Six Sigma Implementation on Engine Assembly Line in Analyzing and Improving the Defects

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Abstract: **Defects in Engine Assembly Line tends to occur resulting from various reasons which can be analyzed and removed with the help of six sigma. To reduce number of engine rejections, DMAIC (Define, Measure, Analyze, Improve and Control) improvement methodology is used. In define phase review, the problem is mapped by the issues causing them. In measure phase review, data is collected and process stability as well as process capability is determined. During Analyzing phase review, the causes are identified by identifying the gaps between ideal and actual process. In improvement phase review, brainstorming is done to arrive at an improvement strategy which is planned and implemented. Finally at control phase review, the control plan is validated and further opportunities are identified. The study reports the improvement in engine assembly defects reducing from 9684 PPM to 1500 PPM. The sigma level is significantly improved from 3.8 to 4.5.**

Keywords: **Engine Assembly, Six Sigma, DMAIC, SIPOC, PPM.**

I. INTRODUCTION

Six sigma is a statistical approach to a process improvement. It involves the use of statistical tool and technique to analyze and improve a process. It is a relentless follow up of variability reduction and defect elimination. Six sigma project in an organisation follows a definite order and has value targets like cycle time reduction of a process, customer satisfaction, pollution reduction, reduction in cost or increase in profit. Capability study measures standard deviation from the mean value and nearest specified value in sigma unit represented by ‘σ’. Process sigma and corresponding defects per million opportunities are provided in Table I.

TABLE I: SIGMA LEVEL vs. DPMO

PROCESS SIGMA	DPMO
6	3.4
5	230
4	6210
3	66800
2	308000

This case study was carried out in an engine assembly and manufacturing plant where most of the complaints were regarding the engine oil level low. Hence, the purpose was the reduction of these defects and to improve the assembly process using six sigma.

II. DEFINE PHASE

A. Problem Statement:

Defects were reported during engine assembly process was maximum in case of engine oil level low. Total PPM calculated was 9684 PPM and sigma level was 3.8 sigma.

B. Goal Statement:

Defects at engine assembly line are to be reduced from 9684 PPM to 1500 PPM.

C. Defined Team:

A functional team was deployed in Engine assembly, engine hot test, engine PDI, CMM and quality check departments with a team leader. Target time for the team was 6 months to achieve the set objective.

D. Project Scope:

The development of engine from manufacturing to engine assembly unloading is described in Fig. 1.

Fig. 1: PROJECT SCOPE IN DETAIL

E. Project Plan:

Project plan was carried out by mapping the process using SIPOC (Supplier, Input, Process, Output, customer) diagram, deployment chart, Prioritized chart and at last potential quick analysis was done and again remapping is done with improved data. Different phases with target dates are given in Table II.

TABLE II: TARGET DATES

PHASES	START DATE	END DATE
Define	1 Jan	31 Jan
Measure	2 Feb	28 Feb
Analyze	2 March	31 March
Improve	1 April	30 April
Control	1 May	31 May

SIPOC diagram was drawn in Table III which determines the important elements of the process flow in the initial stage.

TABLE III: SIPOC DIAGRAM

SUPPLIER	INPUT(S)	PROCESS	OUTPUT(S)	CUSTOMER
Process Engineer	SOP's (Standard Operating Procedures)	Customer review → Equipments validation	Completed work in six months	Vehicle Assembly Dept.
Engine supply unit	Engine components	→ Improvement techniques	Improvement techniques reduced time at each station	
Process Engineer	Tools and equipments			Service Dept.
Human and Resource department(HRD)	Manpower	→ Remapping	Defect free engine	

III. MEASURE PHASE

In this phase, fully developed current status data is been depicted and various indicators are identified which are depicted in Table IV.

TABLE IV: INDICATORS

INPUT	PROCESS	OUTPUT
Manpower skills and knowledge	OP-10 rejection	Total engine defects PPM was 9684 PPM
SOP follow up	OP-10A rejection	
Tools used in assembly	OP-20 rejection	

OP-10, OP-10A and OP-20 are the various inspecting operation units. OP-10 inspects the machining process in CMM like cleaning of cylinder block, cylinder head and crankshaft. OP-10A inspects the assembly process which commences with bearing shell fitment to finally exhaust manifold and alternator fitment. OP-20 inspects the hot-test and final aesthetics check.

Following defects were found out during PDI inspection given in Table V.

TABLE V: ENGINE PDI DEFECTS

S.NO.	PDI defects	Defect frequency	Cumulative frequency	Cumulative frequency percentage
1	Engine oil level low	89	89	46.6
2	Turbo jubilee clip low torqued	24	113	59.16
3	Poor Lacquer	13	126	65.97
4	Fuel filter loose	12	138	72.25
5	Injector dust cover missing	12	150	78.53
6	Starter motor and alternator wrong part number fitted	10	160	83.77
7	Front seal not fitted properly	10	170	89.01
8	Injector cover clip missing	8	178	93.19
9	Dipstick missing	8	186	97.38
10	Flywheel Thread damage	5	191	100.00
Total		191		
Total Production		19723		
Total PPM		9684		

The engine defects were found out after taking into account every aspect like SOP's follow up, Skill and knowledge of the operator, tools adequacy and measurement analysis by calculating cumulative frequency percentage. The above data shows that the engine defects occur at 9684 PPM of total production of 19723.

The voice of customer (VOC) was the dissatisfaction of the customer as the defects were unacceptable and was leading to production loss in engine assembly. Since the engine assembly defects were massive in case of engine oil level low hence VOC was converted into critical customer requirements (CCR) as reduction in these defects.

$$\text{PPM for engine defects} = \frac{(\text{Total defects}) \times 1000000}{(\text{Total Production})}$$

$$= \frac{191 \times 1000000}{19723}$$

$$= 9684$$

Sigma level = 3.8

IV. ANALYZE PHASE

During analysis, Pareto chart was prepared to prioritize the defects. Probable cause, possible cause and finally root cause was found out.

From Pareto chart in Fig2.it was interpreted that 80% of the defects were due to the 20% reasons. If we remove those 20% then the process will be improved by 80%. In our case those 20% defects are the engine oil level low, turbo jubilee clip torque and poor lacquer.

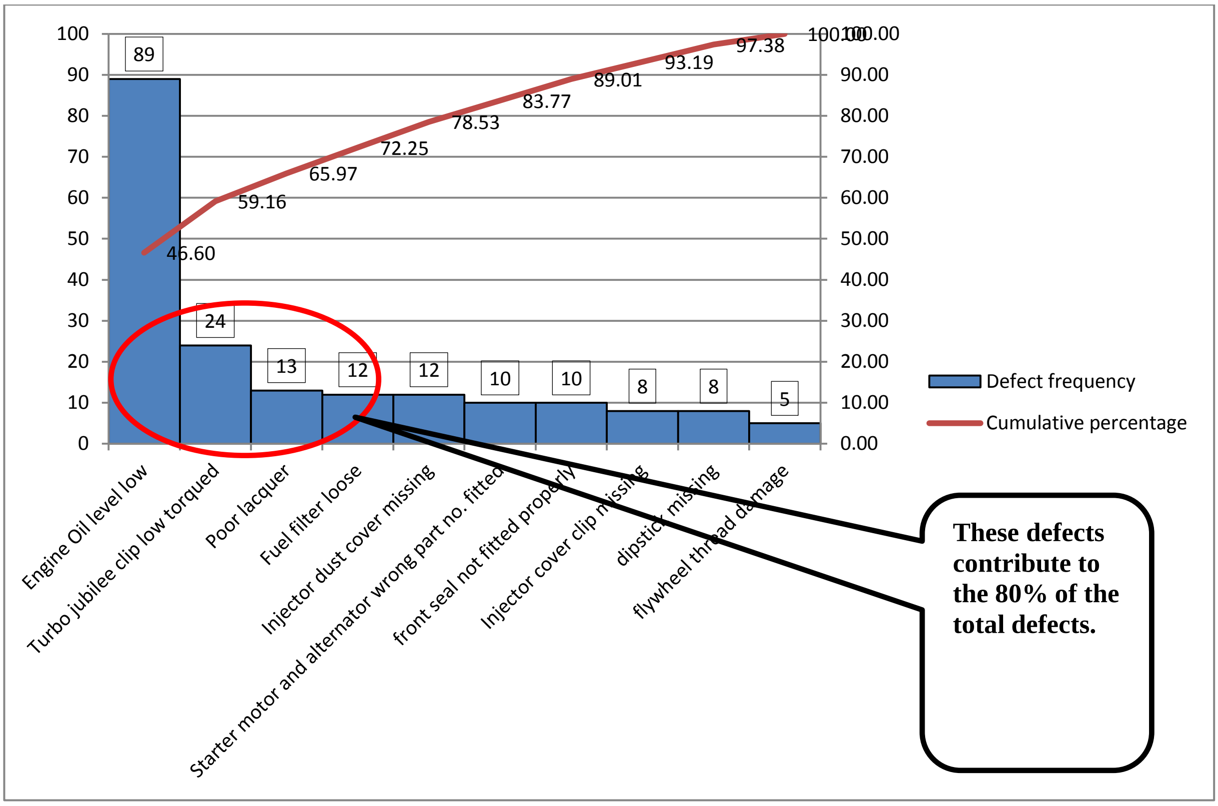

Fig. 2: PARETO CHART FOR ENGINE DEFECTS

Now Why-Why analysis was carried out to arrive at a root cause of the problem. Why-Why analysis for Engine oil level low is shown in Fig. 3.

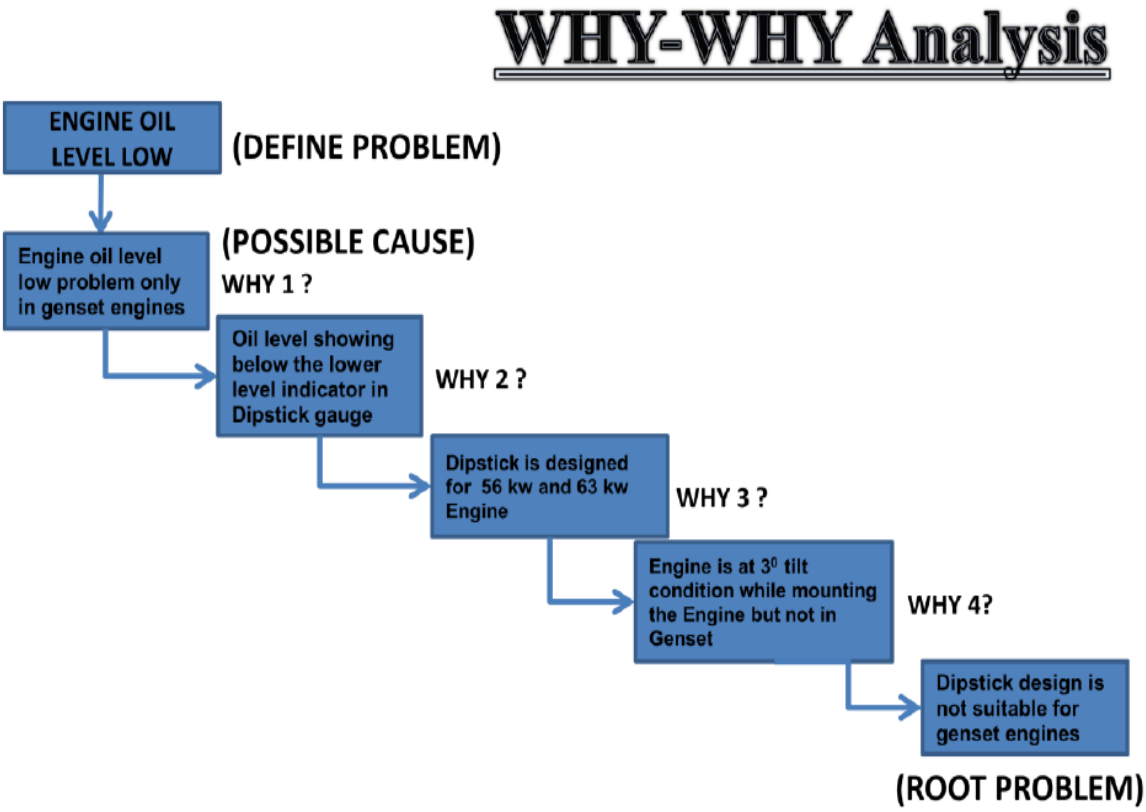

Fig. 3: WHY-WHY ANALYSIS OF ENGINE OIL LEVEL LOW

Root Cause was identified: Dipstick design is not suitable for genset engines. The reason was that in genset engines there is no tilting of the engine when finally placed on the frame but the 56kw and 63 kw engine is placed at 3 degree tilt. Now carrying out cause and effect analysis depending upon six factors : Material, Man, Machine, Method, Measurement and Environment various reasons were found out shown in Fig. 4.

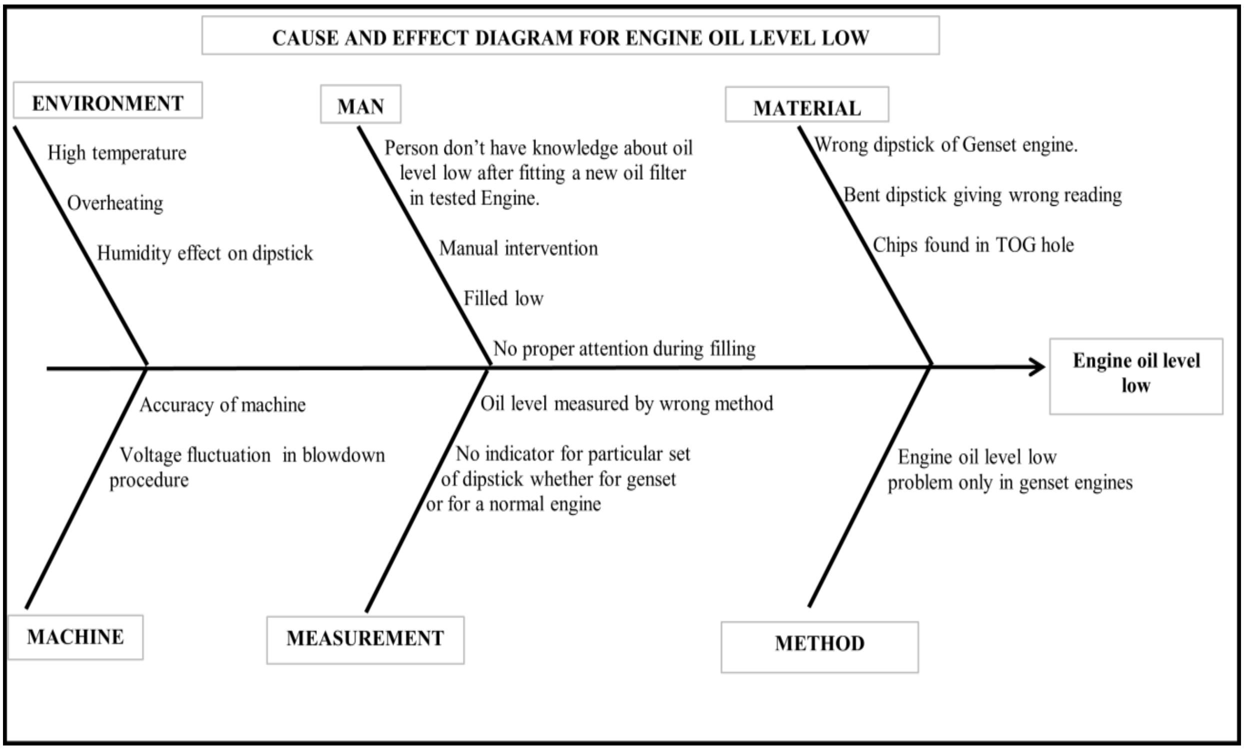

Fig. 4: CAUSE AND EFFECT FOR ENGINE OIL LEVEL LOW (BEFORE)

The reasons found out in cause and effect diagram were validated based on observing each effect on particular stations. If the reason is not valid for the problem it is cut off finally arriving on the actual reason shown in Fig. 5

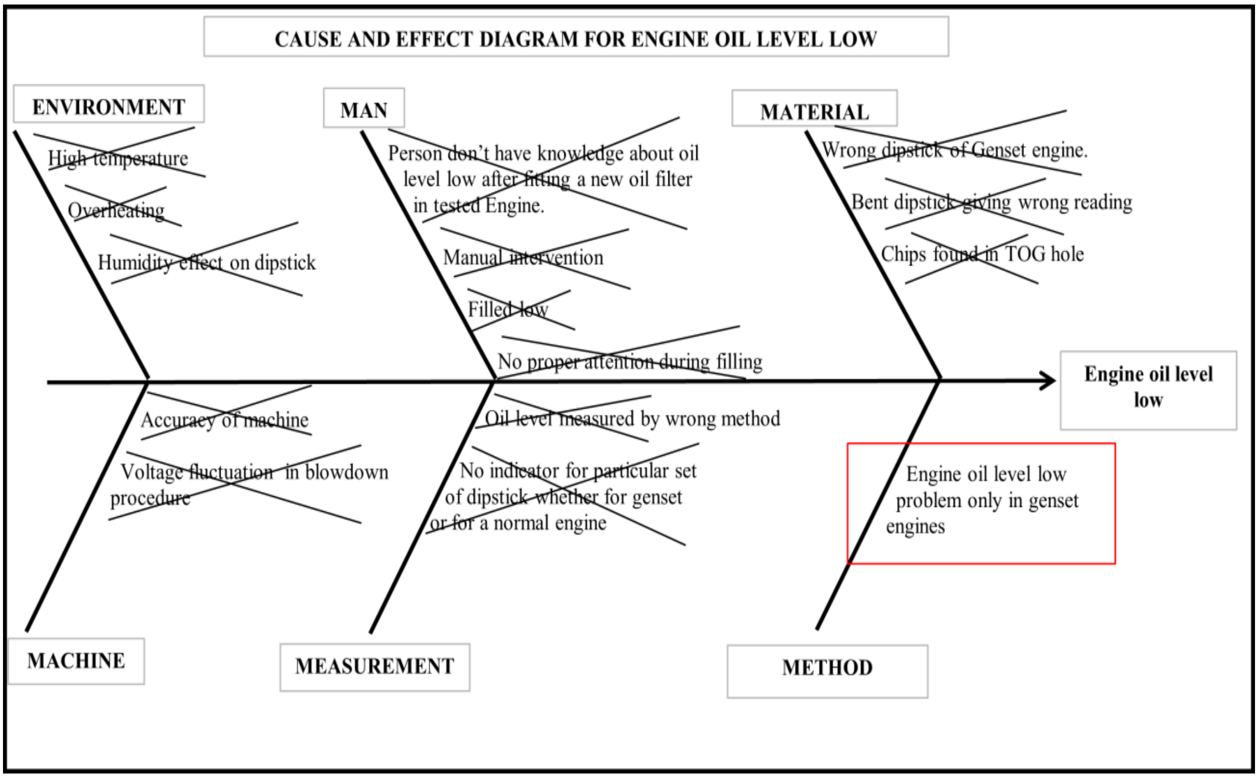

Fig. 5: CAUSE AND EFFECT FOR ENGINE OIL LEVEL LOW (AFTER)

Similarly Why-Why analysis and cause and effect were carried out for Turbo jubilee clip low torque, Poor Lacquer, Fuel filter loose and root cause analysis were found out and solutions were implemented.

V. IMPROVE PHASE

In improvement phase, solutions were found out to prevent the occurrence of the problems, the solution derived was that dipstick required for genset engines were redesigned according to the engine position and properly designed dipstick for 56 kw and 63 kw engines which are at 3^0 tilt condition.

After implementing the derived solutions in target time, the process improvement is shown in Table VI.

TABLE VI: RESULTS AFTER IMPLEMENTING THE SOLUTIONS

Top 10 defects	**Defect frequency after solutions**	**Defect frequency before solutions**
Engine Oil level low	4	89
Turbo jubilee clip low torqued	0	24
Poor lacquer	3	13
Fuel filter loose	0	12
Injector dust cover missing	0	12
Starter motor and alternator wrong part no. fitted	0	10
front seal not fitted properly	1	10
Injector cover clip missing	1	8
dipstick missing	2	8
flywheel thread damage	0	5
Total	11	191
Total Production	7332	19723
Total PPM	1500	9684

For the data obtained after implementing the solutions, Pareto chart was redrawn in Fig.6 and it shows considerable improvement in the process shown:

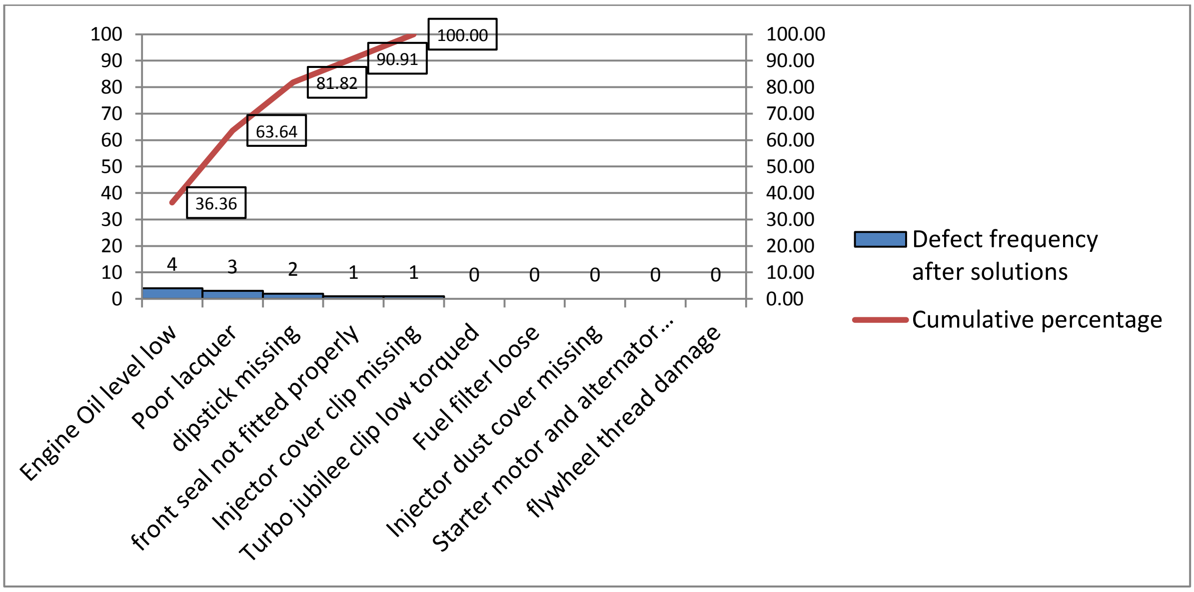

Fig. 6: PARETO CHART AFTER IMPROVEMENT FOR ENGINE DEFECTS

For the implemented solutions, statistical evaluation in Table VII was carried out for the acceptance of the significant results.

Null hypothesis - H_0: Defect proportion before implementation = Defect proportion after implementation

Alternative hypothesis - H_a: Defect proportion before implementation > Defect proportion after implementation

TABLE VII: HYPOTHESIS TESTING

Sample	Total defects	Total Production	Sample-p
1	191	19723	0.009684
2	11	7332	0.001500

Difference in sample-p = p (1) - p (2) = 0.008184

95% CI for difference = 0.0064

Corresponding Z value = 6.95

P-value = 0.00

Result: Since P-value is <0.05, H_0 is rejected.

The above result shows that the alternative hypothesis is accepted and the process after implementing the solutions significantly improved the engine assembly process.

A. Sigma level

As the main objective of this project was to reduce the PPM of the defects in the engine assembly and significantly improve the sigma level. After the DMAIC methodology, process was again remapped and the calculations are as under:

PPM for improved engine defects = (Total defects) x 1000000

(Total Production

= 11 x 1000000

7332

= 1500

Sigma level = 4.5

So, sigma level was improved from 3.8 to 4.5 in the set target time by the team deployed for this task.

VI. CONTROL PHASE

During the control phase, process maps and instructions, control charts, training documents were updated. A system for monitoring the implemented solutions, along with specific metrics for regular auditing was setup. The completed project documentation was submitted to the owner and participants.

VII. CONCLUSION

This project study was carried out in an assembly line to improve the process in line and significantly reduce the defects. It will lead to various factors including customer satisfaction, process time improvement, reduce in poor quality cost and a systematic approach at work. The DMAIC methodology helped the deployed team to complete the given task in set target time and other analysis has also helped to understand the process statistically. Six sigma technique in today's era is opted to maximize efficiency of the production unit and control over every step in the process.

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