Technical study and experimental research on the cloud collaboration model of Soften-standardized

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Abstract: this paper discusses and analyzes the technical ideas of the soften-standardized cloud collaborative manufacturing model of bearing components with seat, including soften-standardized processing, intelligent fitting algorithm, intelligent matching algorithm and product data flow. Because it has obvious advantages compared with the traditional group assembly method, it can be expected that this technology will become a competitive choice for low cost processing and high quality production of large-scale precision assembly components manufacturing enterprises. In order to verify the feasibility of this technology in mass production, a set of experimental methods are designed and verified step by step. The experimental results show that the technology is not only feasible, but also can change the existing factors of production. The failure rate of bearing and bearing can approach zero theoretically and the assembly quality of bearing assembly is higher.

1. Introduction
For the machinery industry of mass production, standardized production mode is widely adopted at present. Enterprises mainly improve the quality of products by improving the requirements of qualified standards for parts production (that is" strong standardization "). As a result, enterprises have to continue to upgrade equipment, personnel, technology and other conventional elements, resulting in rising enterprise costs\textsuperscript{[1]}. In addition, based on the equipment accuracy and process conditions of the enterprise, designers will consciously improve the design accuracy grade of the parts in order to ensure the assembly accuracy of the precision assembly components. In order to ensure that the assembly quality of the parts can still achieve satisfactory results, which will lead to the increase of processing costs?

In order to reduce the manufacturing cost of machining enterprises, researchers have carried out a lot of research in recent decades, and achieved fruitful results. The grouping assembly method is a typical technical method. The grouping assembly method is that in mass production, when the assembly accuracy is too high to meet the requirements by the complete interchange method, the tolerance of each
assembly is magnified to the economic feasibility of processing, and then divided into the same groups. The assembly is assembled interchangeably in the corresponding group\cite{2}. One of the key requirements of the assembly method is to ensure that the precision and the properties of the fit are the same as before, and the tolerance range of the fit should be equal. However, one of the outstanding problems in this traditional group assembly method is that the uneven number of hole shaft parts in each assembly group leads to more unsuitable remaining parts. In 1995, Zhang Yu and others proposed a new grouping algorithm, which can minimize the remaining parts in group assembly, and developed a new method to ensure the balance of the number of group assembly parts\cite{3}. A new one-to-many grouping strategy was proposed in 1998, Kannan and others discussed the problem of one-to-many tolerance grouping of parts, and the optimization effect of the strategy on assembly tolerance was proved by an example, which can effectively reduce the number of remaining parts\cite{4}. In 2004, Yuan Chi and others studied the determination of parts size and deviation in group assembly, put forward a new method to determine the size and deviation of parts in group assembly, and gave the calculation formula to determine the basic size and deviation of each group, which provided the theoretical basis for correctly determining the process dimensions of group assembly\cite{5}.

Because the group assembly method has obvious advantages in using low-precision parts to achieve high-precision assembly, it has been tried by some enterprises in the batch production of precision assembly components, but limited by traditional testing technology and data technology, the group assembly method depends on manual measurement, manual recording and manual selection of machining parts. Therefore, this traditional group assembly method presents two characteristics in practical production: first, the larger the number of parts, the greater the labor cost and time cost of the group assembly method, which often increases the total manufacturing cost of enterprises; Second, because the quality of machining process is affected by human, machine, material, method, ring and measurement, the size deviation of the parts produced in the same batch is not necessarily distributed according to the normal distribution, and more unsuitable parts will be produced when assembling in groups, which leads to the need to make special customization of the unsuitable parts, thus delaying the production plan and increasing the production cost\cite{6}. In addition, the implementation object of the traditional group assembly method is based on the premise that the design matching accuracy of the assembly component is constant, and the corresponding part size tolerance is used as the part produced by the machining control element. The matching accuracy after assembly is the same as that of the original design, and the uniformity of the matching quality is unchanged. The application scope of this method is limited to high precision assembly situations which cannot be satisfied by the traditional complete interchange method. Although the low cost machining and high precision assembly of components can be realized in this range, however, the contribution to the overall processing cost reduction of the complete product range is limited.

In order to break through the technical bottleneck of the traditional "strong standardization" production mode in reducing manufacturing cost, the existing scholars put forward a concept of "soften-standardization ". The purpose of this paper is to "soften "(that is, reduce) the requirement of machining precision grade in manufacturing process, so as to realize an innovative production mode of low cost processing and high quality assembly The biggest difference with the traditional group assembly method is that the implementation object of the soften-standardization technology is based on the reasonable degradation of the design matching accuracy of the assembly, and the parts produced by the corresponding part size tolerance are the machining control elements. The precision of the assembly is higher than that of the original design, and the uniformity of the matching quality is improved. This method is suitable for all assembly occasions and can greatly reduce the overall processing cost of the complete product range of the enterprise. In addition, thanks to the rapid development and popularization of new technologies such as super precision measuring, big data, cloud computing, automatic sorting and intelligent library, cloud collaborative manufacturing model can be realized at lower cost. The traditional group assembly method can solve the problems of labor cost, time cost and unsuitable residual parts cost. Therefore, it can be predicted that the soften-standardized cloud collaborative manufacturing technology will gradually become a competitive choice for low-cost
processing and high-quality production of large-scale precision assembly component manufacturers.

2. Technical thinking of softly standardized cloud co-manufacturing model for bearing assembly with seat

Soften-standardized cloud collaborative manufacturing model is a kind of precision assembly from part processing process design to component assembly production process of the whole process of reconstruction and innovation production model. This paper takes the common production of bearing assembly with seat as an example. The technical flow of the traditional group assembly manufacturing mode is shown in figure 1, and the technical idea of the soften-standardized cloud cooperative manufacturing mode is shown in figure 2.

![Figure 1 Technical Flow of Traditional Group Assembly Manufacturing Mode with Seat Bearing Components](image1)

![Figure 2 Technical ideas of softly standardized cloud cooperative manufacturing model for bearing components with seat](image2)

Compared with the traditional group assembly mode, the softly standardized cloud co-manufacturing mode has the following three obvious characteristics and advantages in reducing the total manufacturing cost: (1) through the soften-standardized processing technology, the matching precision grade required by the original design drawings is reasonably downgraded in the process design stage of the parts, and the requirements of the equipment precision and process level are reduced, thus effectively reducing the manufacturing cost of the machining process; (2) Replacing the traditional inefficient operation modes, such as manual detection and manual selection, by means of hardware technologies such as 3D scanning, laser marking, intelligent database and integrated and innovative software technologies such as cloud database, intelligent fitting algorithm and intelligent selection algorithm, the labor cost and time cost of detection and assembly are greatly reduced; (3) An updated part cloud database based on continuous batch processing and on-line detection, through the cloud intelligent selection algorithm technology, can make each failure to achieve optimal matching of unsuitable parts data rolling into the next cycle of intelligent selection calculation, until the successful selection of matching, greatly reduce the cost of unsuitable remaining parts caused by traditional manual selection and its special custom assembly cost.
2.1 Technical ideas for soften-standardization

The soften-standardization treatment is to reduce the design precision of the bearing assembly with seat reasonably, that is, to reduce the machining precision grade of the inner hole fit surface and the outer circle fit surface of the bearing seat step by step. The limit clearance or limit interference is still within the original design.

At this time, the number of parts pre-assembly can be estimated according to formula (1) according to the width of the design tolerance zone and the width of the matching tolerance zone.

\[ K = \frac{\sum_{i=1}^{n} t_i}{\sum_{i=1}^{n} t'_i} \]  

(1)

K represents the number of pre-clusters, the width of the design tolerance zone for each part, the width of the matching tolerance zone to be achieved, and the parentheses on the right side of the equation indicate upward rounding.

2.2 Technical thinking of intelligent fitting algorithm

A large number of point cloud coordinate data obtained by 3D scanning of bearing seat and bearing will be transformed into dimension data of matching surface by intelligent fitting algorithm. Because the matching surface of bearing assembly with seat is spherical, the ball parameters can be obtained by design algorithm, and then the ball parameters can be solved by least square method. Therefore, the least square method is used to fit the matching point cloud data, and the coefficient matrix is obtained by solving the equations in the least square method, and then the final solution is obtained by the coefficient matrix.[7]

Spherical space equation

\[(x - a_o)^2 + (y - b_o)^2 + (z - c_o)^2 = r^2 \]  

(2)

For the center of the sphere, the r is the radius of the sphere.
Because of the existence of four unknowns in formula (2), the four-point \(A(x_1,y_1,z_1), B(x_2,y_2,z_2), C(x_3,y_3,z_3), D(x_4,y_4,z_4)\) of different planes are randomly selected on the fitting respectively:

1: \((x - x_1)^2 + (y - y_1)^2 + (z - z_1)^2 = r^2\)
2: \((x - x_2)^2 + (y - y_2)^2 + (z - z_2)^2 = r^2\)
3: \((x - x_3)^2 + (y - y_3)^2 + (z - z_3)^2 = r^2\)
4: \((x - x_4)^2 + (y - y_4)^2 + (z - z_4)^2 = r^2\)

A system of equations is obtained by extending, expanding 1, 2, 3, 4 and doing 4-3, 3-2, 2-1, whose coefficient matrix A is:

\[
A = \begin{bmatrix}
a & b & c \\
a_1 & b_1 & c_1 \\
a_2 & b_2 & c_2 \\
\end{bmatrix}
\]

Of which \(a = (x_1 - x_2), b = (y_1 - y_2), c = (z_1 - z_2), a_1 = (x_3 - x_4), b_1 = (y_3 - y_4), c_1 = (z_3 - z_4), a_2 = (x_2 - x_3), b_2 = (y_2 - y_3), c_2 = (z_2 - z_3)\).

Because there are four groups of parallel solutions, the average value of the four groups of solutions is obtained.

2.3 Technical Ideas of Intelligent Matching Algorithm

2.3.1 Grouping of parts

In order to solve the outstanding problem in the traditional grouping assembly method, that is, the number of holes and shaft parts is not balanced, it will be in Zhang Yu[3]Based on the principle of probabilistic equilibrium grouping, a new grouping method is proposed based on the technical idea of soften-standardization processing.

For the bearing assembly treated with soften-standardization, the limit value of each group is calculated first, that is, the upper deviation of the size of the outer circle fit surface of each group of bearings is calculated by formula (4), and the upper deviation of the inner hole matching surface of each
group of bearing seat is calculated by formula (5). Then, the specific grouping number can be obtained according to the width of the matching tolerance zone and the limit value of each group. After defining the grouping number and the limit value of each group, the algorithm is used to generate several groups of random natural numbers, the specific group number is equal to the grouping number, and the sum of natural numbers of each group is required to be the same (considering the problem of calculation, the natural number should not be too small or too large); Finally, according to the comparison of natural numbers to the sum of natural numbers, the actual boundaries of each group are divided, and the grouping results that meet the production requirements are obtained.

\[
es_i = E_i - Y_{\text{max}}
\]

\[
ES_i = \Phi^{-1}\left(\frac{ES_i - \mu_H}{\sigma_H}\right) \times \sigma_H + \mu_H
\]

2.3.2 Selection of parts
The parts in each group obtained by grouping are selected according to the number of groups, and the matching algorithm is designed to calculate the matching tolerance of any part with all the parts in the corresponding group. Because the cooperation between the bearing outer ring and the bearing seat hole is a transition fit, the preliminary selection result is then selected according to formula (6) to select the optimal matching part number and output the matching tolerance of the matching.

\[
\begin{align*}
ES_i - e_i & = X_{\text{max}}(i) - X_{\text{max}} \\
EI_i - eS_i & = Y_{\text{max}}(i) - Y_{\text{max}}
\end{align*}
\]

2.4 Technical ideas for product data flow
The product data flow chart is shown in figure 3.

3. Experimental study on softly standardized cloud co-manufacturing of bearing components
To verify the feasibility of the above technical ideas for mass production, this paper designs a set of intelligent algorithms by matlab 2016a software to simulate the Φ120H7/k6 bearings and bearings in actual production. The bearings and bearings used in the experiment are shown in figs 4 and 5.
respectively. The inner diameter of bearing hole: \( \Phi_{120H7}^{+0.035} \) bearing outer diameter: \( \Phi_{120k6}^{+0.025} \) the maximum clearance \( X_{\text{max}}=+32\mu\text{m} \) is required for the design of bearing assembly because the design tolerance of bearing assembly adopts the base shaft system transition fit, Minimum clearance \( X_{\text{min}}=-25\mu\text{m} \).

In order to simulate the actual situation of mass production and reduce the experimental cost, this experiment adopts three groups of actual processed bearings and bearing seat parts, and obtains the point cloud scanning data through 3D scanner. The feasibility of intelligent fitting algorithm is verified by random simulation. The 3D scanning point cloud data are shown in Table 1, and the specific parameters of bearings and bearings are shown in Table 2.

However, the high machining precision of bearing and bearing seat may lead to the increase of total cost and the decrease of production efficiency. In order to solve this problem, this experiment first uses the soften-standardization technical idea to soften the part requirement, and then uses the least square method, the general equalization principle and so on to design the intelligent algorithm to realize the automatic fitting of the part point cloud data and the grouping selection of the parts.

![Figure 4 Bearing model](image1)

![Figure 5 Bearing seat model](image2)

| Point cloud data number | X axis coordinates | Y axis coordinates | Z axis coordinates |
|-------------------------|-------------------|-------------------|-------------------|
| 1                       | 144.3312019       | 90.9475461        | -6.7804451        |
| 2                       | 144.2909539       | 91.0520777        | -7.0575736        |
| 3                       | 144.2461908       | 90.7962397        | -6.9954814        |
| 4                       | 144.1442696       | 91.2320167        | -6.7281788        |
| 5                       | 144.1035718       | 90.5568543        | -7.0838029        |
| 6                       | 144.0759003       | 91.0216942        | -6.6034230        |
| 7                       | 144.0322697       | 90.2513191        | -6.9423001        |
| 8                       | 143.9689696       | 90.1977196        | -6.7091906        |
| ••••••                   | ••••••            | ••••••            | ••••••            |
| 1075489                 | 78.2557875        | 178.0004352       | -6.7666038        |
| 1075490                 | 78.3683062        | 178.5175949       | -6.8273311        |
| 1075491                 | 78.4977973        | 178.0282855       | -6.8395957        |
Table 2 Bearing diameter and bearing seat hole diameter

| Number | Bearing outer diameter dimensions | Number | Inner diameter dimension of bearing seat hole |
|--------|----------------------------------|--------|---------------------------------------------|
| 1      | 120.01213mm                      | 1      | 119.99912mm                                 |
| 2      | 120.02022mm                      | 2      | 120.02835mm                                 |
| 3      | 120.01195mm                      | 3      | 120.02154mm                                 |
| 4      | 120.01156mm                      | 4      | 120.03211mm                                 |
| 5      | 120.00955mm                      | 5      | 120.03125mm                                 |
| 6      | 120.00356mm                      | 6      | 120.03022mm                                 |
| 7      | 120.02566mm                      | 7      | 120.00125mm                                 |
| 8      | 120.01955mm                      | 8      | 120.03548mm                                 |
| ....   |       | .... |                                           |
| 48     | 120.02498mm                      | 498    | 120.01548mm                                 |
| 49     | 120.00785mm                      | 499    | 120.00985mm                                 |
| 50     | 120.00956mm                      | 500    | 120.02548mm                                 |

3.1 Soften-standardized treatment
The standard tolerance grade of bearing hole is reduced from IT7 grade to IT8 grade according to formula (1), and the standard tolerance grade of bearing is reduced from IT6 grade to IT8 grade.

3.2 Point cloud data fit
Geomagic reverse engineering software measurement function is used to measure the hole and axis diameter of three groups of point cloud data and the least square fitting algorithm is used to fit the three groups of point cloud data to obtain the hole and axis diameter. The measurement results and the operation results of the algorithm are shown in table 3.

Table 3 Comparison of Fitting Error of Algorithm

| Part information | Geomagic Measuring Diameter | Intelligent Algorithm Fitting Diameter | Absolute error | Relative error | Credibility of the results of the fitting algorithm |
|------------------|-----------------------------|----------------------------------------|----------------|---------------|---------------------------------------------------|
| Bearing seat 1   | 120.029914mm                | 120.050620mm                           | 0.0207mm       | 0.017%        | 99.9%                                             |
| Bearing 1        | 120.024841mm                | 120.054260mm                           | 0.0294mm       | 0.024%        | 99.9%                                             |
| Bearing seat 2   | 120.014821mm                | 120.048221mm                           | 0.0334mm       | 0.027%        | 99.8%                                             |
| Bearing 2        | 120.062833mm                | 120.039251mm                           | 0.0236mm       | 0.019%        | 99.8%                                             |
| Bearing seat 3   | 120.067398mm                | 120.073102mm                           | 0.0057mm       | 0.004%        | 99.9%                                             |
| Bearing 3        | 120.051579mm                | 120.040997mm                           | 0.0106mm       | 0.008%        | 99.9%                                             |

It can be seen from the above table that the diameter value obtained by using the algorithm fitting is very close to the diameter value measured by the actual point cloud data. The feasibility of using least square method to process point cloud data is fully explained, and the accuracy of intelligent selection algorithm is ensured by using fitting results.

3.3 Grouping
The intelligent algorithm based on (3), formula (4) and probability-equilibrium grouping principle can automatically calculate the specific grouping number each group width and other data, and compare with the results of unused grouping technology, the specific comparison results are shown in Table 4.
Table 4 Comparison of effects before and after using grouping techniques

| Design coordination | Tolerance Demotion and Deviation Type | Limit deviation of bearing seat | Bearing limit deviation | Packet width | Matching tolerance | Eligibility | Equivalent Standard Tolerance Classes | Effect of tolerance grade improvement after grouping |
|---------------------|--------------------------------------|--------------------------------|-------------------------|--------------|-------------------|------------|----------------------------------------|--------------------------------------------------|
|                     | Φ120H7/k6                            | H7                              | K6                      | H7/k6        |                   |            | Bearing IT 6 and bearing seat IT 7    | Increase by 3 levels                               |
|                     | Upper deviation                      | 0.035                           | 0.025                   | 0.032        |                   |            |                                        |                                                   |
|                     | Lower deviation                      | 0                               | 0.003                   | -0.025       |                   |            |                                        |                                                   |
|                     | Φ120H8/k8                            | H8                              | K8                      | H8/k8        |                   |            | Bearing and bearing seat are IT8      |                                                   |
|                     | Upper deviation                      | 0.054                           | 0.054                   | 0.054        |                   |            |                                        |                                                   |
|                     | Lower deviation                      | 0                               | 0                       | -0.054       |                   |            |                                        |                                                   |
| Group tolerance after soften-standardization | 1                                  | Upper deviation              | 0.0087                   | 0.0087       | 0.0087            | Qualified IT3–IT4 | Increase by 3 levels                           |                                                   |
|                     | Lower deviation                      | 0                               | 0                       | -0.0087      |                   |            |                                        |                                                   |
|                     | 2                                  | Upper deviation              | 0.0150                   | 0.0150       | 0.0063            | Qualified IT3–IT4 | Increase by 3 levels                           |                                                   |
|                     | Lower deviation                      | 0.0087                          | 0.0087                  | -0.0063      |                   |            |                                        |                                                   |
|                     | 3                                  | Upper deviation              | 0.0233                   | 0.0233       | 0.0084            | Qualified IT3–IT4 | Increase by 3 levels                           |                                                   |
|                     | Lower deviation                      | 0.0121                          | 0.0121                  | -0.0084      |                   |            |                                        |                                                   |
|                     | 4                                  | Upper deviation              | 0.0317                   | 0.0317       | 0.0084            | Qualified IT3–IT4 | Increase by 3 levels                           |                                                   |
|                     | Lower deviation                      | 0.0233                          | 0.0233                  | -0.0084      |                   |            |                                        |                                                   |
|                     | 5                                  | Upper deviation              | 0.0383                   | 0.0383       | 0.0066            | Qualified IT3–IT4 | Increase by 3 levels                           |                                                   |
|                     | Lower deviation                      | 0.0317                          | 0.0317                  | -0.0066      |                   |            |                                        |                                                   |
|                     | 6                                  | Upper deviation              | 0.0418                   | 0.0418       | 0.0035            | Qualified IT1–IT2 | Increase by 5 levels                           |                                                   |
|                     | Lower deviation                      | 0.0383                          | 0.0383                  | -0.0035      |                   |            |                                        |                                                   |
|                     | 7                                  | Upper deviation              | 0.0476                   | 0.0476       | 0.0057            | Qualified IT2–IT3 | Increase by 4 levels                           |                                                   |
|                     | Lower deviation                      | 0.0418                          | 0.0418                  | -0.0057      |                   |            |                                        |                                                   |
|                     | 8                                  | Upper deviation              | 0.0540                   | 0.0540       | 0.0064            | Qualified IT3–IT4 | Increase by 3 levels                           |                                                   |
|                     | Lower deviation                      | 0.0476                          | 0.0476                  | -0.0064      |                   |            |                                        |                                                   |

Through the analysis table 5, we can see that the matching tolerance of the bearing and the bearing seat after grouping is greatly reduced compared with that of the ungrouped. The minimum matching tolerance between bearing and bearing seat is -0.0035mm~0.0035mm, and the maximum matching tolerance is -0.0087mm~0.0087mm, tolerance grade of is generally optimized by 3-5 levels, and the assembly accuracy of grouping after Soften-standardization and group processing is greatly improved.
3.4 Selection of counterparts

The matching algorithm designed according to formula (5) is used to automatically select the parts in the database. The selection results are shown in Table 5.

Table 5 Intelligent Selection Results

| Bearing number | Bearing seat number | Fit gap       |
|----------------|---------------------|---------------|
| 1              | 23                  | -0.000201876mm|
| 1              | 75                  | 0.000118659mm |
| 1              | 149                 | 0.000133585mm |
| 1              | 258                 | 0.000129877mm |
| 1              | 343                 | 0.000139696mm |
| 2              | 103                 | -0.000141488mm|
| 2              | 175                 | -0.000419045mm|
| 2              | 226                 | -0.000952833mm|
| 2              | 235                 | -0.000492062mm|
| 2              | 341                 | -0.000237458mm|
| 50             | 11                  | -0.000157303mm|
| 50             | 37                  | 0.000115623mm |
| 50             | 38                  | -0.000440492mm|
| 50             | 60                  | -0.000300614mm|
| 50             | 496                 | 0.000113429mm |

It can be seen from the above table that for each bearing, 5 bearings can be automatically selected to match them, and the uniformity of the matching clearance has been greatly improved. It can be seen that compared with the traditional manual selection, cloud technology and computer-aided selection not only have great advantages in the selection efficiency, but also do not change the existing factors of production. The unqualified rate of bearing and bearing seat can approach zero in theory, and its economic effect is obvious.

3.5 Cloud Collaborative Manufacturing

The following steps can be used in the cloud coordination manufacturing of bearing assemblies: (1) after the production of bearings and bearings is completed, laser marking technology is used to generate unique coded QR code identification on bearings and bearings, scanning QR codes can access the cloud server to obtain all production data for that particular bearing or bearing seat; (2) using advanced non-contact laser 3D morphology scanning technology, 3D point cloud data is collected for a specific matching surface of bearing and bearing seat with unique coding, and the collected point cloud data is uploaded to the cloud server; (3) Intelligent virtual assembly of existing stock bearing and bearing seat data stored on cloud servers is carried out by the production plant of bearing assembly to find out the bearing code and bearing seat code of the optimal pairing; (4) delivery of the optimal pairing bearing and bearing seat to the assembly station as required through intelligent solid warehouse and intelligent distribution system; (5) assembly worker or flexible assembly robot to complete the assembly of the best paired bearing and bearing seat to obtain the best quality bearing assembly.

It can be seen from the above that the cloud collaborative manufacturing model can use big data and Internet technology to organize all kinds of manufacturing resources of manufacturers according to the expected manufacturing model to form a manufacturing cloud and publish them on the cloud manufacturing service platform. Provide personalized customization services for users. With the combination of soften-standardization theory and cloud manufacturing, with the support of cloud computing power, the market demand can respond quickly, so that manufacturers can better control production according to market demand. At the same time, cloud manufacturing can fully mobilize the manufacturing resources of various regions. This manufacturing model can provide high added value.
for manufacturing products, reduce manufacturing costs and provide global manufacturing services under the environment of large network manufacturing resources caused by extensive application of information technology [8].

4. Conclusions
The feasibility of this technology in mass production is preliminarily verified through the experiments and simulation experiments of the softly standardized cloud co-manufacturing of the bearing assembly:

1) Compared with the traditional production mode, the soften-standardization treatment can achieve lower direct processing cost without changing the processing conditions and processes of the parts. At the same time, the assembly accuracy grade and the uniformity of assembly quality are greatly improved.

2) The use of cloud collaborative manufacturing mode, through the design of reasonable intelligent algorithms, and relying on the powerful computing power of cloud computing, it is possible to select parts across regions and factories in the traditional mode. Thus, the overall waste rate and economic benefit of supply chain enterprises are reduced.

In addition, the results of this experiment provide theoretical basis and data support for the next research of softly standardized cloud cooperative manufacturing technology, that is, the shape and position tolerance fitting can be used.

To obtain the best assembly angle between bearing and bearing seat, this provides a new research direction for intelligent flexible assembly of bearing assembly.

Acknowledgments
The research work of this paper is in the team, under the guidance of teachers by teachers in the team members work together to complete the task group of rich professional knowledge of keen academic insight active the academic thinking of the rigorous academic style and deep original ideas, to complete the study gave us a big help, thanks for team hard work!

Sincerely thank Guilin university of technology for our team to complete the study provide the working environment and experiment conditions, thanks to the Guangdong Huazhong university of science and technology, industrial technology research institute to provide data support to this study, thank in this article reprint and reference literature research thought and the owners of the vision, but also in spite of being very busy to glance take time to review this paper professors experts express our heartfelt thanks! Finally, sincere thanks to all concerned.

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