J Ind Eng Int (2018) 14:511–520
https://doi.org/10.1007/s40092-017-0234-6

ORIGINAL RESEARCH

Six-sigma application in tire-manufacturing company: a case study

Vikash Gupta[1] · Rahul Jain[1] · M. L. Meena[1] · G. S. Dangayach[1]

Received: 16 February 2017 / Accepted: 13 September 2017 / Published online: 20 September 2017

Abstract Globalization, advancement of technologies, and increment in the demand of the customer change the way of doing business in the companies. To overcome these barriers, the six-sigma define–measure–analyze–improve–control (DMAIC) method is most popular and useful. This method helps to trim down the wastes and generating the potential ways of improvement in the process as well as service industries. In the current research, the DMAIC method was used for decreasing the process variations of bead splice causing wastage of material. This six-sigma DMAIC research was initiated by problem identification through voice of customer in the define step. The subsequent step constitutes of gathering the specification data of existing tire bead. This step was followed by the analysis and improvement steps, where the six-sigma quality tools such as cause–effect diagram, statistical process control, and substantial analysis of existing system were implemented for root cause identification and reduction in process variation. The process control charts were used for systematic observation and control the process. Utilizing DMAIC methodology, the standard deviation was decreased from 2.17 to 1.69. The process capability index (C_p) value was enhanced from 1.65 to 2.95 and the process performance capability index (C_{pk}) value was enhanced from 0.94 to 2.66. A DMAIC methodology was established that can play a key role for reducing defects in the tire-manufacturing process in India.

✉ Rahul Jain
rjmahesh207@gmail.com

[1] Department of Mechanical Engineering, Malaviya National Institute of Technology, JLN Marg, Malaviya Nagar, Jaipur, Rajasthan 302017, India

Keywords Developing country · Process capability · Six sigma · Tire bead

Introduction

Tire has gone through many stages of evolution, since it was developed first time about 100 years ago. In the beginning, solid rubber tires were used mostly for bicycles and horse-driven carts. First, John Dunlop made a tire which consist a tube mounted on a spoked rim. Then, in 20th century with the arrival of motor vehicles, the use of pneumatic tires was started. The manufacturing process of tires begins with selection of rubber as well as other raw materials including special oils, carbon black, etc. These various raw materials are shaped with a homogenized unique mixture of black color with the help of gum. The mixing process is controlled by the computerized systems to insure uniformity of the raw materials. Furthermore, this mixture is processed into the sidewall, treads, or other parts of the tire. The tire bead wire is used as a reinforcement inside the polymer material of the tire. Bead wire is made up of high carbon steel and the main function of bead is to grasp the tire on the rim. The bead wire of functional tire can work at pressures of 30–35 psi (Palit et al. 2015). Bead wires help to transfer the load of vehicle to the tire through the rim. Due to the increase demand of tires, maintaining the quality and reliable performance becomes priority. In addition, there is need for maintaining the quality in the era of technological advancements in design of pneumatic tires.

The companies have to analyze, monitor, and make improvements of their existing manufacturing systems to comply with the market competition. Different companies use different methodologies, approaches, and tools for implementing programs for continuous quality improvement. Besides these, each company certainly required to use a proper selection and combination of different approaches, tools, and techniques in its implementation process (Sokovic et al. 2010). Variations are generally observed during the manufacturing process of any product. The prime objective of process management or process capability analysis in any organization is to investigate the variability during the manufacturing process of product (Pearn and Chen 1999) which helps organization to monitor and measure the potential of process (Wu et al. 2004). The process capability is determined when the process is under statistics control (i.e., the sample mean on X-bar and R-chart lies within three-sigma limits and varies in random manner). Sometimes, a process which is under statistical control may not produce the products within the specifications limits. The reason for this problem is the presence of common cause or this can be happened due to lack of centering of process mean (i.e., there is a significant different between mean value and specified nominal value). Process capability procedure uses control charts to detect the common causes of variation until the process not comes under statistical control (Boyles 1994; Chen et al. 2009). Process capability indices are used in many areas, i.e., continues measure of improvement, prevention of defects in process or products, to determine directions for improvement, etc. (Kane 1986). Process capability indices are measures of the process ability for manufacturing a product that meets specifications. Three basic characteristics (i.e., process yield, process expected loss, and process capability indices) had been widely used in measuring process potential and performance. Among various process, capability indices C_p and C_{pk} are easily understood and could be straightforwardly applied to the manufacturing industry (Chen et al. 2001, 2002).

Literature review

The quality improvement tools and total quality management (TQM) are still used in modern industry. However, industries tried to incorporate strategic and financial issues with this kind of initiatives (Cagnazzo and Taticchi 2009). After inception of TQM in the early 1980s, six sigma came in picture as an element of TQM that could be seen as current state of evolution in quality management. Six sigma is a strategy that helps to identify and eliminate the defects which leads to customer dissatisfaction in tire industries (Gupta et al. 2012). An organization working on direction of implementing six sigma into practice or working to build six-sigma concepts with improvement in process performance and customer satisfaction is considered as six-sigma company (Kabir et al. 2013). General Electric and Motorola are two well-known companies who implemented six sigma successfully. For successful implementation of six sigma in organization, one must have to understand the barriers and motivating factors of the six sigma (Hekmatpanah et al. 2008). Six sigma aimed to achieve perfection in every single process of a company (Narula and Grover 2015). The term six sigma means having less than 3.4 defects per million opportunities (DPMO) or a success rate of 99.9997%. In six sigma, the term sigma used to represent the variation of the process (Antony and Banuelas 2002). If an industry works as per the concept of three-sigma levels for quality control, this means a success rate of 93% or 66,800 DPMO. Due to less rejections, the six-sigma method was a very demanding concept for quality control, where many organizations still working on three-sigma concept. In this regard, the six sigma is a methodology that enables the companies to review their existing status and guide them in making improvements by analyzing their status via statistical methods (Erbiyik and Saru 2015). For most of the industries, sigma is a level that measures the process improvement and thus can be used to measure the defect rate. Six-sigma define–measure–analysis–improve–control (DMAIC) methodology is a highly disciplined approach that helps industrial world to focus on developing perfect products, process, and services. Six sigma identifies and eliminates defects or failures in product features concerned to the customers that affect processes or performance of system.

The literature reveals that most of the waste in developing countries comes from the automobiles (Rathore et al. 2011; Govindan et al. 2016), and out of the total automobile waste, most of the waste comes in the form of tires. There are several barriers faced during the remanufacturing these wastes (Govindan et al. 2016). Around the world, only few studies have been carried out for the tire industries and these studies are focused on analyzing the profitability of car and truck tire remanufacturing (Lebreton and Tuma 2006), system design for tire reworking (Sasikumar et al. 2010), value analysis for scrap tires in cement industries (de Souza and Márcio de Almeida 2013), and analyzing the factors for end-of-life management (Kannan et al. 2014). In addition, some researchers proposed methodologies for improving the process in tire-manufacturing companies out of which few industries implemented lean and six-sigma methodologies (Gupta et al. 2012, 2013; Visakh and Aravind 2014; Wojtaszak and Biały 2015). Other studies also found implementing just in time (Beard and Butler 2000) and Kanban (Mukhopadhyay and Shanker 2005).

However, numerous studies are available for process improvement in the automobile industries using various methods (Dangayach and Deshmukh 2001a, b; Chen et al.

2005; Dangayach and Deshmukh 2004a, b, 2005; Laosirihongthong and Dangayach 2005a, b; Sharma et al. 2005; Radha Krishna and Dangayach 2007; Krishna et al. 2008; Cakmakci 2009; Prabhushankar et al. 2009; Mathur et al. 2011; Dhinakaran et al. 2012; Dangayach and Bhatt 2013; Muruganantham et al. 2013; Sharma and Rao 2013; Kumar and Kumar 2014; Venkatesh et al. 2014; Surange 2015; Bhat et al. 2016; Dangayach et al. 2016; Jain et al. 2016; Gidwani and Dangayach 2017; Meena et al. 2017).

A review of the literature shows that the DMAIC method is the superb practice for improving the process capability in automobile industries. Hence, the current research concentrates on the use of DMAIC method aimed for process capability enhancement of the bead splice appearing in a tire-manufacturing industry.

Methodology

In this study, the six-sigma DMAIC phases were applied to enhance the process capability (long term) for bead splice. In every phase of DMAIC method, a compound of both techniques qualitative as well as quantitative was utilized. The DMAIC steps followed in the current research are as follows:

Define

In the first phase, the goals were defined to improve the current process. The most critical goals were acquired using the voice of customer (VOC) method. These goals would be helpful for the betterment of the company. In addition, the goals will direct to bring down the defect level and increase output for a specific process.

Measure

Without measuring the performance attributes, the process cannot be improved. Therefore, the ultimate target of measure phase was to establish a good measurement system to measure the process performance. Process capability index C_{pk} was selected to measure the process performance. To compute the process capability index, observations of bead splice variation were taken and MINITAB (version 16.0) was used for analysis.

Analyze

In the analyze phase, the process was analyzed to identify possible ways of bridging the gaps between the present quality performance of the process and the goal defined.

Table 1 Bead splice specification

Main specification range of bead splice to be produce	90 ± 15 mm
Average bead splice of tire	97 mm
Material loss due to Shifting of Splice from Target Specification	93–100 kg/month

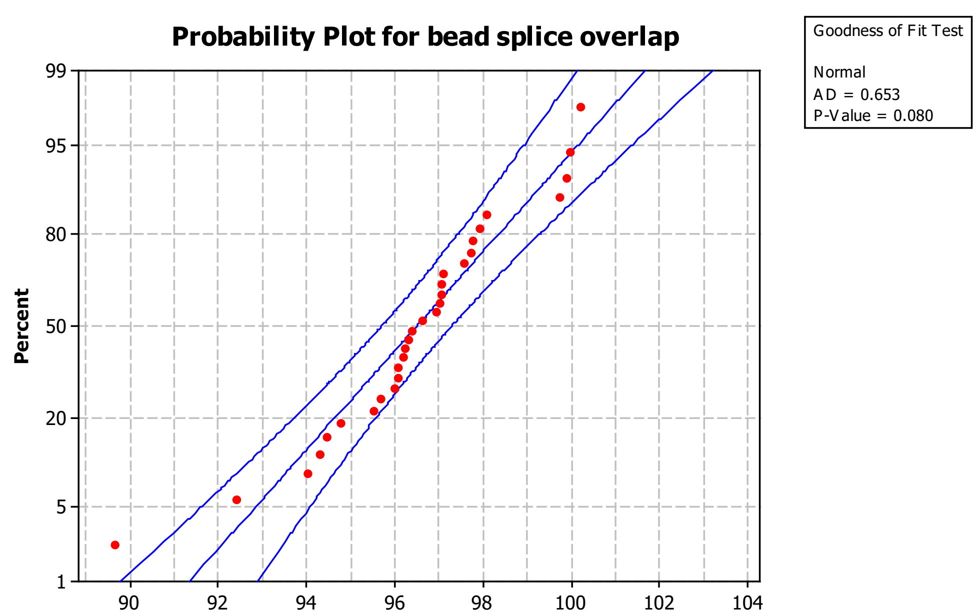


Fig. 1 Normality test of bead splice

In addition, it was started by determining the existing performance statistics obtained with the help of six-sigma quality tools (process capability index). The further analysis of these data was done for finding root cause of the problem using Ishikawa diagram.

Improve

In improvement phase, the alternative ways were searched creatively to do things better and faster at low cost. Different approaches (i.e., project management, other planning and management tools, etc.) were used to establish the new approach and statistical methods were proposed for continuous improvement.

Control

The improvement gained through the previous steps needs to be maintained for continuous success of the organization. Control phase was used to maintain these improvements in process. The new process/improved process was proposed for sustaining the quality control in the organization.

Case study

Company profile

Company A was the leading Indian tire manufacturing who started exclusive branded outlets of truck tires. Company started its first manufacturing plant at Perambra, Kerala state of India in the year 1977. Furthermore, the company started its second manufacturing plant in Limda, Gujarat. Company expanded its business and established third plant at Kalamassery, Kerala in year 1995, where premier-type tires are produced. Then, company established a special tubes plant in the year 1996 at Ranjangoan, Maharashtra. Company increased its capacity to produce exclusive radial tires at Limda, Gujarat plant in the year 2000. In year 2004, company initiated production of high-speed rated tubeless radial tires for passenger cars.

Implementation of DMAIC methodology

Problem definition

In the current research, the problem was identified on the basis of VOC data. The customer complaints on wastage of material due to variation in the bead splice of a particular product were recorded. Table 1 shows the specification of the product (tire).

This wastage increases financial loss to the organization. Therefore, the problem is variations in the bead splice which has to be reduced to minimize the wastages.

Establishment of measures

Initially, the normality test for the collected data was performed and Fig. 1 shows the normal distribution curve for the bead splice data. After passing the normality test, process capability index C_{pk} was calculated to measure the present process performance using the observations of bead splice variation, which is presented in Table 2.

These data were used to create an overall baseline for the system to assess its performance based on the necessary improvement areas established in the define phase. Figure 2 shows that the value of process capability index C_{pk} is 0.94 which is less than 1; hence, the process is not capable.

Table 2 Initial observations

S. no.	Observations
1	97.04
2	100.22
3	97.07
4	96.32
5	89.63
6	94.29
7	96.01
8	99.88
9	96.08
10	92.40
11	94.76
12	97.02
13	95.51
14	96.63
15	95.69
16	94.01
17	99.75
18	96.07
19	97.11
20	96.24
21	96.94
22	99.98
23	97.94
24	97.75
25	94.44
26	97.72
27	96.40
28	97.55
29	96.17
30	98.09

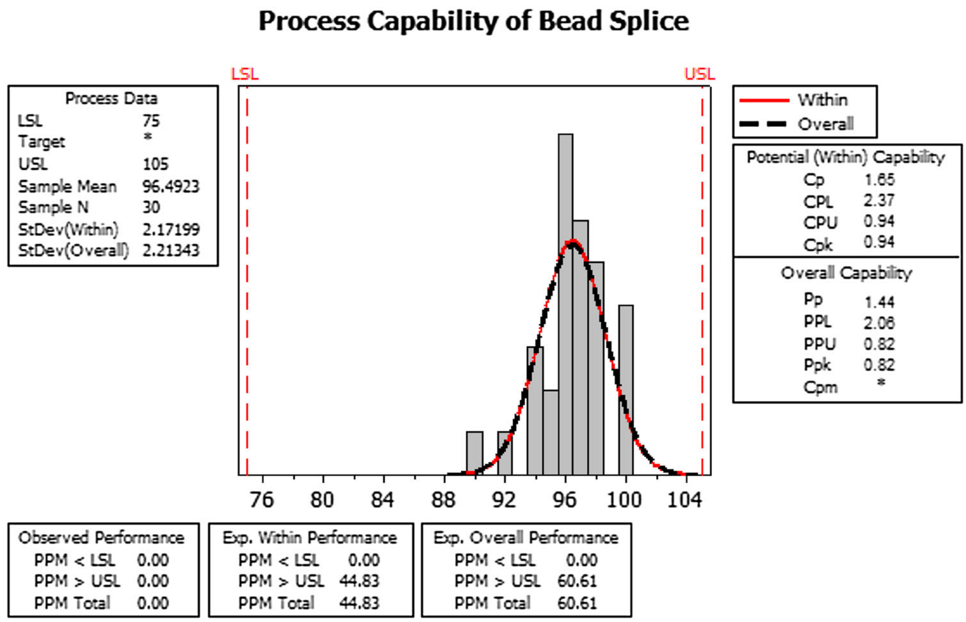


Fig. 2 Process capability diagram of bead splice: before improvement

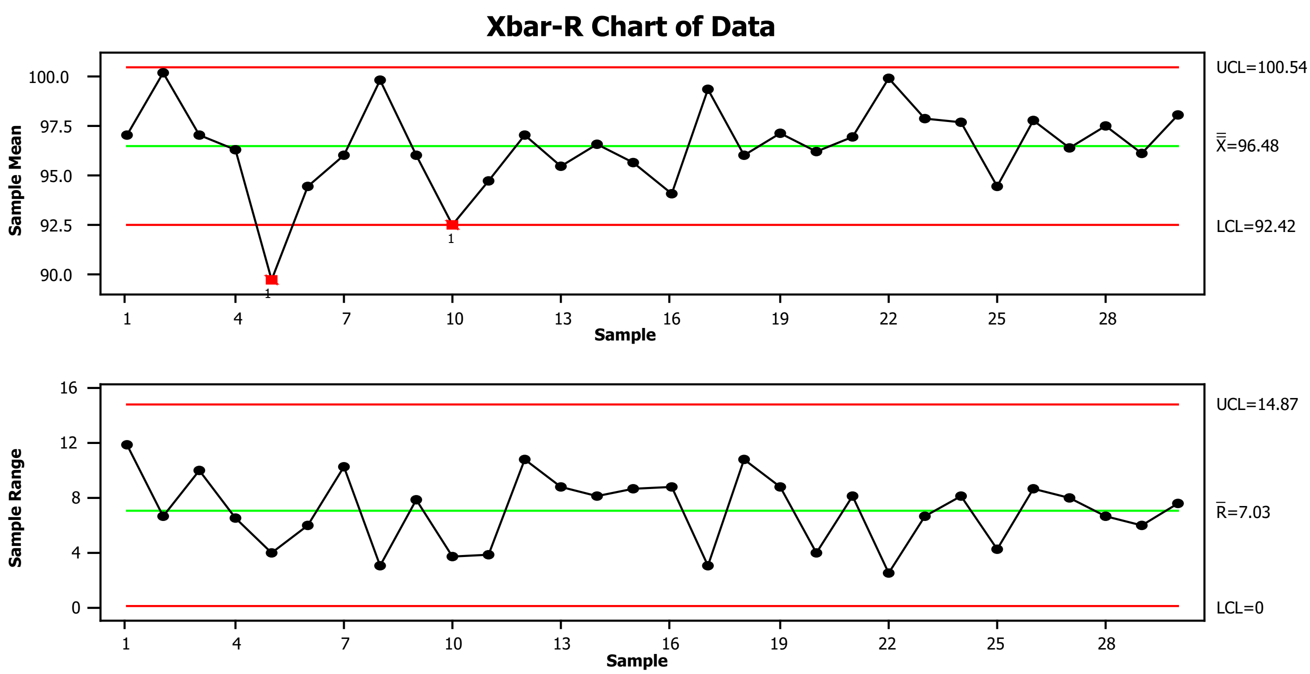


Fig. 3 X- and R-bar chart of present data

Data analysis

In this phase, the data were analyzed and control charts were constructed. Figure 3 shows the X-bar and R-chart for the existing data. From the figure, it is clear that the few points are outside the lower control limit; however, the process is in statistical control.

Identification of root cause The Ishikawa diagram was used for finding the root cause of the problem, which is shown in Fig. 4. The identified causes of the problem are as follows:

- First cause of the problem was bead splice setting on higher side caused by slippage of bead tape from gripper. The slippage of bead tape from gripper was generated due to worn out of the griper key.
- Second cause was variation in the advancer setting caused due to change in skill of worker. This man-to-man variation was caused due to lack of the standard setup guidelines available.

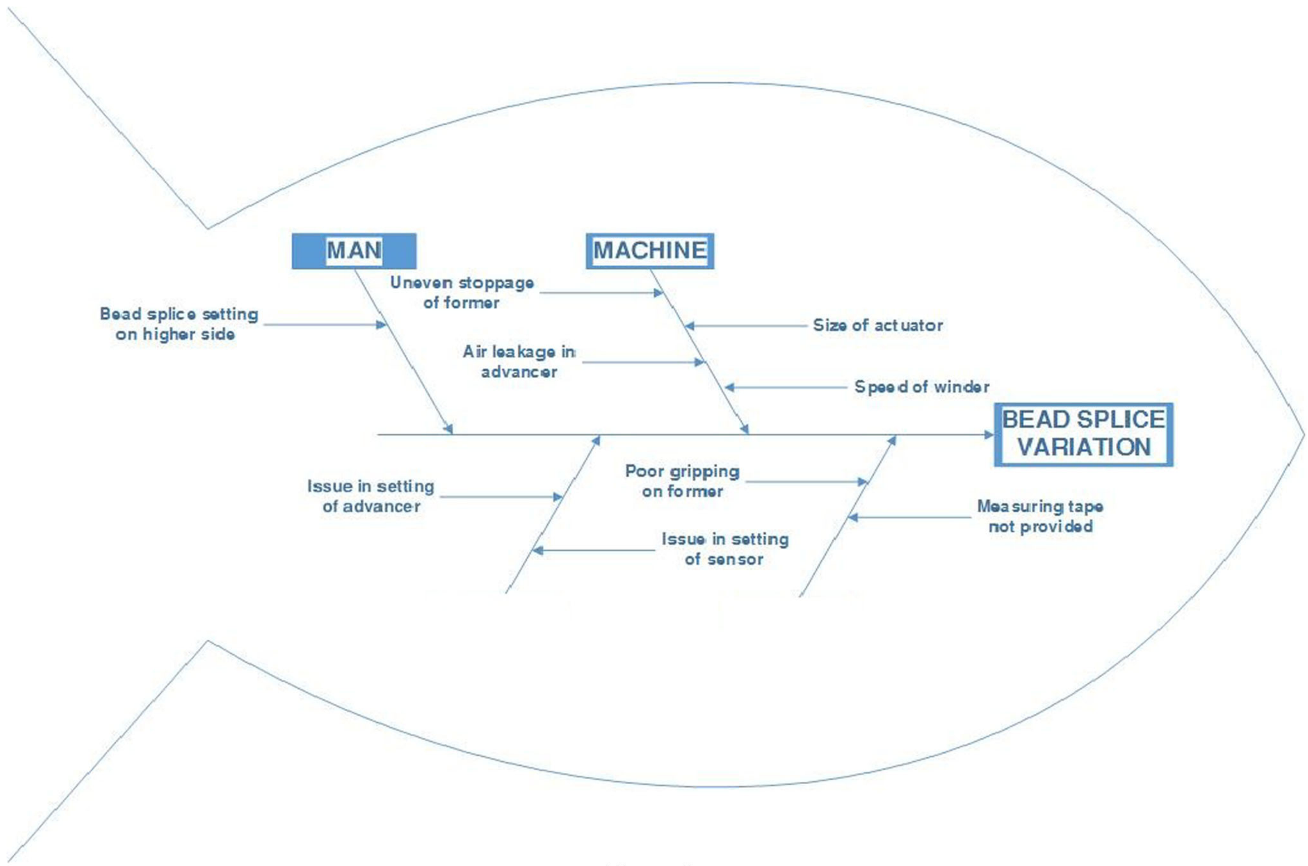


Fig. 4 Ishikawa diagram

Table 3 Corrective arrangements

S. no.	Facts consider for improve	Arrangements
1	Point on higher side	1. Check bead splice after setup
		2. Set advancer as per guideline to get target value
		3. Set proximity as per guideline of former diameter
2	Point on lower side	1. Measuring tape for every line
		2. Follow-up should be done on time-to-time basis

- The third cause was related to the frequency of sensor setting. Setting of sensor is required frequently as the former diameter changes. However, due to non-availability of guideline, sensor setting could not change frequently.
- The last cause was identified that the workers were not using the measuring tape.

Improve

After finding the root causes, the corrective actions were taken, which are presented in Table 3. After implementing these corrective actions, again observations were taken to measure the process performance.

The collected data are shown in Table 4 and run chart for bead splice variation was drawn for the observations taken before and after corrective actions (Fig. 5). From Fig. 5, it is clear that variability in the process reduced drastically.

The process capability index was also computed after implementing corrective actions. Figure 6 shows that after improvement in process, the capability index C_{pk} value is improved to 2.66 which shows that process is capable.

Control

To maintain the achieved process performance of the six-sigma quality level, the above four steps of DMAIC methodology must be applied periodically.

Table 4 Final observations

S. no.	Observations
1	89.0
2	93.1
3	88.9
4	91.1
5	91.5
6	93.6
7	89.6
8	87.9
9	91.2
10	89.1
11	93.8
12	91.1
13	91.1
14	89.1
15	93.0
16	91.1
17	93.0
18	94.0
19	94.3
20	94.0
21	91.4
22	89.1
23	93.1
24	90.4
25	92.8
26	91.3
27	89.2
28	91.4
29	94.1
30	92.9
31	90.1
32	89.2
33	92.9
34	91.4
35	91.9
36	90.1
37	91.2
38	91.1
39	91.5
40	93.1
41	92.6
42	91.7
43	92.8
44	90.0
45	90.1

Conclusion and Discussion

In this research, DMAIC approach was implemented for process improvement in tire industry. First, process capability index C_{pk} of the current process was computed which was found less than 1. Therefore, to improve the value of process performance, the root causes of problem were determined with the help of cause and effect diagram. In addition, substantial analysis of existing system was done for finding the solution of root cause identified. Finally, in the improve phase, statistical analysis was done for identifying the process capability index value which was improved after taking corrective actions. From outcomes of the study, it can be concluded that process performance of a tire-manufacturing plant can be improved significantly by implementing six-sigma DMAIC methodology.

Cause and effect diagram was also used in an Indian study by Gupta et al. (2012), although no manufacturing aspects were discussed. One more exploratory research was implemented for finding the enablers for successful implementation of lean tools in radial tire-manufacturing company in India (Gupta et al. 2013); however, no manufacturing aspects were discussed in this study also. In the current study, six-sigma DMAIC method is used for improving the process performance.

The main aim of this study was to improve the process capability index of the bead splice, which is achieved by increasing the value of process capability index up to 2.66. This study is based on six-sigma DMAIC quality methodology which provides information about the decision-making power for particular type of problem and the most significant tool for improvement of that type of problem in which data used must come from a stable process (under statistical control: Chen et al. 2017).

Six sigma is a standard of measurement of the product or process quality, also having a caliber for improvement in efficiency and excellence of process. The main aim of implementing six-sigma approach is delivering world-class quality standards of product and service while removing all internal as well as external defects at the lowest possible cost. For proper and successful implementation of a six-sigma project, organization must have the required resources, the guidance to the employees by top management, and leadership of top management. The case company follows several quality standards, which have research and development cell, and good coordination system for managing the issue faced on shop floor. Hence, the corrective actions were implemented successfully.

Fig. 5 Run chart for bead splice

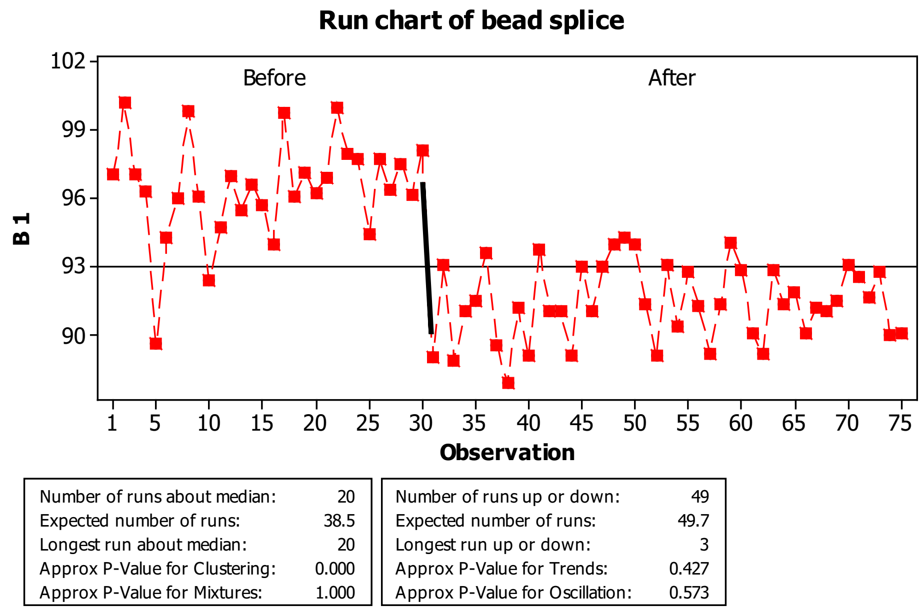
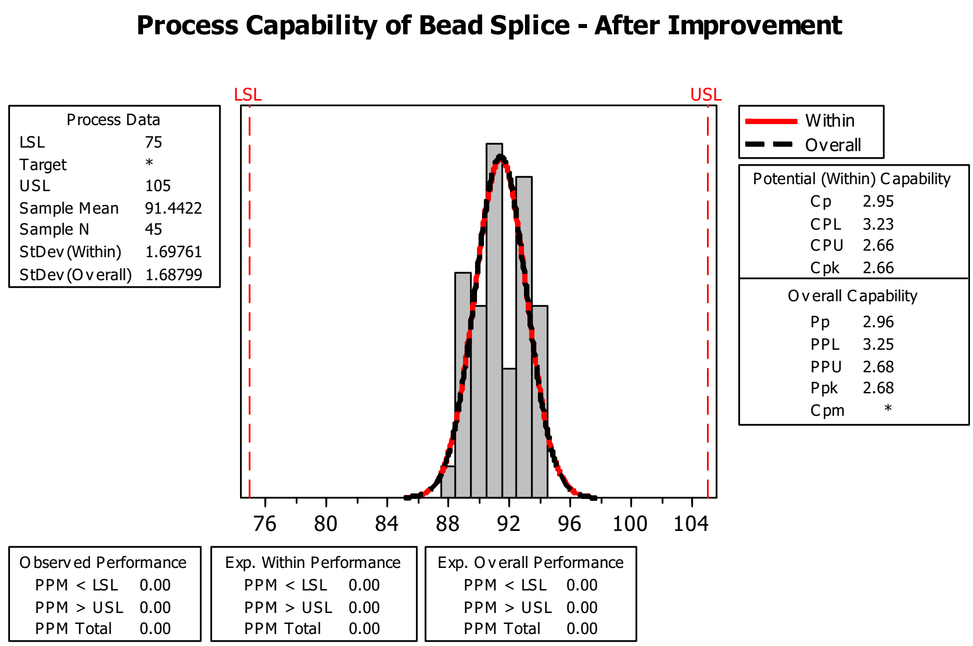


Fig. 6 Process capability diagram of bead splice: after improvement



Acknowledgements The corresponding author grateful to the all authors for their suggestions at every stage of this study. The authors would like to thank the anonymous referees for their valuable comments, which has been improved the contents and format of this paper.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Funding There is no specific funding from any provider source for this study.

References

Antony J, Banuelas R (2002) Key ingredients for the effective implementation of Six Sigma program. Meas Bus Excell 6(4):20–27

Beard L, Butler SA (2000) Introducing JIT Manufacturing: it's easier than you think. Bus Horiz 43(5):61–64

Bhat S, Jnanesh NA, Kamath PP, Nayak RR, D'souza NM (2016) Enhancing the performance of an automobile service industry: lean thinking approach. J Mech Eng Autom 6(5A):40–48

Boyles RA (1994) Brocess capability with asymmetric tolerances. Commun Stat Simul Comput 23(3):615–635

Cagnazzo L, Taticchi P (2009) Six sigma: a literature review analysis. In: Proceedings of the international conference on e-activities and information security and privacy, pp 29–34

Cakmakci M (2009) Process improvement: performance analysis of the setup time reduction-SMED in the automobile industry. Int J Adv Manuf Technol 41(1):168–179

Chen KS, Huang ML, Li RK (2001) Process capability analysis for an entire product. Int J Prod Res 39(17):4077–4087

Chen KS, Chen SC, Li RK (2002) Process quality analysis of products. Int J Adv Manuf Technol 19(8):623–628

Chen SC, Chen KS, Hsia TC (2005) Promoting customer satisfactions by applying six sigma: an example from the automobile industry. Qual Manag J 12(4):21

Chen KS, Ouyang LY, Hsu CH, Wu CC (2009) The communion bridge to Six Sigma and process capability indices. Qual Quant 43(3):463–469

Chen KS, Chen HT, Chang TC (2017) The construction and application of Six Sigma quality indices. Int J Prod Res 55(8):2365–2384

Dangayach GS, Bhatt H (2013) Production scheduling improvements in an automotive sector company. World Acad Sci Eng Technol Int J Mech Aerospace Ind Mechatron Manuf Eng 7(11):2226–2230

Dangayach GS, Deshmukh SG (2001a) Practice of manufacturing strategy: evidence from select Indian automobile companies. Int J Prod Res 39(11):2353–2393

Dangayach GS, Deshmukh SG (2001b) Manufacturing strategy: experiences from Indian manufacturing companies. Product Plan Control 12(8):775–786

Dangayach GS, Deshmukh SG (2004a) Advanced manufacturing technologies: evidences from Indian automobile companies. Int J Manuf Technol Manag 6(5):426–433

Dangayach GS, Deshmukh SG (2004b) Linkages between manufacturing strategy, business strategy and business excellence: a longitudinal study. Int J Ind Eng Theory Appl Pract 11(3):297–306

Dangayach GS, Deshmukh SG (2005) Advanced manufacturing technology implementation: evidence from Indian small and medium enterprises (SMEs). J Manuf Technol Manag 16(5):483–496

Dangayach GS, Bhatt H, Gupta S, Meena ML (2016) Machine layout design through particle swarm optimization in Indian industry. Productivity 57(1):13–21

de Souza CDR, Márcio de Almeida DA (2013) Value chain analysis applied to the scrap tire reverse logistics chain: an applied study of co-processing in the cement industry. Resour Conserv Recycl 78:15–25

Dhinakaran IJ, Ganapathy CM, Kodeswaran T, Murugan K (2012) Quality improvement of lubricating oil pump shaft through statistical process control used in automobile industry. Procedia Eng 38:2053–2062

Erbiyik H, Saru M (2015) Six Sigma implementations in supply chain: an application for an automotive subsidiary industry in Bursa in Turkey. Procedia Soc Behav Sci 195:2556–2565

Gidwani BD, Dangayach GS (2017) Productivity measurement and improvement-an overview. Int J Product Qual Manag 20(3):316–343

Govindan K, Shankar KM, Kannan D (2016) Application of fuzzy analytic network process for barrier evaluation in automotive parts remanufacturing towards cleaner production–a study in an Indian scenario. J Clean Product 114:199–213

Gupta V, Acharya P, Patwardhan M (2012) Monitoring quality goals through lean Six-Sigma insures competitiveness. Int J Product Perform Manag 61(2):194–203

Gupta V, Acharya P, Patwardhan M (2013) A strategic and operational approach to assess the lean performance in radial tyre manufacturing in India: a case based study. Int J Product Perform Manag 62(6):634–651

Hekmatpanah M, Sadroddin M, Shahbaz S, Mokhtari F, Fadavinia F (2008) Six Sigma process and its impact on the organizational productivity. World Acad Sci Eng Technol 43:2070–3740

Jain R, Gupta S, Meena ML, Dangayach GS (2016) Optimisation of labour productivity using work measurement techniques. Int J Product Qual Manag 19(4):485–510

Kabir ME, Boby SMI, Lutfi M (2013) Productivity improvement by using Six-Sigma. Int J Eng Technol 3(12):1056–1084

Kane VE (1986) Process capability indices. J Qual Technol 18(1):41–52

Kannan D, Diabat A, Shankar KM (2014) Analyzing the drivers of end-of-life tire management using interpretive structural modeling (ISM). Int J Adv Manuf Technol 72(9–12): 1603–1614

Krishna R, Sharan Dangayach G, Motwani J, Akbulut AY (2008) Implementation of Six Sigma approach to quality improvement in a multinational automotive parts manufacturer in India: a case study. Int J Serv Oper Manag 4(2):264–276

Kumar SS, Kumar MP (2014) Cycle time reduction of a truck body assembly in an automobile industry by lean principles. Procedia Mater Sci 5:1853–1862

Laosirihongthong T, Dangayach GS (2005a) A comparative study of implementation of manufacturing strategies in Thai and Indian automotive manufacturing companies. J Manuf Syst 24(2):131–143

Laosirihongthong T, Dangayach GS (2005b) New manufacturing technology implementation: a study of the Thai automotive industry. Product Plan Control 16(3):263–272

Lebreton B, Tuma A (2006) A quantitative approach to assessing the profitability of car and truck tire remanufacturing. Int J Prod Econ 104(2):639–652

Mathur A, Dangayach GS, Mittal ML, Sharma MK (2011) Performance measurement in automated manufacturing. Measur Bus Excell 15(1):77–91

Meena ML, Jain R, Kumar P, Gupta S, Dangayach GS (2017) Process improvement in an Indian automotive part manufacturing company: a case study. Int J Product Qual Manag 1–28 (**in press**)

Mukhopadhyay SK, Shanker S (2005) Kanban implementation at a tyre manufacturing plant: a case study. Product Plan Control 16(5):488–499

Muruganantham VR, Navaneetha Krishnan P, Arun KK (2013) Performance improvement and cost minimisation for manufacturing components in a fabrication plant by the application of Lean with TRIZ principles. Int J Product Qual Manag 12(4):449–465

Narula V, Grover S (2015) Six Sigma: literature Review and Implications for future research. Int J Ind Eng 26(1):13–26

Palit P, Das S, Mathur J (2015) Metallurgical investigation of wire breakage of tyre bead grade. Case Stud Eng Failure Anal 4:83–87

Pearn WL, Chen KS (1999) Making decisions in assessing process capability index C-pk. Qual Reliab Eng Int 15(4):321–326

Prabhushankar GV, Devadasan SR, Shalij PR (2009) Journey of Indian automobile components sector: from quality management system certification to innovation via Six Sigma. Int J Indian Cult Bus Manag 2(2):185–210

Radha Krishna GA, Dangayach GS (2007) Six Sigma implementation at an auto component manufacturing plant: a case study. Int J Six Sigma Compet Adv 3(3):282–302
Rathore P, Kota S, Chakrabarti A (2011) Sustainability through remanufacturing in India: a case study on mobile handsets. J Clean Product 19(15):1709–1722
Sasikumar P, Kannan G, Haq AN (2010) A multi-echelon reverse logistics network design for product recovery—a case of truck tire remanufacturing. Int J Adv Manuf Technol 49(9):1223–1234
Sharma GVSS, Rao PS (2013) Process capability improvement of an engine connecting rod machining process. J Ind Eng Int 9(1):37
Sharma MK, Bhagwat R, Dangayach GS (2005) Practice of performance measurement: experience from Indian SMEs. Int J Glob Small Bus 1(2):183–213
Sokovic M, Pavletic D, Pipan KK (2010) Quality improvement methodologies–PDCA cycle, RADAR matrix, DMAIC and DFSS. J Achiev Mater Manuf Eng 43(1):476–483
Surange VG (2015) Implementation of Six Sigma to reduce cost of quality: a case study of automobile sector. J Fail Anal Prev 15(2):282–294
Venkatesh N, Gowrishankar MC, Sumangala C (2014) Study and analysis of implementation of Six-Sigma: a case study of an automobile industry. Int J Product Qual Manag 13(1):19–38
Visakh MJ, Aravind S (2014) Optimization using simulation design of experiments and value stream mapping. Int J Des Manuf Technol 5(3):194–203
Wojtaszak M, Biały W (2015) Problem solving techniques as a part of implementation of six sigma methodology in tire production. Case study. Manag Syst Prod Eng Res Dev 3(19):133–137
Wu CC, Kuo HL, Chen KS (2004) Implementing process capability indices for a complete product. Int J Adv Manuf Technol 24(11):891–898