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Manufacturing of Automobile Engine Crankshaft Dependent on Computational Fluid Mechanics

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Abstract: Crankshaft is one of the most important components of the engine, its function is to summarize the reciprocating work of each cylinder piston, and in the form of rotating motion on the flywheel, and then output work, this paper aims to study the manufacturing and application of automobile engine crankshaft relying on computational fluid mechanics. In this paper, we first analyze the crankshaft structure using fluid mechanics. It focuses on several issues that are not currently yet agreed upon in crankshaft manufacturing, and on the process of detecting and incorporating multi-source information related to the remanufacturing process. Secondly, one of the key techniques, quality analysis and process parameter optimization based on nonlinear multivariate fitting, is deeply explored. We thoroughly study quality analysis based on multivariate nonlinear multivariate fitting and methods to optimize process parameters. The effect of the control parameters on the crankshaft performance is also analyzed. As an example, the effect of the spindle circularity and the crankshaft curvature on the final radial slip mass of the crankshaft is investigated. Based on constructing an uncertainty measurement model of the main crankshaft circularity and the crankshaft curvature, a nonlinear multivariate model is developed to illustrate the effect of the uncertainty on the radial flow of the heavy crankshaft. A batch of actually produced crankaxes was used as an example to study the effectiveness of the model. The experiment proved that the algorithm can increase the production qualified rate to about 85%.

1. Introduction

China's auto industry is booming, with many new cars entering the market every year. Great progress has been made in Chinese market-oriented automobile engine design and production also. Major domestic automobile manufacturers Chery, Brilliance and Geely JAC have all developed engines with independent intellectual property rights, and their performance has been significantly improved, completely breaking the chaotic history of domestic cars without independent engines. In the market, the competition is intensifying, the country's emission requirements are getting higher and higher, the engine upgrading is being accelerated, and many engine models are launched every year. The development of new products requires the addition of new equipment or a new production line of [1-2].

In relying on computational fluid mechanics of automobile engine crankshaft manufacturing and application research, many scholars to its research, and achieve good results, such as: Harrington G H and others verified the quality grading value in the process of remanufacturing product assembly, and put forward a simple and greedy heuristic algorithm, to calculate the different quality of recycling waste parts of the best solution [3]. Sreesha R B et al. proposed a work quality evaluation model based on fuzzy hierarchical analysis (AHP) to quantify the reuse degree of recycled wheeled loader components, and developed a recovery process management system to improve the management of the whole recovery process and improve the workflow efficiency of [4].

The main research content of this paper is as follows: it mainly describes the manufacturing level of the crankshaft in China, introduces the historical development and future development direction of the crankshaft processing, and studies the best combination of the crankshaft processing process based on computational fluid mechanics. This paper describes the comparison and selection of geometric and quality center boreholes. The surface roughness assessment of the crankshaft tube is introduced. Design related experiments to calculate and analyze the influence coefficient of the uncertain overall mean of multiple batches of the crankshaft, and to check the actual production qualified rate of the crankshaft manufacturing technology. Finally, the conclusion and prospect of the topic are mainly emphasized.

2. Research on the Manufacture and Application of Automobile Engine Crankshaft Dependent on Computational Fluid Mechanics

2.1. The Application of the C F D

As a CFD software, the CCM + of STAR has a powerful post-processing function to facilitate the processing and analysis of the results. Major post-processing features include the [5-6]:

(1) Report (reports) and monitor (monitors) function, during the calculation to create a report and monitor, you can observe the average value of the residual difference, CPU time, flux, force, torque, torque coefficient, speed, pressure, temperature, etc., the maximum value and other physical quantity with the calculation changes.

(2) Visual display of grid, scalar physics, and vector physics. STAR-CCM + can display the distribution of physical quantities by creating visual images. The latest version of 12.02 has added ray-tracing technology, which can add shadows, environment and other effects to the image, to make the simulation results more realistic and easier to understand.

(3) Derivative (Derived parts) function, when post-processing, the derivative function can be applied to create points, lines, isosurface, profile, Threshold surface, ISO surface, streamline, etc., conducive to a clearer analysis of the calculation results.

2.2. Crankshaft Manufacturing and Processing Quality Control System Framework and Architecture

The manufacturing and processing process is relatively complex. Each crankshaft itself difference, using the processing process and content is different, and a single crankshaft manufacturing process produced in various kinds of data, such as quality detection information, processing information, etc., in each process node of crankshaft, process, equipment, tools, the underlying quality data classification, extraction, on the basis of analysis and comprehensive data into useful dynamic information, used to drive the processing process. In order to realize the information-driven parts manufacturing and processing scheme dynamic adjustment, real-time tracking of processing quality, active control of process quality, processing quality analysis and process parameter optimization [7-8].

2.3. Real-Time Information-Driven Manufacturing and Processing Quality Control System Framework

In recent decades, the rapid development of information technology, sensing technology, all kinds of information perception and acquisition equipment, such as RFID, photoelectric sensors, stress sensors, etc., is more and more used in the manufacturing process of information collection and process monitoring, in order to realize the parts processing of intelligent identification, positioning, tracking, monitoring and management. In the manufacturing process of processing, many information related to the crankshaft quality, including the crankshaft in different processing stages of its own detection information, equipment information, tool information, environmental information, process operation information, how to real-time collection and effectively use these information, on the basis of information analysis and processing, realize the dynamic monitoring and decision of manufacturing processing process, is the key to realize the quality control of remanufacturing process [9-10].

In view of the challenges of the quality control, in order to improve the quality and performance of the manufacturing quality control system framework. First of all, using multi-source information perception and fusion technology, using CFD software, RFID, handheld terminal, stress, sensor, temperature sensor and other information perception and acquisition source equipment, in the process of manufacturing crankshaft quality detection data, processing equipment parameters, tool parameters, process operation parameters for multi-directional, multi-level, dynamic data acquisition. Then, with the support of industrial network, database, RFID electronic label and other software and hardware, realize the circulation of crankshaft information in each processing process, and provide the collaborative processing information service between processes, so as to change the original static and isolated processing process, and timely obtain the upstream and downstream crankshaft quality related information associated with the current process. Finally, at the data application level, the crankshaft quality data and each process are classified, extracted, analyzed and processed, revealing the quality control mechanism of the crankshaft processing process, and effective process decision and processing process with the support of multi-source real-time state information to guide the processing of manufacturing crankshaft. The traditional processing process only focuses on the technical requirements and processing standards achieved by this process. The real-time information-driven quality control compares the dynamic quality data of the crankshaft with the target parameters of the crankshaft processing, strictly controls the information parameters that have an important influence on the crankshaft quality, and dynamically corrects the processing process [11-12] of the manufacturing crankshaft.

2.4. Model Building

Establish the state space model of manufacturing process quality transfer, for the single process of crankshaft manufacturing, according to the advantages of state space model in system prediction, the manufacturing process knowledge, system parameters, processing parameters and state variables included in the equation, establish the state parameters of the quality to the target state space mapping model. Considering the control parameters in the process processing, formulate the quality standard of each process according to the final quality target of the crankshaft processing according to the real-time information data, and adjust the process processing scheme according to the process quality target to ensure the processing level of the individual process. At the same time, the causes of the manufacturing error in the current process are analyzed to a certain extent, and the parameters related to the process processing quality are accurately regulated to eliminate the defects that have a significant impact on the process processing quality, ensure the stability of the process processing, and improve the quality of the manufacturing crankshaft. See Figure 1 [13-14] for the adjustment principle of the process processing scheme.

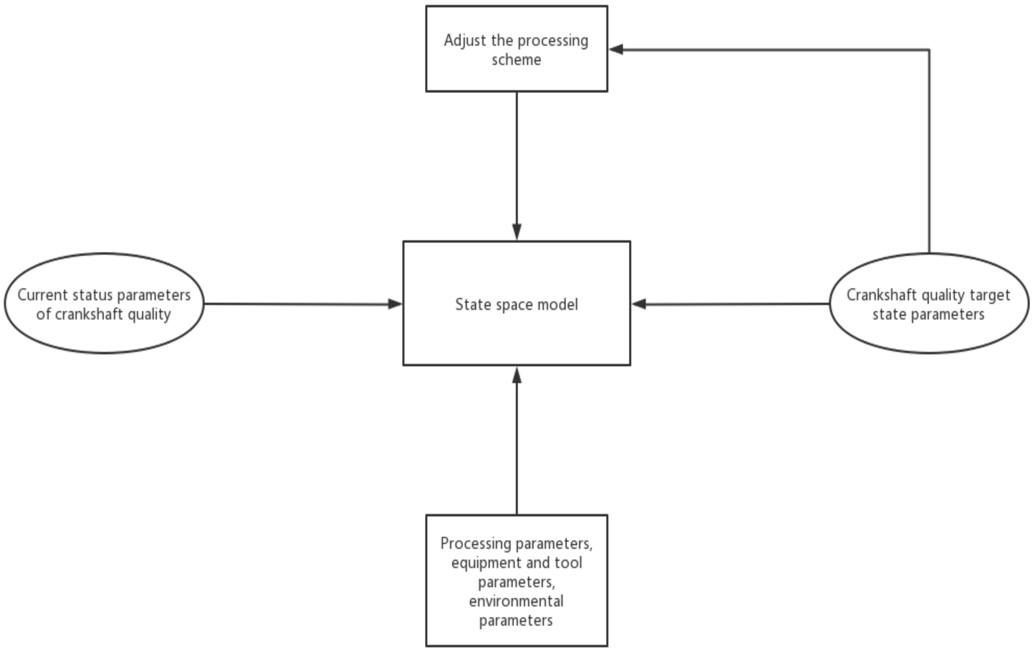

Figure 1. Adjustment principle of process processing scheme based on state space model

2.5. Uncertainty of Spindle Neck Circle

Let the probability that the measured value of the j th spindle neck circle of a batch of manufacturing crankshaft will be distributed in the i th grouping interval be Pij. For Pij, Pij=1. In order to describe it intuitively and conveniently, in this paper, the uncertainty of the roundness of the j th spindle neck of the crankshaft is used to quantify the uncertainty. The expression defining the uncertainty of the spindle neck circle is as follows: [15-16]:

$$\varphi_j^2 = \sum_{i=1}^{t} p_{ij} \left[\frac{\left(c_{ij} + c_{ij}^{'}\right)}{2} - 0 \right]^2 \tag{1}$$

Approach:

$$\varphi_j = \sqrt{\varphi_j^2} = \sqrt{\sum_{i=1}^{t} p_{ij}\left[\frac{\left(c_{ij} + c_{ij}^{'}\right)}{2} - 0\right]^2} \tag{2}$$

3. Research and Design Experiment of Manufacturing and Application of Automobile Engine Crankshaft Relying on Computational Fluid Mechanics

3.1. Analysis of Process Development

(1) Because the connecting rod shaft neck is extremely irregular, and the processing allowance is large, the rough processing of the connecting rod shaft neck cannot use the traditional process of cutting, because of the knife and low efficiency, you can choose external milling or internal milling [17-18].

(2) Due to the large margin of the spindle neck and the connecting rod and axle neck, it is necessary to rough process the workpiece before the semi-finishing, so it is recommended to use external milling and internal milling.

(3) Because the workpiece needs a long time of gas nitrogen infiltration, and nitrogen infiltration requires the workpiece to have a high surface quality (such as clean surface without oil pollution, good surface finish of the workpiece, etc.), nitrogen infiltration needs to be carried out after grinding, and to conduct high-quality cleaning before nitrogen infiltration.

(4) Due to the deformation of the workpiece (the workpiece stress will be released at the high temperature of 520-530 degrees), it is difficult to ensure the coaxial spindle neck of 0.05mm after nitriding. It is necessary to fine-grind the spindle neck after nitriding.

(5) Because nitriding will cause deformation of workpiece, the dynamic balance of workpiece needs to be completed after nitriding.

(6) After the overall nitrogen infiltration of the workpiece, the high hardness of the workpiece is not suitable for cutting. Therefore, the balance of the weight on the balance block needs to prevent nitrogen infiltration, and the seepage of nitrogen prevention material needs to coat the outer circle of the balance block before nitriding. The processing of both ends of the workpiece also needs to be completed before nitriding. Because the thread is not allowed to be hardened, the thread also needs to be coated with anti-seepage nitrogen material before nitriding.

3.2. Experimental Design

This paper analyzes the manufacturing technology of automobile engine crankshaft relying on computational fluid mechanics. Firstly, it calculates and analyzes the influence coefficient of the uncertain overall mean of multiple batch crankshaft. The second is the production of the actual crankshaft manufacturing technology inspection qualified rate.

4. Research and Experimental Analysis of the Manufacturing and Application of Automobile Engine Crankshaft Relying on Computational Fluid Mechanics

4.1. Overall Mean of Uncertainty and Its Influence Coefficient

In this paper, the overall mean of the crankshaft uncertainty of 20 batches is calculated, and the obtained data is calculated according to the definition of the influence coefficient, and the coefficient of each uncertainty is obtained. The experimental data are shown in Table 1.

Table 1. Overall mean of uncertainty and its influence coefficient

	Population mean	Influence system value
Main bearing journal 1	4.54	-0.21
Main bearing journal 2	7.51	-0.33
Main bearing journal 3	7.89	-0.40
Main bearing journal 4	7.61	-0.28
Main bearing journal 5	4.63	-0.16

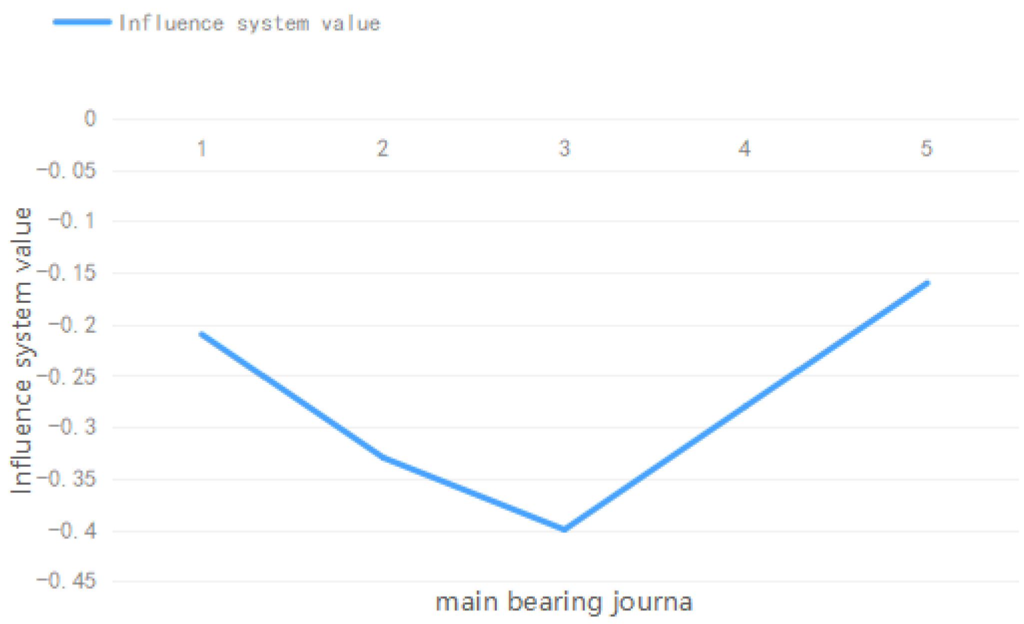

Figure 2. Comparison of influence values of 20 batches

The values of influence coefficient in Figure 2 are all negative. According to the definition of influence coefficient, it is known that when any uncertainty changes within a small enough range near the current overall mean, the smaller the value of the uncertainty, the greater the radial beating pass rate of the crankshaft.

4.2. Crankshaft Qualified Rate

This paper applies the new processing standard to the actual production of enterprises, tracks the remanufacturing crankshaft of multiple batches of new standards, and records the experimental data of 100,200,300,400,500 units in 2 production batches shown in Table 2.

Table 2. Qualification rate of the crankshaft after the implementation of the new standard

	100	200	300	400	500
The first batch of qualified rate	86.4	87.1	90.2	88.2	88.3
The second batch of qualified rate	88.2	88.3	89.4	87.1	90.1

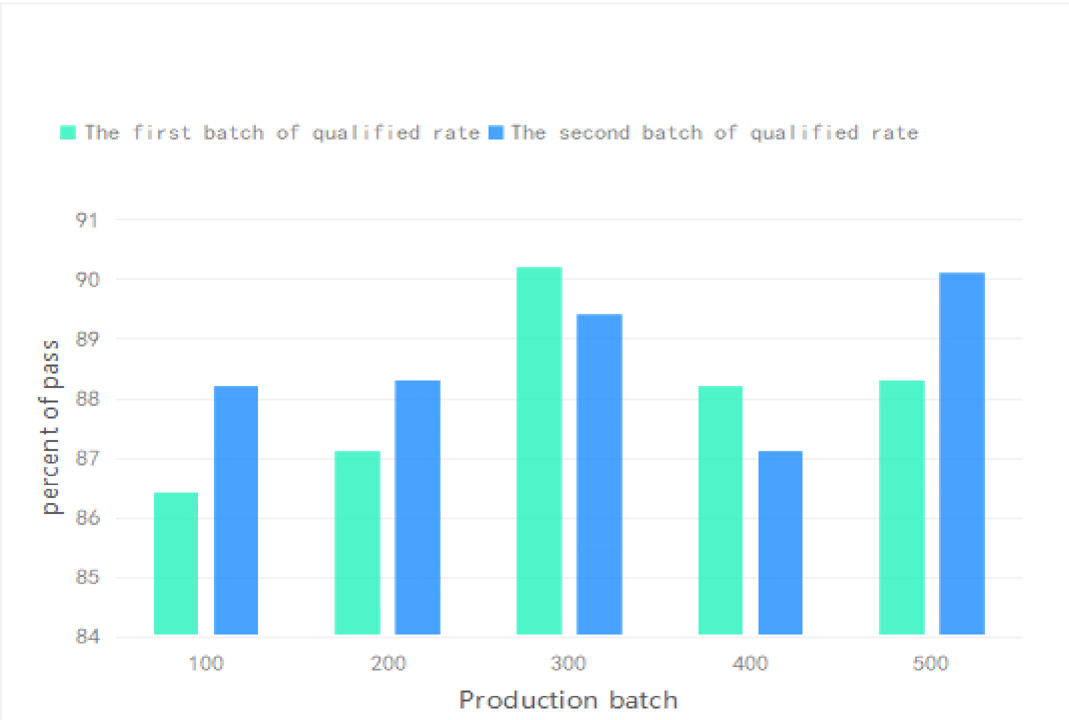

Figure 3. Comparison of the production qualification rate of the two groups of production batches

It can be seen from Figure 3, constructing a multivariate nonlinear model of the bending uncertainty of the crankshaft manufacturing uncertainty and the radial slip can quantify the extent to which the uncertainty affects the radial slip mass. The significance is to discover which uncertainties have the greatest impact on the quality of the crankshaft radial smoothing, and by controlling these uncertainties during the processing process, the radial smoothing grade of the crankshaft during the manufacturing process can be improved.

5. Conclusion

Through the comparative study of crankshaft processing and manufacturing process, combined with the investigation of domestic and foreign host manufacturers and equipment manufacturers, this paper expounds the level and future development direction of crankshaft processing and manufacturing industry in the current world, relies on computational fluid mechanics for analysis, and provides a general guidance for the process development of crankshaft of new cultivars. The paper mainly discusses several chronic problems in the crankshaft manufacturing, such as the comparison of the crankshaft mass center hole and the geometric center hole, and illustrates the good quality of the workpiece blank, which can avoid the blind selection of the quality center, because the crankshaft is one of the most important components in the engine, its complex structure and harsh working conditions require the crankshaft has high processing quality and good fatigue strength.

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Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Conflict of Interest

The author states that this article has no conflict of interest.

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