Centre-drilling Optimization of Rotational Parts Using Reverse Engineering Techniques

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Abstract:- Reverse Engineering has often been used for the purpose of reproducing products or redesigning products from others that already exist. Scanning techniques are commonly used to check a real product's geometric deviations versus a digital model. In this paper it is used a rotating 3D laser scanner to generate a point cloud representing a scanned rotational semi-finished part. Points from cloud will determine the optimal rotation axis of the part via a software tool named AXCEN and conceived by the authors.

Key Words: Reverse Engineering, point cloud, 3D scanner, innovative design, axis recognition, centre-drilling

1 Introduction

Reverse Engineering is the process of obtaining a new product from an existing product without having the original documentation data [1]. This concept has been met in the Japanese industry to face competition and avoid the consumption of resources for a traditional design. Due to the growing importance of Reverse Engineering in the industry, it has appeared in many projects in this field. Like this paper, most of them are studies of clouds of points [5].

Reverse Engineering can be used not only to copy but also to redesign processes or products.

The most extensive documentation is in computer programming, where Reverse Engineering is used to study the source code of competitors and retrieve functions from them [7].

Reverse Engineering technical areas that are used include: industrial, art, medical, entertainment, architecture, and many other fields [2, 4].

In such cases the geometrical shapes of solid objects are digitized using special devices. Digital models are generated which are modified to produce new objects.

Reverse Engineering would have not been developed if the computer would have not been implemented into industrial design [6].

2 Method of determining the semi-finished product axis of revolution

The presented method shows how the axis of a semi-finished product is determined, and how the centring holes will be drilled. Because of deviations on the blank shape, the axis alignment obtained by this method has large deviations from the ideal axis, thus resulting in loss of material, large variations of cutting forces, and great wear of cutting tools.

This paper presents a method for determining the optimal axis position of semi-finished rotational parts necessary for centre-drilling holes.

The method involves using a geometric data acquisition device (a 3D scanner), a software system for processing and cleaning the point clouds, which is able to export files with points coordinates from the cloud, and a program, written by the authors, to calculate the rotational axis of a part.

2.1 Technical solution

When the axis of the semi-finished product is determined, the diameter is measured at the two ends of the part; the centre of this circle is calculated. Then it is divided by twice the diameter, obtaining the axis end points.

Due to dimensional deviations of the semi-finished product form, it is necessary to remove material from the workpiece.

The turned workpiece diameter will be the difference between the semi-finished product diameter and double of biggest deviation.

For increasing accuracy of the rotational axis location, the part is scanned and the point coordinates from the piece surface are measured.

Doing this will determine the deviations from the ideal cylinder by mathematical methods.

When there is a deformation of the workpiece inward, the axis will be moved in the opposite direction of deformation and filler material removed will be reduced from the initial version. This is shown in figure 1.

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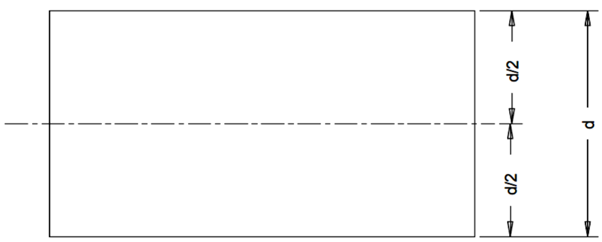
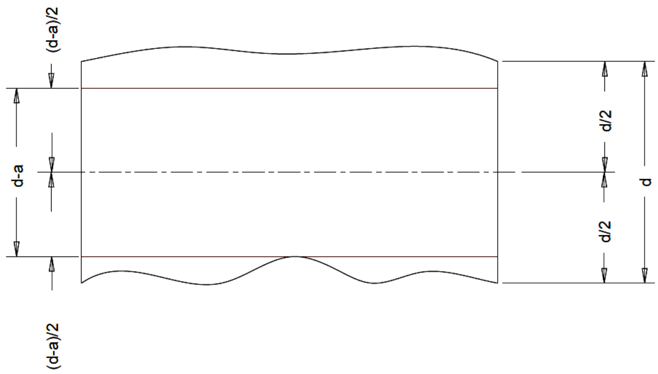
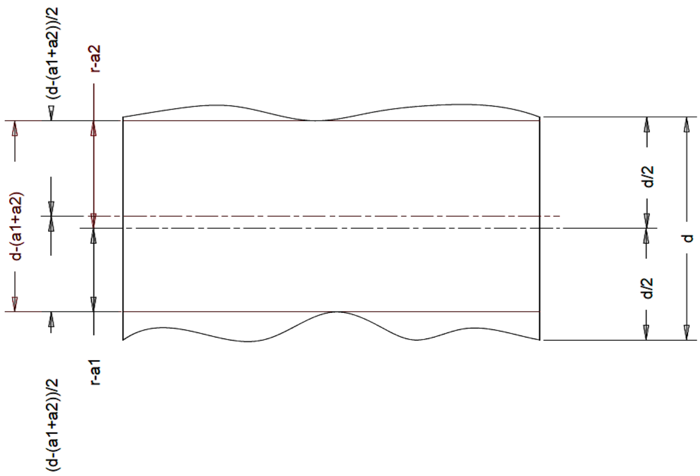


a) Ideal method



b) Classic method



c) Optimal method

Fig. 1 Position of the rotational axis

2.2 The algorithm for axis computing and its implementation

The least squares method is well known, and it can be used to determine the axis [3]. The disadvantage of this method is a low accuracy if the points are arranged in parallel planes.

Rotating scan was used to obtain a high-speed data acquisition.

The part is marked in 4 points (2 for one end and 2 for the other), positioned on the rotating platform with first point marked as starting point of scan and scanning is performed by collecting points in parallel planes.

To implement the method, a program named AXCEN was developed in Visual Basic using text files as input data containing coordinates of points.

The algorithm for the program involves steps that are outlined in the following.

Step 1: Calculate the centre point of the piece by averaging the coordinates of all points from the cloud.

Step 2: Calculate the minimum distance between the centre of the scanned piece and all surface points with the formula (1)

(1)

where: a is the centre point and b is a point on the surface.

Step 3: The centre part is recalculated according to formula (2) where i is an increment, x_c, y_c, and z_c are the coordinates of the centre x_p, y_p, z_p are the coordinates of point on the surface part where the distance d calculated above is minimal.

(2)

Step 4: By adding an error of accuracy at this distance, are located the points in the scanned surfaces imposed by the precision error. A sphere within a rotation surface, tangent to it into at least two points creates a circle at the intersection of the sphere with the surface.

Step 5: The point coordinates near the circle are saved in an array for performing subsequent calculations. These points represent the perpendicular section to the axis of rotation.

Step 6: The distance from a point belonging to all other points in section are calculated by section formula (1).

The maximum distance and the coordinates of the points which were calculated are inserted in a matrix. Then the middle point of segment between the coordinates of these points is calculated by averaging the coordinates of them. Coordinates of middle points of segments are inserted in a matrix.

Step 7: Step 6 is repeated for all points belonging to the section, and are computed to the average of middle point's coordinates of the segments. This result represents the centre of the section.

Step 8: Calculate the coordinates of the point located midway between the first point scanned and the centre of the section point computed at step 7. The coordinates of this point will be used to generate the second point through the axis. It will consider this point like a center point and repeat steps 2 through 7, using this as a starting point.

Step 9: Along the entire axis maximum is measured the deviation to the inside track by formula (1), and the axis will be translated in the opposite direction by

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increments of one. The smaller increment, the better precision will be achieved, but at a lower speed. The procedure is repeated up to the point which determines the maximum deviation is changed. This procedure is repeated for a user-defined number of times to increase the accuracy.

Step 10: The distance from the axis to the marked points are calculated.

Step 11: With the intersection between the arcs of a circle with radius calculated in the previous step and the points marked, the drilling points on the real piece are determined.

In order to highlight the result, the algorithm retains two distinct points on the axis, which are exported in a CAD software system such as ProEngineer, Catia, SolidWorks, etc.

2.3 Stages of method implementation

Steps to be taken to determine the body axis of revolution and centre points are:

1. The starting point for scanning is marked;
2. The semi-finished part is scanned;
3. Point cloud is cleaned by noise points using a dedicated software (eg Dr. Picza, PixForm, Rapidform)
4. AXCEN determines the revolution axis of the scanned part.
5. The centre-drilling points are determined to be the intersection between the axis and the front surface of the part.

3. Case Study

To illustrate the method presented in this paper, a part of cylindrical shape was chosen and it is presented in figure 2. This was chosen with large deviations for observing the difference between the axis through the heads centre points measured and the axis determined by the method.

Fig. 2 The part for axis computing

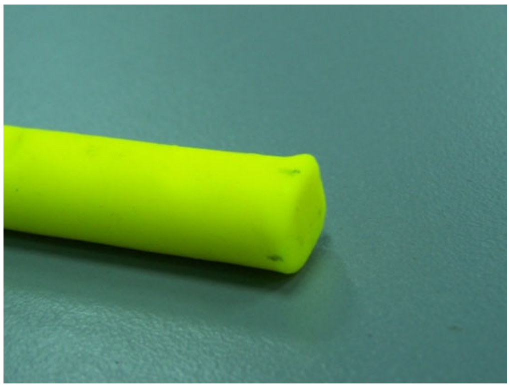

Fig. 3 The marks on the part

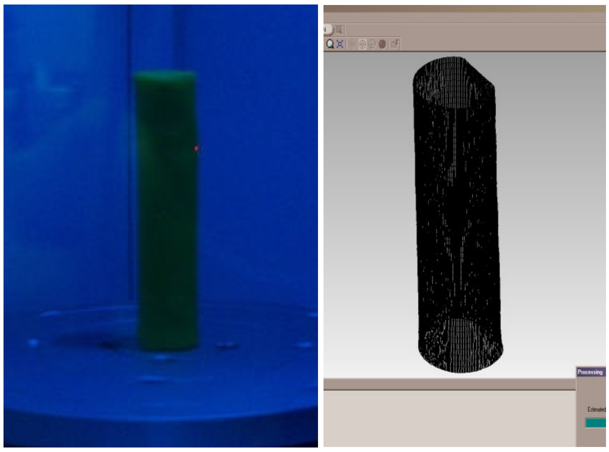

Fig. 4 Scanning process

In figure 3 it shows marking the starting point and using a fixed angle, the marking of the second point.

The part taken in the studio was digitized with PICZA-LPX-1200 3D machine (figure 4).

PICZA device LPX-1200 3D scanner uses a non-contact measuring method. It has a laser beam for capturing the form of a solid part. The part is placed on a rotating platform. The platform rotates and the assembly laser beam transmitter and sensor moves vertically [7].

After the scanning operation, the point cloud is obtained. It is then cleaned of noise points with Dr. Picza specialized software.

Figure 5 presents an area before and after removal of noise points.

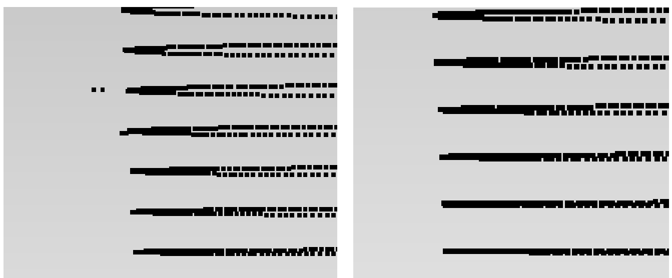

Fig. 5 The points cloud cleaning

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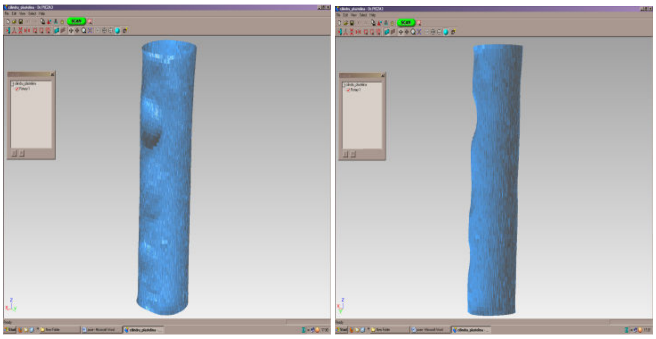

Fig. 6 The scanned part (Dr. Picza)

Digital model of the scanned part (figure 6) is now ready to be exported into a text file in order to calculate its axis.

AXCEN software tool calculates distances from marked points to the axis and the intersection of two arcs centred on marked points with radius determined by AXCEN, the centring-drill points are determined at the two ends of the piece.

The results were imported into ProEngineer environment to see the differences between the classical method of determining the axis and the method proposed in this paper.

In Figure 7 is marked with 1 the semi-finished surface, with 2 rotational surface improved and with 3 surface obtained by the classical method.

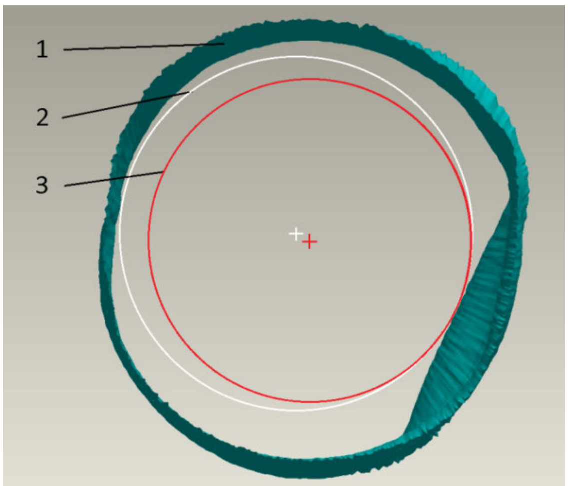

Fig. 7 Difference between methods

Table 1

	semifinish	Classic method piece	Optimized method piece
Volum:mm^3	11545,2	6767,7	8112,1
Axial deviation:mm	-	0	0,537
Diameter:mm	~14,8	11,6	12,7
Lost volum:mm^3	-	4777,5	3433,1
Lost volum:%	-	41	29

Table 1 shows the difference between proposed method and the classic one.

In this case of study the material loss was 12% reduced, therefore a tool consumption and processing time was decreased by 29,3%.

The obtained surface quality is increased by reducing vibration and shock during processing due to better centre-drilling operation.

4. Conclusion

The methodology for determining the axis of revolution in order to centre-drilling parts thereof, presented in this paper, lead to lower added material from turning, reducing vibration during processing, reducing cutting forces, increase sustainability, reducing the cutting tools wear. This methodology is suitable to be applied in the case of forged partially finished parts, where dimensional deviations are very high. The time for determining the axis does not increase. Unlike the usual methods, traditional measurement tools are not required.

Future research direction will be focused on generating maximum profile that can be obtained from a partially finished part and then comparing it with the final product.

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