Online detection of part size based on laser contour scanner

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Abstract: In aerospace die manufacturing, the processing quality of the processed workpiece is an important guarantee for the quality of the final product. Traditional detection methods have high labor intensity and low efficiency. Visual detection can only detect width, not depth information. Based on this, this paper proposes a non-contact laser scanning point cloud processing quality online detection method, through the laser contour scanner to obtain the actual machining parts of the surface point cloud information, and then in the Geomagic Control environment of the actual manufacturing parts point cloud information and SolidWorks theoretical design model comparison analysis. Thus, the manufacturing error of the actual manufacturing parts can be obtained, which provides a fast and accurate judgment method for the quality control of the product manufacturing.

1. Introduction

With the development of precision and intelligence of modern manufacturing industry, it is very necessary to realize the automation of testing process in the final acceptance stage of manufacturing process or products. At present, in the process of aerospace mold processing and manufacturing, most enterprises still use traditional detection means, such as plug gauge, caliper, gauge, which not only has a large amount of labor, but also cannot guarantee the stability of the detection accuracy, and the process is complex and the efficiency is low. The detection accuracy is directly related to the skilled degree of workers \cite{1}. Other detection methods, such as machine vision detection technology \cite{2}, although improving detection efficiency, cannot detect the depth information of concave surface features such as...
holes. CMM has high detection accuracy, but it is limited by the size and space of CMM platform, so it cannot meet the technical requirements of online detection. However, the research of 3D scanning technology in foreign developed countries has formed a new industry of a certain scale, and its products have reached a high level in precision, speed and operability. Especially in the measurement of aviation components, taking the German Zeiss as an example, even for complex aviation components such as integral blades, the four-axis scanning technology based on the Zeiss high-precision air floating turntable system (RT-AB) can ensure the highest four-axis measurement performance in the industry in the same category, and the detection time of integral blades can be reduced by more than 66%. Advanced aeronautical metering software suite Curve, Simulation and Blade Pro meets diversified metering requirements of single Blade, Blade root, impeller and overall Blade disc [3]. In recent years, domestic academic circles have also carried out corresponding research on 3D information acquisition theory and related technologies, and further mastered the basic principles of various foreign 3D scanners. However, most of the domestic work is limited to academic research or sample stage, and the application in production is not much. Therefore, the development of measurement core technology is of great significance.

Aiming at the measurement requirements in the manufacturing process or the final product acceptance stage, this paper proposes an on-line measurement method of machining quality based on laser contour scanner. By using the laser contour scanner to obtain the three-dimensional geometric point cloud information on the surface of the actual machined-manufactured parts, the surface was reconstructed in the Geomagic Control environment and compared with the original theoretical design model of SolidWorks, so as to obtain the deviation degree of the actual machined-manufactured parts' geometric dimensions relative to the design index. In order to judge the qualified or not of the actual manufactured parts, the deviation degree information is further used as the parameter basis of the second correction.

2. Acquisition of test pilot clouds
The laser scanner device radiates laser rays to the surface of the measured object, and the sensor receives the reflected rays. The triangular geometric relationship among the three is used to calculate the depth information of the target [4]. The measurement method of the laser contour scanner is used to collect the surface data of the actual manufactured parts. According to the measurement range and measurement accuracy requirements, the SconControl LLT 2700-25 laser contour scanner of Miridium Company was selected. The measurement range and basic technical performance parameters are shown in Fig. 1 and Table 1 respectively. By integrating the laser contour scanner on the three-dimensional moving platform, the laser contour scanner moves relative to the manufacturing parts, and the three-dimensional moving platform drives the laser contour scanner to collect data according to the planned path and the corresponding trigger frequency, so as to complete the original data collection on the surface of the tested workpiece.
Table 1  Basic performance parameters of laser contour scanner

| Type                                      | LLT2700-25   |
|-------------------------------------------|--------------|
| The width measured by the Z axis          | 25mm         |
| The starting point of the z-axis range    | 90mm         |
| The end of the z-axis range               | 115mm        |
| The starting point of the Z-axis extended range | 85mm     |
| The end point of the Z-axis extended range| 125mm        |
| The length of the scan line in the X direction | 25mm     |
| The resolution in the X direction         | 640 points/Scan line |
| Linearity                                 | ±0.2% FSO    |
| Sweep frequency                           | 100Hz        |
| Working temperature                       | 0-50°C       |

3. Construction of comparative models

3.1. Test Model
As the original point cloud reflecting the features of parts is directly obtained by the laser contour scanner, the amount of point cloud data is huge, up to hundreds of thousands or millions of levels [5]. At the same time, due to the measurement environment and other factors, the point cloud is mixed with noise points [6]. Therefore, it is necessary to pre-process the original point cloud before quality inspection, including deleting noise points (miscellany points), point cloud simplification, point cloud splicing and other operations, so as to obtain intact point cloud data.

3.1.1. Deletion of noise points
The redundant points can be automatically selected and deleted by hand selection or by using commands such as "non-connected items" and "out-of-body solitary points".

3.1.2. Simplification of point clouds
By simplifying the point cloud data, the detection process is accelerated while maintaining accuracy.
3.1.3. Splicing of point clouds
When the scanning equipment cannot scan the whole part at one time, the parts can be divided into several areas for scanning by pasting identification points on the parts, and then the public identification points can combine them into a complete part point cloud data in the later stage.

3.1.4. Feature creation
This feature refers to an object, such as a point, a line, a circle, a slot, a plane, a ball, a cylinder, a cone, etc., which exists or is invented by the model. Features can be created on the reference model and the test model respectively or when the test data is relatively complete, or corresponding features can be automatically created on the test object through the features already created on the reference object to provide reference for the subsequent alignment, size analysis and comparison operations. As shown in Figure 2, the point cloud test model on the upper surface of a rough workpiece after pre-processing is collected.

![Figure 2](image)

Figure 2 The point cloud model of the test after the actual artifacts are preprocessed

3.2. Model to be referenced
The reference objects for subsequent comparison and analysis were completed in CAD design software such as SolidWorks. The theoretical surface reference model is 3D designed in SolidWorks, and the drawing is saved as IGES format, as shown in Figure 3.

![Figure 3](image)

Figure 3 Theoretical Design Surface Reference Model
The default point cloud model is the test model, and the CAD theoretical model is the reference model for subsequent comparative analysis.

4. Error comparison and analysis

4.1. Alignment of models
Before the comparison and analysis between the preprocessed point cloud model and the SolidWorks theoretical model, it is necessary to unify the two into the same coordinate system through coordinate transformation, so as to put them together as much as possible. The deviation size of the comparison model can be seen through comparison. The following four common alignment methods are provided in Geomagic Control.

4.1.1. Alignment of features
Alignment is performed by defining a series of features such as points, lines, circles, slots, planes, spheres, cylinders, cones, and so on, and then matching the test object to the reference object based on these features. This alignment method is suitable for the model with regular shape and obvious features, or for the case that the alignment accuracy of some part is high and the deviation of the alignment part is small. In addition, according to the actual situation, a certain feature can be established in a certain part, and then the matching model can be constrained by feature alignment, so as to ensure the alignment accuracy of the model in this region.
4.1.2. Optimal fit alignment
The principle of optimal fit alignment is based on the participation of all selected points in the calculation to minimize its overall deviation. Optimal fit alignment is suitable for parts with free-form surfaces that are often difficult to create benchmarks or features. The alignment process is usually divided into two stages: coarse alignment and precise alignment. In the coarse alignment stage, a certain number of arbitrary points are selected from the point cloud data to carry out repeated iterative matching with the CAD model to reduce the rotation and displacement misalignment between the point clouds [5]. Second, the precise alignment phase, by selecting more points of cloud, to further improve the quality of alignment.

4.1.3. RPS alignment
This alignment is usually required to create reference coordinates. The flexibility of alignment can be further improved by creating features such as point targets and straight line targets that constrain the specified direction of a feature to simulate the real environment of the site. For example, to simulate the constraint characteristics of a fixture in the specified direction, so that the detection in this environment is more consistent with the actual manual detection, so it is often used for the alignment of product detection on the production line.

4.1.4. The 3-2-1 alignment
The 3-2-1 alignment is done by redirecting the test object so that the three planes of the test object match the three planes of the reference object by creating X, Y, and Z planes on the test object and the reference object, respectively. The characteristic of this method is that when the model has three or more intersecting or vertical planes, the model can be fully constrained and aligned quickly. On the other hand, 3-2-1 alignment ensures the alignment effect of the selected three planes, but sacrifices the alignment accuracy of other parts of the tested object, which tends to cause "one-sided" deviation phenomenon. Moreover, if the error of the selected three plane data itself is relatively large, it will affect the overall alignment accuracy of the tested object.

Through the analysis of the characteristics of the above model comparison method, the CAD reference model in this paper has more than three intersecting or vertical planes, so the 3-2-1 alignment method is adopted, which can quickly and completely constrain the alignment of the model. The alignment process is shown in Figure 4, and the error model after alignment is shown in Figure 5.

![Figure 4 The"3-2-1 alignment" process of the error](image1)
![Figure 5 Error model after alignment](image2)

4.2. Three-dimensional analysis
Three-dimensional analysis is the three-dimensional analysis of parts. By directly comparing the aligned test object with the reference object, the result object is generated and presented in the form of three-dimensional color deviation diagram to reflect the errors of all parts of the whole part. The precreated features or datum can be used for 3D dimensional marking on CAD reference objects. Nine geometric tolerances can be defined, including flatness, cylindricity, plane profile, line profile, position, verticality, parallelism, inclination, and total runout, to control the shape and position of a given geometric element. Since the main purpose of this paper in the process of three-dimensional analysis is to calculate the normal deviation between the actual test model of point cloud and the CAD reference model in the direction of Z-axis coordinates. The positions of target points can be defined according to requirements, so as to obtain the normal deviations of the actual test model of point cloud at each target...
point and the CAD reference model in the direction of Z-axis coordinates, which can be further used as the criterion parameters of the actual machining quality. The 3D analysis results are shown in Figure 6.

Figure 6 Comparison results of the 3D model of the test and the reference object after adding annotations

4.3. Two-dimensional analysis

Two-dimensional analysis refers to the further analysis of the deviation detection information at each point of the section from the two-dimensional plane by intercepting the required section of the part. Comparing the two-dimensional cross-sections corresponding to the defined test object and the reference object, and showing the deviation between the two sections in the form of a beard diagram, as shown in Fig. 7, is the deviation detection information at the position of the corresponding test point between the test object and the reference object at the symmetric cross-section of the blank.

Figure 7 Comparison results of two-dimensional deviations between the test and the reference object

5. Conclusion

In this paper, an online machining quality detection method based on non-contact laser contour scanner is introduced. By comparing and analyzing the surface point cloud information of the actual
manufactured parts in the environment of Geomagic Control with the theoretical design model of SolidWorks, the manufacturing error data of the actual manufactured parts are obtained. It provides a quick and accurate judgment basis for the quality control of product manufacturing. The experimental results show that this method has the advantages of convenient operation, high efficiency and intuitive and understandable deviation results. It can be applied to aviation parts docking, aviation engine blade automatic grinding and other engineering practices, and has achieved good economic benefits in practical application.

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