Int J Adv Manuf Technol (2005) 26: 1284–1288
DOI 10.1007/s00170-004-2116-5

ORIGINAL ARTICLE

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Applications of 3D scanning and reverse engineering techniques for quality control of quick response products

Received: 2 October 2003 / Accepted: 27 January 2004 / Published online: 16 June 2004

Abstract Quick error comparisons of fabricated parts and an original CAD design is often a difficult yet important issue in product quality control. In this paper we present an integrated technique of 3D scanning with reverse engineering and rapid prototyping technologies. This will be applied to the entire quality control phase of quick response products during the manufacturing process. By using 3D scanning and reverse engineering technology in conjunction with rapid prototyping technology, the geometric data of components can be easily and rapidly measured and analyzed. The detailed report can be printed out directly to fulfill the requirement of total quality control for quick response products. The proposed technique is especially suitable for fragile or soft material made products, like thin shell or rubber parts. With its accuracy and ease of operation, this integrated method is able to help manufacturers improve their global competitiveness in the 21st century.

Keywords 3D scanning · Quality control · Rapid prototyping · Reverse engineering

1 Introduction

Recently, the fashion of outlook and profile design for new products has become more streamlined in shape, or arc shaped. It is a challenge for conventional manufacturing processes to fabricate such products quickly and cost-effectively. As the technology matures, reverse engineering (RE), rapid prototyping (RP) and rapid tooling (RT) draw a lot of attention from manufacturers. RE/RP/RT are also known as 3R technologies. 3R applications are likely to be extended into many other areas. The 3R technologies provide a means by which three-dimensional data can be captured in digital form from physical models or samples. It has obvious attributes in terms of shortening the design-to-market process and effective use in conjunction with other time-compression technologies, such as CAD/CAM/CAE [1, 4].

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Generally, the RTV (Room Temperature Volcano) silicone mould (see Fig. 1) is one of the most popular intermediate moulds to substitute mass production moulds. The RTV silicone mould is a quick way to fabricate engineering prototypes in a very short space of time. However, given the nature of the RTV, the mould can only make a limited quantity. The quality and strength of the parts produced is also highly limited by the materials used in this process.

In order to assure the dimensional accuracy of moulds or products, quick error comparisons of fabricated parts and an original CAD design is often a difficult yet important quality control issue in product manufacturing processes. In this paper we present an integrated technique of 3D laser scanning, RE and RP technologies for the entire quality control phase of quick response products during the manufacturing process. A powder type 3DP rapid prototyper (see Fig. 2), and non-contact laser 3D scanning machine with RE software (see Fig. 3) are employed in

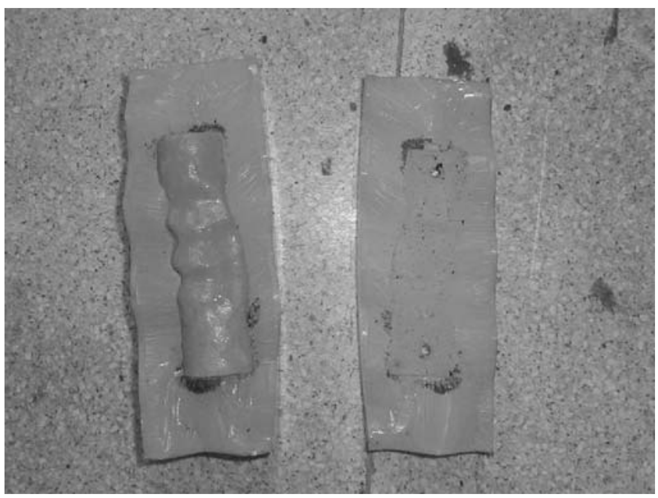

Fig. 1. RTV silicone mould and RP master pattern

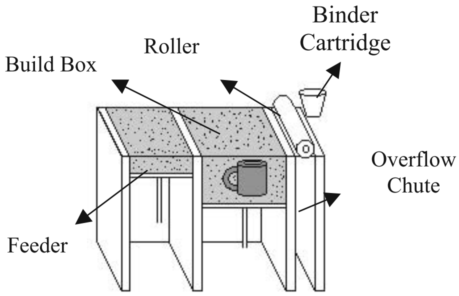

Fig. 2. 3DP powder based rapid fabricator

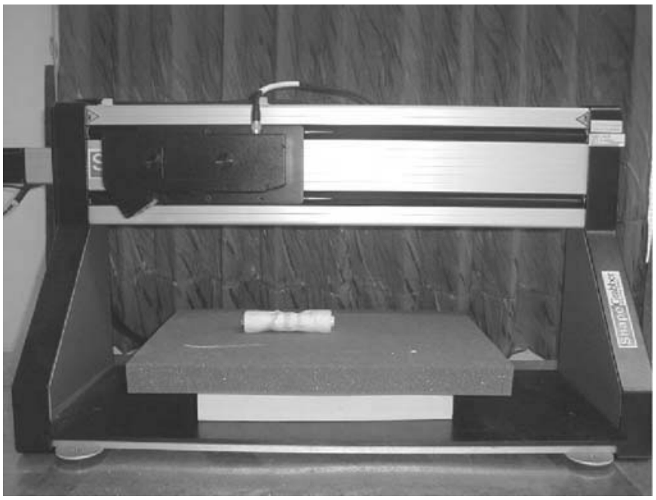

Fig. 3. Typical 3D non-contact laser scanner

this project. The proposed technique is able to provide a means by which the accuracy of fabricated parts can be examined and analyzed quickly. With the virtue of the 3D laser scanning system and RE software, the proposed method could be used during the entire quality control phase of the manufacturing process. This paper is organized as follows: Sect. 2 reviews the principles of 3D scanning and RE technology. Section 3 introduces RP technology. Section 4 presents the experimental setup. Section 5 contains the results of the experiment and a brief discussion of these results. Section 6 presents our conclusion for this study.

2 Reverse engineering

RE is a technique by using 3D scanning to capture three-dimensional data into digital form from physical models or samples quickly converting it into a computerized form [8]. It has obvious attributes in terms of shortening the design-to-market process and effective use in conjunction with other time-compression technologies and rapid replication process, such as CAD/CAM/CAE and RP/RT. There are two phases in the RE process: (1) Digitizing or measuring of a mechanical component, and (2) Three-dimensional modeling of the part from the digitized data. Once the surfaces have been derived from the digitized data, they are processed into a solid model. The solid model can be exported to CAD/CAM or into the STL file for RP systems. Once the file has been transferred to CAD/CAM or RP systems, the replica of the scanned model can be produced [2, 3, 5–7]. Typically, there are four steps in the reverse engineering process: (1) Data digitization, (2) Coordinates reconstruction, (3) Data point manipulation, and (4) Surface approximation.

2.1 Data digitization

The three-dimensional measuring machine (3D CMM) is the most commonly used digitizing system in the reverse engineering process. 3D CMM can be categorized into contact type and non-contact type by their measuring methods. Each has its own pros and cons for different applications.

The typical 3D CMM is a contact type. In the 3D CMM, the probe slightly touches the surface of the measured part during the scanning process. The 3D profile data in X-, Y-, and Z-directions of the parts are captured as long as the contact pressure is high enough to trigger the sensor to capture signals. Via the computing process, the 3D digitized data of the parts are then recorded for later. This is also known as a "point-to-point" 3D CMM system. The 3D CMM system is able to provide accurate measurements, but is time consuming and labor intensive.

Conversely, a non-contact 3D CMM captures 3D data of parts by band scanning of laser or LED photo sources and CCD camera. The most commonly used computing principle is the triangle measuring method. It has a fast scanning speed and is suitable for fragile parts.

2.2 Coordinates reconstruction

After the data parts have been digitized, these parts are processed into a model rebuild process. The first step is the reconstruction of the coordinates. Generally, the component needs to scan several regions in the scanning process. For each scan, each data file has its own coordinate system. During the stitching process, two files of data have to compute and transfer, to synthesize into a single coordinate system. The process of coordinate reconstruction is also a time consuming task, when doing data transformations by computer.

2.3 Data point manipulation

The pre-processing of measured data should include data point manipulation and characteristic line definition. Data point manipulation contains data point sorting, rearrangement, segmentation, reduction, smoothing, and exaction. This process can eliminate the noise of data measuring.

2.4 Surface approximation

Once the noise of digitized data has been removed, the next step is to derive the surface approximation. The surface approximation uses the digitized data as inputs, to derive the surface model