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APPLICATION OF REVERSE ENGINEERING USING CMM FOR MANUFACTURING INTRICATE COMPONENT: A CASE STUDY

A. V. NICHAT[1], N. W. KALE[2], Dr. A. U. AWATE[2], M. R. DHARME[1]

1. Department of Mechanical Engineering, IBSS College of Engineering, University-Mardi Road Amravati.

2. Department of Mechanical Engineering, Prof. Ram Meghe Institute of Technology & research, Badnera Amravati.

Abstract

The aim of this study is to redesign a physical product which has been already manufactured. It is based on an integrated use of Point Cloud Data (PCD) achieved from 3D scans of model from Coordinate Measuring Machine (CMM). This method was found to be simpler and it assists in producing more accurate intricate component and thus more accurate CAD models in the reverse engineering of same parts. In order to obtain CAD model of the component to be applied in the supports design and measurement path, the Reverse Engineering which is the only technique allowing to copy faithfully and to reconstruct complex geometric entities. In this paper an attempt has been made to find out the dimensions of pre-existing splineshaft of gearbox using reverse engineering. Splineshaft is an essential component which establishes a power transmitting between the various gear assembly of gearbox. The geometric data of undertaken component has been obtained by using CMM. The 3D model of splineshaft has been created by using CATIA. The analysis of splineshaft has been performed at various loads ranging from minimum value to maximum value in order to study the behavior of splineshaft by using ANSYS. And the finally for computer aided manufacturing NC part programming is generated by using CATIA

INTRODUCTION

Engineering fields are constantly improving upon designs and methods to make life simple and easier. When referring to technology, simple and easier can be directly related to fast and accurate. Engineering is described as "the application of scientific and mathematical principles to practical ends such as the design, manufacture, and operation of efficient and economical structures, machines, processes, and systems". This type of engineering is more commonly known as Forward Engineering. An emerging engineering concept is utilizing forward engineering in a reverse way. This method is more commonly referred to as Reverse Engineering.

Reverse engineering is the opposite of forward engineering. It takes an existing product, and creates a CAD model, for modification or reproduction to the design aspect of the product. It can also be defined as the process or duplicating an existing component by capturing the components physical dimensions.

2. LITERATURE REVIEW

Bardell et al. (2003):- defined reverse engineering as systematic evaluation of a product with the purpose of replication which involves either direct copies or adding improvements to existing design. They have also proposed a method of automating the verification of an acceptable free-form surface, using coordinate measuring machine (CMM). Computer-aided geometric design (CAGD) is used to analyze the surface for optimum continuity and assess the CMM data accuracy.

Mohammad Shadab et. al. (2006):- presented the applications of the reverse engineering method on the modeling of Pillion step holder of Hero Honda CBZ Motor Bike. The CAD Model of Pillion step holder has been developed by CATIA V5 using the cloud data. The stress analysis of pillion step holder was also done. Results shows that the maximum stress at critical is within the permissible limit as compared to the strength of the material and the deflections in the component is much lesser than the permissible value. Again the stress

is performed on the modified CAD Model. It is found that the maximum stress and maximum deflection is still within the permissible limit. It also helps to understand the behavior of the CAD Model under various loading conditions and further help to modify it.

F. Belarifi et. al. (2008):- This paper propose a method to optimize the module of cutting conical spur gear, after being worn or broken, with the aid of Computer-Aided Design (CAD). It also allows creating a virtual model, by theoretical geometric characteristics, to calculate the volume. The suggested method allows determining the geometric features of a pair of conical spur gear after worn. A simulation package, R2000, was used and special "AutoCAD" software has been developed to accomplish the drawing of 2D wheel conical spur gear, the verification of the system assembly and the drawing of a 3D volume pattern.

A.R. Ismail et. al. (2009):- explained the modeling and machining of four stroke piston engine using Reverse engineering method. The process include digitizing process by using layout machine to capture

the point clouds and following by the Computer Aided Design (CAD) stage and Computer Aided Manufacturing (CAM) stage using Unigraphics NX2 software to reconstruct the piston engine surface. Then, machining process with Computer Numerical Control (CNC) machine is used to create the piston head engine. Finally, the accuracy of the replicated piston engine is checked by using Coordinate Measurement Machine (CMM) and block gauge.

Niranjan Singh et. al. (2012):- In this paper the methodology of Reverse Engineering has been employed to Brake Rod of Bajaj Pulsar 150cc Motor Bike. This paper describes the generation of 2D model of Brake Rod using photogrammetry technique, development of 3D solid model on SolidWorks and Autodesk Inventor, stresses are analysed at different loads. Finally the results of SolidWorks have been compared with the results of Autodesk Inventor. [1]

To avoid the wastage of time if possible the manufacturing information is obtained itself from the manufacturer. In order to reverse engineer a product or a component of a

system, engineers & researchers generally follow the following four stage process:-

- Identifying the product or component to be reverse engineered.

- Observing or disassembling the information documenting how the original product works.

- Implementing the technical data generated by reverse engineering in replica or modified version of the original.

- Creating the new product.

In the first stage in the process, sometimes called "prescreening," reverse engineers determine the candidate product for their project. Potential candidates for such a project include singular items, parts, components, units, subassemblies, some of which may contain many smaller parts sold as a single entity.

The second stage, disassembly of the original product, is the most time-consuming aspect of the project. In this stage, reverse engineers attempt to construct a characterization of the system

by accumulating all of the technical data and how the product works.

In the third stage of reverse engineering, reverse engineers try to verify that the data generated by disassembly is an accurate reconstruction the original system. Engineers verify the accuracy and validity of their designs by testing the system, creating prototypes, and experimenting with the results.

The final stage of the reverse engineering process is the introduction of a new product into the marketplace. These new products are often innovations of the original product with competitive designs, features, or capabilities. These products may also be adaptations of the original product**s** for use with other integrated systems such as different platforms of computer operating systems.

3. INVESTIGATIONS OF EXISTING SPLINESHAFT:

Splineshaft is an essential structure element which provides linkage between gear assembly of gearbox. Its one end is engage with small spur gear and other end is

attached to large spur gear assembly. In this part the investigations of the existing splineshaft have been carried out.

Figure 2. Splineshaft of gearbox and its various parameter

3.1. Measurement of various Lengths, major and minor Diameters:

The various dimensions of splineshaft were measured by using CMM. The different readings obtained are shown in table given below:

4. METHODOLOGY

In reverse engineering, collection of coordinates of every point of contact of

Table 1. Various parameters of splineshaft

Sr. No.	Parameters	Dimensions
A	Diameter of Left spline	34.37mm
B	Diameter of left collar	41.42mm
C	Middle diameter	38.00mm
D	Diameter of right side collar	48.00mm
E	Diameter of bearing rest right	40.00mm
F	Diameter of right spline	34.37mm
G	spline length left	47.00mm
H	spline length right	37.00mm
I	Length left up to collar	54.00mm
J	Length between two collar	114.75mm
K	Length right up to bearing rest	41.00mm
L	overall length	231.75mm
M	bearing rest length right	20.00mm
a	Fillet at left side	50.00mm
b	Fillet at right side	30.00mm

probe with the part surface is the point

cloud data of the part/product.

Different steps are followed in this technique are:-

• Scan by using CMM: - In this technique, splineshaft coordinates are measured by 30 mm; 2 mm 00 degrees probe and manual scanning are used for effective collection of points data.

The CMM used here is the Global Classic-SR.

Figure 3. **Coordinate Measuring Machine**

Global Classic-SR is the most cost effective solution to common shop measurement and inspection applications. Available in configurations to support either touch trigger or analog scanning probes, Classic is ideal as a first CMM, for multiple-unit deployments, or as a cost-effective way to add extra automated inspection capacity to your quality program.

Standard Package contain in Global Classic:

Probe: TESASTAR-I manual indexing probe head

Software: PC-DMIS-2011

Control: UMP360 touch trigger controller

Accessories: Computer package, desk, installation.

Options: Upgraded controller, probes and software

The data conversion depends on software availability in the CMM. Some of the CMM software converts the data into CAD format, like DXF, DWG, STL, IGES, and other forms. It has a PC-DMIS PRO software pack for converting the data into polyline IGES format as small segments depending on pitch. The polylines are then converted into curves/splines and this will reduce the curve generating process.

By using this technique we get PCD which is then imported in CAD software.

• After importing data in CAD software 2D CAD Model is created by using drawing commands.

• The CAD Model is then scaled accordingly with one exactly known dimension. Then all other dimensions are automatically extracted from the CAD Model.

• Finally the 3D CAD Model is created using CATIA software.

5. CAD Modeling of Splineshaft

The software used here for modeling is CATIA. It is CAD/CAE/CAM integration software of French Dassault Systems, which can provides users an integrated digital environment and complexity requirements for users from design to manufacture. [4]

Following steps are required for the development of CAD Model of Splineshaft with the help of available solid modeling technique:-

• Importing PCD in CAD software.

• Scaling accordingly with one exactly known dimension (length of splineshaft) i.e. 231.75mm.

• Creating the features by CATIA.

The first step in reverse engineering process is to import the scanned data, which is in the form of lines, arc, circles etc. in CAD package (CATIA).

Figure 4. Point Cloud Data of Splineshaft imported in CATIA

Above figure shows imported PCD in CATIA, now by using drawing commands all lines, arc, circles are converted into 2D CAD Model.

Finally the 3D CAD Model is created using Solid editing commands.

Figure 5. CAD model of splineshaft

Once a 3D model is finalized, a part drawing can be easily generated from it by using some drafting commands. Then this part drawing is used further for documentation and manufacturing purpose.

Figure 6. Part drawing obtained from 3D CAD model.

6. FEA of Splineshaft

Finite element analysis (FEA) is a technique which is widely used to analyze stress-strain states in various portion of devices under inspection. Software used here for Analysis is ANSYS. For Analysis in ANSYS consist of following steps
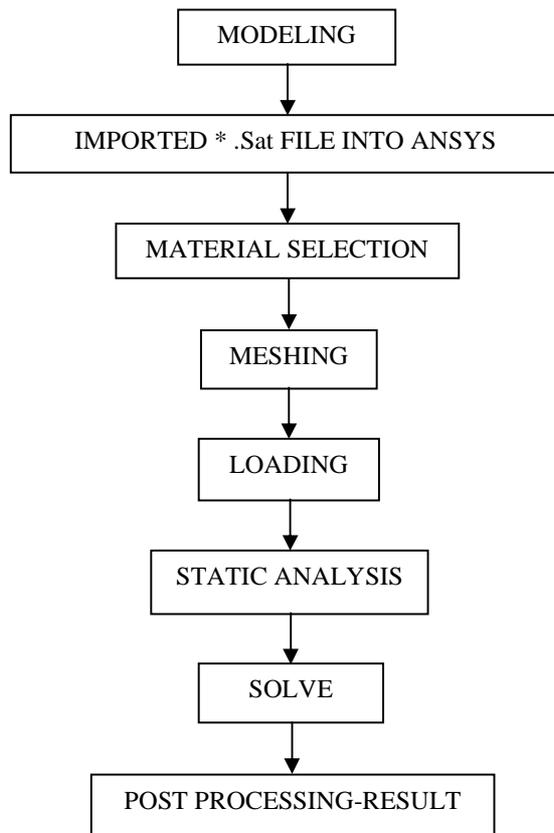
```
┌─────────────────────────────┐
│         MODELING            │
└─────────────────────────────┘
              │
              ▼
┌─────────────────────────────┐
│ IMPORTED * .Sat FILE INTO ANSYS │
└─────────────────────────────┘
              │
              ▼
┌─────────────────────────────┐
│     MATERIAL SELECTION      │
└─────────────────────────────┘
              │
              ▼
┌─────────────────────────────┐
│         MESHING             │
└─────────────────────────────┘
              │
              ▼
┌─────────────────────────────┐
│         LOADING             │
└─────────────────────────────┘
              │
              ▼
┌─────────────────────────────┐
│      STATIC ANALYSIS        │
└─────────────────────────────┘
              │
              ▼
┌─────────────────────────────┐
│          SOLVE              │
└─────────────────────────────┘
              │
              ▼
┌─────────────────────────────┐
│   POST PROCESSING-RESULT    │
└─────────────────────────────┘
```

Figure 7. Flow chart of analysis process
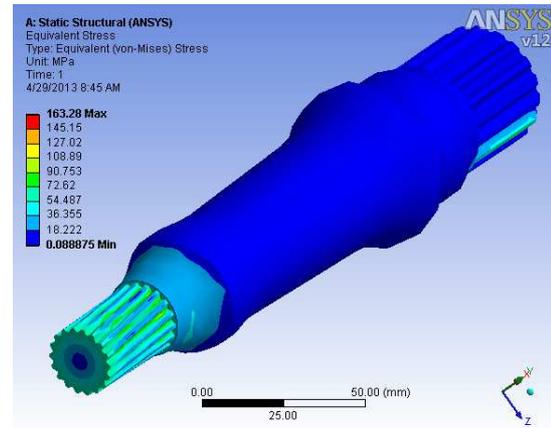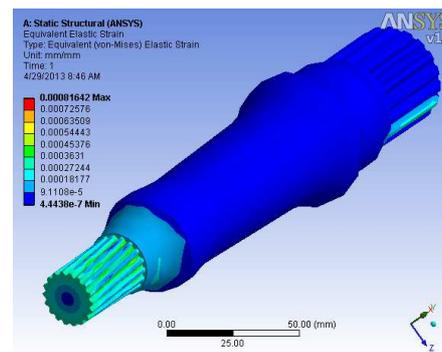
Figure 8. Equivalent (von-Mises) Stress

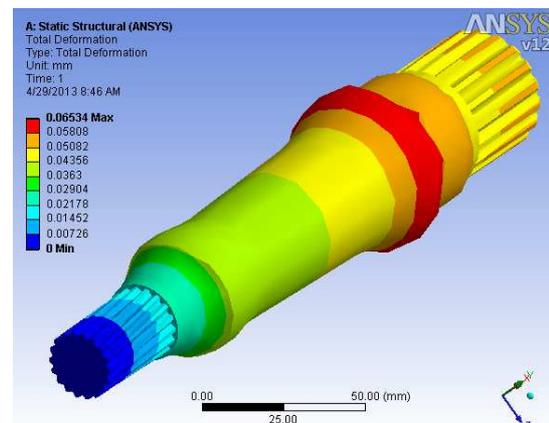**Figure 9. Equivalent (von-Mises) Elastic strain**

Figure 10. Total Deformation in splineshat

Various analyses done on given splineshaft shown in above Figures. Following table shows behaviour of splineshaft after applying various boundary conditions and twisting load on it.

7. CAM of Splineshaft

The CATIA software has provides a 2.5-axis, 3 axis and multi-axis CNC machining modules. Users can compile NC programming using CATIA, both can call a tool from CATIA tool library, and can manually enter the parameters to create the CATIA has powerful CNC machining modules. The basic operation methods of CNC machining include setting processing elements, setting the tool path, setting tool parameters, setting feed/back knife, cutting simulation and generating NC programs. Selecting tool is very important in the NC content, for each machining operation needs to specify a processing tool. [4]

Following steps are required for the development of CAM of Splineshaft with the help of available software technique:-

- Create raw material shaft used for manufacturing the given product.

- Used lathe machining from advance machining tool available in software.

- Define tool used, tool path, tool angle etc.

Table 2. Tabulated Results for splineshaft

	Minimum	Maximum
Load (N)	0	2000
Equivalent (Von-mises) stress in mpa	0.088875	163.28
Equivalent (Von-mises) elastic strain	$4.4438e^{-7}$	0.00081642
Total Deformation (max) mm	00	0.06534

- Simulate of machining operation.

- Defining machine used for manufacturing.

- Finally, we get output file which is generated automatically in the machine readable format generally in NC coding which used G- Preparatory and M- miscellaneous code. By exporting this file on CNC machine we can manufacture same product.

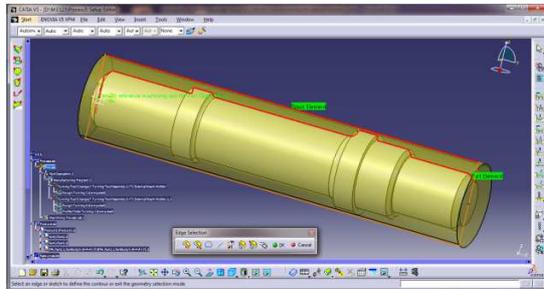In this case study the tool path define is shown with red lines in given below figure

Figure 11. Defining tool path.

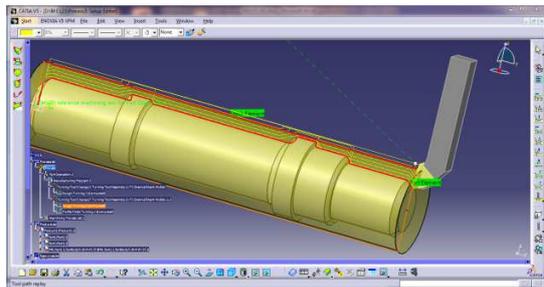Following figure shows the tool used and tool positioning for machining a part

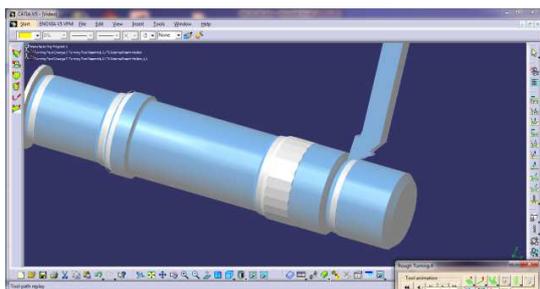**Figure 12. Tool used and its positioning**

Figure 13. Simulation of machining operation

Figure above shows the Simulation of machining operation before going for actual manufacturing of product.

Here, we are defining post processor and emulator as a Cenit® and machine post processor as a **Sinumerik 840D.** Finally, an output extension file as NC code will be generated automatically in the machine readable format generally in NC coding which used G- Preparatory and M- miscellaneous code. The NC coding format generated during this operation is given below

```
;=======================================
;= cPost Standard PP for SINUMERIK 840 D =
;=======================================
N10 G0 G90 G40
N20; ============= TOOL CHANGE ============
N30; DESC:
N40;=======================================
N50 T1 M06
N60 D1
N70 G0 G90 G40 G17
N80 F0 S0
N90 G64 SOFT
N100 G0 X37.791 Y0 Z233.889 S70 M4
N110 G0 X27.791
N120 G1 X25.791 F0 G95
.
.
.
N1740 X17.925 Z3.89
N1750 X13.234 Z-6.171
N1760 X13.336 Z-6.453 F1
N1770 M5 M9
```

N1780 M30

8. CONCLUSIONS AND FURTHER WORK

Reverse engineering is a process that can reduce the product development cycle besides cost saving method. Effective use of reverse engineering application is expected to penetrate market in the future. For the contact method, CMM is the most suitable for measurement of intricate component such as splineshaft. Another faster method which is non contact method using the laser scanning CMM is an alternative that can save more cost and time comparing to the contact method. The 3D CAD model of existing splineshaft of gearbox has been developed by in CATIA using the CMM technique. After getting the solid model, we can generate part drawing easily and by defining tool path, machining operation we get graphical simulation of given shaft as well as NC part programming file generated automatically. By exporting this file on CNC machine we can manufacture same product. After these steps the splines are cut on shaft by using hobbing machine. Hence it serves the purpose of Application of reverse engineering using CMM for

manufacturing intricate component like splineshaft.

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