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Application of Six Sigma Methods to Quality Improvement in Generator Sets

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Abstract: Aiming at the zero-kilometer failure problem feedback from customers, Company A analyzes the production process using Six Sigma methodology, finds out the main causes of quality problems using Pareto charts and fishbone diagrams, reduces the zero-kilometer failure PPM, greatly reduces the risk of poor-quality products flowing to the client and the losses caused by product functionality failure, and enhances the company's brand image.

Keywords: generator sets; six sigma; quality improvement

Introduction

Genset is a device that converts the mechanical energy of an internal combustion engine into electrical energy by means of a generator. Genset mainly consists of five parts: internal combustion engine, generator, radiator, control panel and auxiliary facilities.Company A is an enterprise mainly engaged in generator sets. In the process of product after-sales service, it is found that quality problems often occur in products that are newly sold or run for a very short time. In this paper, Six Sigma methods and tools are used to improve the quality problems occurring in this product, to improve the yield rate of the product, to reduce the zero-kilometer failure PPM, to improve the company's brand image, and to reduce the company's economic losses.

1.Genset production process and its current status

1.1 Production process of generator sets

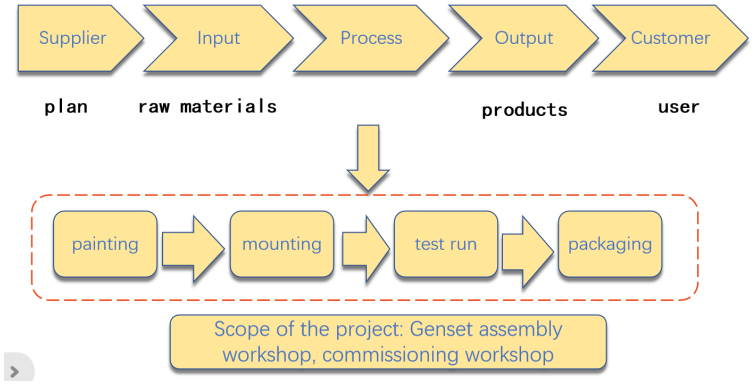

Figure 1 Generator set production journey map

The production process of the generator set mainly includes four parts: painting, mounting, test run and packaging. The production process is shown in Figure 1. Small and medium-sized power generation equipment uses the disk link to connect the internal combustion engine with the generator, and the reliability of the key processes is ensured by stipulating the bolt torque. Large-scale power generation equipment mainly uses flexible coupling to connect the internal combustion engine and generator together, and coaxiality is the key index.

1.2 Current status of product qualitys

The quality department of Company A has defined the failure of equipment within 120h of startup operation as a zero-kilometer failure, and the formula for calculating the PPM for a zero-kilometer failure is as follows:

$$Zero-kilometer\ failure\ PPM = \frac{Nunmber\ of\ zero-kilometer\ failures * 10^6}{Number\ of\ generator\ sets}$$

The number of zero-kilometer failures is the number of zero-kilometer failures of generator sets that occurred in a natural month. The number of generator sets is the number of units sold in the current natural month, extrapolated forward six months, excluding the current month, because of the lag in product quality compared to the current month's production.

The after-sales service system data of company A shows that the annual zero-failure PPM level of the product in 2020 is 13766, of which the zero-failure PPM level in the second half of the year is 15515.In the second half of the year 2020, there is a problem of product quality decline. The P-control chart of zero-kilometer failure is shown in Figure 2,it can be seen that the zero-kilometer failure in March and September has an abnormal point, which indicates that the product quality control is very unsatisfactory, there is a loss of control of the quality of the company's products, there is an urgent need to improve the company's product quality situation.

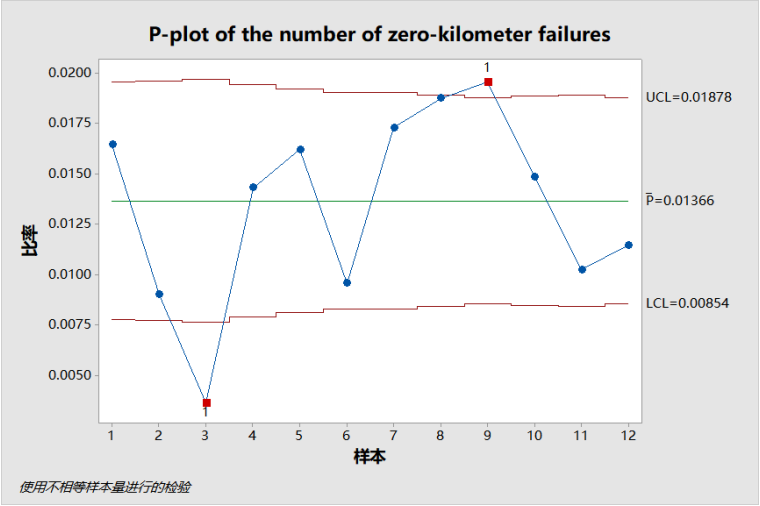

Fig. 2 P-plot of the number of failures at zero kilometers

2. Six Sigma DMAIC Quality Improvement Processes

2.1 Define phase (Define)

In line with the company's strategy, the Improvement Team has adopted the Zero Kilometer Failure PPM as the quality improvement metric for FY2021. The PPM average of 15,515 for the second half of 2020 was selected as the baseline level, with the goal of reducing zero-kilometer failures by 60% to 6,206.

Zero-kilometer failure Plato's diagram is shown in Figure 3, the problems that generate zero-kilometer failures are mainly concentrated in three areas, which are the appearance of bumping and rusting

problems, oil leakage, and the inability to start, and so on. If the above problems can be completely solved, the zero-kilometer failure can be reduced by 84%, and the zero-kilometer failure PPM value can be reduced from the current 15,515 to2,482, which meets the target value of the improvement activity.

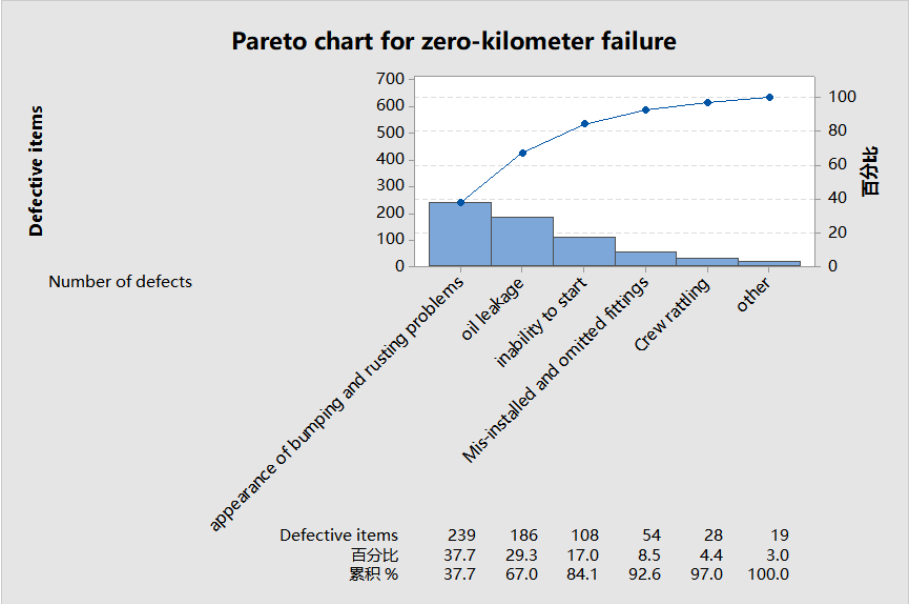

Figure 3 Plato chart for zero-kilometer failure

2.2 Measurement phase (Measure)

The zero-kilometer failure data comes from the company's after-sales service system. The company is currently adopting an active strategy to serve users. When quality problems occur in the course of users' use, the customer service center will send local cooperative service stations to the user's location to carry out after-sales service, with relevant photos and videos and other information as evidence for the whole service, and the service fees of the service stations will be settled through the company's financial settlement system. If the service stations do not register the relevant information through the after-sales service system, the service fees cannot be settled. Therefore, the information of after-sales data is true and reliable.

2.3 Analysis phase (Analyze)

2.3.1 Exterior bumping and rusting problems

The generator sets are used as the main power source for industrial and mining enterprises and inland waterway and marine vessels in remote areas. With the continuous promotion of the company's international strategy, the products are gradually sold to Southeast Asia, Africa, the Americas and other regions, where rainfall is heavy, and the products are transported over long distances by sea or long-term reserves of local dealers cause problems in the appearance of the products of users. Among them, bumps and scratches, peeling and corrosion are the main problems.

The packaging structure mainly relies on PE heat-shrinkable film to isolate salt spray and water vapor. The heat shrinkable film can completely fit the shape of the object, without occupying extra space and uniform force on the packaged items.Company A, because of the large span of product dimensions, small batch, in order to facilitate the procurement and reduce the cycle of raw material inventory, will be close to the shape of the size of the model using the same size of the heat shrinkable film, resulting in part of the model of the heat shrinkable film can not do a complete fit, but only to play a simple effect of the rain, which is likely to cause corrosion of the product.

The internal combustion engine, generator and other components used in the product have been painted in the original factory, and the production process of Company A has undergone secondary painting, and the thickness of the paint film and adhesion can reach or even be much higher than the enterprise standard. Therefore, the corrosion of metal parts appears in the product appearance of sheet metal parts, such as the control box box body, equipment external sound insulation shed body. Therefore, changing the process of painting sheet metal parts is the key to improve the quality of appearance.

2.3.2 Oil leakage

According to the data analysis of the after-sales department, the oil leakage occurs in the chassis oil tank and engine body and pipeline. The main reason for the chassis oil tank leakage is the product factory test process using fast connection directly to the test bench oil supply pipe interface and diesel internal combustion engine oil connection, and not in the equipment chassis tank filled with diesel fuel and. The process causes the oil tank link to appear quality hollow.

The generator sets will be tested before leaving the factory to ensure that the product meets the customer's specifications, but the test process will produce serious noise. Considering the test environment noise reduction and other factors, the four walls of the test bench are installed with noise reduction materials, and the room is in a closed environment, so that leakage of parts is not easy to detect.

2.3.3 Unable to start the unit

Often the unit will not start because the battery has failed and is unable to provide sufficient power for the genset to start.The battery failure mode is analyzed by using the method of fishbone diagram, which is based on four aspects: man, machine, material and method.

People: terminal post false connection or rain cap installation is not in place to cause terminal post oxidation. Terminal block protective cap is not installed in place to cause rain erosion and rust. Terminal block false connection will cause current sparking, will accelerate the terminal block corrosion, in the equipment operation soon after the loss of function.

Machine: Installation equipment failure or installation equipment model and battery terminal model does not match the battery false connection.

Material: The company has formulated a certain reasonable amount of product reserves in response to the cyclicality of the industry. The equipment in stock was not concerned about the life and condition of its batteries during the conversion process, and long-term storage caused the batteries to lose power. They were not charged or replaced before leaving the factory, resulting in insufficient starting voltage for the equipment to provide sufficient power for the starter of the internal combustion engine.

Law: The process documentation does not specify the self-inspection requirements for the process. Resulting in unqualified flow into the subsequent process.

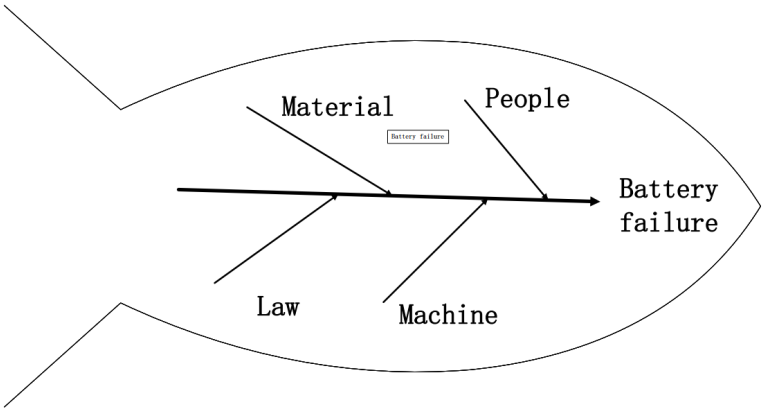

Figure 4 Fishbone diagram of battery failure

2.3.4 Timely improvements

(1) Timely improvement of external collision and rust problems

For different models of internal combustion power generation equipment product size, make the appropriate PE film to reduce the corrosion of water vapor on the external paint film of the internal combustion power generation equipment.

(2) Timely improvement of equipment oil leakage problems

In response to the timely improvement of the oil tank leakage, the quality thinking of "quality forward" requires suppliers to carry out testing before leaving the factory, and the quality inspection personnel check the quality inspection report of the products when the products are imported into the factory. When the customer's large-volume orders appear, the quality inspection personnel will be sent to the supplier's enterprise to carry out on-site inspection and supervise the supplier's manufacturing and airtightness testing process.

For engine body and pipeline oil leakage, we add 0.2% of 131SC oil-soluble fluorescent agent to the engine oil and then irradiate it with high-intensity black light (invisible ultraviolet or infrared rays), the dye will fluoresce strongly in yellowish-white color, and the leakage will be easily detected.Figure 5 show the fluorescence reflection of oil-based fluorescent agent under violet lamp.

Figure 5 Fluorescence reflection of oil-based fluorescent agent under violet lamp

(3) Timely improvement of the problem of equipment not starting

In the assembly process of loading batteries should be pressed and compacted, correctly installed protective caps for the reasons analyzed in the above failure mode to make timely improvements, revise the standard operating instructions. In the packaging process inspection to increase the point of inspection, check the effective date of the equipment battery.

2.4 Improvement

HG/T 2006-2006, GB/T5237.5-2017, SY /T0315-2013, Qualisteelcoat2005 and other commonly used powder coating standards in the salt spray requirements for neutral salt spray 500h or 800h, one side of

the corrosion <2 mm. In the new ISO12944-2017, the requirement of neutral salt spray for liquid coating under C5 and CX environment is 1500h, and the corrosion on one side is <1.5 mm.

Process according to GB/T 9271-2008 requirements. Take sheet metal parts in different locations of the equipment expansion body, respectively, single-layer zinc-rich primer (Group A) and double-layer zinc-rich primer (Group B), and carry out 1500 hours of neutral salt spray test. Adopt the method of Table 1 to observe whether blistering, wrinkling, rusting and peeling.Figure 6 shows the photographs of the medium-sized salt spray test performed on different parts of the plate.

Figure 6 Medium-sized salt spray test for different parts of plates

Table 1 Performance test methods for powder coatings

serial number	sports event	Detection Methods
1	exterior condition	visual assessment
2	Neutral salt spray resistance	GB/T 1771-2007

The consistency of the experimental system's test measurement system was analyzed by selecting two quality inspectors as operators for the consistency analysis (repeatability). The consistency of each operator with the standard.

According to the chi-square test of the data in Table 2, the experimental results proved that the number of zinc-rich primer layers is the main factor affecting the corrosion of the generator set cabin. Increasing the number of zinc-rich primer layers can effectively avoid the rusting of sheet metal parts in the salt spray environment.

Table 2-Medium salt spray test results chi-square test

Paint spraying method	corrode	uncorroded
Single-layer zinc-rich primer	9	6
Double-layer zinc-rich primer	0	15
P=0.00		

2.5 Control phase (Control)

The main task of the control phase is to standardize the improvement process that has been acquired and to continuously monitor this improvement process. Improvement team members update all documents of the control project after project improvement to the quality management system documents through the analysis and summary of the previous improvement phase. The person in charge and the standardized documents that need to be added or updated are summarized.

In 2021 the company's zero-kilometer failure PPM averaged 6,826 compared to the second half of 2020 benchmark of 15,515, a 56% reduction.

3. Conclusion

This quality improvement project is carried out through the Six Sigma management methodology, utilizing the Six Sigma DMAIC management model and tools to improve the zero-kilometer failure of the internal combustion power generation equipment, reduce the defects generated in the manufacturing process, reduce customer complaints, improve customer satisfaction, and enhance the corporate brand image.

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