controlling

1	Valve Guide ID Before fitment is creating the problem.	• Component Search. • Product / Process search. • Paired Comparison. • B Vs C	• SQIP / QA • Materials	• Supplier

V. RESULT AND DISCUSSION

Monthly rejection trend before
Nov 11 to Oct 12

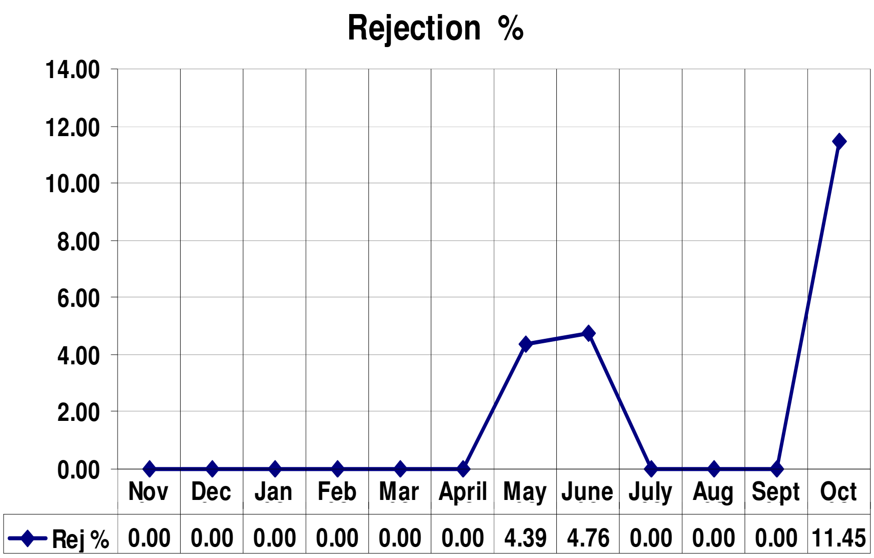

Fig. 4 Rejection Trend in Year 2011 to 2012

Monthly rejection trend after
April 14 to Mar 15

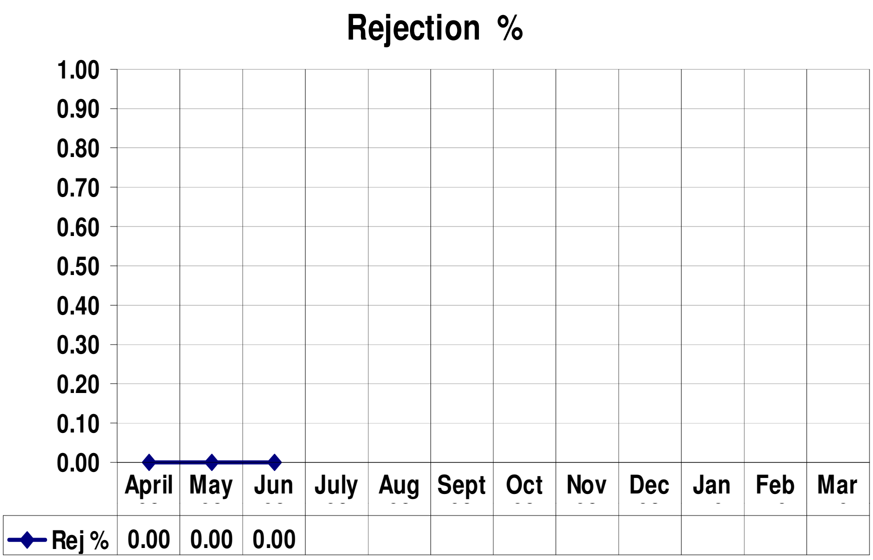

Fig. 5 Rejection Trend in Year 2014 to 2015

VI. CONCLUSION

Tangible Benefits derived through the project

1. Valve Guide Overall scrap reduced from 38500 PPM to 0 PPM.
2. Valve Guide ID undersize scrap reduced from 38500 PPM to 0 PPM.
3. Estimated cost benefits is Rs. 0.28277 Lakhs per year.

Intangible benefits derived through the project

1. Reduction in Valve Guide bore size variation will help to reduced warranty complaints in inlet & exhaust valve wear.
2. Adopted the systematic problem solving methodology of 6 sigma tools

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