Research on High Precision Rapid Online Measurement System of Crankshaft Based on Multi-station

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Abstract. According to the structural characteristics and production requirements of the crankshaft, the online measurement platform of crankshaft was built. The multi-station assembly line is developed to measure, to mark and to classify the parameters and measurement elements of the crankshaft. In addition, SPC software is designed to perform mathematical statistics and analysis on the measurement information. It can distinguish between normal fluctuations and abnormal fluctuations in the production process, can inform the fluctuation state to determine whether it should be adjusted, can compare the fluctuations and provide direction for improvement. Finally, through multiple measurement experiments, the feasibility and effectiveness of the synchronous measurement scheme and data processing method proposed in this paper are verified. The experimental results show that GR&R is less than 9.3%, and measurement accuracy is less than or equal to 1μm.

Keywords. Online measurement, crankshaft, high precision, multi-station.

1. Introduction
Crankshaft is the core parts of an engine. The power performance of cars is decided and restricted by its manufacture quality directly [1, 2]. Therefore, the machining process and detect link of the crankshaft are very important. It is an important indicator of process quality to detect the shape error of the crankshaft’s main journal and connecting rod journal. Off-line measurement or random detect methods have been adopted at home and abroad until now [3, 4]. Apart from this, due to the backward detect tools, many key parameters such as roundness or cylindricity form error could not be tested [5].

The current research direction of crankshaft measurement system is that it can detect all parameters of crankshaft, can get the crankshaft profile quickly to keep up with the production beat and can predict the crankshaft quality intelligently according to measurement data [6, 7]. First of all, from the perspective of technological progress, the research on the rapid online inspection technology of crankshaft is not only the demand for large-scale and high-quality automated processing of crankshafts, but also the inevitable trend of the intelligent development of mechanical inspection technology. Secondly, from the perspective of industry competition, the breakthrough of rapid online inspection technology for crankshaft is a necessary requirement for independent innovation and development in the automated inspection field and participation in international competition [8]. Furthermore, from the perspective of industrial development, the research will also promote the development of...
machinery, electronics, instrumentation, auto parts and other industries, and it will also bring important economic value and social value [9].

2. Crankshaft Rapid Online Measurement System

The crankshaft rapid online measurement system integrates a variety of high-precision sensors, which can not only realize the measurement of various shape and position errors, but also connect with the pre-process and post-process of the measurement station in the automated production line, so as to achieve the efficient full detection of the crankshaft. According to the measurement results, the crankshaft is classified to provide the basis for parts selection. At the same time, crankshaft online measurement system can also analyze the measurement result data, can feed it back to the manufacturing process, and can give suggestions for improvement, thereby forming a closed-loop manufacturing system. The system can realize all-round real-time collection, analysis, monitoring and management of crankshaft processing quality information.

The functional areas in the crankshaft rapid online measurement system are shown in figure 1. It is mainly composed of stepping material shifting conveyor, crankshaft journal measurement station [10], keyway width and connecting rod neck width measurement station, laser marking station, image measurement station, unqualified parts discharging station, touch screen control box, SPC display interface and a set of electrical system.

![Figure 1. Crankshaft rapid online measurement system.](image)

Running process of crankshaft online measurement system is as follows.

Step 1: After tested crankshaft is manufactured, processed and cleaned, it is sent to the entrance of online measurement system by assembly line conveyor belt. Then it is sent into the measurement system by stepping material shifting conveyor.

Step 2: Tested crankshaft is transported to the crankshaft journal measurement station by the stepping material shifting conveyor. At the same time, loading and unloading rocker arm will lift the crankshaft parts from the conveyor to the positioning block of crankshaft journal detection station. The shaft journal measuring arm will measure position error and shape error of shaft journal. After the measurement is completed, loading and unloading rocker arm will send the crankshaft back to the conveyor.

Step 3: The tested crankshaft is transported by the conveyor to keyway width and connecting rod neck width measurement station for detection.

Step 4: After completion of each measurement procedure, the crankshaft is laser marked and measurement results of each crankshaft are stored.

Step 5: Unqualified crankshaft parts are sorted to the elimination station. Then they are scrapped or reprocessed according to the measurement results.
Step 6: Qualified crankshaft parts enter the unloading station. According to the measurement results, they are classified in order to facilitate selection of parts.

The crankshaft rapid online measurement system needs to meet the accuracy and rhythm of its manufacturing and processing technology. So that each processed crankshaft can be measured, to ensure that each crankshaft is qualified. Because the measurement system should be integrated with manufacturing assembly line, the measurement system needs to be adjusted according to unstable factors in workshop environment to reduce errors caused by environmental changes. This paper mainly studies the most critical journal measurement station in crankshaft online measurement system. It can meet the requirements of high precision and high efficiency measurement of online measurement system, and has a good adaptability to measurement environment.

3. Intelligent Processing of Measurement Data

It’s been developed measurement data processing and quality management software successfully. The quality management software has the functions of SPC statistical analysis, data traceability and visualization, and automatic alarm for out-of-control. At the same time, it integrates functions with the enterprise information management system, which provides a good technical foundation for the development of crankshaft processing quality online management system.

In this research, the intelligent processing of measurement data and online quality management technology are proposed. The specific functions are as follows:

a. The preprocessing methods of the original measurement data are studied. To solve the problems of noise in the measurement data, uneven measurement data, and irregular boundaries, a series of research have been carried out, such as data fitting, data filtering and other artificial intelligence methods to achieve singularity elimination, data truncation and continuation, data consistency processing and so on.

b. Error evaluation mathematical models for various geometric tolerances are established as shown in figure 2. Feature points are extracted quickly based on preprocessed measurement data. Evaluation algorithms and evaluation procedures are optimized. Intelligent evaluation of geometric tolerances and comprehensive evaluation of process capabilities are realized.

c. Passive quality inspection is transformed into active quality control through the wireless transmission of measurement information and network remote services further. It achieved real-time sharing, intelligent mining and full traceability of measurement data. It provided decision support for online quality management. The online control management is shown in figure 3.

![Figure 2. Error evaluation model of form and position tolerance (cylindricity, roundness).](image-url)
The realization of the above solutions improves the automation and intelligence level of measurement, enables the measurement data and results to serve the quality management of processing better, increases the ability of online management of processing quality, and reduces the scrap rate.

4. Experiment Analysis
The system prototype developed based on the above content is shown in figure 4 and figure 5. Figure 4 is the complete machine diagram, and figure 5 is the follow-up measurement part. The sensor probe information is transmitted to the industrial computer through the digital channel instrument. The measurement data is stored and processed and the measurement process and results are displayed through the SPC software in the industrial computer. The measurement data in the crankshaft online system is collected and processed by the industrial computer, and a display interface is set to connect with the industrial computer to display the built-in SPC interface, as shown in figure 6.
In order to test the reliability and stability of crankshaft journal measurement device, multiple groups experiments were carried out, and the measurement results were obtained. GR&R was obtained to verify the repeatability and reproducibility of the measurement structure through the analysis of measurement data. Part data of diameter results measured by three people repeated independent experiments on a batch of five crankshafts three times are shown in table 1. The GR&R values of all journal measurements are shown in table 2. The software analysis section is shown in figure 7.

**Figure 6.** SPC system.

**Table 1.** Partial measurement results by three persons repeated independent experiments.

| Person | Serial Number | A     | B     | C     |
|--------|---------------|-------|-------|-------|
| Time   | 1             | 49.97583 | 49.97578 | 49.97570 | 49.97555 | 49.97569 | 49.97569 | 49.97556 | 49.97569 | 49.97580 | 49.97584 | 49.97599 |
| 2      | 49.98090      | 49.98185 | 49.98187 | 49.98181 | 49.98190 | 49.98198 | 49.98212 | 49.98218 | 49.98223 |
| 3      | 49.98537      | 49.98544 | 49.98530 | 49.98529 | 49.98535 | 49.98545 | 49.98542 | 49.98547 | 49.98561 |
| Main journal | 4      | 49.98173 | 49.98162 | 49.98155 | 49.98167 | 49.98166 | 49.98173 | 49.98187 | 49.98192 | 49.98199 |
| J1     | 5             | 49.98202 | 49.98200 | 49.98191 | 49.98197 | 49.98200 | 49.98208 | 49.98213 | 49.98221 | 49.98236 |
| GR&R=5.7060% |

**Table 2.** GR&R values of all journals in the experiments.

| J1  | J2  | J3  | J4  | J5  | P1  | P2  | P3  | P4  |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| GR&R(%) | 5.7060 | 5.0318 | 4.7526 | 8.7819 | 4.7499 | 4.9622 | 8.6830 | 9.2980 | 3.8708 |
It can be seen from table 2 that GR&R of each journal is less than 10%, which meets the requirements of measurement repeatability and reproducibility and verifies the feasibility of journal synchronization measurement system.

![GR&R analysis report of Crankshaft measurement.](image)

Figure 7. GR&R analysis report of Crankshaft measurement.

5. Conclusion
This paper presents a high-speed and high-precision online measurement scheme of crankshaft. According to the pipeline scheme, multi-station is designed to measure, mark and classify the parameters of crankshaft in turn, which can meet the requirements of fast online measurement and is suitable for workshop environment. The same batch of crankshaft are tested repeatedly with the designed measurement system. The results are within the allowable margin of error. Resolution is 0.01μm, GR&R is less than 9.3%, measurement accuracy is less than or equal to 1μm, and measurement beat is less than 45 seconds. The experiments were carried out repeatedly, the feasibility and the reproducibility were confirmed of the measurement system.

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