APPLYING SIX SIGMA TO IMPROVE THE DEFECT RATE OF ELECTRONIC COMPONENTS: A SIX SIGMA CASE STUDY

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ABSTRACT

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This study aimed to improve the touch responses of electronic products. The improvement method was based on six sigma improvement steps. Product quality was improved using define, measure, analyse, improve, control (DMAIC) and statistical quality control methods to reduce the cost and waste of defective products. The project identified five critical processes from the manufacturing process and eight critical to characteristics (CTCs). Then CTCs were identified through the critical to characteristic diagram. The root causes were verified using the experimental plan method, scatter diagram, and double ratio test. This study identified three root causes, namely 'poor reed touch value', 'base cavity width', and 'jig precision'. The last two causes were evaluated, and countermeasures were taken to 'change the size of the base cavity', 'change the design of the assembly jig', and 'change the process of the assembly jig'. The target rate of the overall product defect rate reached 127%.

OPSOMMING

Hierdie studie het ten doel gehad om die aanraakreaksies van elektroniese produkte te verbeter. Die verbeteringsmetode was gebaseer op die ses sigma verbeteringstappe. Produkgehalte is verbeter deur gebruik te maak van definieer, meet, analiseer, verbeter, beheer ("DMAIC") en statistiese gehaltebeheermetodes om die koste en vermorsing van gebrekkige produkte te verminder. Die projek het vyf kritieke prosesse uit die vervaardigingsproses geïdentifiseer en agt kritieke tot kenmerke (CTC's). Daarna is CTC's geïdentifiseer deur die krities-tot-kenmerkende diagram. Die oorsake is geverifieer deur die eksperimentele planmetode, verstrooiingsdiagram en dubbelverhoudingtoets. Hierdie studie het drie hoofoorsake geïdentifiseer, naamlik 'swak roerdotswaarde, 'basisholtebreedte' en 'klem akkuraatherid'. Die laaste twee oorsake is geëvalueer, en teenmaatreëls is getref om 'die grootte van die basisholte te verander', 'die ontwerp van die samestellingshulpstuk te verander', en 'die proses van die samestellingshulpstuk te verander'. Die teikenkoers van die algehele produkdefektesyfer het 127% bereik.

1.   INTRODUCTION

1.1. Research motives

The global electronics industry, including computer, communication, consumer electronics (3C) and home electronics, experienced rapid growth in 2000 owing to the rise of smartphones and the introduction of tablet computers [1]. These handheld communication and mobile wireless devices, combined with traditional computer fixed-network devices, are connected through the internet, and drive the new era of the Internet of Things (IoT). Moreover, the development trend of robotics, autonomous driving, smart

home, cloud, and big data has also confirmed the continual development of the electronics industry in the future.

Taiwan is the world's leading manufacturer of electronic products, and the electronics industry has been booming for the past two decades. Business concepts, manufacturing technology, production management, quality assurance, and product reliability have been continuously improved. 'Made in Taiwan' (MIT) products have also become synonymous with quality assurance. The year 2000 can be seen as a watershed in developing quality activities in Taiwan. Total quality management (TQM) related activities were the focus before 2000; the main activities were related to six sigma and lean production or the Toyota production system (TPS) [2]. At the same time, most of Taiwan's electronics industry has gone to the China to invest and set up factories. With Taiwan as the R&D centre and China as the manufacturing production line, product quality is relatively unstable.

The target of improvement in this study was the tactile switches of 3C products. Tactile switches are one of many switches on printed circuit boards (PCBs), and are widely used in electronic components. They are often used to control electronic products' power on and off, such as medical devices, cell phones, and remote controls. They are widely used in electronic devices because of the advantages of low contact resistance load, low force error, and various specifications. Therefore, it is necessary to improve the process yield and to reduce the defect rate in order to decrease customer complaints and reduce loss. Six sigma is a scientific management model that is based on data and is customer-oriented; it adopts a process perspective and the concept of continuous improvement to improve product process efficiency and effectiveness, thereby increasing customer satisfaction and profitability [3]. Therefore, this study used six sigma activities as examples for improving defective tactile switches.

2. LITERATURE REVIEW

Six sigma is a management technique developed by Motorola in the 1980s. In 1981, Motorola's chief executive officer (CEO) Bob Galvin had asked the company to improve its performance tenfold within five years. Bill Smith, an engineer in the communications division, proposed the idea of six sigma, which required the company to achieve a quality level of 3.4 ppm. As a result of General Electric's E CEO Jack Welch promoting six sigma, GE generated billions of dollars in savings over five years. That impressive performance established six sigma management as a trend in the United States business world [4].

Six sigma is a complete improvement procedure. If the object for improvement is an existing process, the define, measure, analyse, improve, control (DMAIC) phases can be adopted; if the objective is to design a new product/service or to redesign a current product/service, the define, measure, analyze, design, validate (DMADV) phases may be used, as shown in Figure 1. Banuelas et al. (2005) consider six sigma an effective problem-solving strategy [5]. The key success factors of a six sigma project can be summarised as management input and commitment, the selection of items related to corporate goals, training and teamwork, and project progress tracking and monitoring.

Many senior executives want to use six sigma projects to solve the problems that their companies face. However, implementing six sigma is often unfocused. A company's resources are relatively limited, making it difficult to ensure that the project team could find projects that would have a critical impact on the company. The solution is to integrate the six sigma project with the organisation's strategic planning in order to enable the company to achieve breakthrough results in its strategies. Therefore, it is necessary to Integrate six sigma and corporate strategy planning methods to ensure that six sigma projects significantly benefit the company, leading to opportunities for cultural change and breakthrough innovation [6].

Implementing six sigma in Taiwan began around 1990 when the headquarters of Motorola required its Taiwan branch to implement six sigma improvement activities. Real progress occurred around 2000. In addition to GE Medical Systems introducing six sigma, Taiwanese government units established projects to assist companies in implementing six sigma activities [1].
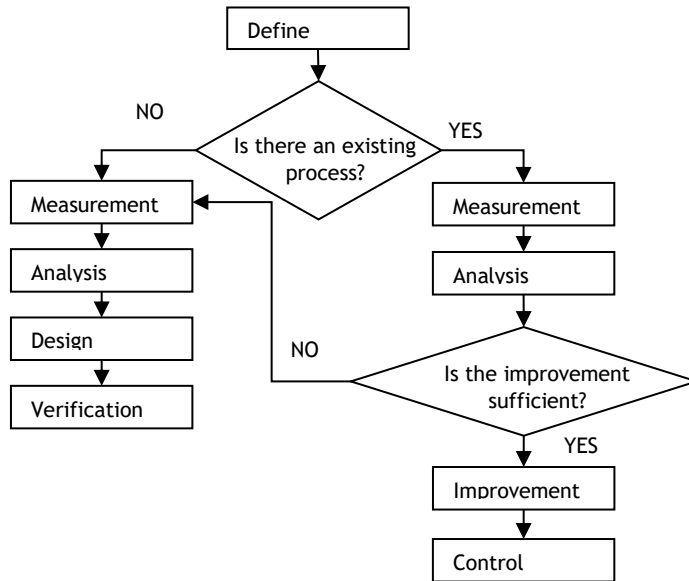
Figure 1: Six sigma phase determination process

3. METHODOLOGY

This study aimed to improve defective products in the existing manufacturing process. Therefore, the five DMAIC phases were used [7]. The content of each step is shown in Table 1.

Table 1: Content of DMAIC phases

Phase	Content
Define	Define problems, customer needs, and project objectives.
Measure	Measure errors and process operations, and collect relevant data.
Analyse	Analyse the data, seek and examine the relationship between cause and effect, and determine the relationship. Then consider all factors and conduct a survey to determine what caused the problem.
Improve	Improve and optimise current processes. Use the analysis data to apply different methods to create a new ideal process and to establish the ability to standardise the operational process.
Control	Control and change future processes to ensure any off-target errors can be corrected.

Define phase: During this phase, we identified improvement opportunities for the project and clearly defined the problem and its scope. First, we completed the project charter, which consisted of the purpose, problem description, objectives, problem scope, project planning, member selection, and estimated benefits. These items can be evaluated and selected, based on customer needs and the company's strategic goals. The sources for selection include corporate external sounds and internal processes. External sources, such as customer complaints and market competition, and internal sources, such as a high defect rate, heavy production, and cost waste, were the basis for selection.

Measure phase: The primary purpose of this phase was to evaluate and understand the current process status, to select the critical-to-quality characteristics (CTQ), and to convert the CTQ to list critical process output variables. The measurement system was first verified to confirm that the data collected and the results of the measurements were correct and could be trusted.

Analysis phase: In this phase, the data collected during the measure phase were presented via tools and methods to identify the root cause of the problem. Using the cause-and-effect diagram, we analysed critical causes and investigated the variation in the quality characteristics from 5M1E, including the workforce, machinery, materials, methods, measurement, and environment. Then we verified the true causes with common tools such as control chat, hypothesis testing, and regression analysis.

Improve phase: This phase involved selecting and implementing the most cost-effective solution in order to improve the system process, eliminate the root cause of the problem, reduce variability, and prevent a recurrence of the problem. The experiment design was the most important statistical tool during this phase. By thoroughly planning the combination of experiments, we could effectively measure the degree of influence between factors, decide which factors affected the process results, and determine the best combination of factors.

Control phase: The improved process, related operational standards, and training documents were adequately communicated to the actual process operators to maintain the improved results. It had to be monitored continuously to ensure that the improved system was effectively and stably maintained. The experience and results obtained during the project improvement process were extended horizontally and applied to other organisational processes in order to achieve continuous improvement.

Companies use the six sigma DMAIC methodology to enhance processes, and immediate and noticeable improvement results can be achieved from the application and analysis of statistical techniques. However, it is gradually realised that there are limits to the extent of these improvements, and achieving a quality level satisfactory to customers is quite difficult. It becomes necessary to redesign processes such as products, procedures, and services in order to exceed customers' expectations in quality, cost, lead time, and service, thereby delighting customers. This design process is referred to as 'design for six sigma' (DFSS).

Unlike the standardised DMAIC improvement steps in six sigma, DFSS does not have a universally recognised set of process steps. DMADV and identify, design, optimize and verify (IDOV) are currently the most common methods. DMADV is the most commonly used DFSS method, consisting of five steps: define, measure, analyse, design, and verify. IDOV is widely applied in the manufacturing industry, comprising four steps: identify, design, optimise, and verify [6].

4.   CASE ANALYSIS RESULTS AND DISCUSSION

The subject of this study was a professional supplier of laptop batteries. This company had been receiving requests from customers to improve the process yield and to decrease the product defect rate, so as to reduce the number of customer complaints and wear and tear.

4.1. Define phase

In the define phase, we first sought to understand the defect phenomena that customers valued, and discovered that the main complaints from customers were about highly defective products A and B after assembly. Then we used a matrix diagram to select the improvement project and understand the current situation, as shown in Table 2 and in Figures 2 and 3. The defect rate of Product A was 7%, and for Product B it was 5.36%. Finally, the theme of this project was defined as 'Defect improvement for Product A'.

Table 2: Project evaluation selection table

Project	Project source			Quality attributes				Measurement indicators	Project selection
	Customer needs	Corporate strategies	Cost factors	Quality	Time of delivery	Cost	Service	Defect rate	
Defect improvement for Product A		⊙	⊙	⊙		⊙		7%	✓
Defect improvement for Product B		⊙	⊙	⊙		⊙		5.36%	

Note: '⊙' means that the project and item were related; '✓' means the project selection
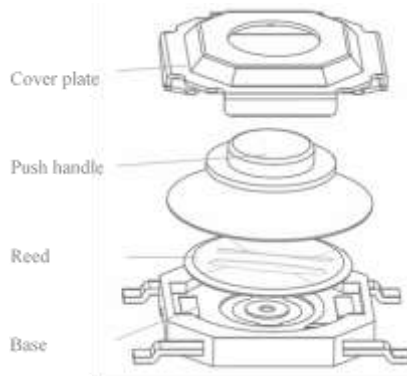
Figure 2: Product A assembly structure diagram

Gathering data about to the number of defective components yielded during a continuous 20-day period of Product A's manufacturing process, we found that the derived average defect was 69 803 defects per million (DPPM), as shown in Figure 3.
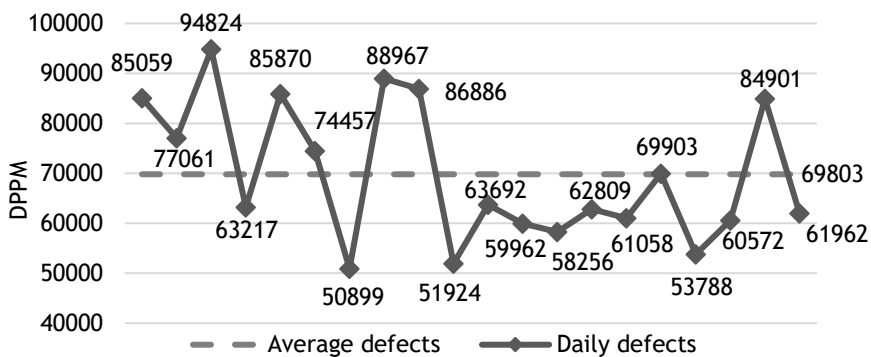

Figure 3: Diagram of total defects for Product A

We then used a Plato analysis to determine the critical items for improvement. The percentage of defective items in the total number of items was found to be 70%~80%, and the direction for improvement was prioritised. Internal data collection at the factory showed that 72.95% of the total defective parts were caused by defect touch, as shown in Figure 4. This important item was a waste of money for the company. Thus we selected defect touch as the target for improvement. Figure 5 shows that the average daily defect touch was 51 480 DPPM.
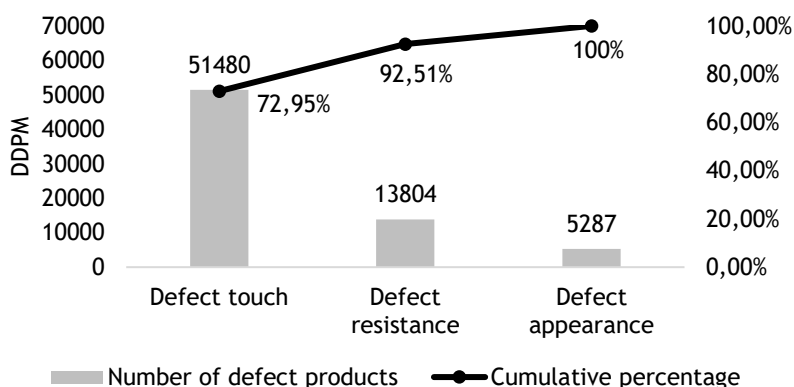

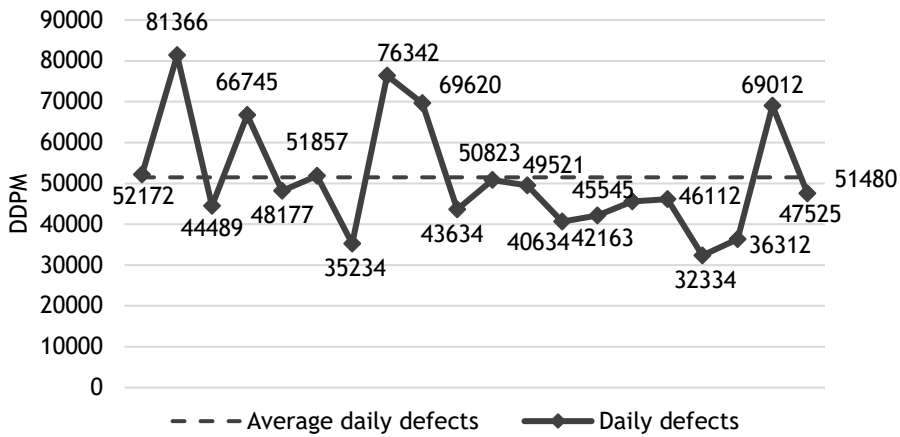**Figure 4: Plato of number of defect products in Product A**

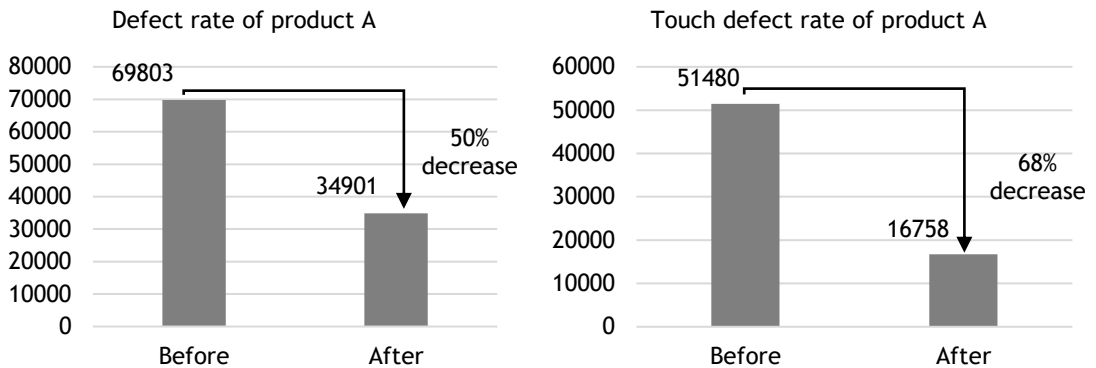**Figure 5: Trend chart of daily defect DPPM for Product A**

Figure 6: Improvement target setting chart

Regarding the improvement target, according to the company's management policy, the defect rate needed to be reduced by 50%. Therefore, the touch defect rate of Product A had to be reduced by 68% to achieve the result, as shown in Figure 6.

4.2. Measure phase

In the measure phase, the CTQs were identified through an inventory of the current process status (see Figure 7). The CTQs were converted into a list of critical process output variables. After the critical improvement process was determined, the CTC was identified in the measure phase, as shown in Table 3. What was important to monitor in the process was determined by grasping the CTC. Then the measurement system analysis was performed for the CTC, as shown in Table 4. Gage repeatability and reproducibility (GR&R) is defined as the process that is used to evaluate a gauging instrument's accuracy by ensuring that its measurements are repeatable and reproducible. The process includes taking a series of measurements to certify that the output is the same value as the input, and that the same measurements are obtained under the same operating conditions over a set duration. GR&R $\leq$ 10% is acceptable for the measurement system; GR&R > 10% and $\leq$ 30% would mean that the measurement system may be acceptable, depending on the needs of the process, or on the risk and cost to determine whether further improvements are needed. If GR&R > 30%, the measurement system is not acceptable. The result was that the personnel and testing equipment of the measurement system was reliable and stable without causing variation. The process capability of the measurement indicators was also assessed judged; the eight identified indicators showed insufficient process capability and needed to be improved. Take the complex process capability (CPK) index as an example: the main investigation is into long-term manufacturing capacity, for which the index needs to be greater than at least 1.33 to represent a stable manufacturing capacity. When the CPK is greater than 1.5, it is equivalent to six sigma. As shown in Table 5, the status of all of the measurement indicators for process capability had not been achieved.
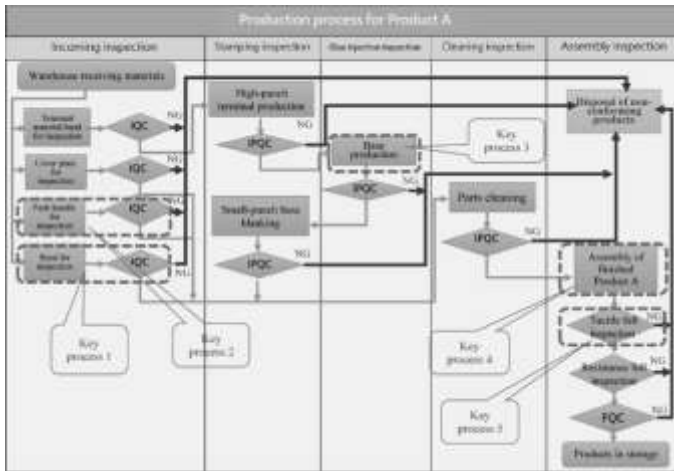
Figure 7: A manufacture flow and key process for Product A

Table 3: Summary of critical to characteristics

CTQ	Driving factor	CTC index
Product A with consistent touch (35~75% of good touch)	Control of touch defect rate of finished products	Touch defect rate of finished products
	Control of finished product touch	Finished product touch value CPK
	Control of base positive drop	Base positive drop CPK
	Control of base negative drop	Base negative drop CPK
	Control of base cavity width	Base cavity width CPK
	Control of base cavity depth	Base cavity depth CPK
	Control of push handle bump height	Push handle bump height CPK
	Control of reed touch	Reed touch value CPK

Table 4: Summary of Measurement System Capability Analysis Results

Indicator name	Testing equipment/personnel	Measurement system analysis results	Judgement
Touch detection capability	Touch testing personnel	Detection rate 93.33%	Counting type measurement system >90% means a reliable measurement system
Product touch value	Load profiler	GR&R=10.399%	GR&R=10.399% <25% → an acceptable measurement system
Base positive drop	Altimeter	GR&R=10.084%	GR&R=10.084% <25% → an acceptable measurement system
Base negative drop	Altimeter	GR&R=10.084%	GR&R=10.084% <25% → an acceptable measurement system

Indicator name	Testing equipment/personnel	Measurement system analysis results	Judgement
Base cavity width	Tool microscope	GR&R=23.44%	GR&R=23.44%<25% → an acceptable measurement system
Base cavity depth	Altimeter	GR&R=20.909%	GR&R=20.909%<25% → an acceptable measurement system
Push handle bump height	Projector	GR&R=4.820%	GR&R=4.820%<10% → a very reliable measurement system
Reed touch value	Touch testing personnel	GR&R=4.0505%	GR&R=4.505%<10% → a very reliable measurement system

Table 5: Summary of measurement indicators for process capability

No.	Item	Standard	Current Status	Conclusion
1	Touch defect rate	15811 DPPM	50712 DPPM	Poor process capacity that needs improvement
2	Product touch value 35%~75%	CPK>1.33	1.16	Poor process capacity that needs improvement
3	Base positive drop 0.10±0.02mm	CPK>1.0	0.74	Poor process capacity that needs improvement
4	Base negative drop -0.08±0.02mm	CPK>1.0	0.25	Poor process capacity that needs improvement
5	Base cavity width 2.5+0.05 mm	CPK>1.0	0.69	Poor process capacity that needs improvement
6	Base cavity depth 0.55±0.01mm	CPK>1.0	0.01	Poor process capacity that needs improvement
7	Push handle bump height 0.9—0.05mm	CPK>1.0	0.49	Poor process capacity that needs improvement
8	Reed touch value 55%~70%	CPK>1.0	0.55	Poor process capacity that needs improvement

4.3. Analysis phase

In the analysis phase, the manufacturing staff, R&D engineers, and quality assurance supervisors brainstormed to develop a CTC diagram based on personnel, equipment, material, method, measurement, and environment, and finally selected seven CTCs, as shown in Figure 8. Then an action plan to identify the root cause was developed for these seven CTCs, as shown in Table 6.
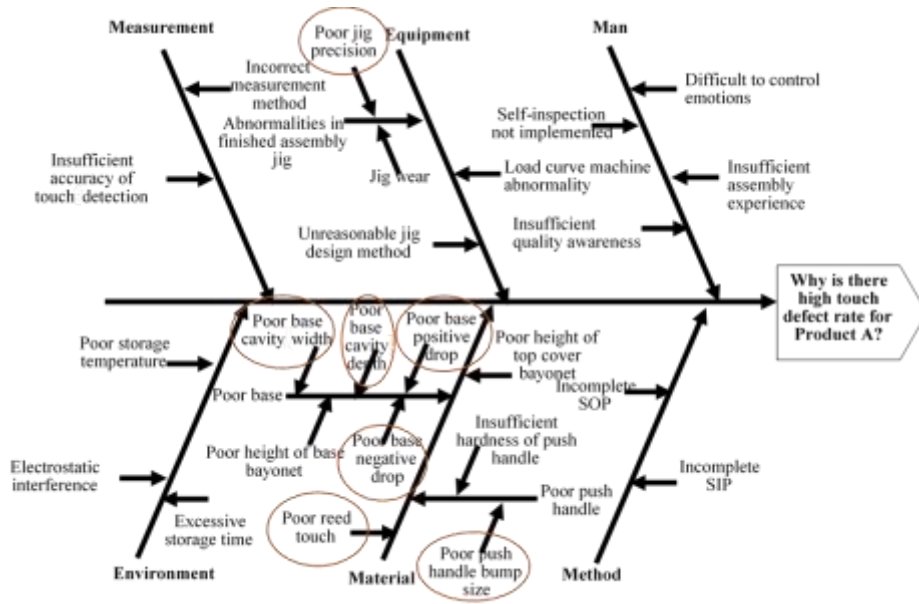
Figure 8: Critical to characteristic diagram

Table 6: Action plan to identify the root cause

Characteristics	Action plan	Identify the root cause	Identify Method
Poor push handle bump size	Correlation between the size of the push handle bump and the touch of the finished product	Identify the root cause 1-1 Identify the root cause 1-2	DOE
Poor base cavity width	Correlation between the cavity diameter size of the base and the touch of the finished product		
Poor reed touch	Correlation between the reed touch and the touch of the finished product		
Poor base positive drop	Correlation between the positive drop of the base and the touch of the finished product	Identify the root cause 2	Dispersion chart
Poor base negative drop	Correlation between the negative drop of the base and the touch of the finished product		
Poor base cavity depth	Correlation between the cavity depth of the base and the touch of the finished product		
Poor jig precision	Correlation between the jig precision and the touch of the finished product	Identify the root cause 3	Dual ratio test

4.3.1. *Identify the root cause 1-1*

A multi-level factorial design was implemented for the causes of 'poor push handle bump size', 'poor base cavity width', and 'poor reed feel value', as shown in Table 7. Four repeated experiments were performed for three factors, so the total number of experiments was 48, as shown in Table 8. The reed p-value = 0.011 < 0.05, as shown in Table 9. The reed touch value was determined to be the root cause because it had the greatest effect on the finished product touch value (Figure 9), with significant differences. However, the interaction of the three factors was not significant (Figure 10), and it was not possible to determine the best value for the combination of the three factors.

Table 7: Selection of experimental factors and levels

Factor		Level 1	Level 2	Level 3
A	Push handle bump size specifications: 0.90+0/-0.05	A1=0.85±0.01 (low)	A2=0.88±0.01(high)	
B	Base cavity width specifications: 2.50+0.05/-0	B1=2.54-2.55 (wide)	B2=2.52-2.53 (narrow)	
C	Reed touch specifications: 55~70%	C1=>60-65% (high)	C2=>55-60% (medium)	C3=>50-55% (low)

Table 8: Summary of experimental results

No.	A	B	C	Finished product touch value	No.	A	B	C	Finished product touch value	No.	A	B	C	Finished product touch value
1	High	Narrow	Medium	41.48	17	Low	Narrow	Low	36.77	33	High	Wide	Medium	35.71
2	High	Narrow	Low	38.03	18	Low	Narrow	Medium	48.56	34	Low	Narrow	Low	37.1
3	High	Wide	Low	41.91	19	Low	Narrow	Medium	48.64	35	High	Narrow	Low	37.29
4	Low	Narrow	Medium	50.3	20	Low	Narrow	High	46.26	36	Low	Wide	High	37.95
5	High	Wide	Medium	42.35	21	Low	Wide	High	50.6	37	High	Narrow	High	36.43
6	High	Narrow	Low	44.42	22	High	Narrow	Medium	42.61	38	High	Narrow	High	40.5
7	Low	Wide	Medium	40.68	23	Low	Wide	Low	39.64	39	High	Wide	High	43.78
8	High	Wide	Low	41.58	24	High	Wide	Low	49.01	40	Low	Wide	High	46.35
9	Low	Wide	Medium	49.16	25	Low	Narrow	Low	44.32	41	Low	Narrow	Low	41.61
10	High	Narrow	High	52.74	26	High	Wide	High	47.87	42	Low	Wide	Medium	49.46
11	Low	Narrow	High	50.75	27	Low	Wide	Low	36.43	43	High	Narrow	Medium	50.4
12	High	Wide	High	54.82	28	High	Wide	Medium	48.2	44	Low	Narrow	Medium	49.45
13	High	Narrow	High	47.21	29	High	Narrow	Low	45.38	45	Low	Wide	Medium	32.63
14	Low	Wide	Low	27.18	30	Low	Narrow	High	54.63	46	Low	Wide	High	50.51
15	High	Narrow	Medium	40.8	31	Low	Narrow	High	39.46	47	High	Wide	Medium	41.08
16	High	Wide	Low	38.68	32	High	Wide	High	45.94	48	Low	Wide	Low	43.96

Table 9: Identified results of various factors

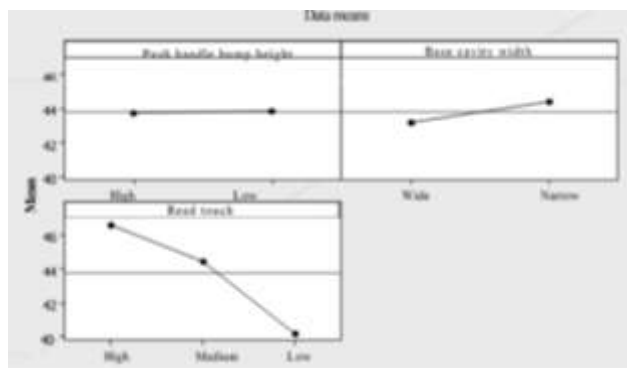| Item	P-value
Push handle bump height	0.730
Base cavity depth	0.263
Reed touch	0.011**
Push handle bump height* Base cavity depth	0.386
Push handle bump height* Reed touch	0.278
Base cavity width* Reed touch	0.403
Push handle bump height* Base cavity depth* Reed touch	0.946

Note: *p<0.5, **p<0.1, ***p<0.01

Figure 9: Main effect plot for means
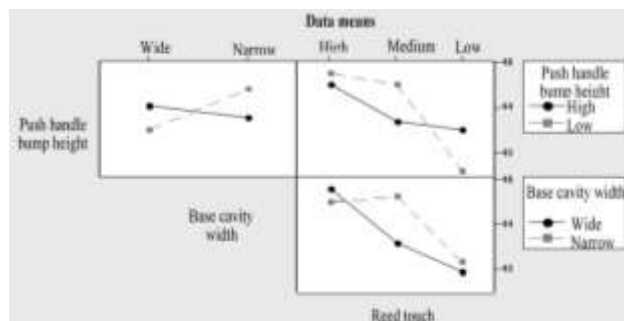
Figure 10: Interaction diagram

4.3.2. Identify the root cause 1-2

The reed had the most influence on touch in the experimental identification results. However, from past experience and discussions with experienced operators and quality assurance units in the field, in addition to the reed affecting the quality of the touch, the gap between the reed and the base also affects the touch. Thus the base cavity width was re-identified, as shown in Table 10. The p-value = 0.002 < 0.05 was obtained from the double ratio test. Therefore, the base cavity width was related to the defect touch rate of the finished product, and was a root cause.

Table 10: Statistics of defect products after for base changes

	Before change of base cavity width (2.50+0.05/-0)	After change of base cavity width (2.50 +0.05/-0)
Total number of products with defect touch (pcs)	9	5
Total number of products (pcs)	200	200

4.3.3. Identify the root cause 2

The 'base positive drop', 'base negative drop', and 'base cavity depth' were plotted against the 'touch value' in a scattering diagram to identify the root cause. The conclusion was that these three factors were not correlated with the touch value, as shown in Figure 11; so they were not considered to be the root causes.
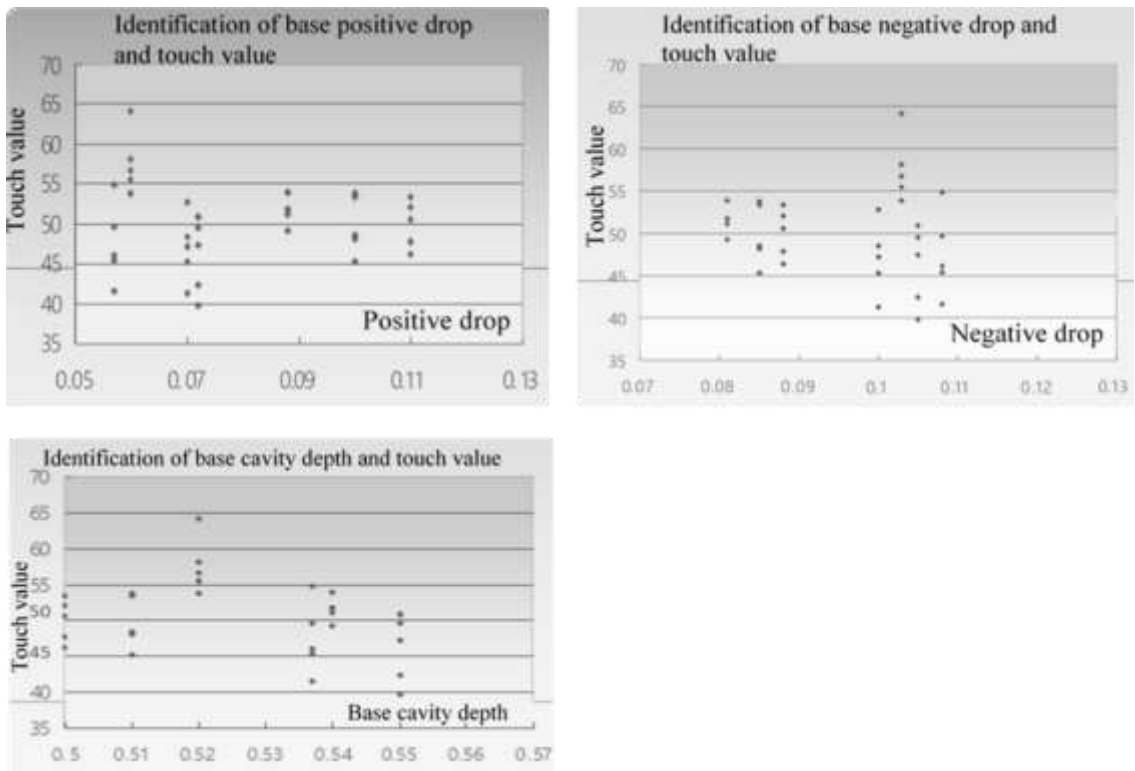

Figure 11: Scatter diagram

4.3.4. Identify the root cause 3

The jig was modified to verify the correlation between jig precision and the defect touch rate of the finished product. The result is shown in Table 11. The more than double ratio between two and four positioning holes was tested, and the p-value = 0.021 < 0.05. Therefore, the correlation between the precision of the jig was related to the defect touch rate of the finished product, and jig precision was a root cause.

Table 11: Statistics of defect products for jig changes

	Before jig change (two positioning holes)	After jig change (for positioning holes)
Total number of products with defect touch (pcs)	18	6
Total number of products (pcs)	500	500

Conclusion: The results of the identification of the root cause yielded three true causes, namely 'poor reed touch value', 'base cavity width', and 'jig precision'.

4.4. Improve phase

During the improve phase, team members brainstormed the three root causes of the problem in the analysis phase and formulated the countermeasures shown in Table 12. Regarding the countermeasure of poor reed touch value, since it was a seller's market, and no other supplier could be found for a short period, no improvement would be made after the evaluation. Countermeasures were proposed for the other two causes.

Table 12: Development of countermeasures

Y	y	X	Verification item	Introduction of countermeasure	Implementation
Drop in total defect finished products 50%	Drop in defect touch 68%	Poor reed touch value	Verification of reed touch value and finished product touch value	Temporarily no improvement was made, as suppliers did not agree to improve product quality since it was a seller's market, and no other suppliers could be found.	✗
		Base cavity width	Verification of base cavity depth and finished product touch value	Measure 1: Change in product design, modification of base cavity width dimensions	✓
		Jig precision	Verification of jig precision and finished product touch value	Measure 2: 2-1 Change in the assembly fixture design to increase the positioning accuracy, use of ball guide column and guide bush; change of material from fireless to hardened material to increase the wear resistance. 2-2 Change in the machining process of assembly jig from CNC machining to slow-wire machining.	✓

The countermeasure for the root cause of 'base cavity width' was 'change in product design, modification of base cavity width dimensions'. In the trial effect of improving the touch value of the assembled finished products with the base cavity size, the touch value of Product A decreased from 51 480 ppm to 20 390 ppm. The overall defect rate decreased from 69 803 ppm to 33 950ppm, and the countermeasure was effective, as shown in Figure 12.
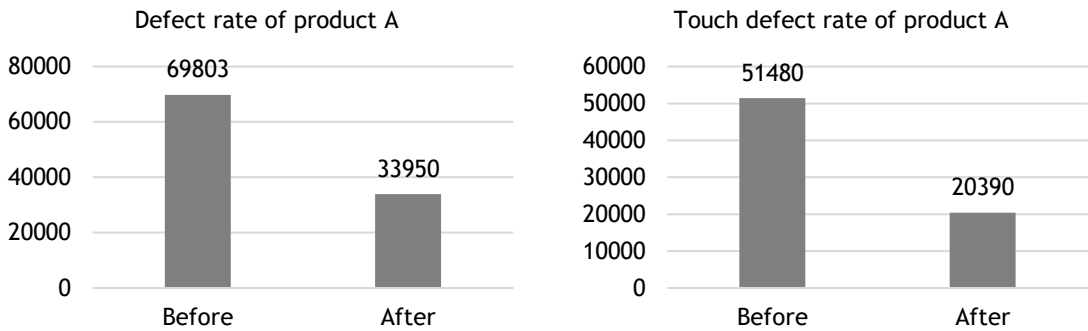
Figure 12: Effect confirmation of implementation of Countermeasure 1

The countermeasures for the true cause of 'jig precision' were divided into two stages: the first stage was 'change in the design of assembly fixture to increase the positioning accuracy, use of ball guide column and guide bush; and change of material from fireless material to hardened material to increase the wear resistance'. The countermeasure in the second stage was a 'change in the machining process of assembly jig from CNC machining to slow-wire machining'. After introducing the countermeasures, the effect of the touch value of Product A decreased from 51,480 ppm to 15,992 ppm and then evolved to 12,230 ppm. The countermeasure was effective, as shown in Figure 13.
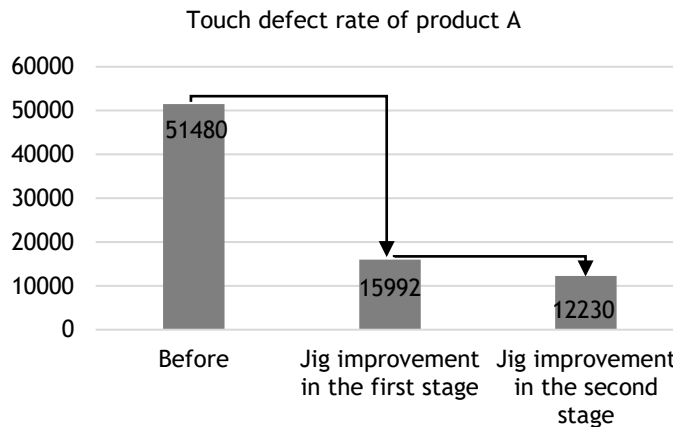

Figure 13. Effect confirmation of implementation of Countermeasure 2

4.5. Control phase

After we had confirmed that the improvement measures could achieve the results in the improve phase, the standardised operation was adopted. Figure 14 shows that the target achievement rate of the overall defect rate of Product A was 127% and the improvement rate was 63.7%; the target achievement rate of the touch defect rate of Product A was 112%, and the improvement rate was 76.3%. The process capability index of base cavity size improved from CPK=0.68 before improvement to CPK=1.28 after improvement. The process capability index of the in-process touch value improved from CPK=1.16 to CPK=1.78. The overall and touch defect rates were tracked continuously using the P-chart control chart, as shown in Figures 15 and 16. The defect rates were within the control limit, and the improvement target was achieved.
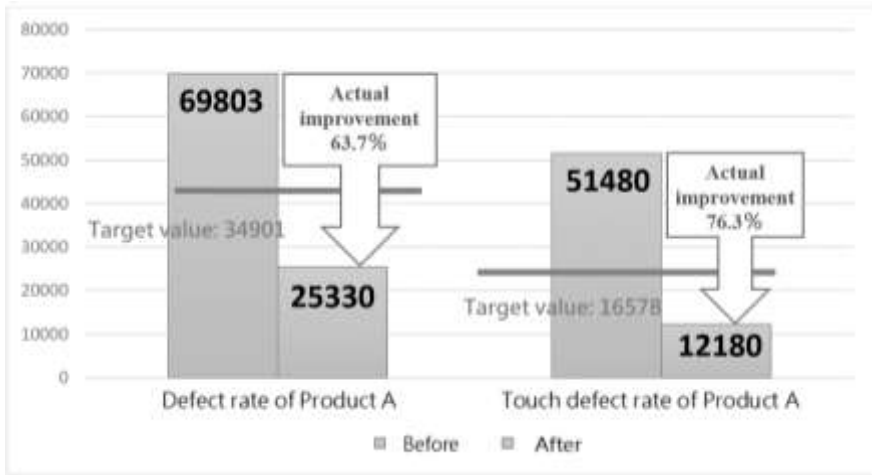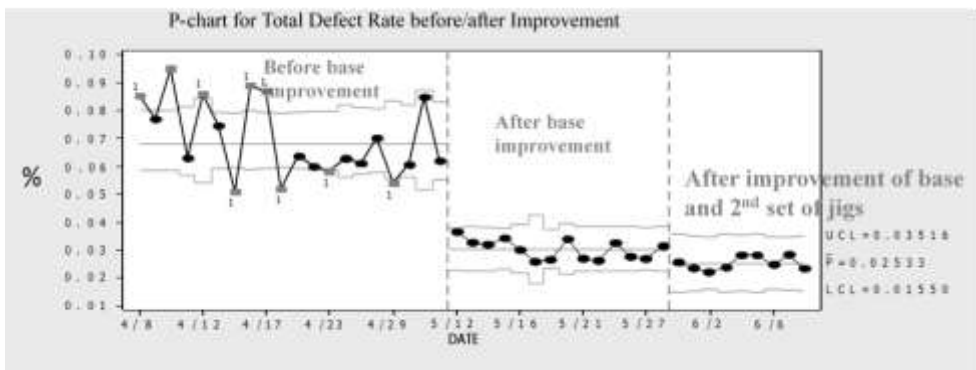
Figure 14: Target effect confirmation

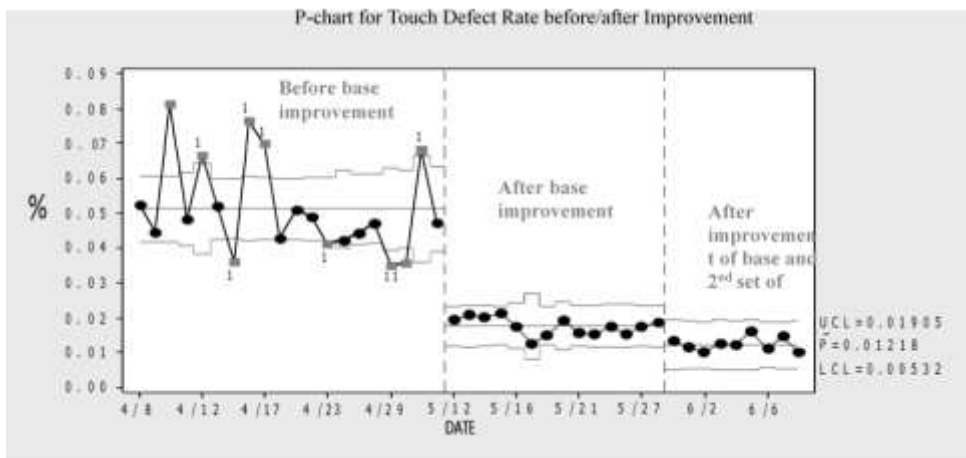**Figure 15: P-chart for total defect rate before and after improvement**

Figure 16: P-chart for touch defects before and after improvement

5.   CONCLUSION AND SUGGESTIONS

This study used the DMAIC phases of six sigma to improve defective electronic component tactile switches. First, in the define phase, the assembly structure of the product was clarified, and the problem to be solved was the product's poor touch and key process areas, as per customer feedback. In the measure phase we analysed the measurement system for the identified CTCs, which was stable. Further analysis revealed three true causes, namely 'poor reed touch value', 'base cavity width', and 'jig precision'. Only the last two true causes were considered in the improvement countermeasures, as the problem with the reed supplier could not be solved quickly. We compared the set targets with the effectiveness in the final control phase. The target rate of overall defect rate reached 127%, the target rate of the touch defect rate reached 112%, and the process control showed stable and controllable results.

After a complete process improvement, the case company reduced the defect rate and adopted a comprehensive and effective improvement process and procedure, which was a significant benefit for the company. In fact, through this project, we found that most of the defects in the assembled products were related to the structure of the products, including the rigour of the product design specifications and the tooling precision. This finding indicates that the product design affected the result, and suggests that quality control should be practised by the source management.

REFERENCES

[1]   **Wang, Z.H.** (2015). *History of quality development in the Republic of China*. Taipei, Taiwan: CSQ.
[2]   **Yang, C.C.** (2004). An integrated model of TQM and GE-Six-Sigma. *International Journal of Six Sigma and Competitive Advantage, 1*(1):97-111.
[3]   **Pande, P.S.**, Neuman, R.P. & Cavanagh, R.R. (2006). *What is design for Six Sigma?* Taipei, Taiwan: McGraw Hill.
[4]   **Bossidy, L., Charan, R. & Burck, C.** (2002). *Execution: The discipline of getting things done*. New York: Crown Business.
[5]   **Banuelas, R., Antony, J. & Brace, M.** (2005). An application of six sigma to reduce waste. *Quality and Reliability Engineering International, 21*:553-570.
[6]   **Hunt, R.A. & Xavier, F.B.** (2003). The leading edge in strategic QFD. *International Journal of Quality & Reliability Management, 20*(1):56-73.
[7]   **Pande, P.S., Neuman, R.P. & Cavanagh, R.R.** (2001). *The six sigma way team fieldbook*. New York: McGraw Hill.