

# Research on Reverse Reconstruction Technology of Drive Screws

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**Abstract.** Reverse innovation design has always been an important topic in the field of engineering. The purpose of this paper is to solve problems in drive screws caused by their complex structure, demand for high shape accuracy and long cycles of design optimization. The reverse modeling technology, the Win 3D scanner and Geomagic Wrap are employed to collect the point cloud data of the drive screw, wrap them into a curved surface, and import them into the reverse engineering software Geomagic Design X to create its highly accurate 3D digital model. In this way, high precision guarantee can be provided for the optimal design of the drive screw, thereby shortening the innovation cycle and laying a technical foundation for the improvement of transmission performance. According to the error analysis software Geomagic Control, the error in the inverse model of the drive screw does not exceed 0.02 mm, which meets the industry's needs. This model can be used for digital production, and can also provide high-precision model support for secondary innovation, which is of great significance for shortening the product design cycle and enhancing the competitiveness of the enterprise.

**Keywords:** reverse innovation design, 3D scanner, digital model.

## 1. Introduction

A transmission is an important component for molding development, and the transmission accuracy of screws in injection molding would directly affect the transmission performance [1, 2]. However, screws in injection molding are not conducive to forward innovation design given their complex structure, time-consuming and labor-intensive optimization design and low efficiency. In recent years, substantial progress has been made in the domestic machinery industry as it has been continuously integrating computer technology in the industrial field and gradually shifted its main mechanical design process from traditional forward design to reverse design [3]. Reverse design is a process of re-innovating the existing model by translating it into a digital model using scanning. It is characterized by low research and development costs and short design cycles, and has unique advantages especially for complex parts. Now it has been widely used in the optimization and innovative design of aircraft, automobiles, electrical appliances, motorcycles and other products [4], as well as the repair of related parts. Reverse design has gradually evolved into an important means of digesting and absorbing advanced technologies [5, 6]. In this paper, the reconstruction technology of the drive screw will be explored to provide technical support for improving the overall performance of the transmission.

## 2. The Basic Process of Reverse Design

Reverse engineering is a professional technique for translating physical objects into digital models. It is an important means of recreating new product designs, especially for irregular parts. Therefore, it has developed rapidly in recent years [7]. The reverse design process is shown in Figure 1. This methodology has combined the advantages of forward and backward design. As a new modeling method, it can effectively solve the difficulty in modeling special-shaped structural parts.

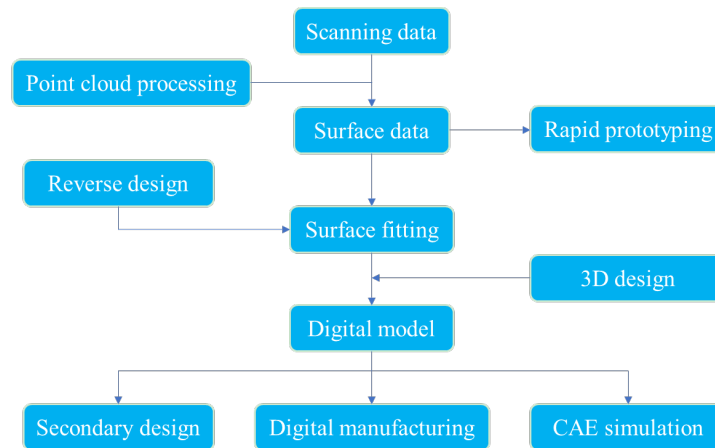


Figure 1. A Basic flowchart of reverse design.

### 3. Reverse Design of the Drive Screw

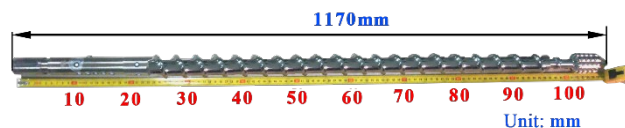


Figure 2. Drive Screw.

#### 3.1 Research subject and equipment

The drive screw is the key component of the transmission system (Fig. 2). It is used to transmit displacement. Higher shape-accuracy of the screw is helpful to boost the performance of the whole transmission system. In this paper, a drive screw is taken as the research subject and the reverse design technology is adopted to create a highly accurate digital model, which can guarantee the optimal design of the model and shorten its optimization cycle. The main software and hardware devices used in this process are Win3D laser scanner, Geomagic Wrap software for point cloud processing, and Geomagic Design X for reverse modeling.

#### 3.2 Reverse modeling method

##### 3.2.1 General idea. First

Collect point clouds on the surface of the drive screw using a laser scanner; perform segmented scans since the length of the screw exceeds the working range of the laser scanner, and then cluster the acquired point clouds. Second, edit the point cloud data, and use an appropriate algorithm for the synthesis of a smooth surface. Finally, fit the surface to get a high-precision three-dimensional model of the drive screw.

##### 3.2.2 Scanning Preparation

The laser scanner is the main equipment for collecting point clouds. It uses the grating phase-shift measurement technology to project the fringes onto the surface of the screw, and the grating modulates the amplitude and phase of the fringes. The modulated fringe signals are collected by the computer to obtain point clouds of the screw surface. Win3D scanner is used and it meets the accuracy requirements of the drive screw, with a scanning range of 600 mm, a single scan of less than 3 seconds, and a scanning error of less than 0.03 mm, as shown in Figure 3. For the operation process, the first step is to start Win3D scanner and Geomagic Wrap, and click the “Scan, Calibration Switch” button in Geomagic Wrap to enter the calibration interface. Then adjust the brightness of the scanner through adjusting parameters such as exposure, gain, and contrast in “Adjust Camera Parameters” to help achieve high-quality imaging. By adjusting the height and pitch angle of Win3D scanner, make the

coordinate systems represented by the black and white crosses coincide as much as possible. In this way, the accuracy of the scanner is calibrated.

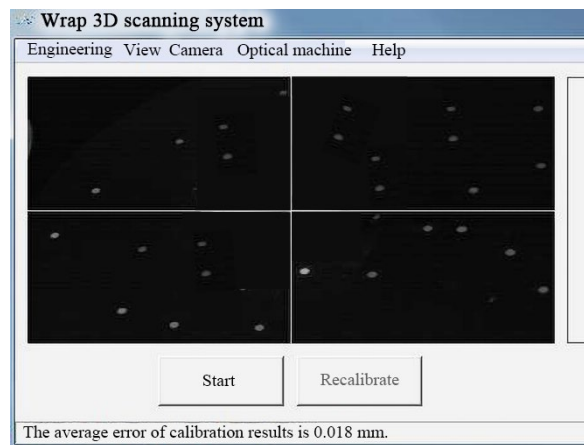


Figure 3. Accuracy calibration of Win3D scanner.

### 3.2.3 Point cloud data collection.

Point cloud data collection is the process of acquiring point cloud data from the surface of the object to be tested with the help of a laser scanner. The integrity, accuracy and smoothness of the point cloud will affect the accuracy of reverse engineering in model reconstruction. In this project, Win3D laser scanner used is easy to operate and highly accurate. The scanning scene is shown in Figure 4. After installation and adjustment, put the drive screw model on which a developer is sprayed evenly on the calibration slice. Perform segmented scans and splicing since the length of the screw exceeds the scanning range of the laser scanner in order to obtain point cloud data with high accuracy and excellent integrity.

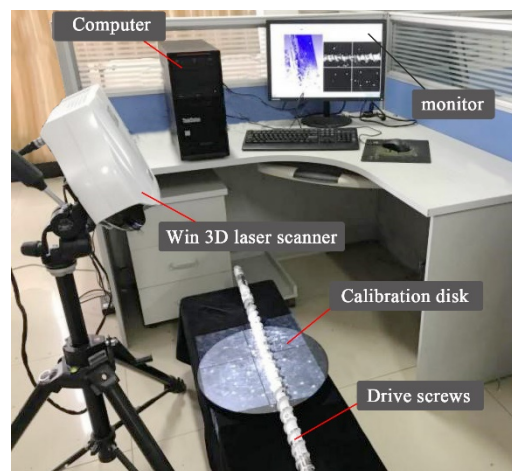


Figure 4. The scene where drive screw point clouds were scanned.

### 3.2.4 Point cloud processing.

After collecting the point clouds of the drive screw, it must be optimized to provide high-quality data for reverse modeling. The process flow is shown in Figure 5. First, remove noise from each segment of the drive screw, get the segmented point clouds, splice them in turn to obtain the overall point clouds of the drive screw, and wrap them to form a corresponding surface file. In order to obtain a high-precision reverse model, it is necessary to do surface repair on the point cloud surface of the screw, including hole patching and surface smoothing. In this way, a smooth model of the drive screw slice is created. Save it in \*.stl format and import it into Geomagic Design X for parametric reverse modeling.

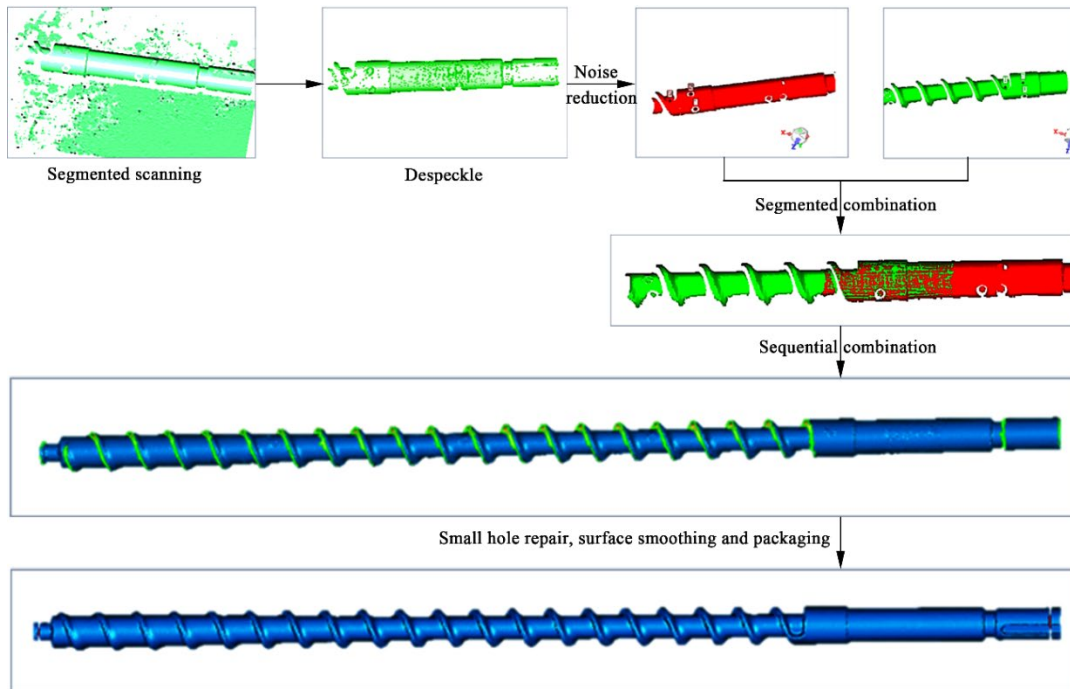
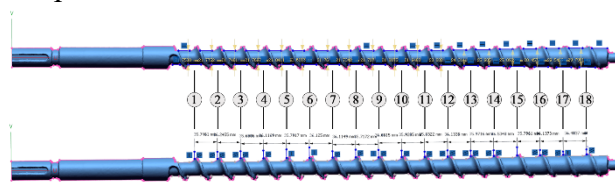


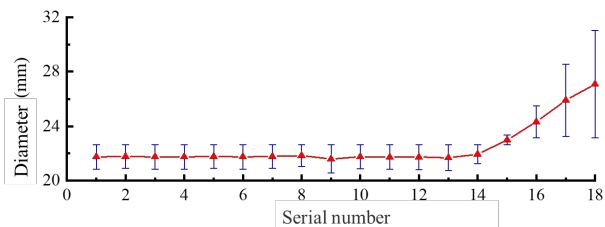
Figure 5. The process flow diagram of the point clouds of the drive screw.

### 3.2.5 Reverse modeling and error analysis

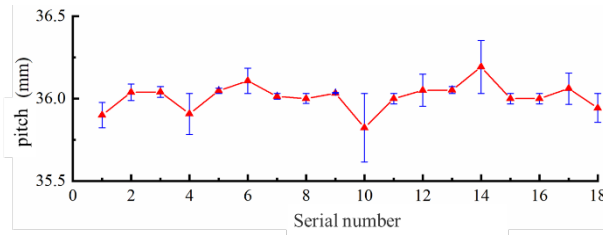
After importing the drive screw slice in the \*.stl file format into Geomagic Design X, in accordance with the structure of the injection screw, the screw body model is built first, followed by the screw thread structure model, and finally reverse engineering is done based on the Boolean combinations of the two. Accordingly, the body diameter and pitch distribution of the screw need to be analyzed using the operating method shown in Figure 6a. According to the structure of the screw, the slice file is divided into 18 segments, and the diameter and pitch are measured in segments. The measurement results are demonstrated in Figures 6b and 6c. It can be seen from Figure 6b that the diameters of the first 14 segments of the screw are evenly distributed, with an average value of 21.76 mm; the diameters of the 14-18 segments increase linearly, with a growth rate of 1.29. Figure 6c shows that the average screw pitch is 35.99 mm, and the coefficient of variation is 0.76%.



a. A schematic diagram of drive screw diameter-pitch positions measured



b. Drive screw diameters measured



c. Drive screw pitches measured

Figure 6. Diameter-pitch measured in the point cloud data of the drive screw

As per the measurement results, following the steps in Figure 7, the screw body is drawn in Geomagic Design X, the screw thread features are drawn in the 3D modeling software NX12, and imported into Geomagic Design X for Boolean operations with the screw body to obtain the 3D digital model of the drive screw.

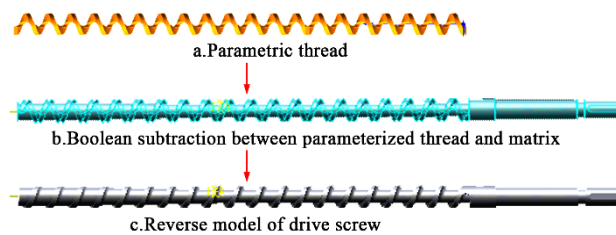
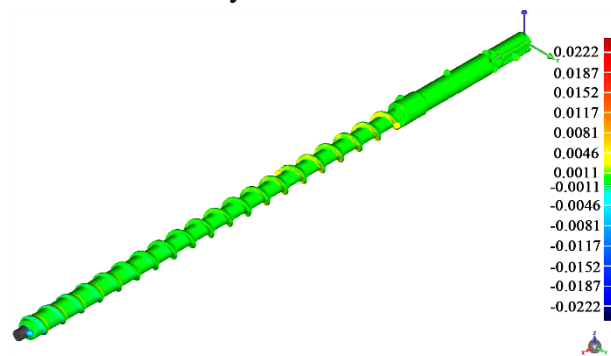
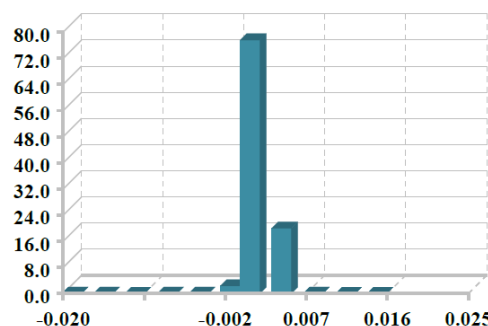


Figure 7. Parametric modeling of the drive screw

After the reverse modeling process completes, an error check should be run. A model is acceptable for use only when the errors are within the allowable range. The error analysis software Geomagic Control is used to test the reverse model of the drive screw, as shown in Figure 8. The measured error is less than 0.02 mm, and 96% of the error ranges between -0.0011 and 0.0011 mm. Hence, the reverse model has high accuracy and meets engineering needs. It can be used as a three-dimensional model of the screw for digital optimization design and manufacturing, and is of great significance to the research of improving transmission accuracy.



a. Cloud diagram of the errors of the drive screw body



b. Percentage of error distribution of the drive screw body

Figure 8. Error analysis diagram of the drive screw body

## 4. Results and Discussion

### 4.1 Reverse modeling

Reverse modeling is a new modeling method. The general process of reverse modeling is to collect point clouds of the measured object using a laser scanner, and process the point clouds to get a corresponding slice model. Afterwards, the reverse modeling software is used to fit the surface model to get a corresponding parametric model. This method is efficient, much faster than the traditional forward modeling method, and can enormously shorten the product design cycle. Moreover, it has important value in the restoration of cultural relics and human bones.

### 4.2 Drive screw and reverse design

A drive screw is the key component of the transmission system and would directly affect the transmission accuracy. Improving the accuracy of the screw is of great significance for improving the performance of the transmission system. Most of the previous studies used the forward design method to improve the transmission accuracy of the screw and achieved exceptional results. However, forward design has high investment costs, low efficiency and long design cycles. In this paper, the reverse design method can be used to design the structure of the injection screw with high precision, and then the forward optimization can be carried out, which can achieve a multiplier effect.

## 5. Conclusion

A drive screw is a high-precision part in the transmission system and can exert a direct influence on the transmission performance. In order to increase the accuracy of the screw, reverse engineering is accomplished in this paper and a digital model of the screw is obtained with errors of less than 0.02 mm. This model meets the engineering needs and can be used for the digital manufacturing of the screw. It can also provide high-precision model support for optimal design. Meanwhile, this reverse design method can resolve the difficulty in modeling and optimization design of special-shaped parts, and has remarkable characteristics like higher efficiency, lower design cost and shorter innovation cycles. In addition, it can help promote the restoration of cultural relics and human bones.

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