Ensure Material availability & Reduce line Stoppages by Improving the Quality of Material

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Abstract: Now A Days in the Global Market Competition Is Very High & If Maintain The Place In Global Market Quality Is Very Important. This topic describes the importance of the material availability online in time at assembly line and it also describes how material shortages affects daily production schedule. Material availability at point of use can be a problem for many companies, i.e. parts are not always available at the assembly line exactly when needed. 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 Drive shaft 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 strength of the raw material of drive shaft is less which influenced the amount of defective drive shaft. After tensile test of the raw material, change of raw material has been done because of less tensile strength of the raw material. As a result, a reduction of about 0% in the "lower pull load" defect was achieved, which helped the organization studied to reduce its defects per million opportunities (DPMO) from 16,0127 to 95 and thus improve its Sigma level from 2.49 to 5.23.

Keywords*: Six sigma, DMAIC Methodology, Quality improvement, Defect reduction*

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1. INTRODUCTION

The research study was carried out in a unit based in Vadodara, India which manufactures moulded case circuit breaker also known as MCCB. The objectives for the implementation of the lean in the company are as follows:

- To Ensure material timely available at assembly line.
- To Reduce line stoppages because of material shortage.
- To Increase production.

2. SIX SIGMA METHODOLOGY

The Six Sigma methodology is one of the most successful quality management initiatives. Six Sigma is defined as a multifaceted, customer-oriented, structured, systematic, proactive and quantitative philosophical approach for business improvement to increase quality, speed the deliveries up and reduce costs. [9] Six Sigma is recognized as a problem-solving method that uses quality and statistical tools for basic process improvements.

Fig-1: Steps of six sigma methodology

❖ DMAIC:

The DMAIC means Define, Measure, Analyses, Improve and Control. These all work together to create the DMAIC process. This process is incredibly important in six sigma process because it is what helps bring a diverse team together. This is what helps them complete a process or model so that they can share their work and get the job done. DMAIC is used for an existing business process

3. GENERAL OVERVIEW OF LITERATURE REVIEW

Siddharameshwar M. et al. [1]studied the problem faced in manufacturing company at Volvo group truck organization at India, is material excess and shortage in an assembly line due to error in a Bill of Materials (BOM) and other factors. This research paper shows that the reduction material request and line return can be achieved with 79.34% & 81.77% respectively in a VOLVO GROUP TRUCK ORGANIGATION of Volvo India Pvt. Ltd. By a standardizing a bill of material with eliminating 80.54% Error of total number of an Error.

Dr. Rajeshkumar U. Sambhe [2]focused on a case of provoked mid-sized auto ancillary unit consisting of 350-400 employee and employed Six Sigma (SS) methodologies to elevate towards the dream of SS quality level. The goal was to Reduce internal PPM from 18909 PPM to 2500 PPM for Lighting stalk assembly. They started implementing new processes according to Defects per Millions Opportunities (DPMO) to be reduce which can be called as Design of Experiments (DOE).

DayanandYadav [3] used Lean Six Sigma tools to improve the bottleneck activity in project department of industry & improved productivity. The case study gives a clear indication of high returns of invested time of team for Lean Six Sigma methodology implementation. Lean Six Sigma is the logical next step for a company pursuing excellence in existing process or products, also designing new products and services

PloytipJirasukprasert et al. [4] applied Six Sigma Principles and DMAIC Problem Solving Methodology to reduce defect in a Rubber Gloves Manufacturing Process. This paper demonstrates application of Six Sigma and DMAIC to reduce product defects within a rubber gloves 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. They achieved reduction of about 50% in the "leaking" gloves defect, 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.

.KRISHNAN. PV et al. [5] found that the Two Wheeler Manufactures Company faced the problem of work in process inventory. The main objective of this paper was to find the work in process for the optimal size using lean techniques. They have almost reduced 50 % work in process inventory cost when they shift over from conventional to kitting system.

ShashankSoni et al. [6] discusses the quality and productivity improvement in a manufacturing enterprise through a case study. In this Paper identifies the root causes of failure for welding process at a manufacturing plant and proposes to use Operational Six Sigma technique to eliminate the problem. The study proposal a real time monitoring system by which the shear strength of the weld can be eliminated, without destructive resting. Due to 100% inspection, error made by the selective sampling can be eliminated, reducing the scrap page cost.

Chintan C. Rao et al. [7] reviewed on Six Sigma Implementation in Small Scale Foundry. This Paper Focuses On The General Overview Of Publication And The Case Industry, The Company By Using DMAIC Methodology. From this study conclude that six sigma is a breakthrough improvement methodology with the use of six sigma it is confirm that they get a min.50% improvement.

M. Shanmugaraja [8] have done analysis for controlling the defects in aluminum die casting industry. In this analysis, casting process of a two-stroke engine oil pump body is concentrated. The selected component has often rejected due to blow hole defects. This paper has explored that how best casting industries can take steps to control or minimize defects through Six Sigma program. The confirmation experiment showed that the rejection rate was reduced to 4.8% from 17.22%.

Nitesh M. Kathar et al. [9] used application of Six Sigma and DMAIC to reduce product defects wihin an Engine manufacturing organization. The paper follows the DMAIC methodology to investigate defects, root causes and provide a solution to reduce/eliminate these defects. The study reports process quality improvement through reduction in defects from 17162 PPM to 714 PPM. They Cost of poor quality (COPQ) has been significantly reduced from 45 % per annum (18% to 10% of sale).

Darshak A. Desai et al. [10] analyzed the impact of Six Sigma on developing economy.The paper provides an insight into what kind of benefits Indian industries are gaining from Six Sigma. As revealed from the study that with some exceptions, different sizes as well as different sectors of the Indian industries have achieved more or less similar benefits from Six Sigma.

4. DMAIC Project on vendor quality problem

The following are the current problem which is faced by the L & T Company.

- Less production outcome against customer demand
- Material is not timely available at assembly line.
- Assembly line is stopped due to this shortages.

The all above problem is raised due to the incoming material quality. Vendors are sent material timely but the material are rejected during quality checking and it will be created shortage of material at assembly line. For this I collected three month data of material shortages and found the most critical material. This fig 2 shows that the most critical material which are responsible for the assembly line stoppages.

Fig-2: Graph of three months repetitive 2-bin shortage of item

Fig 5.1 shows that the drive shaft and bracket are the most common critical component which are responsible for the assembly line which are leads to production loss ultimately it will created company loss. & the main reason behind the shortage of critical item was quality problem.

4.1 Define Phase

The first stage of the Six Sigma and DMAIC's methodology is "define". This stage aims at defining the project's scope and boundary, identifying the voice of the customer (i.e. customer requirements) and goals of the project.SIPOC diagrams give a simple overview of a process and are useful for understanding and visualizing basic process elements.

SIPOC Diagram

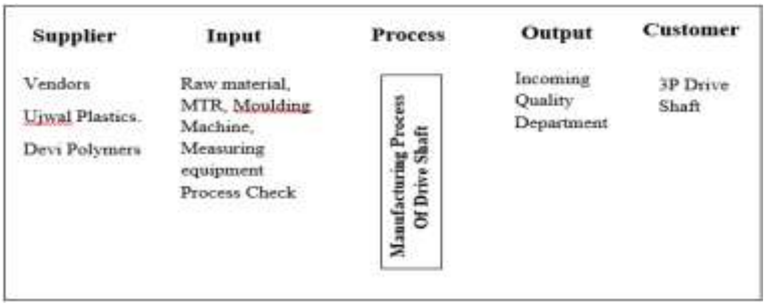

Fig-3: SIPOC Diagram

4.2 Measure Phase

The "measure" phase of the DMAIC problem solving methodology consists of establishing reliable metrics to help monitoring progress towards the goal(s), which in this research consisted of reducing the number of quality defects in the drive shaft manufacturing process. I collected 4 month data of drive shaft lots which had been checked & measured current sigma level & also measure defect level of drive shaft by using Xbar-R chart which shown below.

Current sigma level calculation for drive shaft making process	
3P DRIVE SHAFT	*March-Jun'16*
Number of Drive Shafts Received	11060
Rejected Drive Shafts	1771
Opportunities per unit	1
Defects per unit (DPU)	0.160127
DPMO	160127
Sigma Level	2.49

Table 1 – Sigma Level Calculation

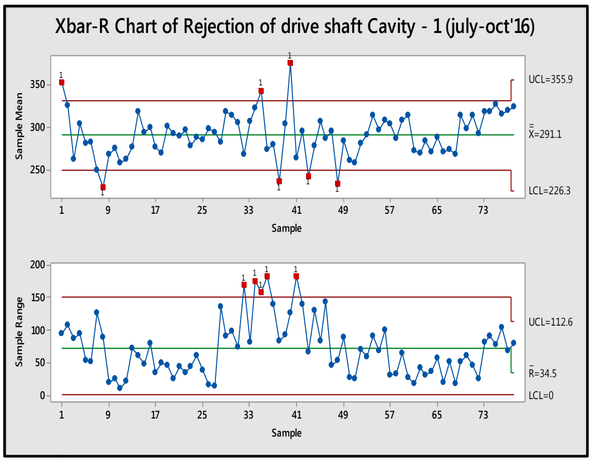

Fig-4: Xbar-R chart of rejection of 3P drive shaft – Cavity-1(Jun '15-Jun '16)

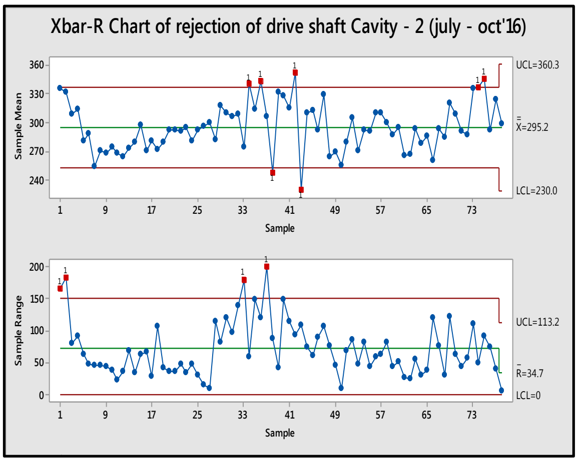

Fig-5: Xbar-R chart of rejection of 3P drive shaft – Cavity-2(Jun '15-Jun '16)

4.3 Analysis Phase

This phase is concerned with analyzing and benchmarking the key product/process performance metrics.We found out the all possible causes which are responsible for the rejection of drive shaft during brainstorming session & made cause & effect diagram which shown in fig 6.

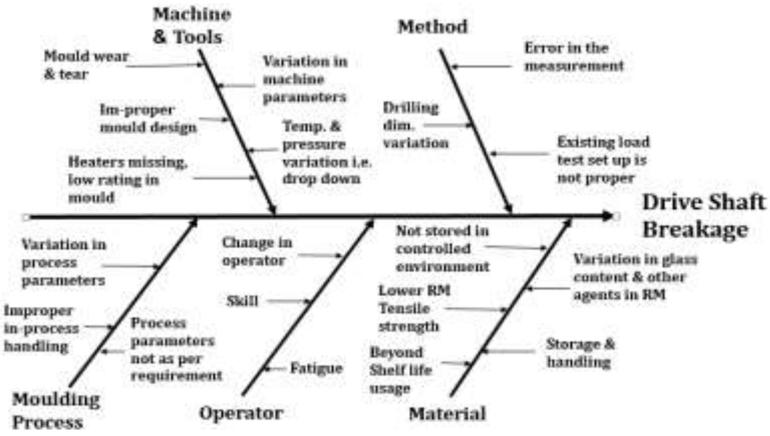

Fig-6:Cause and effect Diagram for moulding process

After making cause & effect diagram for moulding process of drive shaft we made cause & effect matrix. The cause and effect matrix is a tool which is used to prioritize potential causes identified using a cause and effect diagram. Based on cause & effect matrix we made pareto chart, the purpose of pareto chart to represent the most common sources of defects, the highest occurring type of defect, or the most frequent reasons for customer complaints.

Scale:	
0	None
2	Low
4	Med-Low
6	Med
8	Med-High
10	High

		Output variabls (Ys Effects)	1 Drive shaft breakage	2 No continuty	3 Lower pull load value	4 Moulding defects	5 Mis-alignment in assembly	6	7	
	Input variabls (Xs. Causes)	Output Rating	10	8	6	4	2			Rank
1	Drilling Dimensions variation		6	6	6	6	8			184
2	Exsiting load test set up is not proper		2	0	8	2	0			76
3	Error in the measurement		2	0	8	6	0			92
4	Variation in the machine parameters		8	8	8	2	2			204
5	Temprature Variation		8	8	8	2	2			204
6	Pressure drop during curing time		8	8	8	2	2			204
7	Mould wear and tear		6	6	6	0	0			144
8	Mould design		2	2	2	0	0			48
9	Heater missing, low rating used		6	6	6	6	2			172
10	Variation in the process parameters - charge weight, charge size		8	8	8	2	2			204
11	Process parameter not set as per process sheet/MTR		8	8	8	2	2			204
12	Im-proper handling during process		6	6	6	6	6			180
13	Change in the operater		6	6	6	6	6			180
14	Unskilled operater		8	8	8	8	8			240
15	Fatigue due to continuous working		8	8	8	8	8			240
16	RM used beyond shelf life		10	10	10	8	8			288
17	RM not stored in the controlled environment		6	6	6	2	2			156
18	Low RM tensile strength		10	10	10	8	8			288
19	Variation in glass content & other agents in RM		10	10	10	8	8			288
20	Im-proper handling & Mounting		6	6	6	6	6			180
	Total		134	130	146	90	80			3776

Table-2: Cause & effect matrix

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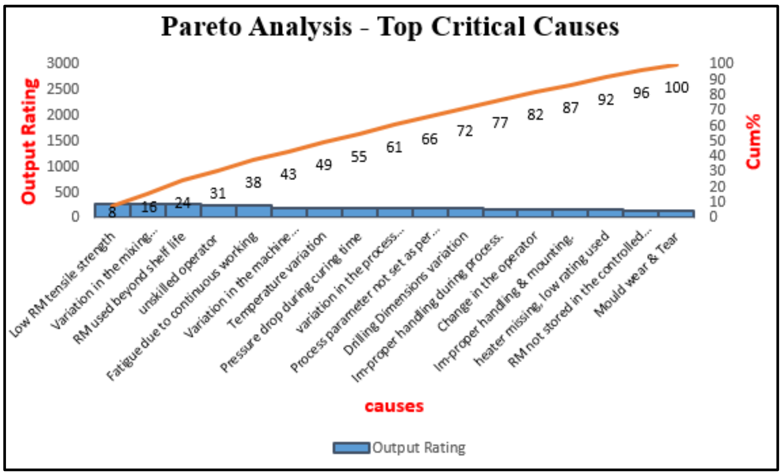

Fig-7:Pareto analysis for top critical causes

We first validated that whether drilling dimension variation was affected on lower pull load or not, for that we took 25 random sample of drive shaft with cavity-1 & cavity-2. Measure dimension of all sample and took 5 sample of each cavitywith known dimensions as highest & lowest range are Tested for Pull load strength & following are the observations.

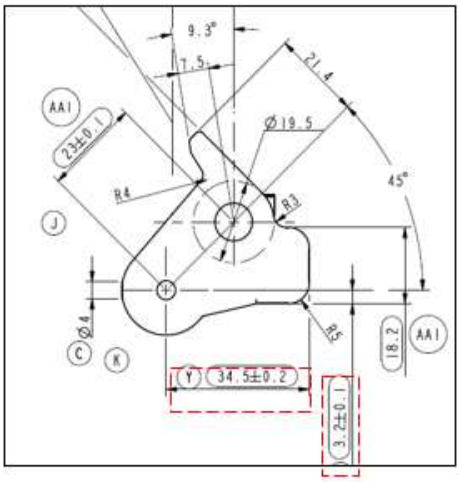

Fig-8: Drilling Dimension in drawing

	Cavity - 1			
	3.2 ±0.1		34.5 ±0.2	
Sr. No.	LEFT	RIGHT	LEFT	RIGHT
1	2.95	3.19	34.58	35.03
2	2.93	2.95	34.53	34.93
3	3.00	3.09	34.73	34.92
4	3.00	2.96	34.64	34.94
5	3.04	2.93	34.65	35.05
6	3.04	3.07	34.55	34.78
7	3.06	3.04	34.57	34.90
8	3.07	3.01	34.65	34.86
9	2.99	3.02	34.62	34.82
10	2.95	3.07	34.61	34.84
11	2.93	3.01	34.67	34.97
12	2.99	2.97	34.69	34.96
13	3.07	3.12	34.67	34.81
14	2.94	2.95	34.60	34.91
15	3.00	3.07	34.82	34.92
16	2.95	3.08	34.73	34.80
17	2.98	2.97	34.78	34.96
18	2.93	3.14	34.67	34.87
19	2.93	2.90	34.65	34.97
20	3.05	2.93	34.83	34.93
21	2.96	3.01	34.78	34.84
22	3.02	3.07	34.68	34.83
23	3.08	2.99	34.55	34.94
24	3.00	2.95	34.59	34.92
25	3.00	2.90	34.63	34.89
Min.	2.93	2.90	34.53	34.78
Max.	3.08	3.12	34.83	35.05
Average	2.99	3.02	34.66	34.90

Table-3: Cavity-1 Drilling Dimension observation

	Cavity - 2			
	3.2 ±0.1		34.5 ±0.2	
Sr. No.	LEFT	RIGHT	LEFT	RIGHT
1	2.98	2.95	34.74	34.78
2	3.02	3.05	34.61	34.67
3	3.03	3.02	34.74	34.81
4	3.03	3.00	34.71	34.74
5	3.00	2.91	34.79	34.90
6	3.05	3.00	34.93	34.80
7	3.03	2.91	34.68	34.86
8	3.05	3.19	34.90	34.86
9	2.98	2.91	34.82	34.92
10	2.81	2.91	34.83	34.71
11	3.06	3.10	34.81	34.65
12	2.96	2.97	34.78	34.95
13	2.97	2.95	34.92	34.90
14	3.02	2.92	34.52	34.86
15	2.93	3.06	34.69	34.85
16	2.88	2.85	34.65	34.79
17	3.01	2.95	34.64	34.88
18	3.05	2.94	34.67	34.86
19	2.95	3.01	34.63	34.83
20	2.99	2.92	34.63	34.89
21	3.00	2.89	34.64	34.89
22	2.91	2.80	34.67	34.65
23	2.95	3.05	34.90	34.87
24	3.03	2.99	34.70	34.94
25	3.03	2.89	34.91	34.90
Min.	2.81	2.80	34.52	34.65
Max.	3.06	3.19	34.93	34.95
Average	2.99	2.97	34.74	34.83

Table-4: Cavity-2 Drilling Dimension observation

	Cavity - 1				Pull Load (Min. 250Kg)
	3.2 ±0.1		34.5 ±0.2		
Sr. No.	LEFT	RIGHT	LEFT	RIGHT	
6	3.04	3.07	34.55	34.78	375.10
11	2.93	3.01	34.67	34.97	259.80
15	3.00	3.07	34.82	34.92	385.70
20	3.05	2.93	34.83	34.93	310.20
21	2.96	3.01	34.78	34.84	301.20

Table-5:Cavity-1 pull load test observation

	Cavity - 2				Pull Load (Min. 250Kg)
	3.2 ±0.1		34.5 ±0.2		
Sr. No.	LEFT	RIGHT	LEFT	RIGHT	
7	3.03	2.91	34.68	34.86	299.9
13	2.97	2.95	34.92	34.90	304.4
14	3.02	2.92	34.52	34.86	326.8
23	2.95	3.05	34.90	34.87	275.9
25	3.03	2.89	34.91	34.90	304.6

Table-6:Cavity-2 pull load test observation

As per Design specification drilling dim. Not withstand in the limits as 3.2 (±0.1) & 34.5 (±0.2). Hence specification tolerance are re- define 3.2 (+0.1/-0.3) & 34.5 (+0.5/-0.2) in the form of SOP w.r.t. drilling process in the thermoset Component & product reliability Observed Pull Load values of the drive shafts with maximum & minimum dimensional variation observed in the range of 259.80 – 385.70kg in cavity -1 & 275.9 – 326.8kg in cavity-2. Hence it is concluded that drilling dimensional variation within specified limits as per SOP not affects the pull load strength of the Drive Shaft & no need to change in the existing set tolerance limit as per SOP.

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We have done process analysis to find out whether the process is being running as per MTR (mould trial report) or not. We have checked the all process related things such as raw material storage and control, charge making set up, charge pattern and charge weight, check mould closing, temperature of the mould cavity, clamping pressure on moulding machine, warpage prevention fixture and weight of drive shaft with flash. All process analysis which we have done are shown below.

Fig-9: Charge making set up

Fig-10: Charge Pattern & weight

Fig.12 shows that Temperature at Cavity portion of the mould is obs. as 163°c against required 162°c. The temperature we found that was as per MTR report. Fig 13 shows thatClamping pressure observed 310kg/cm2 same as required.

Fig-11: Check Mould closing

Paper placed between the Die stopper and cavity of the mould in open conditionis not able to remove in closed condition.Hence Mould closing is found ok as no gapbetween Die Stopper and Cavity.

Fig-12: Temperature at mould cavity

Fig-13: Clamping pressure on moulding machine

Fig.12 shows that Temperature at Cavity portion of the mould is obs. as 163°c against required 162°c. The temperature we found that was as per MTR report. Fig 13 shows thatClamping pressure observed 310kg/cm2 same as required.

Fig-14: Drive shaft weight with flash

Fig.14 shows that drive shaft weight with flash. Weight of Drive Shaft with flash observed 144gms as required.

4.4 Improvement Phase

We have done tensile test on raw material of the drive shaft which is come from supplier 1 & supplier 2. After that we found that there was problem of strength of raw material that's why we changed the raw material which come from supplier 1 with supplier 2. And rejection of drive shaft due to lower pull load value is stopped. Following are the observation.

Material	SMC 516/25 of Devi Polymers					Statistical analysis	
Test details	Tensile strength - Min. 700kg/cm²						
Specimen No	Cross sectional area			Tensile Load (Kg)	Tensile strength (Kg/cm²)	Avg.	Standard Deviation
	Width (mm)	Thk. (mm)	Area (cm²)				
LE-1	25.08	3.26	0.82	710	868.39		
LE-2	25.05	3.17	0.79	473	594.59		
LE-3	25.01	3.29	0.82	727	883.54		
LE-4	25.12	3.27	0.82	550	669.57		
LE-5	25.09	3.26	0.82	472	577.08		
LE-6	25.13	3.25	0.81	449	553.16		
LE-7	25.16	3.21	0.81	840	1040.07		
LE-8	25.18	3.23	0.81	572	703.30		
LE-9	25.01	3.26	0.82	513	627.97		
LE-10	25.09	3.29	0.83	619	749.88		
LE-11	25.07	3.21	0.80	416	516.93	681.46	177.29
LE-12	25.11	3.27	0.82	479	583.37		
LE-13	25.15	3.23	0.81	691	850.62		
LE-14	25.16	3.25	0.82	552	675.08		
LE-15	25.07	3.26	0.82	815	997.21		
LE-16	25.12	3.23	0.81	460	566.94		
LE-17	25.16	3.21	0.81	471	583.18		
LE-18	25.12	3.22	0.81	711	879.01		
LE-19	25.18	3.28	0.83	617	747.65		
LE-20	25.08	3.16	0.79	297	374.75		
LE-21	25.03	3.21	0.80	356	443.08		
LE-22	25.16	3.23	0.81	412	506.97		
M-1	25.1	3.4	0.85	393	460.51		
M-2	25.09	3.36	0.84	373	442.45		
M-3	25.16	3.3	0.83	910	1096.02		
M-4	25.04	3.32	0.83	614	738.58		
M-5	25.18	3.28	0.83	403	487.95		
M-6	25.1	3.25	0.82	1011	1239.35		
M-7	25.08	3.3	0.83	489	590.84		
M-8	25.01	3.26	0.82	498	610.80		
M-9	25.11	3.29	0.83	345	417.62		
M-10	25.06	3.26	0.82	344	421.08		
M-11	25.11	3.27	0.82	793	965.78	667.11	266.10
M-12	25.1	3.23	0.81	324	399.64		
M-13	25.19	3.28	0.83	982	1188.53		
M-14	25.11	3.21	0.81	580	719.58		
M-15	25.18	3.23	0.81	553	679.93		
M-16	25.03	3.28	0.82	475	578.57		
M-17	25.07	3.27	0.82	291	354.97		
M-18	25.1	3.2	0.80	326	405.88		
M-19	25.2	3.22	0.81	511	629.74		
M-20	25.07	3.3	0.83	631	762.71		
M-21	25.06	3.26	0.82	669	818.89		

Table-7: Tensile test report of raw material (supplier-1)

RE-1	25.16	3.3	0.83	458	551.62		
RE-2	25.22	3.23	0.81	353	433.34		
RE-3	25.18	3.21	0.81	755	934.08		
RE-4	25.09	3.26	0.82	510	623.52		
RE-5	25.16	3.3	0.83	808	973.17		
RE-6	25.11	3.28	0.82	831	1008.98		
RE-7	25.2	3.23	0.81	314	385.77		
RE-8	25.11	3.15	0.79	378	477.90		
RE-9	25.04	3.28	0.82	538	655.05		
RE-10	25.14	3.25	0.82	553	676.83		
RE-11	25.23	3.23	0.81	945	1159.61	687.67	209.73
RE-12	25.17	3.2	0.81	362	449.44		
RE-13	25.14	3.23	0.81	501	616.98		
RE-14	25.2	3.26	0.82	453	551.42		
RE-15	25.11	3.23	0.81	539	664.57		
RE-16	25.07	3.25	0.81	549	673.81		
RE-17	25.17	3.26	0.82	527	642.26		
RE-18	25.06	3.21	0.80	605	752.09		
RE-19	25.13	3.2	0.80	535	665.29		
RE-20	25.2	3.2	0.81	790	979.66		
RE-21	25.1	3.19	0.80	453	565.76		

Table-7: Tensile test report of raw material (supplier-1)

Material	SMC 405/25 of Mahindra Composite,					Statistical analysis	
Test details	Tensile strength - Min. 700kg/cm2						
Specimen No	Cross sectional area			Tensile Load (Kg)	Tensile strength (Kg/cm²)	Avg.	Standard Deviation
	Width (mm)	Thk. (mm)	Area (cm²)				
L1	25.08	3.22	0.81	1178	1458.69		
L2	25.19	3.3	0.83	1054	1267.94	1341.08	205.65
L3	25.18	3.26	0.82	893	1087.87		
L4	25.17	3.23	0.81	1260	1549.83		
M1	25.17	3.27	0.82	1247	1515.08		
M2	25.12	3.25	0.82	1154	1413.52	1281.94	225.53
M3	25.21	3.19	0.80	816	1014.67		
M4	25.12	3.26	0.82	970	1184.50		
R1	25.17	3.27	0.82	615	747.21		
R2	25.12	3.25	0.82	1015	1243.26	1183.44	297.61
R3	25.21	3.19	0.80	1121	1393.93		
R4	25.12	3.26	0.82	1105	1349.35		

Table-8: Tensile test report of raw material (supplier-2)

4.5 Control Phase

The control phase is where the new system is in place and it is institutionalized by modifying various Systems, polices, procedures, budgets, and instructions to make it work for the entire company. After changing the raw material the rejection level of drive shaft is reduced. Fig.15 shows that the before-after rejection level of the drive shaft of cavity-1 and Fig.16 shows that the before-after rejection level of the drive shaft of cavity-2 and both graphs are shown that process is under control

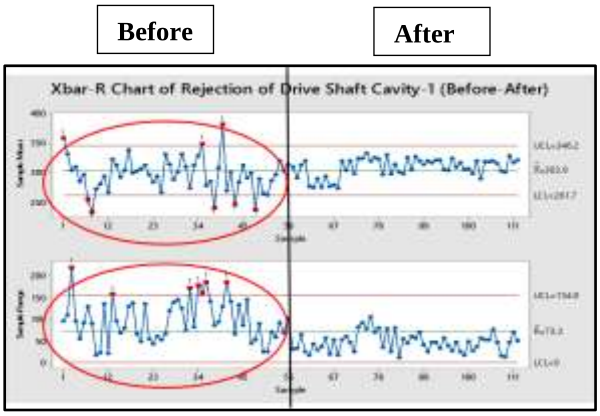

Fig-15: Comparison of before – after improvement for Xbar-R chart for of rejection of drive shaft Cavity-1

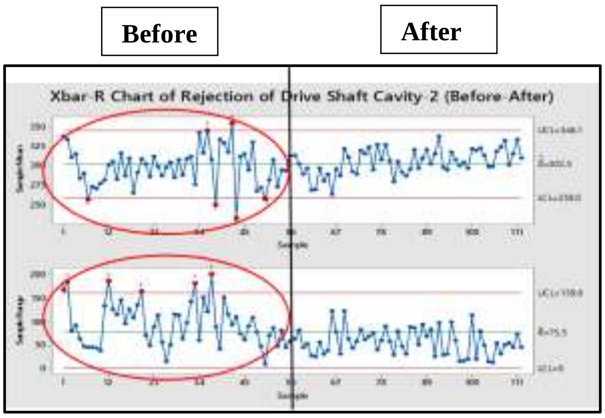

Fig-16: Comparison of before – after improvement for Xbar-R chart for of rejection of drive shaft Cavity-2

The sigma level of the drive shaft making process is also improved after changing the raw material of the drive shaft. The sigma level has been improved from 2.49 to 5.29. Fig.17 shows comparison of before after improvement of 2 bin empty item & fog.18 shows that comparison of before after improvement of production.

Table-9: Comparison of Sigma level before and after improvement

Fig-17: Comparison of before–after improvement of 2–bin empty item (Drive shaft)

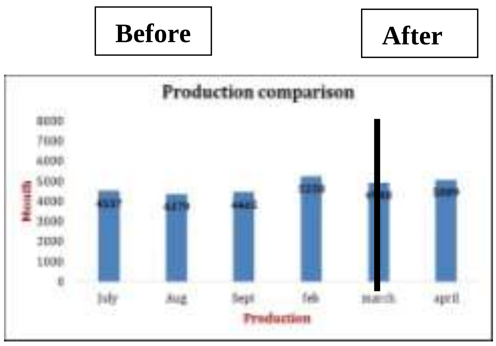

Fig-18: Comparison of before–after improvement of Production

6. CONCLUSION

We conclude that, the process was being running as per MTR specification and there was no problem related to process, only there was problem of strength of the raw material. So we changed the raw material, after changing raw material of the drive shaft we could stop the rejection of drive shaft lots due to lower pull load value. The rejection level due to lower pull load value has been reduced up to 16% to 0%. Because of reduction in rejection level of drive shaft the SIGMA LEVEL has been increase up to 2.49 to 5.23. As a result material is timely available at assembly line, ultimately shortage of drive shaft has been reduced.

REFERENCES

[1]"Study and Analysis on Reduction of Material Request and Line Return In a Volvo Truck Assembly Line" Siddharameshwa M; Dr. Vijaykumar,International Journal of Advanced Research in Computer Engineering & Technology, 2014

[2] "Six Sigma practice for quality improvement – A case study of Indian auto ancillary unit" Dr. Rajeshkumar U. Sambhe, IOSR Journal of Mechanical and Civil Engineering, 2012

[3] "Study of Productivity Improvement Using Lean Six Sigma Methodology" DayanandYadav, International Review of Applied Engineering Research, 2014

[4] "A Case Study of Defects Reduction in Rubber Gloves Manufacturing Process by Applying Six Sigma Principles and DMAIC Problem Solving Methodology" PloytipJirasukprasert, Jose Arturo Garza-Reyes, Horacio Soriano-Meier, Luis Rocha-Lona, Industrial Engineering and Operations Management, 2012
[5] **"**Work in process optimization through lean manufacturing"
krishnan. pv, vijayaramnath.b, dr. mohan. K. pillai, international journal of engineering research, 2011
[6] "Reduction of welding defects using six Sigma techniques" ShashankSoni, Ravindra Mohan, LokeshBajpai, S K Katare, International journal of mechanical engineering & robotics research, 2013
[7] "A Review of Six Sigma Implementation in Small Scale Foundry" Chintan C. Rao, &Darshak A. Desai, International Journal of Innovative Research in Science, Engineering and Technology, 2007
[8] "Defect control analysis for improving quality and productivity: an innovative Six Sigma case study" M. Shanmugaraja& M. Nataraj, Int. J. Quality and Innovation, 2011
[9] "Engine Assembly & Testing Process Quality Improvement Using DMAIC Approach (Six-Sigma) - Case Study" Nitesh M. Katharatarajan, Dr. S. A. Sonawane, Mr. Santosh Badve, International Journal of Engineering and Technical Research (IJETR), 2011
[10] "Impact of Six Sigma in a developing economy: analysis on benefits drawn by Indian industries" Darshak A. Desai, &Mulchand B. Patel, Journal of industrial engineering & management, 2009
[11] "Role of Inventory Management on Customer Satisfaction among the Manufacturing Firms in Kenya"Thogori M. & Dr. Jane GathenyaInternational Journal of Academic Research in Business and Social Sciences, 2014
[12] "Application of 7 Quality Control (7 QC) Tools for Continuous Improvement of Manufacturing Processes"Varsha M. Magar; Dr. Vilas B. ShindeInternational Journal of Engineering Research and General Science, 2014
[13] "Inventory Management- A Case Study"Dr. Angel Raphella. S, Mr. Gomathi Nathan. S, Ms. Chitra. G, International Journal of Emerging Research in Management &Technology, 2014