

# Gear Quality Evaluation Based on Cloud Service

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**Abstract** The design and manufacture of gears have gradually been digitized, intellectualized and networked. The quality evaluation based on gear measurement is the key to ensure the quality of gears manufacturing. In order to digitize and informationalize the gear quality evaluation process and solve the problem of "information island" in gear measurement, this paper puts forward a gear quality evaluation scheme based on cloud service. First, the framework of gear quality evaluation cloud service is introduced, and the method of publishing and invoking the gear cloud service function based on REST is proposed. Then this article studies the gear accuracy evaluation method and statistical analysis method based on cloud service, and analyzes the gear quality evaluation cloud service process. Finally, a gear quality cloud evaluation system is developed, and the function and software of the cloud platform are tested through actual measurement. The test results show that, compared with the traditional scheme, the cloud service scheme of gear quality evaluation can realize the integrated sharing of gear measurement data and digitization and information of gear quality evaluation process. The service of evaluation results can improve the efficiency of gear quality evaluation.

**Keywords** Cloud service, Gear quality, Gear data format, Accuracy evaluation, SPC statistical analysis

## 1. Introduction

The design and manufacturing of gears have gradually realized digitization, intelligence, and networking. Quality evaluation based on gear measurement is the key to ensuring the quality of gear manufacturing. In the new model of gear intelligent manufacturing [1], intelligent production, network collaborative manufacturing [2], personalized customization, and remote operation and maintenance services [3] have put forward new requirements for gear quality evaluation, that is, the evaluation results should be integrated into the entire life cycle of gear intelligent manufacturing [4] to ensure closed-loop measurement of the entire gear manufacturing process.

In recent years, with the development of new technologies such as cloud computing, big data, and the Internet of Things, a new service-oriented cloud measurement model has been proposed [5]. By building a scalable cloud measurement platform, we can achieve the integration and sharing of measurement resources, thereby solving the problem of "information islands" among different information systems within an enterprise. The Hexagon Q-DAS quality data system integration solution opens up the whole process of quality data collection-upload-statistics-mining-report, thus realizing the life cycle management of quality data. In the field of gear informatization, scholars at home and abroad

have also carried out various exploration. On the issue of heterogeneity of gear data format, the Association of German Engineers (VDE/VDI) issued the Gear Data Exchange Format (GDE) data format standard for data exchange in the field of gear design, processing and measurement, which has been applied in the production and operation of ZF gear products [6]. In gear manufacturing, Klingelnberg GearEngine cloud computing system has been developed to enhance product tracking capabilities and optimize complete process flow. The system is capable of identifying and managing gear production-related devices and equipment, controlling production processes and fully tracing product quality [7]. In addition, in 2018, Gleason began integrating KiSSsys and FEM software with GEMS design and manufacturing software, thereby eliminating the "data barrier" between gear design and manufacturing [8]. In the field of gear measurement, from the initial mechanical measurement to the combination of mechanical and electronic measurement, to the current multi-disciplinary integration of measurement methods such as optics, mechanics, electronics, and information [9], the ability to obtain gear quality information continues to improve. However, there are still "data barriers" between gear processing machines, measuring instruments, and end users, resulting in the inability of gear measurement results to be fed back into gear design and manufacturing. Therefore, how to integrate massive gear measurement resources into the production process and transform them into gear quality evaluation services that can bring value to users is a key direction of current research.

This article aims at the problem of "information islands"

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based on gear measurement, and conducts research on gear quality evaluation methods based on cloud services. Firstly, it introduces the cloud service framework for gear quality evaluation, as well as the methods for publishing and invoking cloud services. Then, the gear error characterization method, the gear accuracy standard algorithm, and the statistical analysis method of gear quality information are analyzed. In addition, a quality evaluation scheme based on cloud services is proposed and a prototype system is developed. Finally, an example test verifies the feasibility and effectiveness of this scheme.

## 2. Gear Quality Evaluation Cloud Service Architecture

The basic steps of gear measurement include data acquisition, data processing, data storage and conversion, measurement results presentation, and feedback on the gear manufacturing process [10]. With the continuous progress of gear measurement technology and the changes in the application methods of measurement data, traditional measurement models have been unable to meet the needs of measurement systems in the direction of technological integration, personnel collaboration, equipment integration, and information and data sharing [11]. The gear measurement cloud service system framework based on the cloud measurement model is an overall optimization of existing solutions, enabling digitization of the measurement process and visual presentation of quality data.

### 2.1. Framework of Gear Quality Evaluation System

The framework of the gear quality evaluation system under the cloud architecture proposed in this article is shown in Figure 1. Through data integration and cloud service programs, the interconnection and sharing of the entire gear measurement process data is achieved. Under this framework, the entire system is divided into data layer, data processing layer, service layer, and user layer.

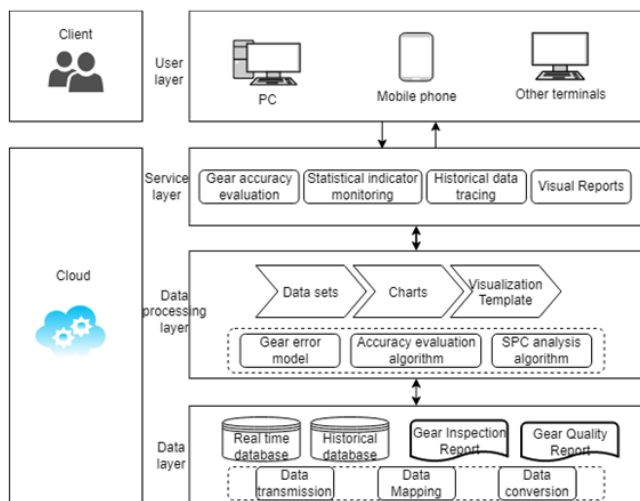


Figure 1. Framework of gear quality evaluation system

- (1) The data layer first standardizes the gear measurement data to form a GXML document [12], and then transfers it to the cloud platform. Then, through data mapping, data conversion, and other methods, it is stored in a database for invocation by the business layer. In addition, documents such as gear inspection reports and gear quality reports are also stored on the cloud platform for immediate invocation by users.
- (2) Data processing layer The processing of gear quality data is an important component of the system. The main content includes gear error model, accuracy evaluation algorithm, and SPC statistical analysis algorithm. Firstly, the basic gear parameters, measurement parameters, measurement raw data, and error curve data are preprocessed according to the specification requirements of the gear quality data model, and then mapped and stored in the gear center database; Then, data sets, data charts, and report templates are sequentially defined based on the business model.
- (3) Service layer The web service layer encapsulates gear parameter information, measurement data, and standard information based on business logic functions. It uses web services to provide users with services such as gear accuracy evaluation, statistical indicator monitoring, historical data traceability, and visual reporting.
- (4) Users with different needs at the user level complete the acquisition of services through PCs, smartphones, and other smart terminals.

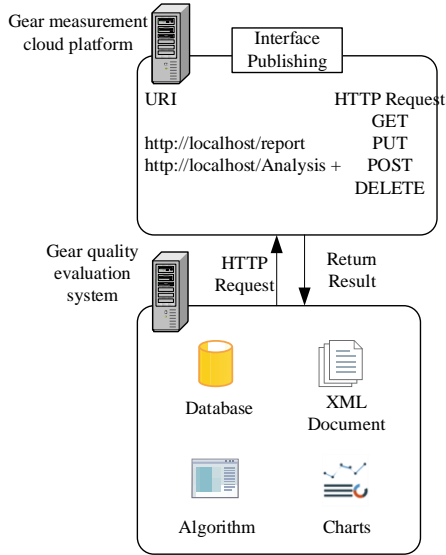
### 2.2. Cloud Service Publishing and Invoking Methods

In the software architecture of the quality evaluation system, the web service layer provides application components as services [13], encapsulates gear quality data resources as data services, and publishes services using a unified style interface, which will facilitate access and integration of gear quality data resources. This paper proposes a REST based data service encapsulation and description method for service-oriented encapsulation and unified description of gear quality data.

REST is an abbreviation for "Resource Representational State Transfer". "Resource" means resources, i.e. data resources circulating on the Internet, such as text, audio and video, etc; "Representational" means a representation, such as TXT, JSON, XML, PNG, and other formats; Generally speaking, REST refers to the state change of data in some form in the network. RESTful Web Services, as an implementation of Web services technology, is a lightweight and efficient Web service [14].

This article uses a REST based Web Services interface to provide users with gear quality cloud evaluation services. The service invocation process is shown in Figure 2. The Web Services interface can be understood as a combination of a resource unique locator URI and four access methods

of the HTTP protocol, namely GET, PUT, POST, and DELETE [15]. For example, to access the URI of “<http://localhost:8080/report>”, the GET method in the HTTP protocol is used, which means subscribing to a gear detection report from the server. The POST method in the HTTP protocol is used to apply for a new gear detection report from the server. As the caller of the gear cloud measurement service, the main function of the gear quality evaluation system is to integrate static and dynamic attribute data, and call the Web Services interface to achieve data cloud access.



**Figure 2.** Release and invocation of gear cloud service functions based on RESTful

### 3. Gear Quality Evaluation Based on Cloud Service

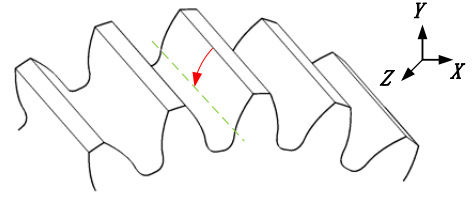
#### 3.1. Characterization Method of Profile Deviation

The current gear accuracy evaluation system is based on the "line measurement" method [16]. When evaluating major deviation items such as tooth profile, helix, and pitch, the evaluation basis is to measure a few characteristic points and characteristic curves. For tooth profile deviation and helix deviation, usually 3-4 teeth symmetrically distributed on the gear are selected. A characteristic curve is measured for each gear tooth in the left and right tooth surface profile and tooth direction directions. For tooth pitch deviation, measure the points on the pitch circle of each tooth surface on the gear center cross section, and measure the characteristic points of the tooth pitch one week later.

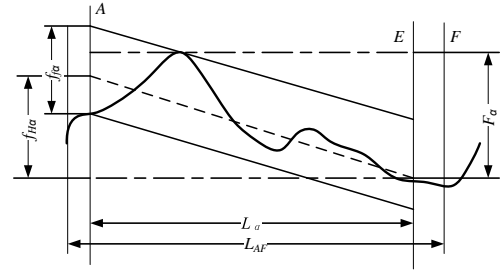
##### 3.1.1. Characterization Method of Tooth Profile Deviation

Select the gear tooth to be measured and measure the tooth profile on a plane at one end in the middle of the gear tooth surface. A tooth profile deviation curve can be obtained from each measured tooth surface. According to the tooth profile

deviation curve, the accuracy of the tooth profile deviation of the gear tooth can be evaluated, as shown in Figure 3 and 4.



**Figure 3.** Tooth profile measurement method



**Figure 4.** Tooth profile deviation

Each tooth profile deviation curve is composed of  $N$  discrete points, and the set of discrete points can be expressed as:

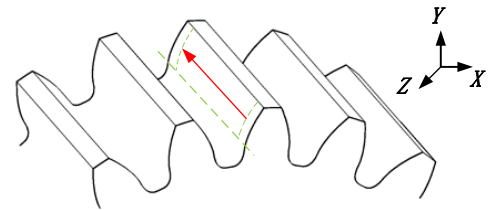
$$A_1 = \{(x_1, y_1, z_1) (x_2, y_2, z_1) \cdots (x_N, y_N, z_1)\} \quad (1)$$

Expand any measurement point  $(X_N, Y_N, Z_1)$  on the actual tooth profile according to the involute principle to obtain the actual tooth profile deviation curve, as shown in Figure 4, the deviation information of each tooth profile can be expressed as:

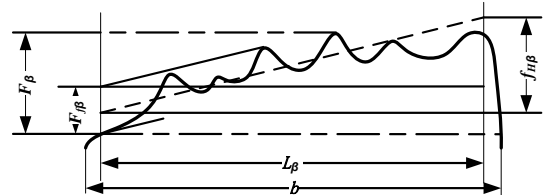
$$E_1 = (e_{1,1} \quad e_{2,2} \quad \cdots \quad e_{N,N}) \quad (2)$$

##### 3.1.2. Characterization Method of Helix Deviation

Select the tooth to be measured, and measure the middle of the tooth surface along the tooth width direction, and each tooth surface to be measured can obtain a helical deviation curve. According to the helix deviation curve, the accuracy evaluation of the helix deviation of the gear teeth can be carried out, as shown in Figure 5 and 6.



**Figure 5.** The helix measurement method



**Figure 6.** Helix deviation

The measured actual helical curve is composed of  $N$  discrete points, and the set of discrete points can be expressed as:

$$A_2 = \{(x_1, y_1, z_1) (x_2, y_2, z_2) \cdots (x_N, y_N, z_N)\} \quad (3)$$

Expand any measurement point  $(X_N, Y_N, Z_N)$  of the actual helix deviation curve in the tooth width direction, as shown in Figure 6, to obtain the actual helix deviation curve and the helix deviation information of each tooth Can be expressed as:

$$E_2 = (e_{1,1} \quad e_{2,2} \quad \cdots \quad e_{N,N}) \quad (4)$$

### 3.1.3. Characterization Method of Tooth Pitch Deviation

Select part or all of the gear teeth to be measured, measure the left and right tooth pitches of the tooth surfaces of the gear teeth on a certain end plane in the middle, and obtain the left and right tooth pitch deviation curves. According to the tooth pitch deviation curve, the precision evaluation of the tooth pitch deviation of the gear can be carried out, as shown in Figure 7 and 8.

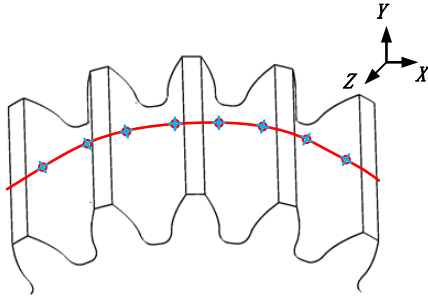


Figure 7. Tooth pitch measurement method

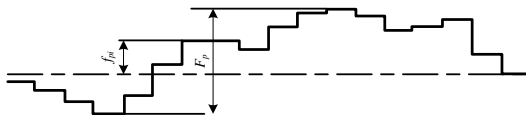


Figure 8. Tooth pitch deviation

Each tooth pitch deviation curve is composed of  $N$  discrete points, and the set of scattered points for left and right tooth distances is:

$$A_{3L} = \{(x_2, y_2, z_1) (x_4, y_4, z_1) \cdots (x_{2N}, y_{2N}, z_1)\} \quad (5)$$

$$A_{3R} = \{(x_1, y_1, z_1) (x_3, y_3, z_1) \cdots (x_{2M-1}, y_{2M-1}, z_1)\} \quad (6)$$

The pitch deviation information of each tooth can be expressed as:

$$E_{3L} = (e_{2,2} \quad e_{4,4} \quad \cdots \quad e_{2N,2N}) \quad (7)$$

$$E_{3R} = (e_{1,1} \quad e_{3,3} \quad \cdots \quad e_{2N-1,2N-1}) \quad (8)$$

### 3.1.4. Solve Deviation Information

To evaluate the accuracy of gears, it is first necessary to

analyze and calculate the deviation degree of the actual tooth profile from the design tooth profile curve from the deviation curve. Both tooth profile deviation and helix deviation belong to shape and position deviation. In practical applications, in order to facilitate computer solution, the least square method is usually used to fit the gear deviation curve. Here, taking the tooth profile deviation as an example, least-square fitting is performed on the tooth profile deviation curve. The equation for the average tooth profile trace can be expressed as:

$$y = kL + b \quad (9)$$

As shown in Figure 4, the calculation formulas of total tooth profile deviation  $F_\alpha$  tooth profile shape deviation  $f_{fa}$  and tooth profile inclination deviation  $f_{H\alpha}$  can be expressed as:

$$F_\alpha = \max(E_1) - \min(E_1) \quad (10)$$

$$f_{fa} = \max(E_1 - y) - \min(E_1 - y) \quad (11)$$

$$f_{H\alpha} = kL_\alpha \quad (12)$$

The method for solving the helix deviation is the same as that of the tooth profile deviation, and will not be repeated here. The calculation method of pitch deviation is described below.

As shown in Figure 8, the cumulative total pitch deviation  $F_p$  of the left tooth surface, any single pitch deviation  $f_{pi}$ , and single pitch deviation  $f_p$  can be expressed as:

$$F_p = \max(E_{3L}) - \min(E_{3L}) \quad (13)$$

$$f_{pi} = F_{pk} - F_{p(k-1)} \quad (14)$$

$$f_p = \max |f_{pi}| \quad (15)$$

```

1 <GMResults>
2   <MeasurementResultsSet n="100">
3     <MeasurementResults id="1">
4       <MeasuredParameters>
5         <ProfileMeasurements>
6           <Status>
7             <MeasurementStatus>PASS</MeasurementStatus>
8           </Status>
9           <ToothNum>5</ToothNum>
10          <Values>
11            <FA>9.6</FA>
12            <ffa>6.7</ffa>
13            <fHA>8.5</fHA>
14          </Values>
15        </ProfileMeasurements>
16        <HelixMeasurements> ... </HelixMeasurements>
17        <PitchMeasurements> ... </PitchMeasurements>
18      </MeasuredParameters>
19      <InspectionStatus>
20        <InspectionStatus>PASS</InspectionStatus>
21      </InspectionStatus>
22    </MeasurementResults>
23    .....
24  </MeasurementResultsSet>
25 </GMResults>

```

Figure 9. Example of GMResults module

In the gear quality cloud evaluation system, the measurement result data of a single gear is stored in an XML file according to the GXML format [12]. Figure 9 is an example of the measurement results module GMResults.

This module mainly contains tooth profile deviation data ( $F_a$ ,  $f_{fa}$ ,  $f_{H\alpha}$ ), Helical Deviation Data ( $F_\beta$ ,  $f_{H\beta}$ ,  $f_{H\beta p}$ ) And pitch deviation data ( $F_p$ ,  $F_{pk}$ ,  $f_p$ ), in addition to including the measurement status of the gear and the tooth number of the measured tooth profile.

The above analysis analyzes a gear deviation characterization method based on "line measurement". The gear error model established using this method can be used to evaluate the quality and accuracy of gears. The cloud platform implements this algorithm and standardizes and stores the measurement results in an XML document for subsequent invocation of cloud services.

### 3.2. Gear accuracy Evaluation Standards

The international accuracy standard ISO1328 for cylindrical gears has been revised several times, and three versions have been formed: 1975, 1995, and 2013 [17]. In gear manufacturing enterprises, due to continuous international trade, new and old international standards are basically coexisting. Therefore, when evaluating the accuracy of gears, it is necessary to consider the conversion between different accuracy standards. Generally, there are two methods for determining the allowable value of each deviation in gear standards: calculation method and table lookup method, and table lookup method has more priority than formula method. However, starting from ISO1328-2013, the new gear accuracy standard mainly focuses on formula calculation, and no longer appends various deviation allowable value tables.

A considerable portion of software for gear accuracy design is designed based on the method of looking up tables, which establish a database of listed gear accuracy parameter values, and query the database through programming; The other part calculates various parameters of gear accuracy with the help of formulas, and then processes the calculated data with reference to the principle of rounding in the new national standard. The results obtained by the two methods are consistent, while the computational method is more conducive to computer program processing. Therefore, this article makes full use of the fast computing speed of computers and uses formulas to calculate tolerance values. The interface of the gear accuracy tolerance value query software is shown in Figure 10.

Gear parameters		Accuracy standards: ISO 1328-2013 Accuracy class: 6	
Number of teeth:	19	Calculate tolerance	
Module:	3.75	Profile tolerance, total	F <sub>oT</sub> 13
Pressure angle:	20	Profile form tolerance	f <sub>foT</sub> 10
Rotations:	Left	Profile slope tolerance	f <sub>fpT</sub> 8.5
Helix angle:	15	Helix tolerance, total	F <sub>βT</sub> 12
Tooth width:	34	Helix form tolerance	f <sub>βfT</sub> 8.5
Modification:	0.3424	Helix slope tolerance	f <sub>βpT</sub> 8.5
		Single pitch tolerance	f <sub>pT</sub> 9
		Sector pitch tolerance	f <sub>pkT</sub> 13
		Cumulative pitch tolerance, total	f <sub>pT</sub> 28
		Runout tolerance	r <sub>rT</sub> 22

Figure 10. Gear accuracy tolerance query interface

### 3.3. Statistical Process Analysis of Gear Quality Information

The statistical process control (SPC) can be used to control the quality of the gear machining process, that detect whether the gear deviation value deviates from the preset index, and analyze the stability of the gear process. A large amount of data needs to be processed in SPC applications, so that the traditional manual calculation method can no longer meet the complex calculation requirements. Combining computer information technology with SPC analysis methods, using intuitive graphical analysis and numerical analysis of results, is conducive to quickly understanding the causes of gear processing errors [18].

#### 3.3.1. SPC Statistical Analysis Principle

SPC is based on three statistical principles: normal distribution,  $3\sigma$  criterion and small probability principle, to control and manage product quality [19]. The control chart is the main statistical tool used by SPC to analyze the quality process and quality results. According to the probability theory, the distribution law of the processing error  $\sigma$  obeys the normal distribution. It can be seen from the analysis of the basic properties of the normal distribution that the distribution area within the range of  $3\sigma$  from the center line on the data distribution map is about 99.73%, and the probability of being outside the range of  $3\sigma$  is 0.27%. For the gear manufacturing process, the gear manufacturing error always has a certain degree of periodic fluctuation. When a certain process is controlled, the distribution of the detected gear deviation data should conform to the " $3\sigma$  criterion". When the detected gear deviation data exceeds the limit of the control value, that is, it falls outside the  $3\sigma$  range, based on the "small probability principle", the probability of such an event occurring is only 0.27%, which means it is impossible.

#### 3.3.2. Statistical Analysis Process of Gear Quality

In this paper, the final measurement is selected as the object of SPC statistical analysis on the gear quality data to monitor the random fluctuation and abnormal fluctuation of the gear product quality. The tooth profile shape deviation, tooth profile tilt deviation, and tooth profile total deviation are used as key monitoring parameters. Statistical analysis of gear quality information, through the control chart can be real-time understanding, analysis, and grasp the change law of gear quality characteristic data over time, and identify abnormal states in time.

The SPC analysis process is shown in Figure 11: to clarify the key process of product quality in the gear production process; to determine the process parameters of the gear process; to collect the measurement data at the instrument end and group the measurement data according to the sample size; to select the appropriate one according to the sample size Control Charts. Before drawing the control



chart, it is first necessary to calculate the mean control limit, standard deviation control limit and process standard deviation control limit; calculate the process capability index, and use this as a basis to analyze whether the gear quality is in a controlled state.

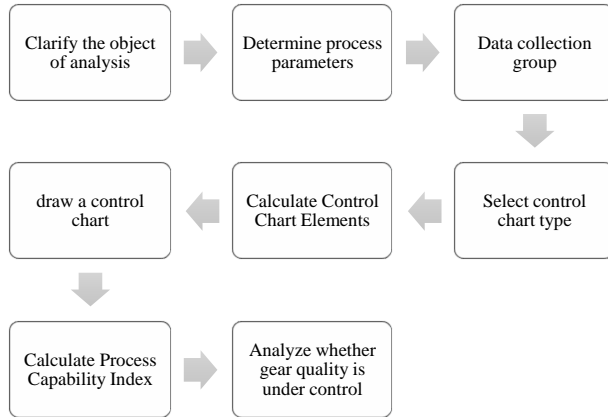


Figure 11. SPC analysis process

```

1 < StatisticalStudiesResults n="1">
2   <ResultsStats n="1">
3     <StatsItem>FA</StatsItem>
4     <WriteTime> 2022-07-10T07:59:02 </WriteTime>
5     <GroupId>15</GroupId>
6     <measurementUnit>μm</measurementUnit>
7     <ValueStats>
8       <TotalNumber>
9         <Value>30</Value>
10      </TotalNumber>
11      <NumberSubgroups>
12        <Value>10</Value>
13      </NumberSubgroups>
14      <Average>
15        <Value>1.984466667</Value>
16      </Average>
17    </ValueStats>
18  </ResultsStats>
19 </StatisticalStudiesResults>
  
```

Figure 12. Example of GMStatistics module

GMStatistics mainly describes SPC statistical analysis information for statistical deviation items. Figure 12 shows an example of GMStatistics. This includes the total number of samples, sample grouping, sample average, upper and lower control limits for average, upper and lower control limits for standard deviation, and process capability indexes Cp, Cpk, etc. In addition, it also includes some auxiliary information, including gear number, writing date, measurement unit, etc.

The above introduces the statistical principle of SPC, and analyzes the application of SPC in quality control of gear processing process, which can better integrate with the current trend of digitization, informatization, and intelligence in the gear industry. SPC is used to manage and analyze product quality through control charts, which can help gear companies identify problems in the product manufacturing process, reduce resource consumption, control quality costs, and improve product quality.

### 3.4. Cloud Service Process of Gear Quality Evaluation System

The cloud service model of the gear quality evaluation system is very helpful for integrating gear quality evaluation into the gear production process. As shown in Figure 13, REST APIs are used to implement mutual calls between different services, followed by secondary encapsulation and publishing. The worker invokes the interface to obtain gear accuracy evaluation information to verify whether the gear processing meets the accuracy requirements. The technician invokes the statistical analysis interface to obtain the quality statistical information of the gear, thereby analyzing whether the gear processing process is stable. The management personnel call the visual report interface to obtain the overall quality profile of the gear, providing a decision-making basis for decision makers to adjust the gear processing process.

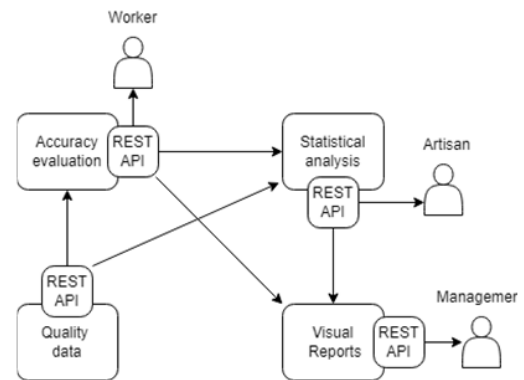


Figure 13. Cloud service process of gear quality evaluation system

## 4. Example Test of Gear Quality Evaluation System

### 4.1. Single Gear Quality Evaluation Program Test

Table 1. Test gear parameters

Number of teeth	Modulus	Pressure angle	Helix angle	Modification coefficient	Accuracy class
19	3.75 _	2.0	1.5	0.3424 _	6



Figure 14. Hexagon three-coordinates measuring machine

The gear measurement equipment used in this paper is a Hexagon three-coordinate measuring machine, and the measurement software is PC-DMIS, as shown in Figure 14 and 15. Use a three-coordinate machine to select the left and right tooth profiles of four symmetrical gear teeth for measurement, and store the measurement information in the gear center database. Gear parameters are shown in Table 1.

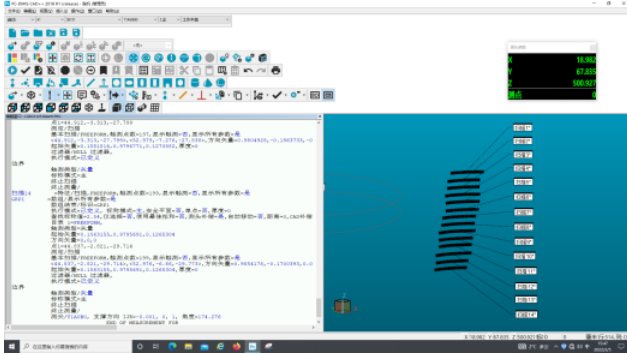


Figure 15. PCDIMS software measurement page

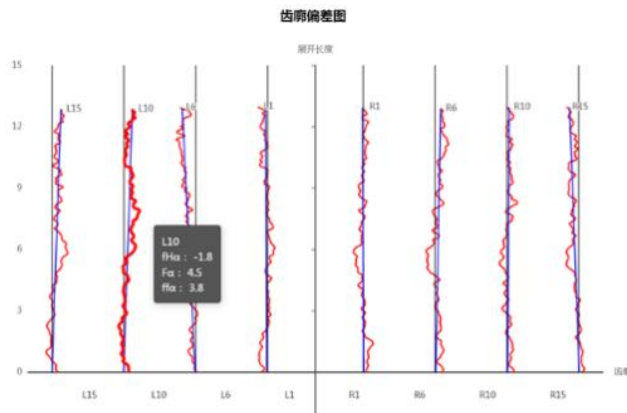


Figure 16. Visualization chart of tooth profile deviation

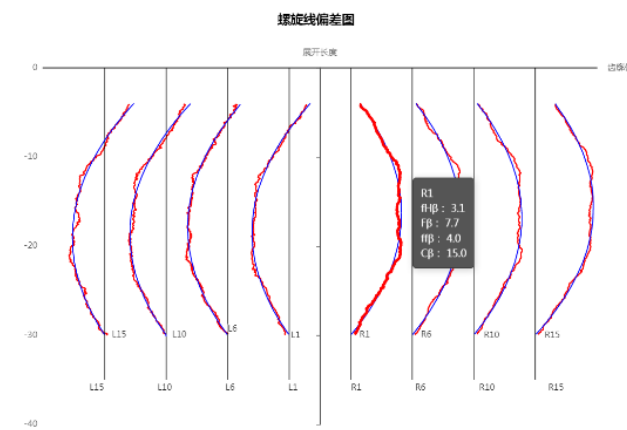


Figure 17. Visualization chart of helix deviation

The gear comprehensive measurement data and its accuracy evaluation results are represented as multidimensional and multivariate data with correlation. The user queries the gear order information based on the gear unique identifier. The server receives the request and obtains the gear quality measurement data from the server

based on the gear unique identifier. Then, gear error analysis and accuracy evaluation are performed according to the data standard, and the error analysis and evaluation results are stored in the database. The evaluation results of tooth profile deviation and helix deviation are shown in Figure 16 and 17. Interactive charts based on ECharts can interact with users through hovering, clicking, and dialog boxes to highlight key indicator data of gear deviation results. Compared to paper reports, this method has clear layers, intuitive information, and rich charts, which can help users improve information acquisition efficiency.

#### 4.2. SPC Statistical Analysis Function Test

Perform SPC statistical analysis on the gear error, and store the statistical analysis results in the database. SPC statistical analysis was carried out on 100 sets of gear tooth profile total deviation data samples, which were divided into 20 groups, and the number of sub-samples in each group was 5. As shown in Figure 18 and 19, the tooth profile deviation data can be viewed and managed directly on the page, and the data can be exported to EXCEL format.

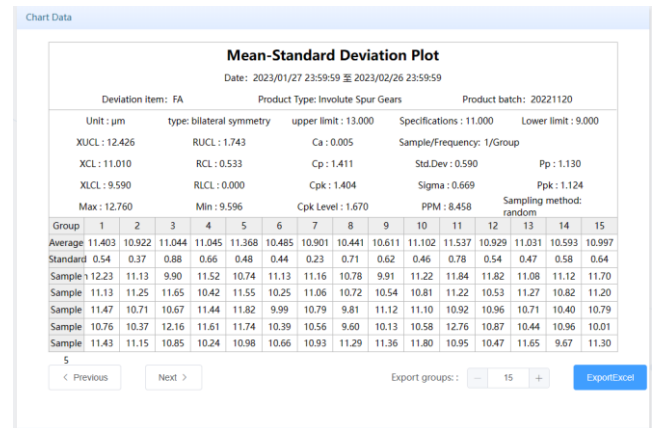


Figure 18. Chart data page

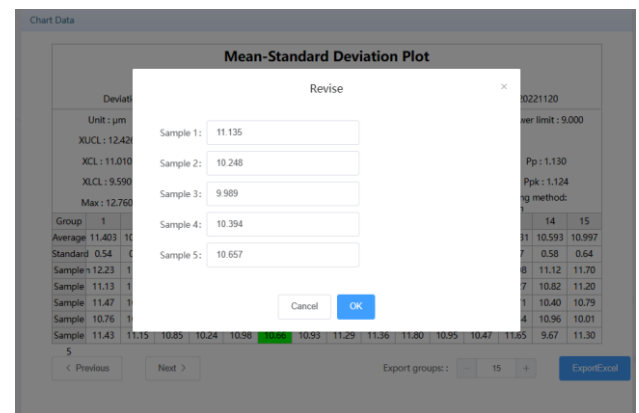


Figure 19. Data management page

In order to make the control chart provide richer and more comprehensive information, this paper selects  $\bar{X} \sim \bar{S}$  chart for analysis. The mean control limits for calculating the total deviation of the tooth profile are  $\bar{X}$

=11.008,  $UCLx=12.426$ ,  $LCLx=9.590$ , and the standard deviation control limits are  $\bar{S}=0.533$ ,  $UCLr=1.743$ , and  $LCLr=0$ . It can be seen from Figure 20 that the quality characteristic points do not exceed the control limit, and the deviation data in the sample conform to the discrimination criterion of the control chart. Therefore, the gear quality is in a statistically controlled state. If you want to view historical gear quality data, you can select date, deviation item, product type, product process and chart type to filter and query on the page shown in Figure 21.

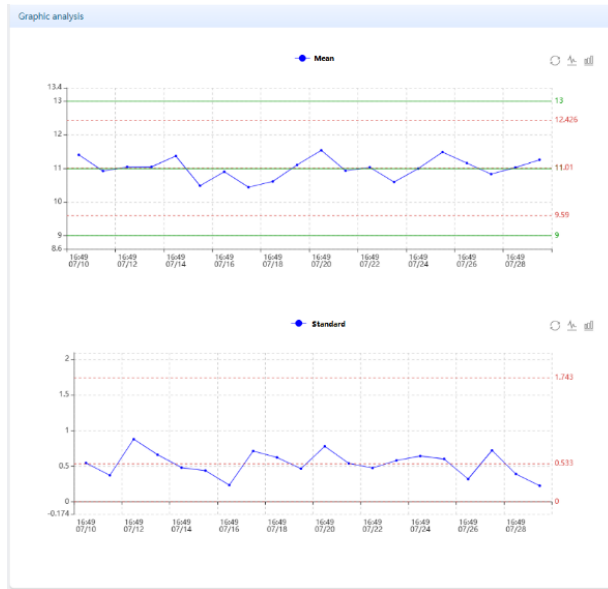


Figure 20. SPC control chart page

Figure 21. Data query page

#### 4.3. Analysis of Test Results

Through the example testing of the gear quality evaluation system, this article has realized the storage and conversion of gear quality data, data processing, and visual display, completed the informatization and networking process of the gear quality evaluation process, and verified the feasibility of the REST-based gear quality evaluation cloud service solution proposed in this article. The gear experiment results show that compared with traditional solutions, the gear evaluation cloud service solution is beneficial to the integration and sharing of gear measurement resources. The specific performance is as follows:

- (1) Realize the integration of gear quality information resources. Through the integration of gear

measurement process data, cloud storage is realized, improving the efficiency of gear quality data exchange, and providing a data foundation for statistical analysis and error traceability of gear data.

- (2) Digitize measurement results and visualize data in the form of cloud services. Users can invoke and process gear quality services through a browser by invoking the web service interface. Through visualization, comprehensive information about gear products can be intuitively and accurately expressed, improving the efficiency of gear quality evaluation.
- (3) Cloud service based gear quality evaluation and statistical analysis provide consistent quality evaluation services for multinational and transregional manufacturing enterprises, enabling enterprises to control product accuracy information in the processing process in real time, thereby helping managers make scientific decisions.

## 5. Summary

Aiming at the "information island" problem of quality information in the manufacturing process of gear products, this paper studies the digitization and informatization methods of gear quality evaluation process, proposes a gear quality evaluation scheme based on cloud services, develops a gear quality evaluation cloud service system, and tests it in this system. The test results show that the gear quality evaluation method based on cloud services can solve the digitization and informatization problems of the gear quality evaluation process. Cloud data storage and visual representation of gear quality evaluation results provide convenience for users to intuitively and efficiently understand gear manufacturing quality, and can effectively improve the efficiency of gear quality evaluation. The system integrates gear quality information into the gear production process through a service-oriented approach, and the service-oriented evaluation results can improve the efficiency of gear quality evaluation. The method and scheme proposed in this paper can be further popularized in the design, manufacturing, and operational status evaluation of gears.

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