Software and Application of Big Data Analysis Platform for Complex Casting Manufacturing Process Quality

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Abstract: The complex castings used in major equipment in industries such as aerospace, automotive, rail transportation, and engineering machinery are prone to defects such as porosity, deformations, and inclusions due to the coupling effects and fluctuations of key process parameters. This leads to common problems such as "key quality points exceeding standards" and large quality fluctuations, seriously affecting the reliability and stability of major equipment manufacturing products. In this paper, a systematic study on the model-method-technology of typical defect quality big data was conducted. Firstly, relevant models were constructed, such as the single piece quality tracing model, the multi-source heterogeneous information fusion model, the model of production parameters and intrinsic relationship of typical defects, and the model of comprehensive element time-varying disturbance and defect evolution mapping. Then, five key technologies were developed, including high-precision and efficient online monitoring and prediction of typical defects, tracing the causes of quality problems in multiple links, and quality control based on the relationship between production fluctuations and metallurgical defect evolution. Based on the above research, data collection, cleaning, mining, sensitivity analysis, and relationship modeling algorithms were established for the casting production process. Special core algorithms for predicting defects such as shrinkage, looseness, and gas entrapment were proposed, achieving high-precision prediction of typical defects. A "1+N" quality big data analysis software and hardware integrated platform was developed. After applying the integrated platform to the five major industries of aerospace, automotive, rail transportation, engineering machinery, and aerospace industries, the results showed an accuracy of quality prediction of ≥80% and a reduction in defects of ≥30%, leading to the formulation of solutions and key demonstrations in these industries.

Keywords: complex castings; manufacturing process; quality big data model; single-piece model; high-precision defect prediction; quality traceability and root cause analysis; 1+N software platform

1 Introduction

Casting is the foundation of manufacturing industry and the preferred technology for forming complex metal parts of major equipment such as aviation and aerospace. There are some common problems in the manufacturing process of complex castings, such as "the key quality points are out of tolerance and the quality fluctuates greatly", which lead to the reliability and service life of major equipment can not meet the requirements, and seriously affect the establishment of a manufacturing power. With the development of artificial intelligence technology, big data technology can effectively study the influence of process parameter fluctuation on complex casting defects, and become a new way and method to effectively solve the above common problems [1].

To this end, Firstly, this research has studied quality big data model and management method. Then, quality intelligent control and process optimization technology is studied. In addiction, the core algorithm, software and platform for quality big data analysis of complex casting manufacturing process are developed and applied. Finally, the application demonstration was carried out in the five major industries of aviation, aerospace, automotive, rail transit and construction machinery to realize the control of key quality points and quality fluctuations of complex core castings, and achieve quality improvement.

Experimental Procedure

As shown in Figure 1, firstly, data is the basis of this research, so we study the quality big data model and management methods first. For this:

(1) The production equipment was transformed by PLC to automatically collect part of the production data, and then the whole process data of castings from process design to quality detection are collected;

(2) Due to the variety of data forms collected, the flexible fusion method of multi-source heterogeneous data is studied. The semi-structured data is processed by row and column retrieval model, and the three-dimensional features of castings are extracted by deep learning model, so that the unstructured data and semi-structured data can be directly stored in the relational database.

(3) A one-piece quality traceability big data model was established to correlate the design, production and quality data of castings, providing the basis for quality traceability and data mining.

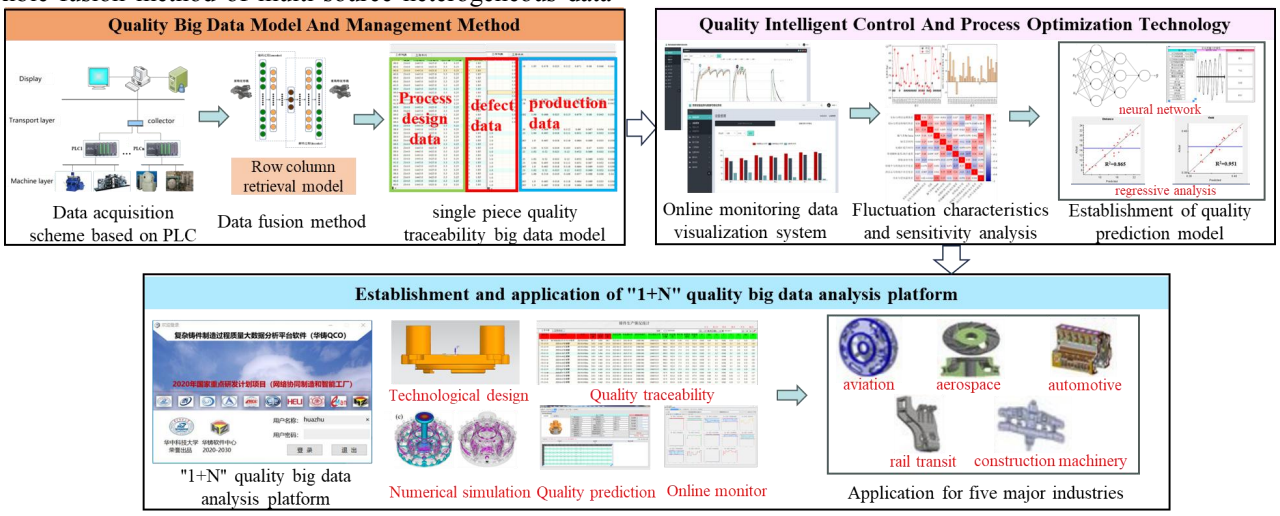

Figure 1 Framework of this paper

Then, In addition to accurately collecting data, the use of artificial intelligence technology to achieve quality control is another major study content. Hence:

(1)Visualization system was developed. And fluctuation characteristics and sensitivity of the collected parameters was analyzed;

(2)The mapping relationship between process parameters and defect evolution was analyzed by regression analysis and neural network method, and the mapping relationship model between time-varying disturbance of all factors and defect evolution was established. Based on this model, a quality prediction method is developed.

In order to improve the quantity and quality of data, this study also developed algorithms related to numerical simulation, data cleaning and sensitivity analysis. Finally, a "1+N" quality big data analysis platform was established based on the above research combined with other software like Huazhu CAE, ERP.

Result and discussion

After verified in typical casting of five major industries, including aviation, aerospace, automotive, rail transit and construction machinery., as shown in Table 1:

(1)The defect prediction accuracy of the "1+N" platform for typical castings in the five industries has exceeded 90%.

(2)According to statistics, after using the "1+N" quality big data analysis platform, the defect rate of typical castings in the five industries has decreased by more than 30%.

Table 1. Verification result

Casting type	Prediction accuracy	Defect rate before use	Defect rate after use
Gearbox	98.97%	20.00%	10.00%
Outlet pipe	99.94%	3.30%	2.10%
cylinder block	95.00%	5.42%	1.83%
pickaxe arm	96.00%	20.00%	3.80%
Steering axle	94.00%	6.00%	3.16%

Acknowledgments

National Key Research and Development Program (2020YFB1710100), National Natural Science Foundation (52275337, 52201042, 52090042, 51905188). The authors would like to thank all the organizations and members of the project team of the National Key Research and Development Program "Software and Application of Big Data Analysis Platform for Quality in Complex Casting Manufacturing Processes".

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