RESEARCH ON THE MODEL ANALYSIS METHOD OF REMANUFACTURING-ROUGHCAST BASED ON REVERSE ENGINEERING

Shen Canduo, Zhu Sheng, Li Chao
Remanufacturing Technology Committee of CAPE, Beijing 100072, China
e-mail: shencanduo@126.com
Zhang Haiyu, Yuan Zhijie
No.2 Subsidiary Construction Company, China Petroleum Pipeline Bureau, Xuzhou 221008, China

Abstract

The paper purposes to realize the accurate measurement and the quantificational estimation of remanufacturing-roughcasts, whose shape and configuration are usually complicated and ambiguous. Referencing the model analysis theory in reverse engineering, a new method is put forward. Furthermore, the key techniques involved are emphatically demonstrated, which mainly including the digital measurement of remanufacturing-roughcasts, point cloud pre-processing, three dimensional models registration and compare, remanufacturing-model visible analysis and so on.

Keywords: remanufacturing, reverse engineering, digital modelling, visible analysis

1 Introduction

Remanufacturing for disused parts is the process of restoring their nominal shape and upgrading their quality and properties. With more and more attentions to the computer aided technologies (such as CAD, CAE, CAM), the traditional method of design and manufacture, which relies on experience and mistake-excluding, is now tending towards the modern advanced domain that relies on information [1, 2]. Accordingly, for realizing modern remanufacturing it is the first precondition that the measurement and the estimation of remanufacturing-roughcast, which are mostly the parts that have been subjected to wear, corrosion, chipping off or breaking out on surface, and so whose shape and configuration are usually ambiguous before remanufacturing. Therefore, research on quantification, accuracy and visibility of this course is very significantly.

Viewing in the production's model reconstruction, reverse engineering can be limited defined as a general denomination of the integration of computer aided technologies, digital measurement technologies and model reconstruction technologies involved in the transition from product prototype to digital model [3]. Referencing above theory, this paper puts forward a new model analysis method of remanufacturing-roughcast based on reverse engineering, which also thorough considers the characteristics in total course of remanufacturing for the sake of better guidance in practical work. As follows, the basic principle and the steps of this method are particular introduced, and the key problems involved are emphatically demonstrated.

2 Basic principle and steps

The basic principle of this new method is that, firstly obtaining the digital model of remanufacturing-roughcast through digital measurement and data pre-treatment; then it is registering and comparing with the CAD model of standard part, so that the remanufacturing model can be extracted; and also the visualization of error map and the displaying of remanufacturing model makes the part integrality analysing easily; finally all these are helpful for remanufacturing process in practice. In details, the basic steps can be described as follows:

1) Building the CAD model of standard part. Here are three cases: (a) if only dimension is known, the gradate design method can be used; (b) if standard part exists, the reverse engineering is exclusively introduced; (c) if only remanufacturing-roughcast exists, going to step 2) and then rebuilding the standard model through the features deduced from the intact positions.

2) Obtaining the digital model of remanufacturing-roughcast via reverse engineering. In this course, it is mainly including: (a) the surface digital measurement of injured part; (b) point cloud pre-treatment.

3) Extracting the remanufacturing model. It is achieved by registering and comparing of 3D models: the digital model of remanufacturing-roughcast and the CAD model of standard part are firstly match-aligning in the same reference frame; then the values of everywhere error on two models' surface are computed; lastly, the errors' values and corresponding positions are extracting as remanufacturing model.

4) Analysing the remanufacturing model. Respectively in the form of multicolour map and 3D (three-dimensional) solid, the errors' values and the remanufacturing model could be shown in screen or printed on paper. And so, it is realized that the visible analysis and the man-machine mutual estimation of remanufacturing-roughcast.

3 Key techniques

3.1 Digital measurement of remanufacturing roughcast

3.1.1 Digital measurement device

According to whether the device is contact or not with the object measured, digital measurement devices are divided into contact type and no-contact type. Now, the common using digital devices in reverse engineering are CMM (coordinates measurement machine), laser digital scanner and industrial CT [4, 5]. Different device has its strong point due to various working principle. When selecting measurement device, some factors must be comprehensive considered, such as the size and the shape of remanufacturing-roughcast, the precision and so on.

In the paper, the instances of remanufacturing-roughcasts are torsion shaft, taper gear and etc, and the digital measurement device adopts the equipment of "Robot + Scanner + Position-adjuster" designed by national key laboratory for remanufacturing. Scanner namely Lu050 3D laser scanner produced by Lumenera Company, whose scan precision is 0.048mm and depth of field 30.0mm; robot is used grasping scanner and moving together to extend scan area, which is ABB IRB2400/16 robot, having 6 freedom degrees and in a certain pose its repeat precision is 0.06mm; position-adjuster is a part fixer set, whose carrying capacity is 9800N and repeat precision is 0.1mm (where R＝250mm).

3.1.2 Work before measurement

Before using the measurement device to obtain data, there are many actual problems must be solved [5].

1) Calibration and precision. All measurement techniques must be calibrated. For this equipment of "Robot + Scanner + Position-adjuster", calibration consists of interior calibration and external calibration. Interior calibration indicates to define the laser scanner nonlinear transformation from object to image, which is the key to obtaining 3D coordinates of object measured and directly determined the measure precision; external calibration means to clarify the mutual relationships of scanner, robot and position-adjuster, the motion error in scan path can also bring the reduction of measure precision.

2) Scanning area location. Before measuring, the shape of roughcast, characteristic parameters of selected device, measure accessibility and etc must be fully considered for locating the area needs to be scanned. Besides injured places, scanning area contains also aptly intact positions, lightness injured zones or regions with basic features (such as: plane, cylinder or sphere). The point clouds of those areas can apply in multi-view jointing and models register ensuring the estimation accuracy.

3) Surface treatment. Before scanning, well-cleaned surface of remanufacturing-roughcasts can avoid data distortion and attain a better scanning result. Sometimes, white lacquer or photographic developer needs sprayed equably on the surface.

4) Scanning mode planning. According to the structural features of parts, scanning modes can be accepted in rotated mode or plane mode, automatic mode or manual mode, and so on. E.g., the partition mode employs the approach of scanning smaller area every time and joint together as finally result, which can reduce absolute error; multi-orientations mode is good answer to the shielding problem aroused by complexity shape.

3.1.3 Measuring process

1) Instance 1 of remanufacturing-roughcast. A worn torsion shaft, whose radius is 30mm, is shown as figure 1. Severity worn occurred on column surface near the head.

(a) Scanning area: worn surface, partial intact column surface and terminal face. Intact column surface is used for fitting cylinder, and terminal face for plane. They are helpful for models' registration.

(b) Scanning mode: plane mode is adopted in measuring terminal face, and rotated mode for column surface. Because the shaft length is longer, partition scanning approach is carried on at twice. Finally acquired data are shown as figure 2, figure 3 and figure 4.

Fig. 1: worn torsion shaft

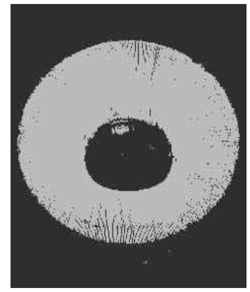


Fig. 2: terminal face data

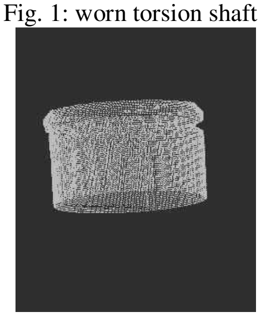


Fig. 3: surface data 1

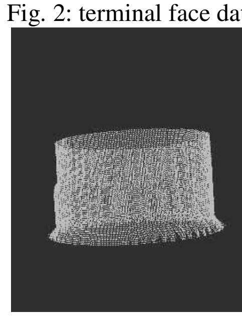


Fig. 4: surface data 2

2) Instance 2 of remanufacturing-roughcast. It's a disused taper gear as figure 5 shown. Many of teeth are damaged on tooth bearings.

(a) Scanning area: besides of damaged tooth bearings, back surface of taper and end face should also be scanned, which are foundations of point cloud jointing, fitting and registration.

(b) Scanning mode: scanning end face adopts plane mode; and apparently taper gear is a revolving body, so rotated mode can achieve both back surface scanning and tooth bearings scanning. The figure 6 shows the result of rotated mode and it is obvious that the data in tooth root is not entirety since the shielding problem. Scanning again in another orientation can recover the missing data. As figure 7 shown, there are four sections point cloud, which can well-recover the missing data of figure 6.

Fig. 5: disused taper gear

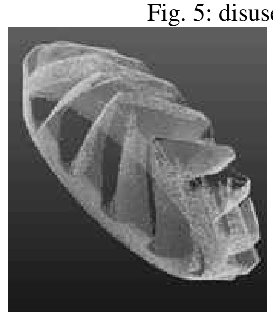


Fig. 6: taper gear data

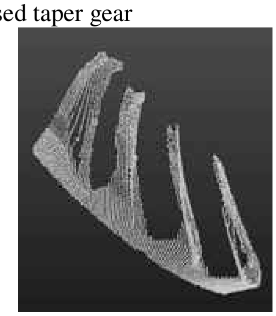


Fig. 7: tooth root data

3.2 Point cloud pre-processing

The data captured by the laser scanner names “point cloud” because of its huge number. Aim of point cloud pre-processing is to acquire satisfying data, which mainly through data filtering, data reduction, data jointing and data partition. All those techniques must be associated and developed with the feature of remanufacturing.

3.2.1 Data filtering

Data filtering, also namely smooth filtering is used for removing or reducing the errors and noise points. As for the point cloud of remanufacturing-roughcast, filtering should be executed aiming on the area data, but not the whole cloud. After achieving the features recognition and partition of point cloud, areas with basic features would do data filtering, which can improve the accuracy.

3.2.2 Data reduction

The density of point cloud is so high that it is needed to reduce the data quantity. In conditions of keep the shape features of roughcast and guarantee the registration accuracy, data reduction is to delete unnecessary points as more as possible. It is a good method that, setting the density of point cloud in intact area smaller but in injured area larger, and some ambiguous area should be treated as injured area.

3.2.3 Data jointing

Data jointing is a process to gather many independent point clouds together in the same reference frame, relief the overlap sections of two measurement data and gain the integrity data of measured surface. Figure 8 is the jointing result of three measure data of torsion shaft.

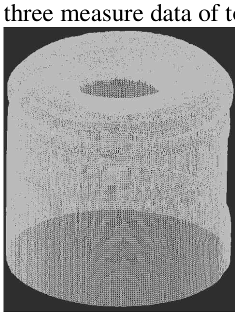
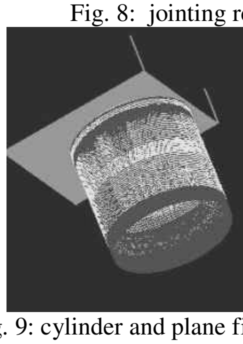


Fig. 8: jointing result of torsion shaft



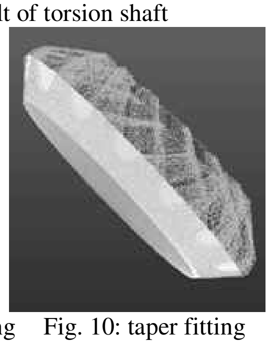


Fig. 9: cylinder and plane fitting   Fig. 10: taper fitting

3.2.4 Features recognition and partition

As the discussions above, there are usually some sections of point cloud with basic features existing. For the point cloud of remanufacturing-roughcast, features recognition and partition is mainly to differentiate those sections to fit the basic features for registration, such as plane, cylinder, taper and sphere. If those sections are very obvious, manual partition may be employed. As figure 9 shown, intact column surface and terminal face of torsion shaft are intercepted and used for fitting cylinder and plane respectively; similarly figure 10 denotes that, back surface of gear is separated and used fitting taper.

3.3 Registration of standard part model and remanufacturing-roughcast model

3.3.1 Registration when features exist

When the basic features are obvious for remanufacturing-roughcast, according to the characteristic and amount of features, there are two registration cases:
1) Correct features could sufficiently limit the freedom of point cloud. Feature registering method ensures accurate registration. The specific steps are:
(a) Point cloud pre-processing and create the registration features, see figure 9.
(b) Using step-by-step registering method. First aligning the central lines of standard column and fitted cylinder; then matching the flat surface of standard model with the fitted plane. The finally result is shown as figure 11.
2) Correct features can be founded, but they can’t limit the freedom of point cloud. Restrict and best registration is feasible, in which the registration of basic features is priority and the best registration sequentially.

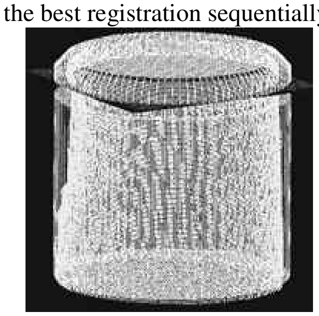
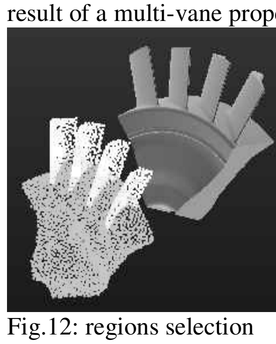


Fig. 11: feature registering result of torsion shaft

3.3.2 Registration when no features exist

If the part model belongs to free surface or the basic features is difficult to found, only the best registration should be used. The key problem is to select the regions of point cloud.
In remanufacturing-roughcast model, intact positions and lightness injured zones should be selected undoubtedly, and the best registration is oriented the points selected and the standard CAD model. When extensive surface is injured or severe deformation occurs, all of point cloud should be selected and used for best registration, here the calculated amount is large and algorithm is complex, but registration effect may be badly. Figure 12 and figure 13 displayed the regions selection and the best registration result of a multi-vane propeller.



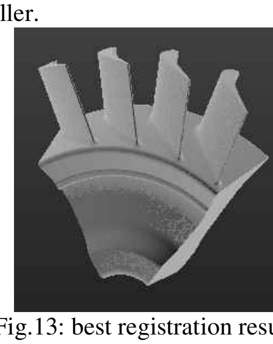


Fig.12: regions selection   Fig.13: best registration result

3.4 Remanufacturing model extracting and analysing

The principle of remanufacturing model extracting is that, computing everywhere distances from injured surface to standard model as the loss errors on remanufacturing-roughcast surface and then recording the error values and corresponding positions. Remanufacturing model can be provided as the digital information for remanufacturing technologies.

As a representation of loss errors, the multicolour map makes easily the intuitionist and exact analysis of each point, which realized quantification of remanufacturing-roughcast. Figure 14 shows the worn status of torsion shaft. Bottom section appears green colour, in which error is less than 0.2mm, meaning intact or lightness injured. Blue colour mostly distributes near the head, in which error is more than 3.0mm, denoting severity worn.

The multicolour map doesn't have the general standard, so 3D model is constructed by extracting the injured positions with loss error and hence to realize visibility of the remanufacturing model (see figure 15). Moreover, the volume and the weight of remanufacturing model can be computed in SOLIDWORK software. Given the material density is $0.0078 g/mm^3$, the result is table1.

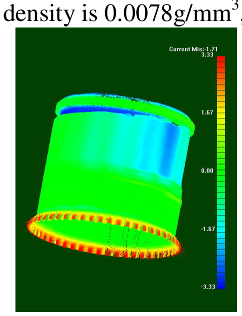


Fig.14: multicolour map

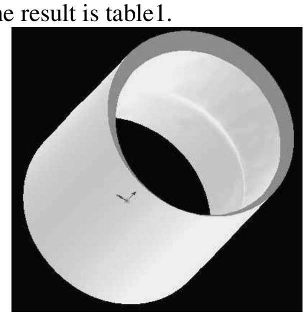


Fig.15: 3D model displaying

item	△X (mm)	△Y (mm)	△Z (mm)	volume (mm^3)	weight (g)
value	59.958	59.935	73.257	22251.464	173.562

Table1: computed result of torsion shaft remanufacturing

4 Conclusions and prospects

With the development of remanufacturing, research on the model analysis of remanufacturing-roughcast is now becoming a hotspot. Since remanufacturing-roughcast is complicated and ambiguous, the goals for measure and analysis are quantification, accuracy and visibility. The new method put forward in this paper, explores a feasible way for achieving those goals. Presently, there are some problems to be worth researched and developed. Such as: Which error factors existing in model building? What influences they introduced? How to control them? Also, considering the subsequently remanufacturing forming based on additional process, the dimensionality reduction technologies, lamination or bead-planning of the model, are contents needed farther studying.

Acknowledgements

These foundation supports are gratefully acknowledged:
National Natural Science Foundation of China (Project No. 50235030), National Basic Research Foundation of China (Project No. 413270403), Foundation of China Education Ministry.

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* shencanduo@126.com; phone: 86-10-66718477; Room 311, Department of Remanufacturing Engineering, Dujiakan 21th, Fengtai district, Beijing, China, 100072