International Journal of Engineering & Technology
CENTRE OF PROFESSIONAL RESEARCH PUBLICATIONS
ISSN 2049-3444
International Journal of Engineering and Technology Volume 5 No. 9, September, 2015

Computer Aided Reverse Engineering and Rapid Prototyping of Motorcycle Rear Hub

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ABSTRACT

The paradigm shift to the modern means of manufacturing (Advanced Manufacturing Technology, AMT) and its impact to SME's especially in the production of automotive parts (Rear hub for motorcycle) using reverse engineering and Rapid Prototyping (RP) from rapid product development is the focus of this paper. The many advantages of lower risk failure as well as reduction of time-to-market as a result of shorter product life cycle are achievements in this work. The evolution of rapid prototyping technologies have become possible today to obtain parts representative of mass production within a very short time, these reverse engineered products (parts) are no doubt of standard quality and can fit to where similar parts are removed. This paper therefore covers the CAD modeling of CY 80 motorcycle rear hub using the generated dimension from Coordinate Measuring Machine (CMM) in Creo-element/Pro-e 5.0 and rapid prototyping of the hub. The work found out inability of using point cloud to create a 3D axis-symmetry model. This work recommended further addition of commands to enhance axisymmetric modeling in the coordinate measuring machine CAD software.

Keywords: *Computer Aided Manufacturing, Computer Aided Design, Rapid Product Development, Rapid Prototyping Technology, Rear Hub, Coordinate Measuring Machine (CMM).*

1. INTRODUCTION

Reverse engineering is the process of reproducing the geometry of an available physical object, systems, concepts and many more with additional innovations or direct copies. The Reverse Engineering method could either be manual or computer aided. In both cases, it requires extraction of information about geometry to develop the part drawing for duplication and manufacture [1].The manual method involves the use of measuring instruments like Vernier-caliper, micrometer screw gauge, radius gauge etc. The computer aided system can either be contact or non-contact method. The probe at the tip of a contact measurement device, such as a coordinate measurement machine (CMM), must make contact with the part surface to record the location of the surface points. The non-contact type usually employs laser beam or X-ray for scanning or measurement. Non-contact devices include optical, laser, Computed Tomography (CT), Magnetic Resonance Imaging (MRI), etc., usually work very well with freeform surfaces, e.g., biological parts.

Rapid Prototyping is a manufacturing process where a 3D physical model is fabricated directly from a Computer-Aided Design (CAD), in which the ideas of designers and engineers take a three dimension [2]. A big economical advantage is that products made by rapid prototyping express a low risk failure and the manufacturing process takes less time and lower costs than the conventional techniques [3].

Fused deposition modeling is the building of a product up in thin layers of thermoplastic wire-like filaments. The filaments of heated thermoplastic are extruded from a tip that moves in the X-Y plane. Several materials are available for the process including Acrylonitrile Butadiene Styrene (ABS) and investment casting wax. ABS offers good strength, and more recently polycarbonate and polysulfone materials have been introduced which extend the capabilities of the method further in terms of strength and temperature range. Support structures are fabricated for overhanging and are later removed by breaking them away from the object. The technique is used for assessing a product's final appearance and geometry, as well as for operation and functional part testing [4].

The integration of reverse engineering and rapid prototyping has shortened the product development cycle. It is used in building prototypes to check form, fit and to create durable net shape of finished product from CAD models [5]. One of the major steps in reverse engineering is recovering part geometry from the physical sample. The geometry recovering process consists of two steps, the scanning or measurement to capture the part geometry in discrete points, and converting points into useful surface forms. This work tends to find an alternative of producing 3D model from the generated dimension instead of the point cloud.

Computer-aided design is the use of computer technology for the design of objects, real or virtual. The design of geometric models for object shapes, in particular, is often called computer-aided geometric design (CAGD). However CAD often involves more than just shapes. It also involves simulation, and development of mathematical model for design. While computer-aided manufacturing (CAM) is the use of computer-based software tools that assist engineers and machinists in manufacturing or prototyping product components. Its primary purpose is to create a faster production process and components with more precise dimensions and material consistency, which in some cases, uses only the required amount of raw material (thus minimizing waste), while simultaneously reducing energy consumption. CAM is a programming tool that makes it possible to manufacture physical models using computer-aided design programs. CAM creates real life versions of components designed within a software package.

Integration of CAD and CAM environment requires an effective CAD data exchange. Usually it had been necessary to force the CAD operator to export the data in one of the common data formats, such as IGES or STL, that are supported by a wide variety of software [3].

Madenci and Guven stated the use of axisymmetry in analyzing rotating parts [6]. The use of symmetry analysis reduces model size, CPU time required for solution while delivering the same level of accuracy in the result.The physical system under consideration exhibits symmetry in geometry, material properties, and loading, and then it is computationally advantageous to model only a representative portion. If the symmetry observations are to be included in the model generation, the physical system must exhibit symmetry in all of the following:

• Geometry
• Material properties
• Loading
• Degree of freedom constraints

These were adequately taken care of in this work.

2. METHODOLOGY

The first step of RE methodology is to generate a 3D model. In this work, the 3D digitizing techniques aided by specialized software for model reconstruction and analysis was used.
The steps followed to achieve the work were:

i. Part Digitization: This is the process of acquiring point coordinates from part surfaces. A digitization method was achieved with the use of Coordinate Measuring Machine and AC- DMIS software.
ii. CAD modeling: IGES files of the point cloud data from CMM digitization were generated using AC-DMIS® software, geometric model was created using generated dimensions in Creo-Elements®.
iii. 3-D model was produced using Rapid prototyping machine.

A. Parts Digitization

Data points at the hub surface were taken using CMM and A.C DMIS software. Before the digitizing process, proper probe assembly and calibration of the layout machine is needed to be done to avoid system error. The CY80 motorcycle rear hub that was used as the reverse engineering component was studied first for proper selection of probe.

B. Probe Assembly Process

Ball stylus (single) widely used for every basic element measurement was employed in this work. There is a small ruby ball at the front end of stylus with utmost less form offset, which is applied to contact the work piece to be measured to obtain the accurate measuring point's coordinates

The selection of the styli and stylus kit should be based on the specific requirements of work piece measurement, and the main factors to be considered are the length of styli, effective measuring length, diameter of ruby ball, component and extensions, etc. No matter what the final selection of styli and its accessories is; it should not only meet the requirement of probe head load but also the application to practical measurement [7].
The probe assembly is generated from probe head till stylus configuration. Figure 2.1 shows the assembled probe.

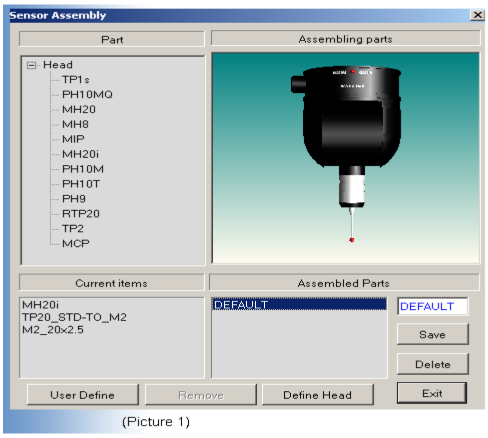


Figure 2.1 Assembled probe [6].

Probe Head Calibration

i. The name of assembled file which needed to be calibrated and selected was in the pull-down menu, "Rot stick will be read automatically according to the calibrated and assembled probe mode. A0B0 as shown in Figure 2.2 was used to collect a point on the polar of datum ball.

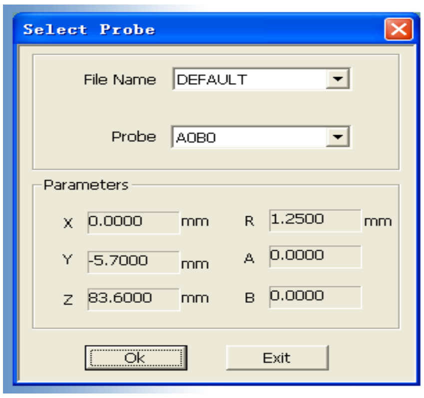


Figure 2.2 Select probe dialog box [6]

ii. The “start” button on figure 2.3 was clicked to commence the calibration. Ten points were collected on the datum ball with stylus angle of A0B0 (A=0, B=0) automatically. This step was repeated for angle A0B90 (A=0, B=90).

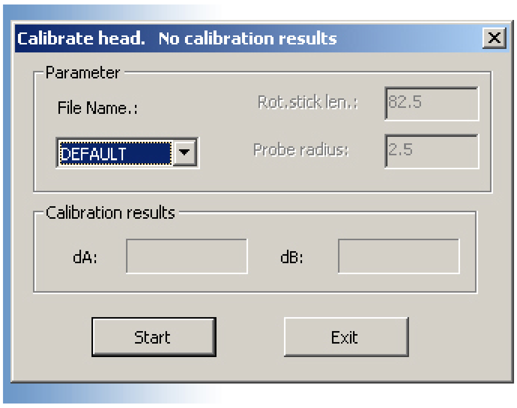


Figure 2.3 Calibrate head dialog box [6]

C. Measurement

The dimensions of hub were generated using the CMM joystick and AC-DMIS software interface Figure 2.4 and 2.5 show the process and the CAD is shown in Figure 2.6

Figure 2.4 Measurement set up on the hub

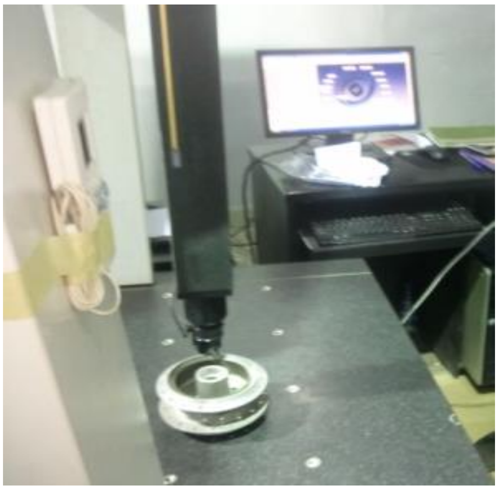


Figure Hub 2.5 Data acquisition using CMM

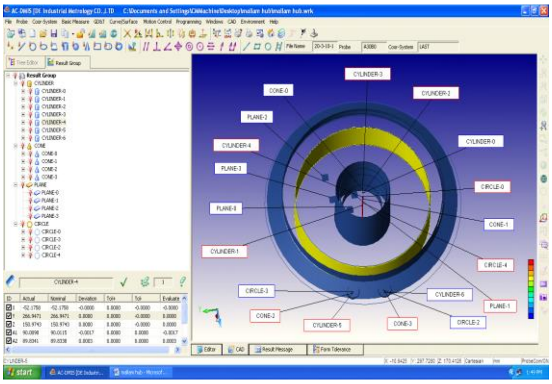


Figure 2.6 CAD Surface of the hub

D. CAD Modeling

Initial Graphics Exchange Specification (IGES) files of the point cloud data from CMM digitization were generated using Dimensional Measuring Interface Standard (AC- DMIS) software. Geometric model can be created using the extracted features (point Cloud) or generated dimension. In this study the generated dimensions were used to create the 3-D model using Creo-element®. This is because cyclic symmetry which will be used in the analysis and the 3D model must be created using revolve tool. The 3D solid model shown in Figure 2.7 was modeled using the dimensions generated by AC-DMIS software in Creo-element®. .

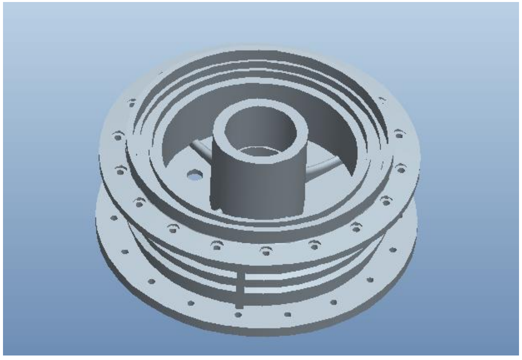


Figure 2.7 3D model of the hub

E. Rapid Prototyping

HTS is a high efficiency rapid prototyping system; it consists of gantry frame, platform movable along Y direction, worm extruder movable along direction X and Z, filament material feeding system, and control system. The extruder and the feeding system are driven by the same step motor. Once the external PC sends control signal, the worm is driven by the step motor; meanwhile, the plastic filament is fed into the extruding cylinder through a timing belt or gears and roller mechanism. Then the plastic filament is melted by a heating rod embedded in the brass nozzle and deposited on the platform. The external PC calculates the cross section data alone Z direction of 3D model of object and the deposition path for each cross section. The deposition path data is then transferred to control system; each layer is built by the resultant motion of platform and extruder.

After one layer is built, the extruder is raised a layer thickness (usually about 0.1~0.2 mm), the next layer is then build, the steps as above are repeated until the object is formed [7].

F. Pre-build process - CAD file conversion

HTS RP system only accepts stereo lithographic (STL) file [8]. All CAD files must be converted to STL format before use on HTS System. The CAD model (hub) was saved as STL file in Creo-element as shown in Figure 2.8.

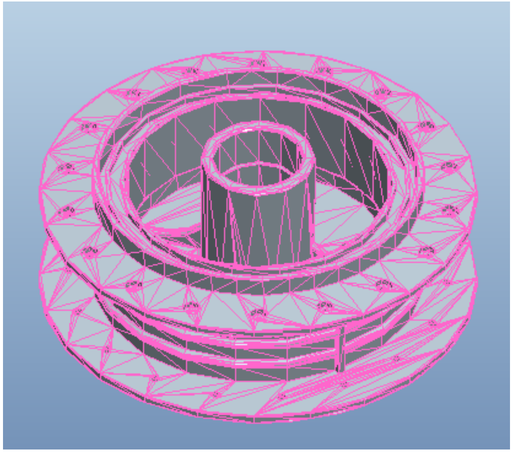


Figure 2.8 STL CAD of hub model

2.5.2 Parameter set up

Before producing the part, the machine was switched to the "ON" position, the nozzle temperature and chamber temperature (controller's temperature) were allowed to setup data (normally 10~15mins). The HTS software was run, and STL file opened. The parameters must be specified. This determines part position, use of support, layer thickness [7] Figure 2.11 shows the parameter used in this work. Since the hub has flanges support, it was generated automatically.

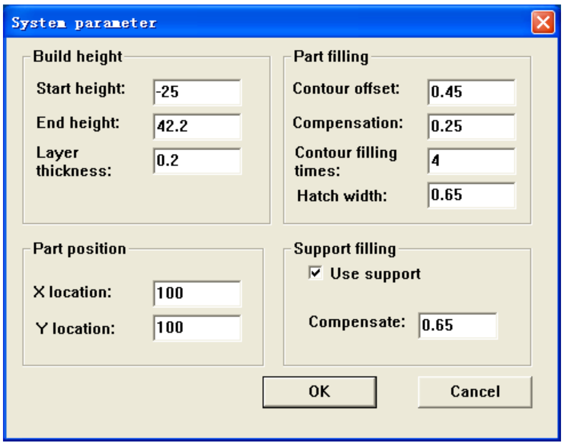


Figure 2.9 System parameter dialog [7]

G. Filling data

The filling data was generated with 468 layers; this would have taken 37.3 hours to build the prototype. The model was scaled by 0.8 which reduced the number of layers to 374 layers and building time to 20 hours.

H. Nozzle adjustment

The nozzle was moved to the X-Y center (140,125), and then along the Z direction 0.1mm that is the gap between the nozzle and pasteboard

I. **Building process**

The auto mode was used to run the system automatically from the menu bar. It took the machine twenty hours to complete building the model. Figure 2.10 shows the building process. In case of power failure the previous file was loaded and the machine continued from the last step. When the process was completed as shown in Figure 2.11, the model was removed from the paste board.

Figure 2.10 Finished Product of the hub

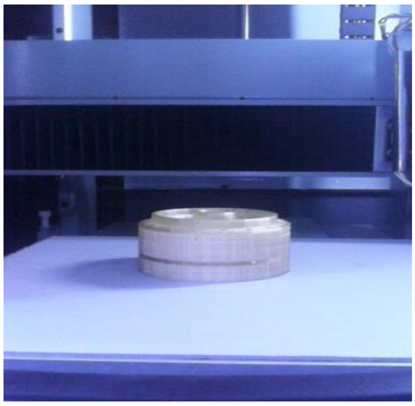
J. **Post Build Process**: This is the finishing process, which involved removing the supports and cleaning the model.

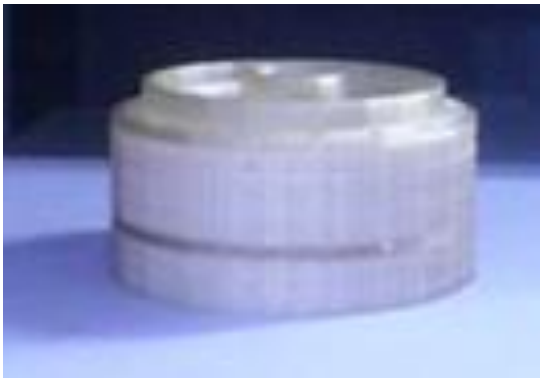
3. RESULT AND DISCUSSION

In reverse engineering using contact method for modeling a 3D axisymmetric model; the generated dimensions can be used instead of the point cloud to create a 3D model using Creo-element software. This is because revolve or axisymmetric tool being used to create the model is not available in coordinate measuring machine (CMM) and AC-DMIS standard basic measuring software package. Axisymmetry is important for analyzing rotating component, because it reduces analysis time and computer memory usage. Figure 3.1 shows the rapid prototyped brake hub from 3D CAD model. It will be observed that the surface is not smooth. This is due to the resolution of the STL file from the CAD model and is one of the draw backs of rapid prototyping using fused deposition method.

4. CONCLUSION

This work has presented reverse engineering using contact method to create a 3D model with the generated dimensions instead of the point cloud method and the use of axis-symmetry model in finite element analysis. It was shown that the use of axis-symmetry reduces simulation time as well as computer memory usage. CMM CAD software should incorporate tools for modeling axis-symmetry using point cloud.





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