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Optimizing Continuous Improvement in Automotive Manufacturing through SPC and Q-DAS Integration

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Abstract: ***Statistical Process Control (SPC) is extensively employed in quality control within the automotive manufacturing sector, with various control charts and theoretical research being practically implemented. However, the majority of automotive enterprises utilize SPC tools merely to comply with the demands of Advanced Product Quality Planning (APQP) and Production Part Approval Process (PPAP), while the exploration of integrating SPC tools into process quality control remains merely superficial. This article examines the elements influencing quality stability, including human factors, machinery, materials, methodologies, and environmental conditions, and employs Q-DAS statistical analysis software for practical application in process quality control, offering viable approaches for the continual enhancement of product quality in the future.***

Keywords: Statistical Process Control (SPC); Q-DAS; Automotive Manufacturing; Continuous improvement

1. Introduction

SPC, also known as Statistical Process Control, is one of the five major tools for quality management in the automotive manufacturing industry. It was proposed by the American author Hubert Hart in 1924. If the process is in a statistically controlled state, it indicates that the process is stable and can continuously provide customers with stable product quality. SPC can effectively reflect whether the production process is stable and whether there are any abnormal situations. The note 10.3.1 in the IATF16949 standard describes that "continuous improvement is implemented when the process has statistical capability and stability, or when the product characteristics are predictable and meet customer requirements. Based on the guidance of the second edition of the Statistical Process Control Manual [2], a preliminary understanding of the implementation and methods of SPC has been gained, but a clear implementation process has not been formed. And in practical operation, it requires a lot of preliminary preparation work, as well as cooperation and persistence among various departments within the enterprise. Therefore, it is difficult to see results in work. This article focuses on the analysis of 5M1E factors in practical situations, with a focus on studying the relevant factors that affect process stability. Q-DAS software is used to integrate data and monitor in real time, timely detect unstable situations, and work with other relevant departments to analyze and improve, laying the foundation for continuous improvement.

2. Concept of Statistical Process Control

SPC research is conducted by determining whether the changes in the control chart curve are in a controlled state, and then analyzing whether the process capability index meets the requirements. If there is an abnormal situation, analyze whether it is caused by ordinary or special factors. Eliminate abnormal factors, optimize common factors, and ultimately achieve the goal of continuous improvement.

2.1 Control Chart

When the process is in a stable state, the quality characteristics exhibit a normal distribution, as shown in Figure 1. If there is an abnormal situation, the distribution will shift, as shown in Figure 2.

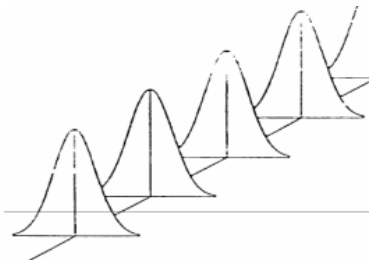

Figure 1: Normal distribution

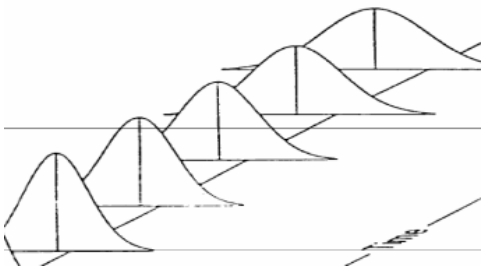

Figure 2: Non normal distribution

Dividing the normal distribution into regions with ± 3 σ as the control limit, the probability of falling within this range is 99.73%. If the control limit is not exceeded, the process is considered controlled. Hugh Hart suggested turning the normal distribution map 90 degrees, resulting in a control chart as shown in Figure 3.

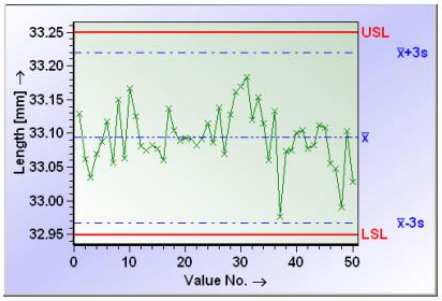

Figure 3: Control Chart

Control charts can be divided into analysis control charts and control charts according to their purposes. In the early stage, engineers establish control charts for analysis, eliminate special factors to control the process, and after the process capability meets the requirements, convert the analysis control chart into a control chart, and continue to use the control limits of the analysis control chart for later data monitoring.

Control charts are divided into count control charts and measurement control charts based on data characteristics. If the collection of samples is a numerical characteristic, a metrological control chart is used, and if the collection of samples is to determine the qualified quantity, a counting control chart is used. The measurement control chart can be classified according to Table 1 based on different sampling methods [3].

Table 1: Classification of Control Charts

Category	*Control chart*	*Symbol*	*Sample size n*
Measurement control chart	Xbar-R Chart	$\bar{x}$-R	*20-25*
	Xbar-S Chart	$\bar{x}$-s	
	Median Range Chart	Me-R	
	x-MR Chart	x-MR	*20-30*
Counting control chart	Control chart for the number of non-conforming products	Np	*20-25*
	Nonconforming Product Rate Control Chart	p	
	Nonconforming Number Control Chart	c	
	Unit Nonconforming Number Control Chart	u	

2.2 Criteria for Judging Control Charts

Divide the control chart into 6 zones, with each zone having a width of 1 σ, located above and below the center line. UCL and LCL are the upper and lower control limits, respectively, and the judgment criteria are 8 modes of process abnormalities. When these 8 types of anomalies appear at points on the control chart, they are judged as anomalies [4]. But it is difficult to meet all the criteria. Most companies only need to meet criterion 1, which means that a point falls outside the control limit, as shown in Figure 4.

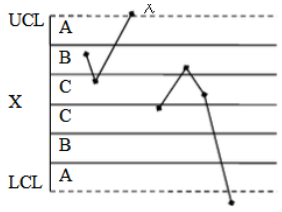

Figure 4: Control Chart Criteria 1

2.3 Process Capability Research

Process capability refers to the degree to which a process meets product quality requirements under controlled conditions, and is the ability of a process to ensure quality. Process performance refers to the actual processing capability of the reaction process, without considering whether the process is controlled.

The process capability index Cpk can refer to the following values to determine whether the quality requirements are met.

Table 2: Cpk Requirements

Grade	*Cpk value*	*Method*	*Description*
A	Cpk≥1.67	Adequate process capability	The larger the Cpk value, the more stable the manufacturing process capability.
B	Cpk≥1.33	Sufficient process capability	
C	1.0≤ Cpk<1.33	Process capability is acceptable	
D	Cpk<1.0	The manufacturing process should be improved	

3. SPC Process Factors

When insufficient process capability is identified, process factor analysis should be conducted. Identify the dominant factors affecting abnormal fluctuations in the process and take corresponding measures to restore the process to a stable state. There are two reasons for abnormal fluctuations: ordinary reasons and special reasons. The common cause is the continuous deterioration in the process, and it is usually difficult to eliminate the common cause. It mainly relies on management and investment costs to reduce the common cause deterioration. Special reasons refer to abnormal events or external factors that occur during the process, and often after identifying and removing the abnormal points, the process stability can be restored.

The analysis of abnormal causes mainly focuses on finding the factors that cause process instability from the aspects of human, machine, material, method, and environment. Operator related factors may include carelessness, lack of operational proficiency, and failure to follow instructions, but these can be mitigated by increasing automation, establishing a responsibility system, and enhancing work experience. Machine equipment factors include machine tool accuracy issues, tool wear, and other situations, which can be reduced by strengthening equipment maintenance and regular inspections. Material factors can be avoided by strengthening incoming material inspection, supplier management, etc. The factors of process methods can be avoided by controlling the version of process documents, setting permissions, designing error prevention devices, setting measurement methods, etc. Environmental factors include temperature, humidity, vibration, and pollution, but can be avoided through reasonable workshop design and daily 5S work.

Based on the above analysis, most of the influencing factors are actually completely preventable. Establishing a reasonable automated production line, reducing personnel intervention, doing a good job in daily equipment maintenance, fixing process processing methods, designing a constant temperature workshop, etc. can avoid most possible abnormal factors. Therefore, in the process of continuous improvement, identifying special change points in stable production conditions can identify and solve problems. This article will use practical cases to introduce how to improve process capability.

4. Q-DAS Practical Application

4.1 Data Collection

On the automated production line, multiple identical devices continuously produce automotive transmission housings. Sampling is conducted once per shift, with 5 pieces sampled per shift for 25 consecutive shifts. A control chart for analysis is drawn, and the upper and lower control limits are determined after the process is stable. Convert the analysis control chart into a control chart, observe the changes in data points when data enters, identify the reasons for any changes, and correct them.

As shown in Figure 5, a total of 125 data points were entered into the Q-DAS software, with stable fluctuations and no abnormalities. Therefore, the process capability can be calculated and the upper and lower control limits can be fixed. By observing that there are no points exceeding the control limit in the control chart, the process is stable and Cpk is 2.21, indicating sufficient process capability, as shown in Figure 6, the analytical control chart can be converted into a control chart.

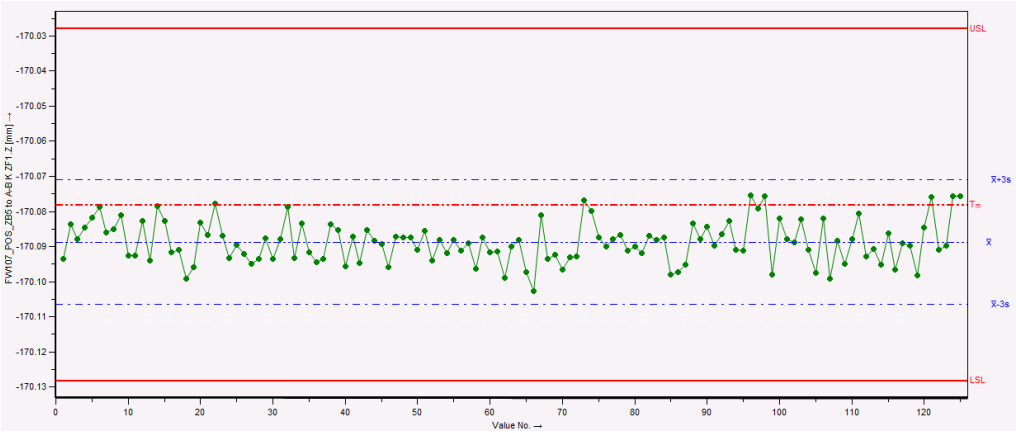

Figure 5: Control Chart for Analysis

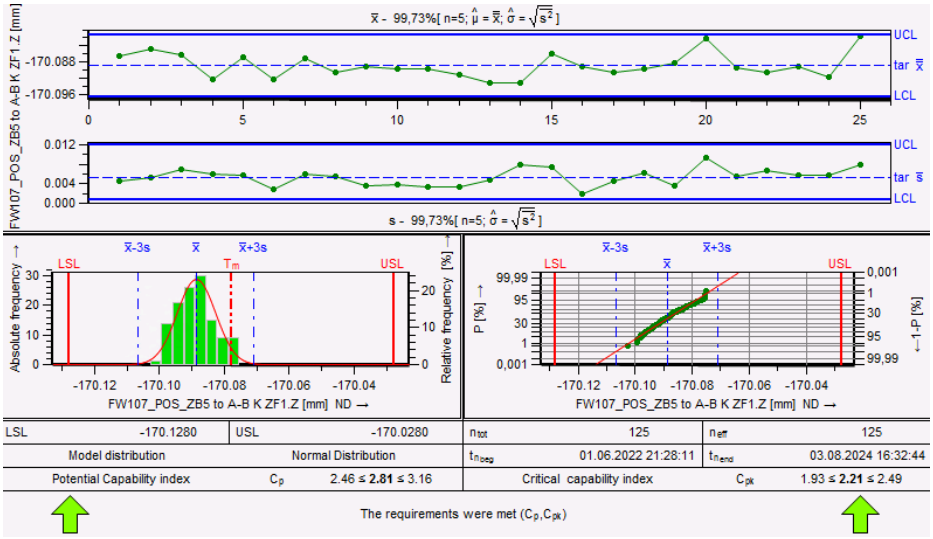

Figure 6: $\bar{X}$-S control chart

4.2 Q-DAS Control Chart

In continuous production, the control chart enters a new set of data, as shown in Figure 7. It was found that it far exceeded the upper control limit, and the Cpk value had dropped to 1.20, as shown in Figure 8.

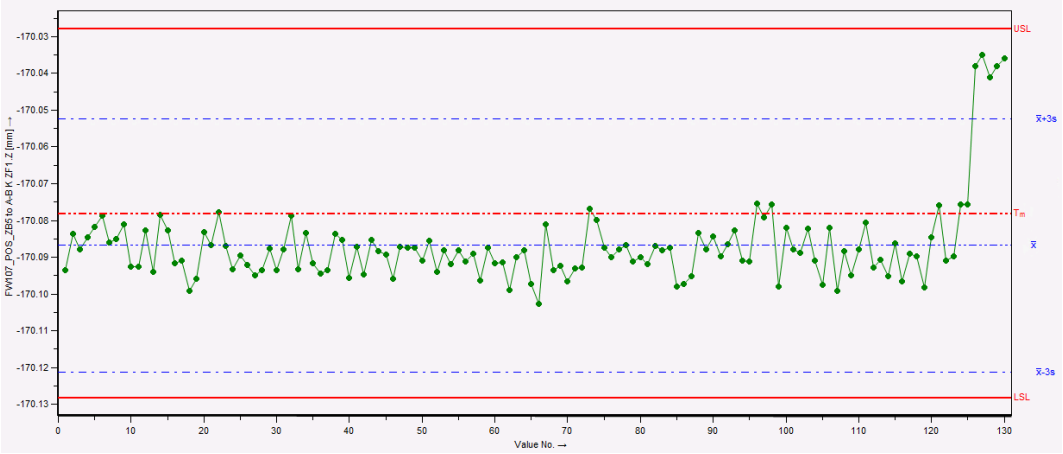

Figure 7: Outliers

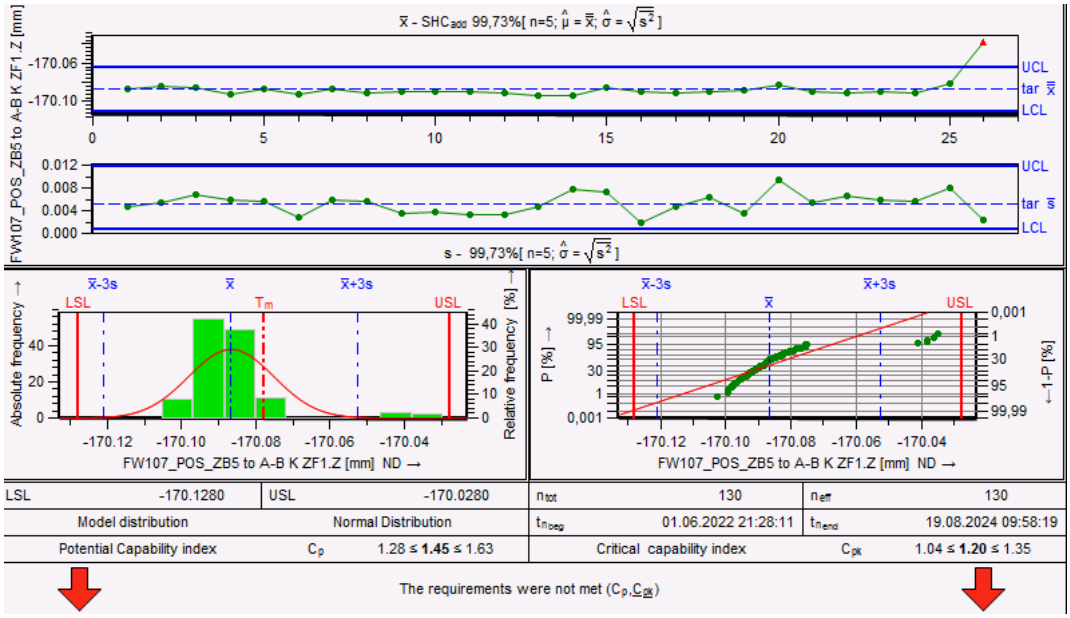

Figure 8: Insufficient process capability

At this time, it belongs to abnormal fluctuations, and it is necessary to analyze the special reasons for the occurrence in a timely manner, and analyze which factor has changed in the human-machine material method environment. In daily processing records, tool monitoring alarms were found, and abnormal tool wear was discovered during tool inspection, which led to abnormal fluctuations in data points. After replacing the qualified tool, the data points returned to normal, as shown in Figure 9.

After removing outliers, the control chart returned to normal fluctuations with a process capability Cpk of 2.25, meeting production needs, as shown in Figure 10.

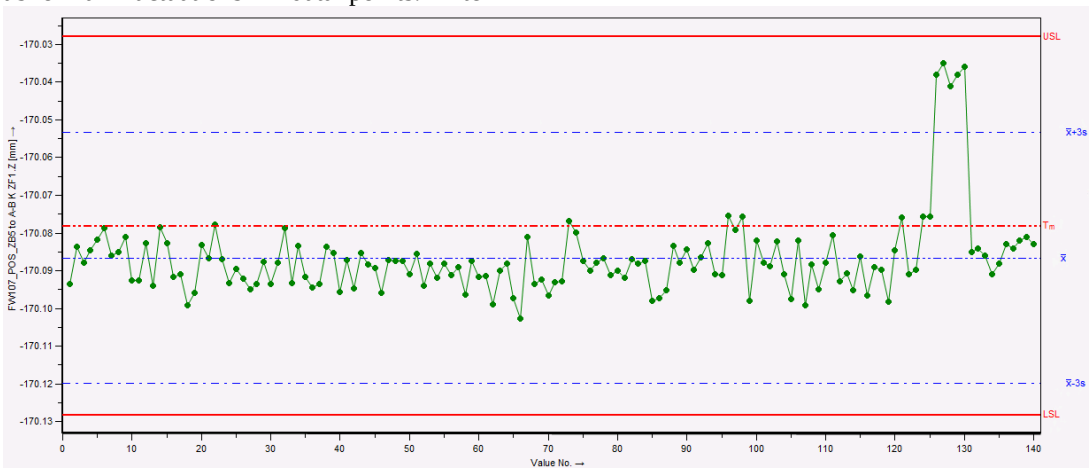

Figure 9: Process Improvement

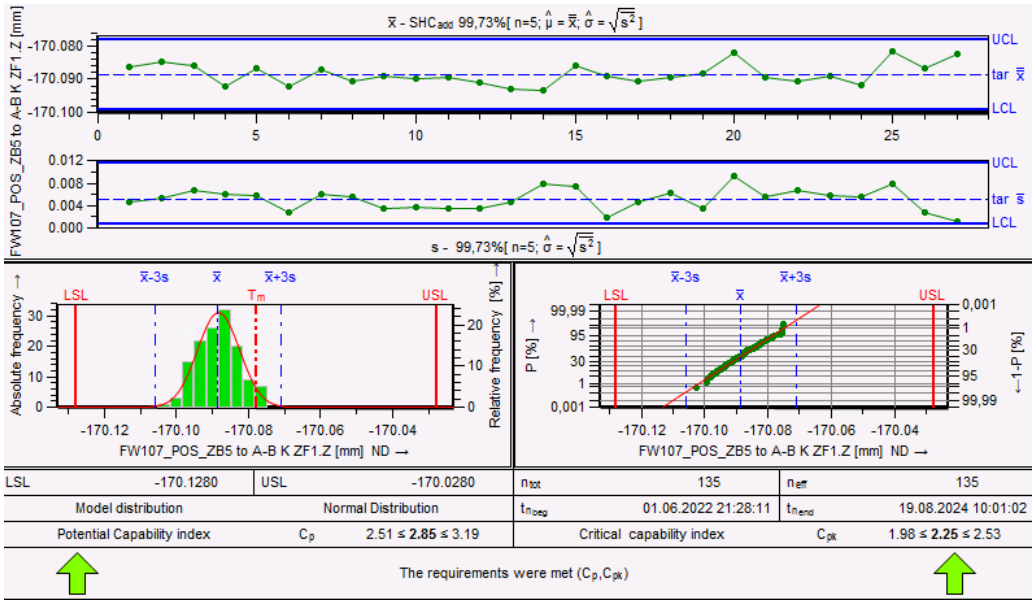

Figure 10: Adequate process capability

5. Conclusion

In summary, by analyzing the impact of the five elements of human, machine, material, method, and environment on process capability, identify which element has undergone special changes and make corrections accordingly. This study is significant as it provides a detailed analysis of how SPC tools, particularly Q-DAS software, can be effectively integrated into the automotive manufacturing process, moving beyond compliance to achieve continuous improvement in product quality.

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Author Profile

Chen Zhang graduated from Tianjin University of Technology and Education with a master degree in mechanical engineering, and has been engaged in mechanical design and processing technology since 2016, currently engaged in APQP of auto parts products technology and quality.