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Quality Control System of Parts Processing Based on SPC

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Abstract

In the traditional production line manufacturing process, quality information is discretized, data acquisition and storage information are not timely, process quality status cannot be monitored in real time, etc., resulting in untimely handling of product quality abnormalities, waste of production costs, and inaccurate judgments of process capabilities. Taking the headstock box processing production line as the research object, a dynamic quality control solution for parts processing based on EWAM is proposed, and QMS quality is established by the integration of exponential weighted moving average method optimization, OPC real-time data acquisition system, web development platform, MySQL database, etc. Control architecture model. Through the real-time collection and transmission of quality data during the manufacturing process of the spindle box production line, the information data for process quality monitoring can be obtained. Combined with EWAM, the control range of key quality characteristic values in the machining process of the spindle box body is analyzed, and the drawn SPC control curve is displayed on the client, which effectively improves the real-time and accuracy of quality control.

Keywords

Headstock box, statistical process control, exponential weighted moving average method, quality control system.

1. Introduction

With the development of science and technology, the deep integration of Internet technology and manufacturing has ushered in the transformation of traditional manufacturing towards intelligence. However, in the process of intelligent manufacturing, the collection of product quality information data is not timely and real-time dynamic analysis is not carried out, resulting in a large number of Product production loss [1]. In the manufacturing process, product quality control management has the functions of monitoring, preventing, analyzing, and improving the production process [2], which helps to avoid the loss caused by the untimely discovery of quality problems. At present, in terms of quality control, most manufacturing companies use manual measurement or use workshop intelligent data collectors to record data, and use relevant data analysis software to analyze and produce quality control charts, but they lack real-time data processing. It is impossible to realize real-time and dynamic product quality monitoring and analysis during the manufacturing process, which is not conducive to the intelligent production quality, real-time control and process capability judgment of the enterprise [3].

In response to this problem, domestic and foreign researches on quality control technology and related theories in the manufacturing process have launched various developments. Sagar Sikder et al [4]. proposed and verified a new multi-process quality control method for manufacturing processes based on collaborative prediction, which integrates offline and online

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multi-variable quality control in predicting, monitoring, diagnosing and adjusting out-of-control scenarios Strategy; Nunes Eusebio et al. [5] proposed to design a quality control plan in the manufacturing process based on a stochastic dynamic programming model to achieve a quality control plan that meets the expected quality level at the lowest cost; Marco Gewohn et al. [6] proposed to build a The user's quality visualization model is used to monitor and evaluate the quality status of the automobile assembly process; Hongfei Guo et al. [7] used VAD-based evaluation methods to establish a process quality control system model for quality control problems. Zhou Tao et al. [8] proposed the process quality intelligent diagnosis method based on neural network and the process quality adjustment method of the expert system to realize the online analysis of quality data for digital factories; Gong Lixiong et al. [9] designed based on statistical process control theory The SPC quality information system is used to realize the monitoring and early warning of the on-site production process to ensure that the production process is in a controlled state; Xu Dawei et al. [10] established similar process sets and introduced measurement system analysis theory to control the process capability The MSA method was integrated with it, and the quality control method was initially improved; Zhang Yuedi et al. [11] proposed a multi-process process capability index model that simultaneously considers the process capability of the production process and the processing economy, which solves the bearing manufacturing process Many processes are used to evaluate processing quality problems.

In view of the above-mentioned research findings, in the quality control of the manufacturing process of the small-batch production line, the following aspects need to be improved: 1) How to complete the real-time quality control and detection information synchronization in actual production. 2) Fewer data samples lead to weak deviation detection capabilities and poor control effects. 3) Real-time release of quality control information and management issues.

For this reason, this paper takes the machine tool spindle box production line as the research object and proposes a dynamic quality control system for the small batch production line manufacturing process. Use real-time data acquisition platform and data transmission technology to build a dynamic SPC quality control system architecture, and use exponential weighted moving average method to improve the conventional control chart in the detection process of almost any size deviation monitoring deficiencies, to achieve real-time dynamic quality Control and improve the quality of the manufacturing process of the production line.

2. Process quality SPC control optimization based on SPC

SPC (Statistical Process Control) is a method based on mathematical statistics. Control charts have been widely used in the field of quality control. At present, the Shewhart control chart is the most widely used, but its application analysis requires a large number of data samples to support, and there are The detection ability of small deviations is weak, and the rate of missed judgment is high. Compared with the conventional control chart principle, EWMA constructs a control chart by changing the weights used and limiting the number of S to realize the detection and analysis of any deviation in the process [12]. Therefore, the paper adopts the $\bar{X}$-R process quality control method based on EWMA to realize the effective improvement of the SPC quality control method. The principle process of the $\bar{X}$-R quality statistical process control chart based on EWAM is as follows:

Organize the data with subgroup as the unit, calculate the mean $\bar{X}$ and range R of each subgroup, establish a control chart according to the principle, and realize the monitoring of the quality status. Suppose the total number of observations in the subgroup is n, and the single observation value is x, then

$$\bar{X} = \frac{\sum_{i=1}^{n} x_i}{n}; \ R = x_{max} - x_{min} \tag{1}$$

ISSN: 2664-9640

Where x_i is the sample detection value, x_{max}, x_{min} are the maximum and minimum values of the subgroup samples respectively, calculate the control line of the mean control chart: calculate the average value of the subgroup mean $\bar{\bar{X}}$, the average value of the subgroup range $\bar{R}$ then

$$\bar{X} = \frac{\sum_{i=1}^{k} \bar{X}_i}{k}; \bar{R} = \frac{\sum_{i=1}^{k} R_i}{k} \tag{2}$$

Then, the control line of the $\overline{X}$ control chart is:

$$\begin{cases} UCL_{\bar{x}} = \bar{\bar{X}} + A_3\bar{R} \\ CL_{\bar{x}} = \bar{\bar{X}} \\ LCL_{\bar{x}} = \bar{\bar{X}} - A_3\bar{R} \end{cases} \tag{3}$$

Then, the control line of the $\overline{R}$ control chart is:

$$\begin{cases} UCL_s = D_4\bar{s} \\ CL_s = \bar{s} \\ LCL_s = D_3\bar{s} \end{cases} \tag{4}$$

A_3, D_3, and D_4 in the formula are all unbiased constants corresponding to the mean or range.

In order to more accurately identify the slight deviation of the quality status in the monitoring area, the exponentially weighted moving average method is used to weight the measured values of each group of data to establish an EWMA control chart. According to this principle to construct a control chart with specific attributes, the statistics Z_i of the control chart need to be calculated before construction

$$Z_i = \lambda X_i + (1-\lambda)Z_{i-1} \tag{5}$$

Where is the weight constant, which is usually $0 < \lambda \leq 1$. The initial value Z_0 in the above formula takes the target value of the process, which is $Z_0 = E(X) = \mu_0$

When the observed value is an independent random variable, the variance of Z_i of the EWMA statistic is σ_{zi}^2:

$$\sigma_{zi}^2 = \sigma(\frac{\lambda}{2-\sigma})[1-(1-\lambda)^{2i}] \tag{6}$$

Where: σ is the standard deviation of the sample data

Construct a control chart based on the EWMA statistics and its variance, where the control line of the control chart is:

$$\begin{cases} UCL = \mu_0 + L\sigma\sqrt{\frac{\lambda}{2-\lambda}[1-(1-\lambda)^{2i}]} \\ CL = \mu_0 \\ LCL = \mu_0 - L\sigma\sqrt{\frac{\lambda}{2-\lambda}}[1-(1-\lambda)^{2i}] \end{cases} \tag{7}$$

In the formula, L is the width coefficient of the control line, and generally takes the value $L \approx 3$, where the λ value in the range of $0.05 \leq \lambda \leq 0.25$ has better performance in practice, and the smaller the λ value in the range is suitable for smaller values. Offset

The $\bar{X}$ control chart is very sensitive to whether the data obeys the normal distribution. When the data does not obey the normal distribution, the control effect will decrease. The EWMA control principle uses an exponentially weighted moving average method to make the effectiveness of detecting process deviations and early warnings independent of the distribution of the data. The combination of the two improves the efficiency and accuracy of the quality process control management system.

ISSN: 2664-9640

3. Production line processing flow

The machining process of the spindle box body is mainly composed of two parts: the surface of the spindle box and the rough and finishing machining of the spindle mounting hole. Horizontal plus 1 mainly completes the side of the box, the outer side of the guide rail, the front end, the spindle mounting end surface, the slider mounting surface, and the nut Rough machining of the bottom surface of the seat; reaming and tapping of the mounting hole; rough boring of the spindle mounting hole and rough milling of the mounting surface of the balance cylinder, plus 2 to complete the side of the box body, the outer side of the guide rail, and the front end surface , Finish machining of the spindle mounting end surface, the sliding block mounting surface, and the bottom surface of the nut seat; the drilling of the mounting hole and the finishing of the balance cylinder mounting surface. The processing flow of the entire production line is shown in Figure 1:

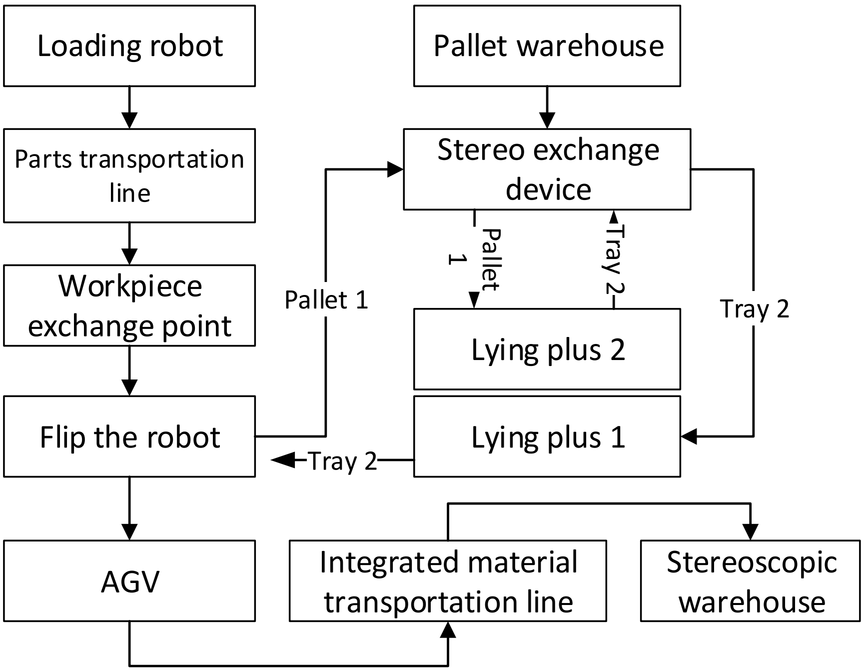

Figure 1. The processing flow of the spindle box production line

4. Design and implementation of the spindle box processing quality control system

4.1. QMS quality control system framework

Integrating the key quality characteristic value control points in the entire headstock box processing process, in order to realize the quality control system management of the production line processing process, a QMS system framework is built with the combination of Internet WEB technology, database, and data acquisition platform. As shown in Figure 2, the system is mainly composed of four parts: equipment layer, data acquisition layer, server layer, and display layer.

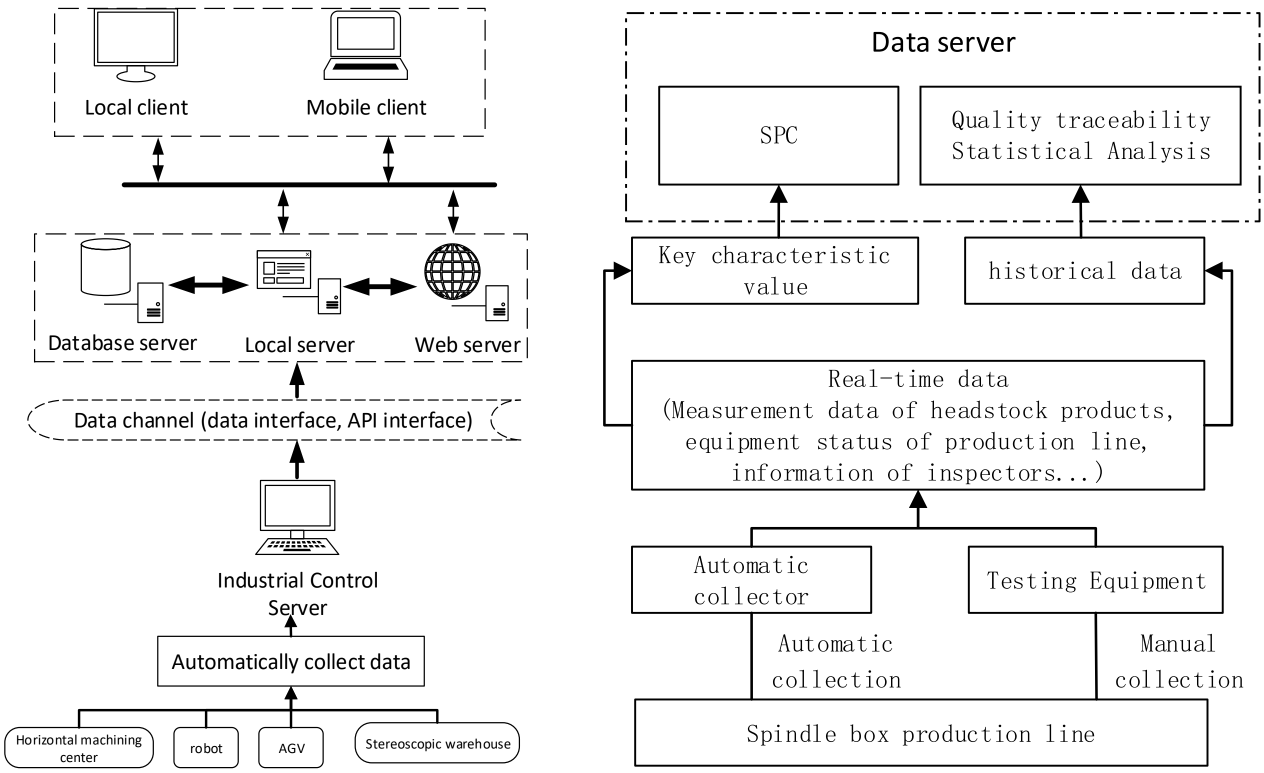

Figure 2. System framework

Data collection during the manufacturing process of the headstock mainly includes: parts processing process data, production line equipment status information, product ID information, product quality abnormal data, testing equipment data information, and quality control improvements and staff information. All kinds of different data information are collected manually or automatically. The real-time collected data is rendered into various control charts through the QMS system. The recorded historical data is used for later product quality traceability and statistical analysis of historical information, and provides data support for the improvement of product quality control in the manufacturing process. The data collection and transmission process is shown in Figure2

4.2. Database model design

According to the quality management requirements of the spindle box production line, the overall management system is realized.

The overall database structure of the QMS system, as shown in Figure 4, mainly includes the basic information table of inspectors, the basic information table of management personnel, the inspection task list, the quality standard table, the quality statistical data table, the control chart analysis setting table, and the product information table. , Product fault diagnosis table, quality history traceability table, management authority table and other database tables. The model explains the connection relationship between the tables, including the primary key and foreign key constraints of the tables between the databases, and establishes a standard standardized data model.

The database model used in the industrial control data collector of the production line is shown in Figure 3. It mainly includes production equipment such as horizontal machining centers, robots, transportation lines, AGV trolleys, and vertical warehouses. The product information tables in the two data models are associated with the overall QMS system data.

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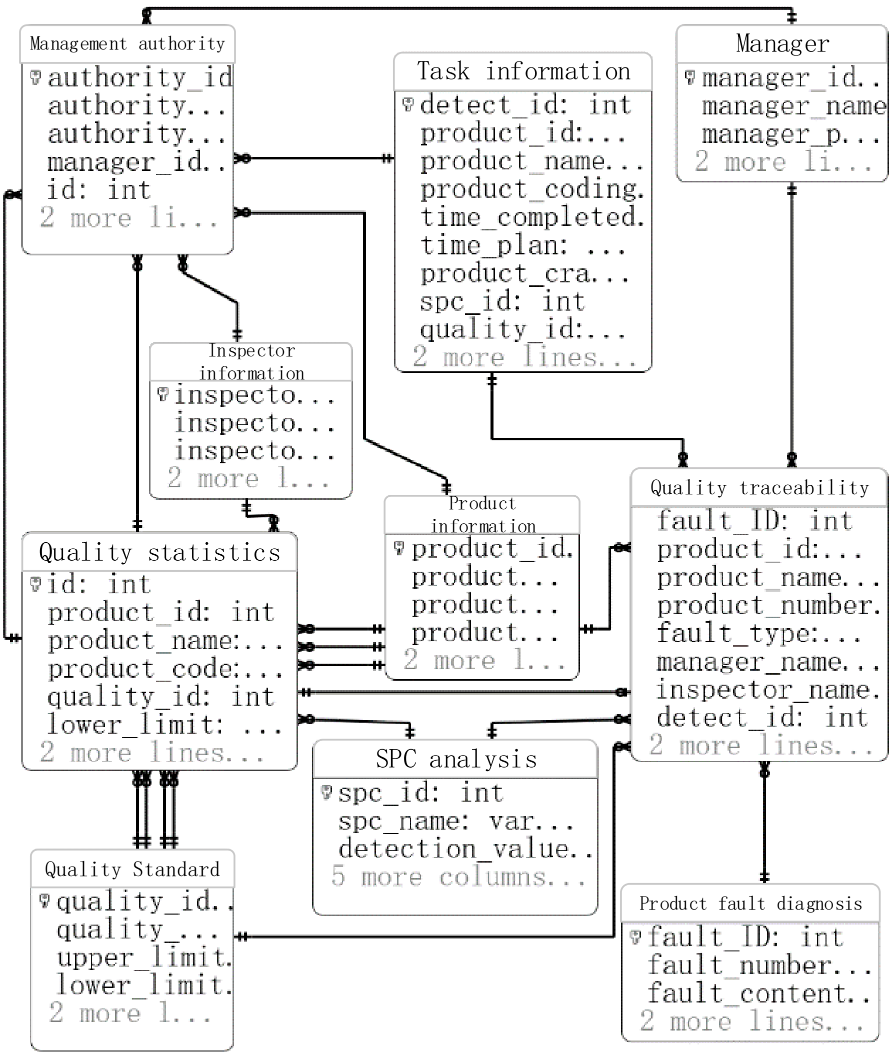

Figure 3. Database model

4.3. Control system software architecture design

According to the QMS quality control management framework and standardized database model, combined with the idea of separating the front and back ends of the WEB technology, the QMS system software is designed and developed. As shown in Figure 5, it is mainly composed of automatic collection of equipment layer data, overall system business deployment, system realization functions, data communication transmission interface, database processing and analysis, and real-time data display and release.

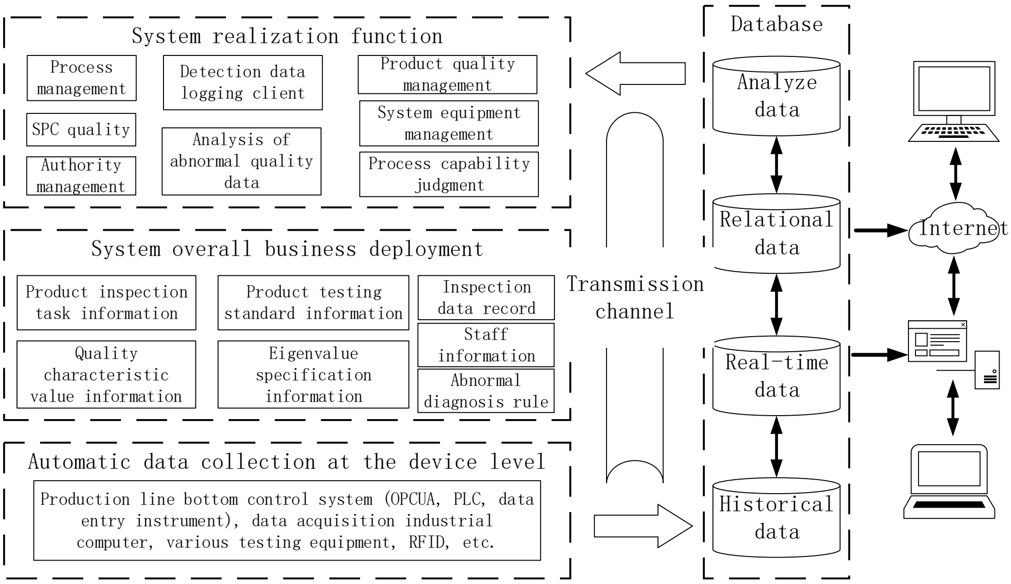

Figure 4. QMS software framework

Automatic data collection at the equipment level mainly uses control system communication protocols such as Modbus and OPC UA to automatically collect the status information of the current production line equipment. The data collection industrial computer, RFID and various testing equipment collect product quality data and transmit the data information in real time. To the corresponding database. The automatic data collection server provides support for the data collection requirements of each functional module, and dynamically collects data from the production process in real time.

The overall business deployment of the system includes: product testing task information, quality characteristic value information, product testing standard information, staff information, abnormal diagnosis rules, quality abnormal data analysis, etc. The overall realization functions include system process management, system equipment management, product quality management, system authority management, testing data recording client, SPC quality control, quality characteristic value specification information, process capability determination and other business contents.

The data transmission between each layer of the QMS system is mainly router, WebSocket, http, socket and other data interface protocols to realize the transmission of data between layers. The key parts of the automatic data collection server, database, WEB server, etc. realize the key data of the entire system through interface transmission Real-time collection, storage, transmission, and display. The data generated during the manufacturing process of the spindle box production line can be efficiently transmitted and used in a system.

The data information in the database establishes a relationship between the various databases, and the management operation of the database is carried out according to the management business logic of the system. At the same time, the historical data is also stored in the database, which is convenient for quality management to trace and analyze the production process information.

The release of key data information is mainly to realize the real-time push of quality data, analysis data and quality monitoring conditions during the manufacturing process of the entire production line to workers and management departments. Display the real-time status of the current production line, including the capability index, qualification rate, repair rate, production status, etc. of each process. Quality information is shared between various departments through the Internet, local server publishing on the client, and web page display information.

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5. Conclusion

This paper constructs a dynamic quality control management system for parts manufacturing process based on EWAM, and clarifies the improvement of monitoring methods, the framework principle of QMS system, database model, and system software design. The system uses real-time production line manufacturing process data information to dynamically analyze the current production quality status to ensure the stability and accuracy of product quality process control. And the system architecture was successfully applied to real-time dynamic quality control of actual production lines, which verified the real-time and correctness of the system. Manufacturing companies with small batch parts production mode with few quality control data samples provide a feasible quality control plan.

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