Study on the Application of 6 σ Method in Shoemaking Enterprise Quality Improvement

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Abstract. With the development of science as well as technology and the influx of shoemaking companies abroad, our traditional shoemaking enterprises face greater pressure to survive, and product quality problems are in urgent need of improvement. Aiming at the quality problems of M shoemaking enterprise, DMAIC method is used to conduct the product quality improvement, and a mathematical statistics software Minitab is used to analyze the data. Moreover, the optimum combination of the key influencing factors is determined by orthogonal experiment design as well as a set of specific quality improvement plans are put forward. Finally, the production process capability of M enterprise is improved, the product bonding strength is enhanced, customer satisfaction is improved, and the thoughts of product quality improvement and reference are provided for domestic traditional shoemaking enterprises.

1 Introduction

6 σ quality management research can be traced back to the end of the 20th century [1], Since the beginning of 21 century, 6 σ quality management has been gradually introduced to China and now is growing with a booming tendency. At present, 6 σ methods have been applied in manufacturing enterprises, construction enterprises site, the internet trading system, serving-oriented enterprises, retail industry, state organs, logistics and other fields [2-4].

China is one of the world's largest shoe-producing countries, and the continuous entrance of foreign shoemaking enterprises has brought the Chinese shoemaking enterprises opportunities and challenges [5], which promote domestic shoemaking enterprises to introduce the advanced theory of 6 σ to face the increasingly fierce competition.

M corporation is a pretty prior domestic shoemaking enterprise and the production lines are traditional. Their customers reflected that there were some quality flaws of their products, and the most serious problem—glue problem accounts for more than 40% and in the face of increasingly fierce market competition, it is necessary to improve the problem of glue. Therefore, M corporation applies the DMAIC method in the production process to reduce product defective rate, improve quality, reduce bad costs, better meet the needs of customers, enhance core competitiveness and improve the quality of products, the company provides a reference for other domestic traditional production lines of manufacturing enterprises or shoe-making enterprises.

2 The specific application of DMAIC method in quality improvement

6σ is a complex system as well as a management change to the enterprise [6].The DMAIC approach is an abbreviation for the 6σ breakthrough improvement method and it is constituted by the first letter of Define, Measure, Analyze, Improve, and Control [7],it is a very rigorous process approach of process control and problem-solving of manufacturing. DMAIC method continuously improves the process by identifying the issues which are focused, establishing data collection methods, analyzing the causes of process variation, eliminating variation and providing improvement scheme, while monitoring the long-term process improvement. Stages of DMAIC form a closed-loop system where the former stage prepares for the latter stage, and the latter stage is the deep development of the previous stage.

From the production process of M company, it is known that the cause of the problem of glue including the defect of glue, unreasonable drying time after brushing and unqualified curing, but the cause of quality problems is not clear, in this case, M companies choose 6σ DMAIC method for the project research.

2.1 Definition phase

With the development of science & technology and economy, in recent years, as the old shoe company, M companies began to introduce advanced production equipment and production concepts, and continuously improve its production capacity and production quality. This article is a study of product quality improvement of M shoemaking enterprises and aims to help them improve the production process and product quality and finally win the market.

In this paper, customer’s needs in many aspects are captured by “listening to the voice of the customer” and the “customer’s voice” is transformed into the critical customer requirement (CCR), which converted into measurable items and indexes of output management [8].The percentage of M corporation’s product quality problems which concluded from the customers’ definition and collection of customers’ needs are shown in Figure 1.

Fig. 1. The reflection of customer.

In this paper, through the analysis of “the customer’s voice” and KANO, the product quality problems are identified as the key customer requirements, and after analyzing the Pareto which can reaction the quality problem from the customers, it is found that the glue problem of the product is the main problem that the customer complains a lot. So, this article will set improve the quality of the products problems as project object, and focus on improving the problem of glue.

2.2 Measuring phase

In the measurement phase, the existing measuring system—bonding degree measuring instrument is needed to analyze to ensure that the measured data is real and effective.

Ten products are chosed as samples to measure and record the data in this experiment. The other two inspectors measure 10 samples three times respectively, and the data is shown in Table 1.

Table 1. The results of the bonding degree measuring tools.

No.	Quality inspector 1	Quality inspector 2
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	1(N/mm)	2(N/mm)	3(N/mm)	1(N/mm)	2(N/mm)	3(N/mm)
1	2.73	2.75	2.74	2.74	2.72	2.71
2	3.94	3.90	3.91	3.93	3.96	3.95
3	3.17	3.15	3.20	3.18	3.20	3.18
4	3.48	3.48	3.47	3.46	3.47	3.45
5	2.81	2.85	2.83	2.83	2.83	2.82
6	3.11	3.13	3.14	3.11	3.12	3.10
7	3.32	3.33	3.33	3.35	3.30	3.32
8	2.96	2.93	2.94	2.98	2.95	2.95
9	3.13	3.11	3.13	3.12	3.16	3.13
10	3.84	3.83	3.82	3.82	3.85	3.83

Using Minitab to process data [9], and then use it to analyze the accuracy of the machine, the results are shown in Figure2.

Fig. 2. Bonding degree measurement machine variance analysis report.

It can be seen from the Minitab results:

- 1) the variation of component between the measurement component is much bigger than the measuring tool R&R, the variation of component between the measurement component is 99.82%, and the combined measuring tool's is 0.18%,this means that the most parts of the total variation are caused by the difference of the measuring parts, so the variation caused by measuring system is very small.
- 2) There are a lot of differences between measurement components, and they are displayed with the broken line.
- 3) The difference between the operators is very small, and it is displayed with the straight line.
- 4) By X-bar control chart, most of the balls are falling outside the control line, this shows that the variation is mainly because of the difference between the measurement parts.

According to the automotive industry action group (AIAG) measurement system analysis manual 4th edition, it can use the following guidelines to determine whether the measurement system is acceptable: if the variation column (tolerance, process)of the total gage R&R contribute less than 10%, so the measurement system is acceptable; between 10% and 30%, whether the measurement system is acceptable or not depends on specific application, measuring equipment cost, maintenance cost and other factors; more than 30%, the measurement system cannot be acceptable, and the system should be improved. When the class number is less than 2,the measurement system is no value for the control process, because it is unable to distinguish the parts; when the number of class is 2,the data can be divided into 2 groups, such as high and low; when the number is 3,the data can be divided into 3 groups, like high, middle and low;5 or higher numbers shows the measurement system can be acceptable [10].

From the above Minitab processing results, it is said that the combine measuring tool R&R study variation (SV) values is 4.27%<10%,and the distinguishable class number is 25,so the measurement system is acceptable.

In addition, the process capability is analyzed in measuring phase. In order to know the process capability of M, each batch of this experiment took out only a sample, take 5 out each day, continuous for 7 days, and all the samples were measured with adhesion, get 35 sets of data. Using Minitab to analyze the collected data, get the results as shown in Figure 3.

Fig. 3. Process capability analysis before improvement.

The results show that the data is normally distributed, and the $Cpk = -0.51$. The benchmark value is 1.33, so the process capability of M needs to be improved.

2.3 The analysis phase

According to Pareto diagram can get that the main quality problem of M company is the glue problem, in order to solve this problem, this paper uses cause and effect diagram, analyzes in people, machine, material, method, environment five aspects, gets the fishbone diagram as shown in Figure 4.

Fig. 4. Fishbone diagram.

Through the analysis of the key factors mentioned above and the cause analysis on the fishbone diagram, it can make sure that the main factor is in the XLQ— $\phi 1700 \times 400$ horizontal vulcanizing tank. Because the main cause of the glue problem are raw materials, pressing and vulcanization process. The raw materials used by M company have been relatively fixed. There is no big difference, the glue used in production is purchased from the market, and after some processing, the glue can be used, so, the goal of improving is set as shoes pressing and vulcanization process. Shoes pressing begin after brushing glue, baotou and a series of preparations, put all the components of the shoe together with the glue, and pressure together. The vulcanization process occurs after all of the brush glue, baotou, pressing and a series of processing works, and put semi-finished shoes in vulcanizing pot to sulfide.

The study found that the main factors influencing the bonding process including whether workers operating specification and the cooling time length after pressing. The main factors influencing the sulfide concentration are listed as the following three points: 1) the work pressure of the sulfide cans, 2) the working temperature of the sulfide cans, 3) the working ability of the equipment is insufficient. The dependent variable is set as X_1 : temperature and fan speed are not changed, and change the tank pressure; X_2 : tank pressure and fan speed are not changed, and the tank temperature is changed; X_3 : the cooling time after pressing. Because the glue problems mainly reflect in the adhesiveness of the products, the adhesive degree of the product is set as Y , next will study the effect of the dependent variable X to Y .

2.4 Improvement phase

In improvement phase, the key influence factors of the optimal combination are found by designing experiments. According to the test, the relationship between cooling time, maximum temperature, maximum pressure and adhesion was obtained, and they are showed in Table2, 3, 4.

Table 2. Relationship between cooling time and adhesiveness.

Number	Cooling time (s)	Sampling number	adhesiveness (N/mm)
1	60	10	4.17
2	120	10	4.63
3	180	10	5.16
4	240	10	5.62
5	300	10	6.13
6	360	10	6.32
7	420	10	6.31
8	480	10	6.25
9	540	10	6.17
10	600	10	5.78

Table 3. Relationship between temperature and adhesiveness.

Number	highest temperature (C°)	Sampling number	adhesiveness (N/mm)
1	130	10	4.67
2	131	10	4.83
3	132	10	5.12
4	133	10	5.64
5	134	10	5.92
6	135	10	6.27
7	136	10	6.19
8	137	10	5.72
9	138	10	5.26
10	139	10	4.75

Table 4. Relationship between top pressure and adhesiveness.

Number	Top pressure (MPa)	Sampling number	adhesiveness (N/mm)
1	0.33	10	4.73
2	0.34	10	5.31
3	0.35	10	5.72
4	0.36	10	6.19
5	0.37	10	6.23
6	0.38	10	6.32
7	0.39	10	6.17
8	0.40	10	6.04
9	0.41	10	5.92
10	0.42	10	5.83

Through the table 2,table 3,table 4,it can be seen that cooling time after compression, the temperature of the vulcanizing tank and vulcanizing tank pressure can influence the adhesiveness of the products, therefore, it need to conduct the orthogonal experiment, get the optimal parameters of the three factors.

Next, conduct the orthogonal test on the drying time, temperature and pressure on three levels and three factors, first, assuming that the three parameters were independent of each other, there is no interaction, then orthogonal experiment factors level table as shown in Table 5.

Table 5. Factor level of orthogonal experiment.

Level	Factor		
	A. Cooling time (s)	B.Temperature (C°)	C. Pressure (MPa)
1	360	134	0.36
2	420	135	0.37
3	480	136	0.38

Orthogonal experiments needs to design orthogonal table, this experiment is 3 level and 3 factors, therefore, uses L9 (33) orthogonal table to arrange experiments, take 10 samples each experiment, measure their adhesiveness, and the average value is obtained as the experimental result Y, like Table 6 shows:

Table 6. Orthogonal experiment table.

No.	Factors			Results
	A	B	C	
1	1	1	1	5.76
2	1	2	2	6.13
3	1	3	3	6.04
4	2	1	2	6.23
5	2	2	3	6.41
6	2	3	1	5.97
7	3	1	3	6.13
8	3	2	1	5.91
9	3	3	2	5.86

Having a variance analysis in table 6 by Minitab, and Table 7 shows the result.

Table 7. Variance analysis of main factors improvement.

Source	SS	MS	F	P
A	0.1075	0.0537	1.51	0.294
B	0.0564	0.0282	0.64	0.560
C	0.1500	0.0750	2.63	0.151
Total	0.3139	0.1569		

Among them, SS stands for sum of squares (factors) between groups and the sum of squares in the group (error),MS stands for sum of squares divided by the number of degrees of freedom of the mean square, F stands for test statistics, P stands for significance level, and the P value is smaller, the influence is more significant. When the general P value is less than 0.05,it just means the factor has a significant effect. Table 4-12 is shows that factors C (vulcanizing tank top pressure) is the largest impact on adhesiveness, and the second is factor A (the cooling time after pressing), while the smallest one is factor B (the highest temperature in the curing tank).The main effect diagram of the average level of each factor is shown in Figure 5.

Fig. 5. The average level of factors effect diagram.

Then according to the Figure 5 “average level of factors effect chart” to determine the optimal parameter combination, the best combination by analyzing available for $A_2B_2C_3$ corresponding parameters: after brushing glue, the dry time will be 420s, the top temperature inside the vulcanizing tank will be 135℃,the top pressure inside the vulcanizing tank will be 0.38 MPa.

2.5 Control phase

After the implementation of several stages of DMAIC management method, the main factors affecting the glue problem is found, and the corresponding solution is proposed. And the specific factors were optimized to get the best combination of parameters. Then, as the implementation of the DMAIC, the project has entered the phase of control, monitoring the whole production process, feedback the implementation effect of DMAIC.

This paper has checked the products which were produced from the improved production process by sampling inspection. Also take 5 samples from different vulcanization tanks every day, take seven day in a row, and test the adhesiveness of each sample,35 groups of improved data were obtained.

The collected data were analyzed by Minitab software, get Xbar-R control chart, as shown in Figure 6.

Fig. 6. Xbar -R control chart of control stage.

From this figure, $\bar{x}$ control chart’s center line is at 6.3062,indicates that the process falls within the scope of the specification, and all of the points fall withinthecontrol limits, it shows that the process is stable. The center line of R control chart at 0.0504,also within the maximum allowable variation, so there is no greater variation in the process.

Process capability is obtained by the processing of Minitab, figure as shown in Figure 7.

Fig. 7. The process capability of detection after improved.

Figure7 indicates that the improved sample average number is 6.31 N/mm, obviously higher than that of improved before: 5.95 N/mm, and the improved Cpk is 1.10, higher than the process capability before: -0.51, so, the improvement is useful.

3 Conclusion

In this paper, the DMAIC improvement method of the Six Sigma theory is used in the traditional footwear enterprise product quality improvement project, found the major factors that impact the product quality problems, such as the drying time, curing tank temperature, pressure and so on, and using the orthogonal experiment method to determine the optimal parameter combination, a practical and effective improvement scheme is obtained. Successful implementation of DMAIC method, the process ability of process has been changed from -0.51 to 1.10, the adhesive strength of the product is increased from 5.95N/mm to 6.31N/mm, the customer's satisfaction has been improved, and enhance the competitiveness of the enterprises, implements the sustainable development of enterprises. At the same time also provides a reference for the development of similar enterprises to improve.

Acknowledgement

This research is supported by soft science research plan of Guizhou province (project number: 2016GZ67308) and the key projects of Guizhou province [2014]6004.

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