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SIX SIGMA IMPLEMENTATION ON A PRODUCTION LINE: A CASE STUDY

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ABSTRACT

In this world of competition, maintaining product quality is an important criterion of companies. Six Sigma is a tool which is used to reduce the rejections and improve quality. This paper describes the implementation of Six Sigma on a production line. The production line manufactures camshafts, facing an elevated rejection rate. The DMAIC (Define Measure Analyze Improve Control) methodology assists to minimize the number of rejections. The rejected camshaft is either send to scrap or for rework. To unravel the source of defects, Six Sigma provides a statistical approach to comprehend the root cause of defects. By deducing possible reasons for defects, it is easy to perceive the source of all variations. By implementing Six Sigma the quality level of production line has been improved.

KEYWORDS: Quality, Six Sigma, DMAIC methodology, Pareto Analysis and Fishbone Diagram.

1. INTRODUCTION

The letter 'Sigma' is derived from a Greek letter which is used to describe variation (Desai and Shrivastwa, 2010). Sigma represents the standard deviation of the processes. A standard deviation constitutes the variation that has occurred in a process. Six Sigma is an approach which improves the organization's products and processes by reducing the defect and enhancing customer satisfaction (Kumar, et al, 2014). Six Sigma can reduce defects to 3.4 parts per million in a process service and product (Shinrkar and Kallaurkar, 2010). The methodology that is used in six sigma in DMAIC, stands for Define, Measure, Analysis, Improve and Control. In the method, each of five steps is taken respectively to obtain a statistical and reliable result (Youssouf, et al, 2014).

In the present scenario, to maintain the quality of the products and services that companies are providing are of great importance. Many approaches have been followed to maintain the equality but six sigma is one the successful approach that is capable to locate the main cause of failure and also provide improved results with a systematic approach and statistical quality control (Westgard, 2016). This paper discusses all the phases of DMAIC method that is applied to a live production line to reduce the number of rejection of camshafts. The objective of this paper is to eliminate the key aspects of the rejection. The paper is concluded with improved results and quality by the application of six sigma.

2. LITERATURE REVIEW

Six Sigma is a procedure that emphasizes on understanding and documenting of the business process, data collecting and data using, making effective decisions on systems or processes and reducing variation (Desai and Shrivastava, 2010). It is a method to analyse data with statistics and to find the key factor of problems and reduce or eliminate its variations to improve

processes and ultimately improve quality and productivity. Statistical techniques are very effective and powerful means to quantify the variability of processes, analyse the variability with reference to product requirements, and eliminate this variability from product manufacturing

The paper describing the new approach of designing the control panel using Six Sigma Methodologies (Shiurkar and Kallaurkar, 2010) is an observational procedure which is executed with the help of different tools of Six Sigma. The FEMA technique, Hypothesis Test, Chi-Square Tests are conducted to evaluate the improvement in the design and manufacture of Control Panel.

The key factors involve in productive six sigma project implementations are identified as the profits and confronts of six sigma practices (Kumar et al.,2014). The principles of sustainable development should be accounted for the changes in current policy change in the economy and society. The organizations should create the way for a balanced and integrated approach in terms of economic, social, political, environmental and security interests. The major tool that is used in practice for perfection is Six Sigma and its implementation has been progressively increasing in business.

An automotive industry in turkey works for improvement in the supply chain of their finished parts also use Six Sigma DMAIC tools (Erbiyik and Saru, 2015). The aim of six sigma is to define, measure, analyze, correct and improve the variables which affect the quality of supply chain process in order to overcome the number of defects and failures and also to propose the improved method for the processes. In this study prevailing structure of Six Sigma is explained related to how to define the complicated problems with the help of statistical methods which are encountered in the supply chain with enough knowledge and relevant comments that can be employed in measurement and analysis of the supply chain.

A literature review and main future research areas on Six Sigma (Nonthaleerak and Hendry, 2006). This paper has done the study over 200 Six Sigma papers to classify them according to their content and methodology used. The study is a concern with developing a scientific foundation of methods used. Thus by merging Six Sigma with other methods or tools such as lean tools. The research is carried out to find an explanatory multi-case study for both nonmanufacturing and manufacturing industries of the Asian region.

Literature review and case discussion related to the topic provides a direction to accomplish the research. In the present case study efforts have been made to execute Six Sigma on the live production line manufacturing camshafts. The research work is carried out in industry located in Pithampur, Madhya Pradesh, India.

3. PROBLEMAND OBJECTIVES

In the present study, the main research problems are the high rejection of camshafts due to defects. Due to these defects, the camshafts were either treated as scrap or sent to rework. The aim of this project is to implement Six Sigma on the production line to reduce the defects by eliminating the root cause of the defects. In this section, only the research problems have been discussed but to find out by which course of action the clarification and the reason behind these problems can be completely eliminated is described in methodology.

The main objectives of this research work are to reduce the rejection of camshafts due to defects. The objectives are listed below :

- To curtail the number of defects in the production line.

- To find the ultimate cause of all the rework done on the production line.
- To maintain the quality of jobs produced.
- To attain quality in the way that the process or project is organized and managed.
- To exploit the involvement of customers, suppliers, workforce, and management in order to outdo or meet the expectations of customers for quality control.
- To develop skills to achieve sustainable quality improvement through process improvement.

4. METHODOLOGY

Six Sigma methodology emphasize by providing a better value for money by reducing costs and by improving customer satisfaction. DMAIC a very powerful methodology is used to attain Six Sigma quality. Each step has a unique role in completing the whole six sigma process. DMAIC stands for :

D- Define, M - Measure, A - Analysis, I - Improve and C - Control.

In present research implementation of DMAIC Methodology done and the five phases are discussed below.

4.1 Define

As per company's policy of maintaining quality, the camshafts which are manufactured at the production line are considered as scrap, if they do not fulfil the given criteria. These scraps are either rejected or send to rework based on the type of error camshaft is suffering. To eliminate this problem various reasons for rejection and rework are listed. Table 1 shows various reasons for defects.

Table 1 Different Type of Errors

Sr. No.	Name of Error	Effects of error	Number of Defects
1	Crack	Camshaft with a crack will be immediately rejected.	16
2	Dent	Camshaft having a dent on it is either send to rework or get rejected if not cured by rework.	112
3	Wheel mark	Camshaft having mark of grinding wheel will be send to rework.	21
4	Center shift	Camshaft having its center shifted will be immediately rejected.	42
5	Linear dimension	Camshaft having error in its linear dimension will be send to rework or get rejected if not cured by rework.	17
6	Diameter minus	Camshaft having its journal diameter below lower tolerance limit will be immediately rejected.	314
7	Keyway operation	Camshaft having an error in keyway is either send to rework or get rejected if not cured by rework.	60
8	Slot operation	Camshaft having error in slot is either send to rework or get rejected if not cured by rework.	11
9	BCD undersize	Camshaft having full cam undersize will be immediately rejected.	48

To evaluate which error is contributing more to the cause of defects in the production line a Pareto diagram was formed. Based on reading from Pareto analysis, it was found that dia

minus and dent were the major cause of rejections in the production line. Pareto diagram representing the different types of defects is shown in Figure 1

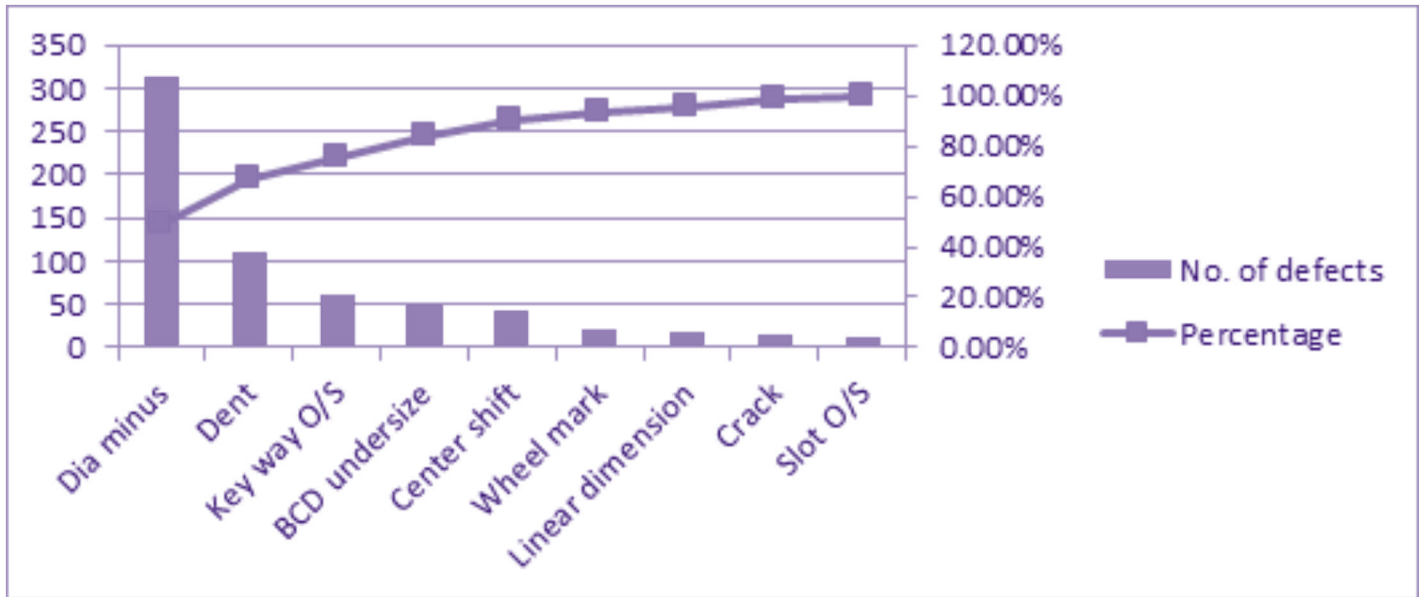


Figure 1 Pareto Diagram of Different Types of Defects

4.1 Measure

To measure the defects occurred in the production line, last one year data was collected. It was found that the average scrap produced in production line was 10025 ppm. A chart showing the total scrap is shown in figure 2.

Based on data gathered it was also discovered that the average rejection of journal diameter rejection due diameter minus defect is about 6700 ppm, shown in figure 3 and average rework is about 38100 ppm. The rejection due to dent is about 1800 ppm.

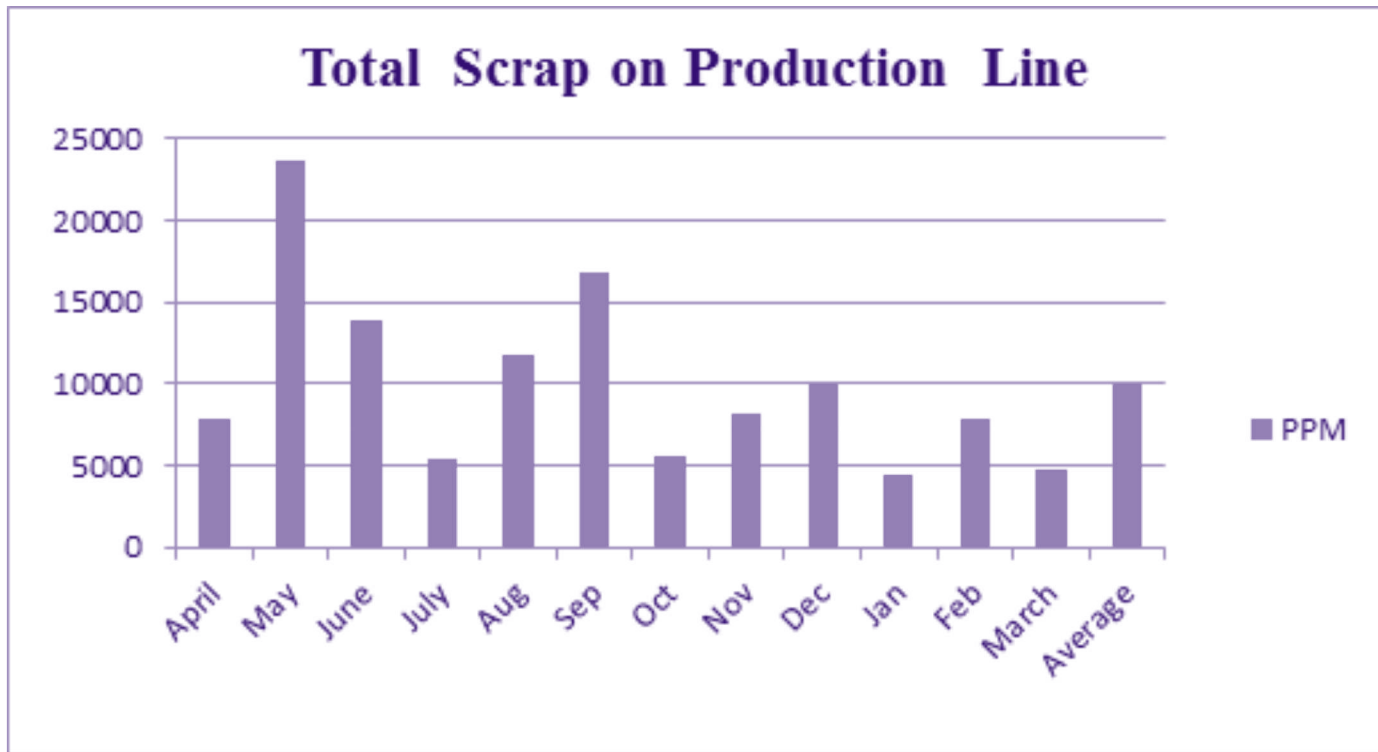


Figure 2 Total Scrap on Production Line (2016-17)

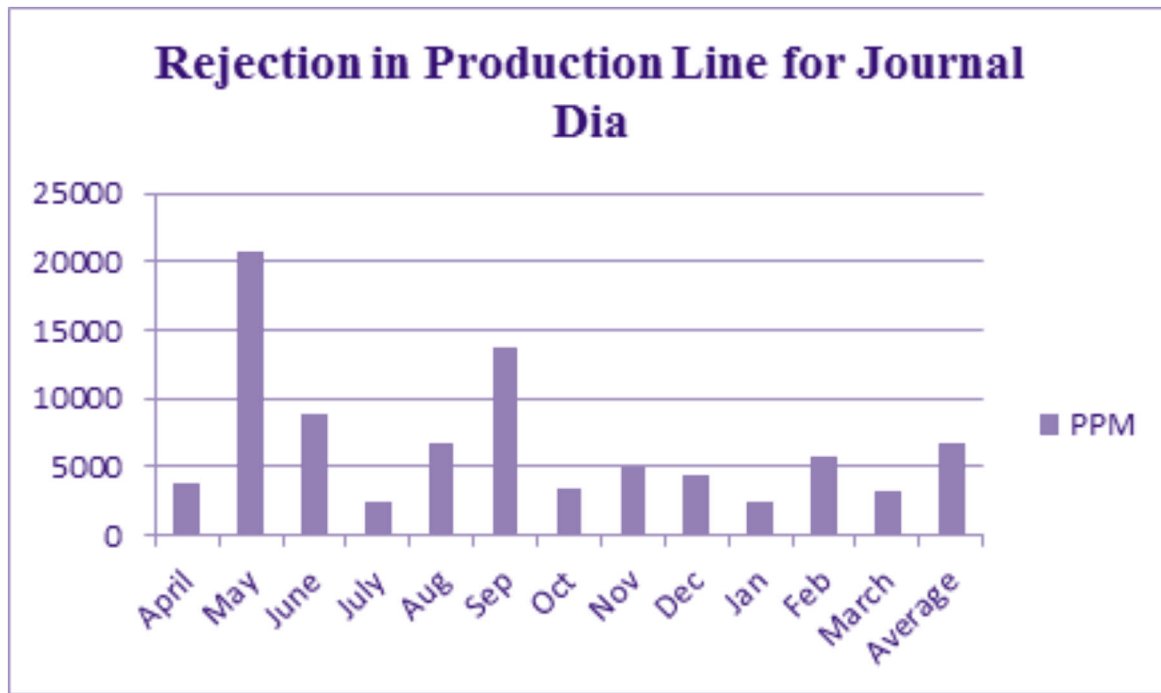


Figure 3 Rejections in Production Line for Journal Diameter (2016-17)

4.3 Analysis

In the analysis phase, a deep scrutiny is done on the major defects to find the root causes of the defects so that the present system can be further improved. By determining the key factors of the defects, it is easy to eliminate the defect by abolishing the

cause of the defect. To unravel these causes, fishbone diagram for each defect i.e. dent and diameter minus were made. The fishbone diagram helps to resolute the basic causes of the defects. The fishbone diagram for dent and diameter minus are shown in figure 4 and figure 5 respectively.

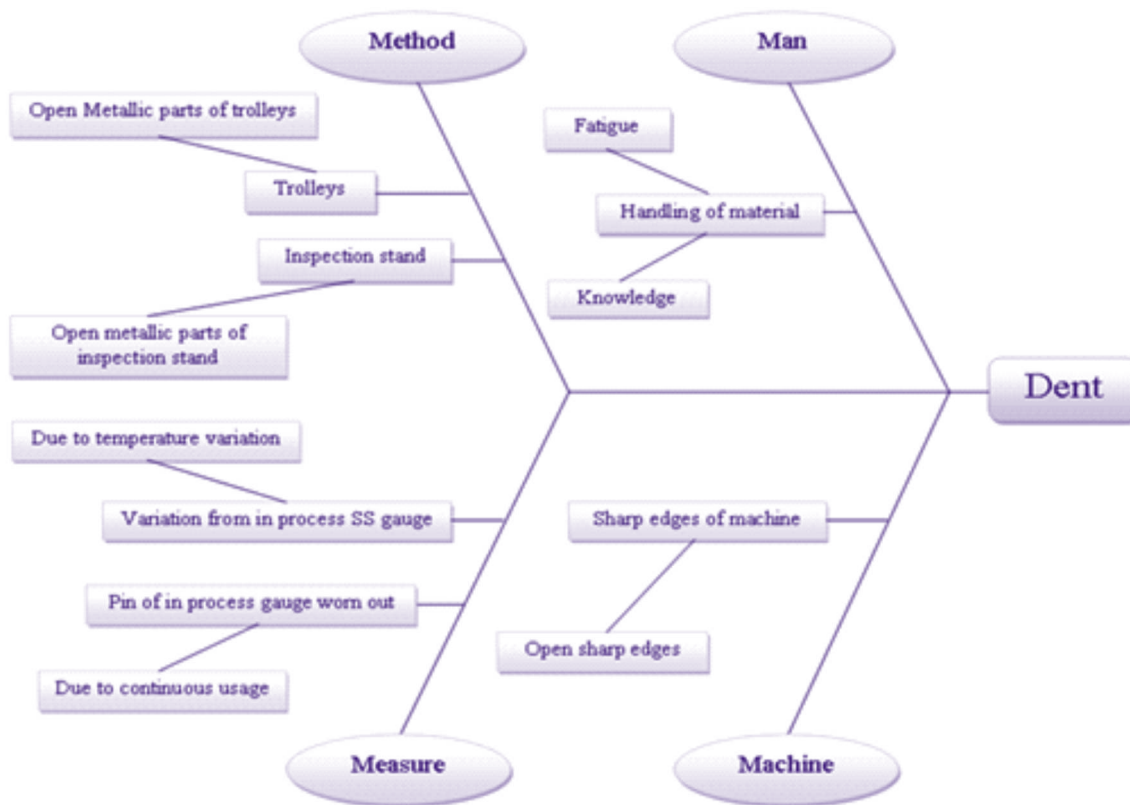


Figure 4 Fishbone Diagram for Dent



Figure 5 Fishbone Diagram of Diameter Minus

4.4 Improve

To improve the defects that are occurred in production line, a number of actions were taken. These actions were taken to

eliminate the major cause of defects. The table showing the improvement actions that were taken and also their benefits is shown below in table 2.

Table 2 List of Improvement Actions

S No	Input Variable	Action	Benefit
1	Cutting oil temperature	Interlocking arrangement introduced to stop the machine if the temperature rises above 35°.	If the cutting oil temperature rises above 35° machine will stop. This will reduce variation in diameter.
2	Hydraulic oil system pressure	Temperature indicator installed on the machine, and cleaning of radiators serrations during PM activity added in PM plan.	Low system pressure will result in slow movement of Marposs gauge & will result in variation in diameter. By maintaining the temperature within a range will avoid this problem.
3	Purging Pressure (Cleaning of grinding wheel)	Checkpoint in daily machine check sheet.	Will help in proper cleaning of the glazed wheel.
4	Online Marposs Operating Temperature range	Coolant pipeline provided on online gauge	Avoid fluctuation caused by malfunctioning of Marposs transducer.
5	The condition of the Marposs finger	The condition of figures daily checked by operators point added in daily machine check sheet.	This will avoid diameter variation caused due to the uneven wearing of Marposs pins.

6	Mechanical Zeroing of Marpos	Zeroing master with known size prepared.	Due to the availability of Master of known size wrong zeroing of the gauge is avoided and thus variation in diameter is avoided.
7	Electrical zeroing of Marpos	During the start of each shift, the offset is zeroed. This checkpoint is included in daily machine check sheet.	This will avoid accumulation of offset as against the actual size of the master.
8	Gauge not return	The condition of cable checked during PM activity.	Will avoid gauge not return problem
9	No major dent	Metallic part of the conveyor covered.	Avoids dent
10	Clamping pressure of steady at rough cam grinding operation.	Pressure gauge installed and included in the daily check sheet	Avoid clamping mark on journal due to excess pressure
11	The condition of an insert at steady support	Insert change frequency decided as 15 days	Will avoid line mark on journal caused due to damage to the steady insert
12	Lapping oil temperature	To avoid temperature variation, lapping oil supplied from centralized oiling station.	This will avoid diameter variation caused due to temperature variation.
13	Millipore value of lapping oil	To properly maintain the Millipore value of oil it is connected with centralized oiling station.	Will reduce the scratch mark problem on the journal, by avoiding entrapment of dust particle between film and camshaft.

After implementation of improvement actions, the result was highly improved. The data was collected over a time period and it was found that the average scrape produced by the production line was dropped from 10025 ppm to 8700 ppm, a chart showing

the improved results is presented in figure 6. The average rejection of camshaft is also reduced from 6700 ppm to 5517 ppm, a chart showing the improved result is presented in figure 7.

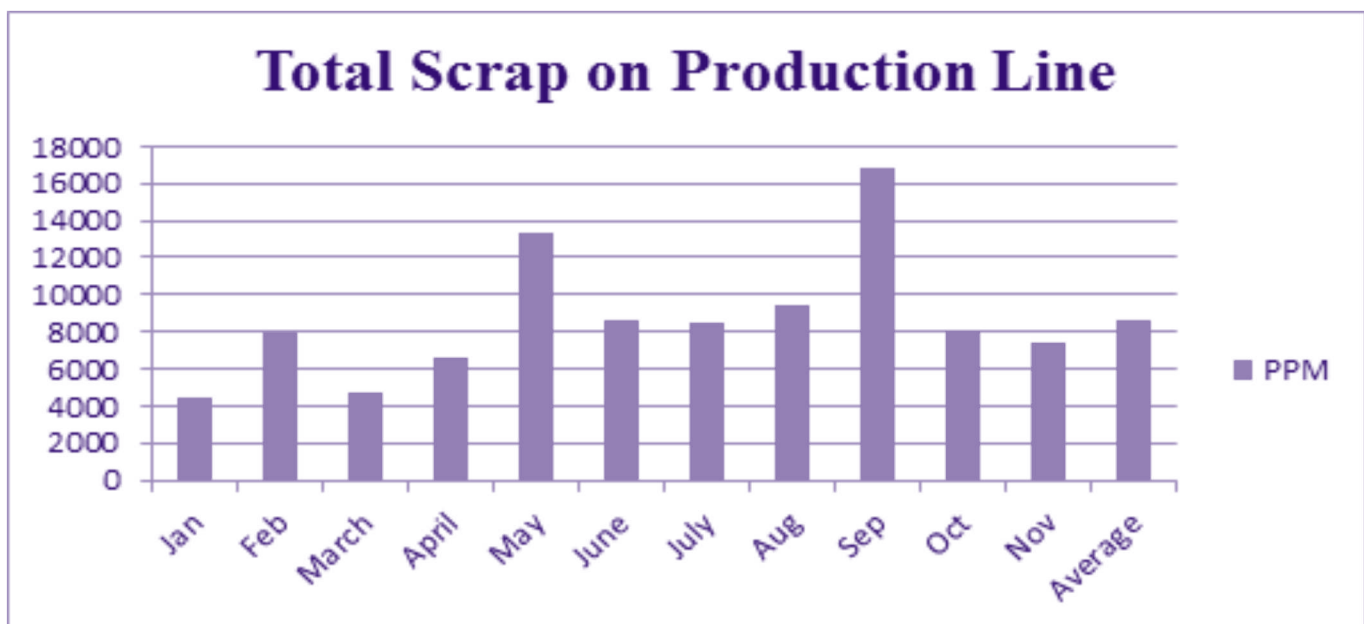


Figure 6 Total Scrap on Production Line in (2017)

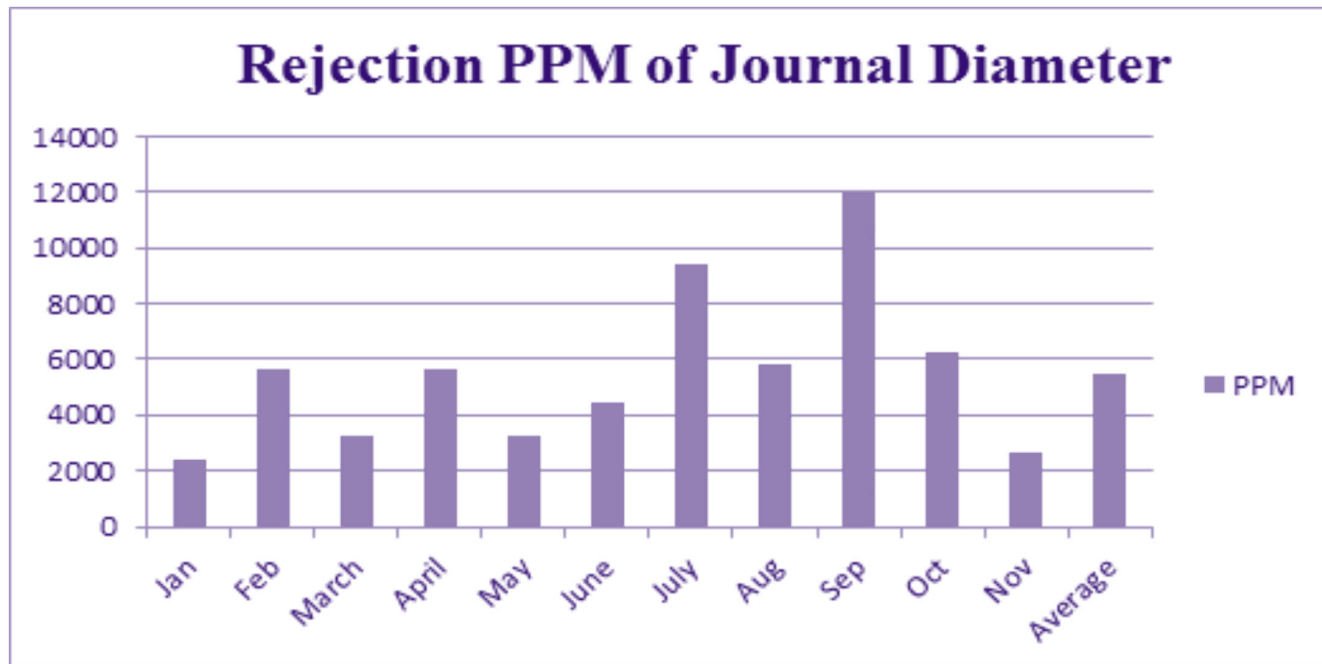


Figure 7 Rejections in PPM of Journal Diameter (2017)

4.5 Control

To control this problem, checking of the camshaft is done after passing through each workstation. So that if any kind of defect may occur it will be immediately acknowledged and proper actions to cure this problem will be taken. It will help to the reason of defect at the time of its origin itself and it will also help to improve or make corrections on the machine itself.

5. CONCLUSION

After implementing Six Sigma, the production line began to show favourable results. It was found that the average scrape produced by the production line was dropped from 10025 ppm to 8700 ppm that is a reduction of 13.68%. The average rework is reduced from 38100 ppm to 26041 ppm that is a reduction of about 31%. The average rejection of camshaft is also reduced from 6700 ppm to 5517 ppm, the result with a reduction of 17.65%. The rejection contribution from dent has seen a significant improvement. It has a reduction from 1800 ppm to 700 ppm that is a reduction of about 61%. Hence, it can be said that Six Sigma is a powerful tool which can be applied to any process or operation and is able to reduce defects to a minimum. It is able to provide a systematic approach to detect the source of the defect and eliminate it.

REFERENCES

1. A. Agrawal, and K.K. Garg, "Critical Success Factors Analysis For Six Sigma Project Implementation", *Industrial Engineering Journal*, Vol. 10, No. 8, pp. 44-47, 2017.
2. H. Alidrisi, "Prioritizing Critical Success Factors For Six Sigma Implementation using Interpretive Structural Modelling", *American Journal of Industrial and Business Management*, Vol 4, No. 12, pp. 697-708, 2014.
3. A.K. Atri, (2016), "Improving an Assembly Process in a Manufacturing Company using Six Sigma Methodologies", *International Journal of Engineering and Innovative Technology (IJEIT)*, Vol 6, No. 4, pp. 24-28.
4. G. Barluenga et al. , "Quality Control Parameters for on-site evaluation of pumped Self- Compacting Concrete", *Elsevier Limited, Construction and Building Materials*, Vol 154, pp 1112-1120, 2017.
5. H. Dale Besterfeld, et al., "Total Quality Management", *Pearson Educations*, pp 13-212, 327- 413, 533- 621, 2008.
6. H. Bhalla, and R.C. Gupta, "Improving Efficiency Of Precision Instruments Using Six Sigma Methodology", *Industrial Engineering Journal*, vol. 10, No. 11, pp 17-22, 2017.
7. D. Bhardwaj, and Akhil, "Optimization of Productive Management using Six Sigma in Small Scale Industries", *International Journal of Enhanced Research in Science and Engineering*, vol 3, No. 7, pp. 158-164, 2014.
8. Campos (2011), "Management Assessment Tool Of Lean Manufacturing And Six Sigma: A Brazilian Case Study", *XVII International Conference on Industrial Engineering and Operation Management*, Belo Horizonte, Brazil.
9. M. Campulova, et al. (2017), "Control chart and Six sigma based algorithms for identification of outliers in experimental data, with an application to particulate matter PM10", *Elsevier Limited, Atmospheric Pollution Research*, vol 8, No. 4, pp 700-708, 2017.
10. A. Chakarbarti, and K.C. Tan, "Applying Six Sigma in the Service Industry: A Review and Case Study in Call Center Service" *IEEE International Conference*, Singapore, vol 2, pp 728-732, 2006.

11. A. Chakarbarty, and K.C. Tan, (2008), "Case Study Analysis of Six Sigma in Singapore Service Organizations", *IEEE Xplore*, DOI: 10.1109/ICSSSM.2008.4598532.
12. A.K. Chitale, and R. C. Gupta, "Material Management-Text and Cases" PHI Learning Pvt. Ltd., PP 315-323, 2014.
13. A. K. Chitale, and R.C. Gupta, "Product Design and Manufacturing", PHI Learning Pvt. Ltd., pp. 368-370, 407-454, 2014.
14. J. Dean, and D. Bowen, (1994), "Managing theory and total quality: Improving research and practice through theory development", *Academy of Management Review*, vol 19, No. 3, pp.392-418.
15. Tushar N. Desai, and R. L. Shrivastava, "Statistical Concepts Associated with Six Sigma – An Overview" *Industrial Engineering Journal*, vol-II, No.12, 2010.
16. H. Erbiyik, and M. Saru, "Six Sigma Implementation in Supply Chain : An Application for an Automotive Subsidiary Industry in Bursa in Turkey", Elsevier Limited, *Procedia – Social and Behavior Science*, vol 195, pp. 2556-2565, 2015.
17. N.V. Fursel, et al., "Understanding the Benefits and Limitations of Six Sigma Methodology", *International Journal of Science and Research Publications*, vol 2, No.1, pp 1-9, 2012.
18. K. Ganguly, (2012), "Improvement Process for Rolling Mill through the Dmaic Six Sigma Approach", *International Journal for Quality Research*, vol 6, No. 3, 2012.
19. A. Jiju, et al, "Six sigma in small- and medium-sized UK manufacturing enterprises-Some empirical observations", *American Journal of Industrial and Business Management*, vol.04, No.12, 2005.
20. P. Kankariya, and K. Valase, "Performance improvement in Garment Industries by Reducing Defects using Six Sigma Methodology", *IJSRET*, vol 6, No. 3, pp. 228-236, 2017.
21. P. Kumar, S. Singhal, and J. Kansal, (2014) on "A Case Study of Six Sigma and its Competitive Advantage in Indian Industries", *Design and Research Conference, IIT Guwahati, Assam*, volume 445, pp 1-7, 2014.
22. N. Jeffrey Lowenthal, "Six Sigma Project Management: A Pocket Guide", *New Age International Pvt. Ltd.*, 2010.
23. M. Mahajan, "Statistical Quality Control", *Dhanpat Rai and Co. (P) Ltd.*, 2007.
24. D.S.L. Marzagao, and M.M. Carvalho, "Critical success factors for Six Sigma projects", *International Journal of Project Management*, volume 34, No 8, pp 1505-1518, 2016.
25. A. Mishra, et al. (2015), "Six Sigma Methodology In A Plastic Injection Molding Industry: A Case Study", *International Journal of Industrial Engineering and Technology (IJEIT)*, vol 7, No. 1, pp. 15-30.
26. E. Nedeliakova, V. Stefanцова, and S. Kudlac, (2017) "Six Sigma and Dynamic Models Application as an Important Quality Management Tool in Railway Companies", Elsevier Limited, *Tenth International Scientific Conference, Transbaltica, Procedia Engineering*, vol 187, pp 242-248, 2017.
27. P. Nonthalerak, and L. Hendry, (2006), "Six Sigma: Literature review and key future research area", *Int. J. Six Sigma and Competitive Advantage*, vol 2, No. 2, pp. 105-161.
28. S. H. Patel, and D.A. Desai, (2018), "Literature Search Consisting of the Areas of Lean Six Sigma Usage in Indian Smes", *Industrial Engineering Journal*, vol 11, No. 1, pp. 30-39.
29. J. Pathak, T. N. Desai, and A. Chounan, "Six Sigma In A Indian Chemical Industry A Case Study" *Industrial Engineering Journal*, vol 6, No. 12, pp. 31-37, 2013.
30. R. Reosekar, et al., "Design and Development of Six Sigma Implementation Frame Work for Indian Industries" *IJEBEA*, 5(2), pp. 147-152, 2013.
31. M. Rusko, and R. Kralikova, "Application of Six Sigma Method to EMS Design", *Faculty of Materials Science and Technology Slovak University of Technology*, No. 30, pp. 39-44, 2011.
32. U. Shiurkar, and S. P. Kallurkar, "Implementation of Six Sigma Tools for Design of Control Panel" *Proc. of National Conference, MET's Institute of Engineering, Nasik*, pp. 146-154, 2010.
33. A. K. Singh, and D. Khanduja, "Defining Quality Management in Auto Sector: A Six-Sigma Perception" Elsevier Limited, *Procedia Material Science*, vol 5, pp. 2645-2653, 2014.
34. A. Valles, et al. "Implementation of Six Sigma in a Manufacturing Process: A Case Study" *International Journal of Industrial Engineering*, 16(3), pp. 171-181, 2009.
35. J. O. Westgard, and S. A. Westgard, "Six Sigma Quality Management System and Design of Risk-based Statistical Quality Control" Elsevier Inc., *Clinics Laboratory Medicine*, volume 37, No. 1, pp. 85-96, 2016.
36. A. Youssef, C. Rachid, and V. Ion, "Contribution To The Optimization Of Strategy Of Maintenance By Lean Six Sigma", Elsevier Limited, *Eight International Conference On Material Sciences, Physics Procedia*, volume 55, pp 512-518, 2014.

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