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COMPUTER AIDED REVERSE ENGINEERING WITH CMM FOR DIGITIZATION AND DATA EVALUATION

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Abstract: *Reverse Engineering Applications has become quite popular in the recent years. It has potential of duplicating the existing item with manual or computer aided means. This paper presents the computer aided reverse engineering approach for surface digitization and data evaluation using CMM. Digitize data is exported in a CAD software for creating a CAD model and data evaluation. Methodology is explained and two case studies are used to illustrate the approach.*
Key words: *Reverse engineering, CMM, surface digitization*

1. INTRODUCTION

Reverse engineering begins with an existing physical object and various approaches can be implemented to duplicate the shape parameter of the object. The physical shape of the object can be duplicated by manual or computer aided means. Reverse engineering covers variety of applications, some of them are:

- Generating design information for the object whose technical blue prints are not available or missing.
- Improving the production cycle and knowing the limitation of the various manufacturing processes.
- CAT scan computer aided tomography is being used to duplicate the human body parts to diagnose exact cause of the disease.
- Analyzing the competitor's product to understand the manufacturing details and achieving the benchmarking.

This paper focuses on the reverse engineering and generate a CAD model of the ablative liners of the nozzle system after static firing and propellant casting mandrel which are quite critical in the performance of the booster rockets.

2. METHODOLOGY

The primary step in the reverse engineering approach is to finalise strategy for gathering the digitized data from the original part. It depends upon the various factors like required accuracy of the model, accessibility, calibration, surface finish, time, cost and available digitization resources. There are various approaches which can be employed for the purpose of reverse engineering like mechanical or contact type, optical, magnetic resonance imaging, Acoustic, X-Ray CAT scan method. Depending upon the suitability any of these can be employed to generate the digitized data.

The approach of surface digitization using Co-ordinate Measuring Machine (CMM) is considered to be quite effective and is described below.

CMM (Co-ordinate Measuring Machine) generally have mechanical type of probing system, in which there is a physical contact between the probe and the part while gathering the data. Probe takes data at a point by touching the part or a continuous scanning mode where probe always in touch with the part while scanning, continuous scanning is much faster than the point to point data, it generates tremendous amount of data in a short time but accuracy is slightly lesser than the point to point mode. CMM is used as a tool to generate the point data and main challenge lies in converting data into required CAD format, filter data points if required and generate curves, surfaces and finally a solid model which is can be used for NC code generation, rapid prototyping, reference mathematical model as a design input parameter and various other applications.

Most of the CMM are equipped with the measuring software only and unable to generate the CAD model by itself. Some machine software provides CAD converter software which can generate the standard IGES file for export. Horizontal Arm CMM (Figure 1.) is used for ablative liner digitization using Metrolog-II software and Bridge type CMM is used for generating the scan data of casting mandrel using PCDIMS software. These machines don't have feature to directly generate CAD model from raw data, hence after digitization raw data points (x, y, z) are exported from the CMM in a text file format and processed for generating the CAD model and data evaluation.

CMM can be fitted with various types of probe heads. In this case a touch trigger type probe head is used for digitizing object's profile feature. The scanned file is saved in the text format and a data formatting software (**Trans soft**) is created in visual basic for translating the raw data file to the suitable CAD format without which its very difficult to handle and to import/export raw points.

CMM are used to generate the 2D slice data for the object. When step size between two consecutive points is small, quite huge amount of data is generated and 2D curvature based filters may be used to filter the close proximity data point with same slope in tolerance range. These slices are transferred in the CAD workstation and assembled with Auto CAD/ Solid works Software which can be used to visualize and process data file to get the wireframe and solid model from the scanned data. Auto CAD/ Solid Work software provides application program interface (API) with which user defined macros are created in the visual basic using in-built functions of the software

Process which is used to generate 2D/3D model are listed as follows. (i) A 2D data script file can be generated using the Tans soft software from the (3D) raw data file, after importing the script file and individual slices can be visualize in Auto CAD software and if required editing can be done. (ii) 3D model generated in the solid works as follows. (1) Open new solid work part **file/new**. (2) Create base coordinate system or use default. (3) Create other reference plane for importing 2D profile from menu select **insert\reference geometry\plane.** (4) Select the reference plane. (5) Import 2D Auto CAD file (*.dwg) insert**dxf, dwg** in the solid works **select** the layer to be imported, define the **curve tolerance** and **unit** of importing data, modify the curve if required. (6) Repeat the step from 2 to 5 till all profiles are imported in the solid work software. (7) Choose from menu **insert\base\loft.** It is used to create solid surface between two profiles

One important step is to check weather the CMM software is taking care of probe radius compensation before exporting the data from the CMM' software, if probe compensation is not done then imported profile needs to be offset for probe radius.

Fig. 1. Horizontal Arm CMM
Scanning of Nozzle Ablative Liner

3. CASE STUDY

Two cases studies will elaborate the method previously explained. The main objective of first case study is to evaluate the ablative thicknesses left after static firing in the divergent liner (length and Diameter = 1200mm) of FNS (flex nozzle system) and generate the liner's eroded surface where pattern of eroded thicknesses is not known. In another case study actual solid model of casting mandrel (length =4000mm and diameter = 300mm) is generated which is used to correct the mandrel profile.

In first case study the main objective is to calculate the erosion thickness, char thickness and left over virgin material thicknesses. Also surface model for erosion surface required to be generated. Since the erosion phenomenon is very difficult to predict, the details of eroded surface are not known before hand. The setup shown in the figure 1 is used for scanning the divergent liner. Horizontal Arm Co-ordinate measuring machine with Renishaw PH10M motorized probe head is used. First the job is manually aligned on CMM. A Probe attach with Probe head PH10M can be oriented in number of different orientations with ±0.5µm repeatability of position. Depending upon the profile orientation, reach and accessibility of probe at particular orientation, different probe orientations were used with single probe of Ø 0.989mm. All required orientations were selected and probe was calibrated for selected orientation using the inbuilt Automatic calibration software before starting digitization process. Part coordinate system origin (0, 0, 0) was created using the based plane and a reference circle at the smaller end of divergent liner (Figure 2.).

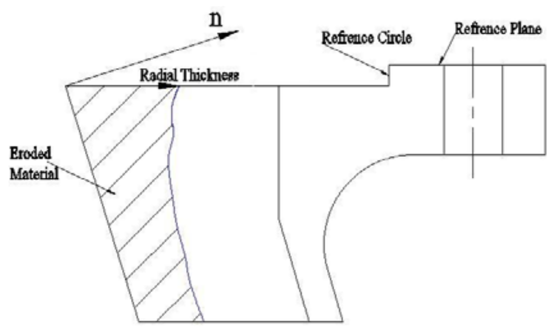

Fig. 2. Divergent liner sectional view

Point to point data scanning was done in manual mode and scanned co-ordinate (x, y, z) data file was exported in *.txt format. A macro (Visual Basic script) was created to compare and plot the data with the original profile (before firing) in radial thickness direction instead of thickness variation in the nominal direction of liner and surface was

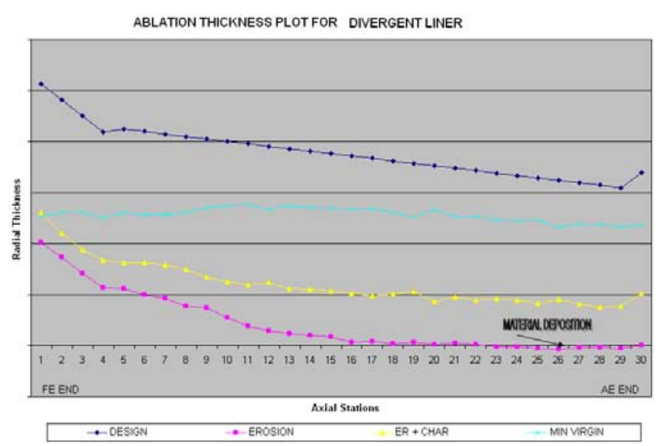

Fig. 3. Divergent liner Ablative Radial Thickness Plot

created using methodology explained earlier instead of **loft** command **revolve** command was used to generate max erosion and char surfaces (Figure 4.). CMM limitation of evaluating measured data point only in nominal direction was over come with this method. Similar method also adopted to digitize convergent ablative liner of FNS and hence erosion surface model for total nozzle system was created. The details of thickness variation in the nozzle liner along axial direction from gas entry section to the exit section of the nozzle are shown in the figure 3.

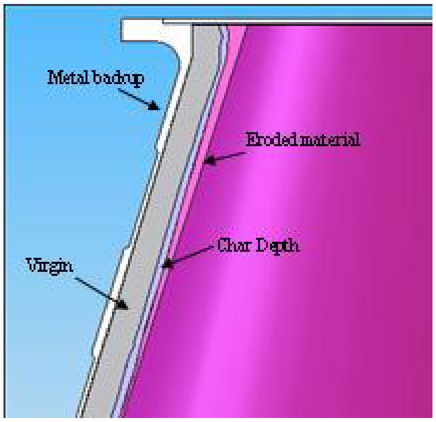

Fig. 4. X-sectional view of CAD model generated form measured data of FNS divergent ablative liner

In second case study the casting mandrel with star configuration was digitize to get its shape after machining operation and based on the generated model error corrections were implemented on the same mandrel. The main objective was to check the twist and tapering allowance on the mandrel. Size of the mandrel was quite large (l=4000 mm, d=300 mm) and due the mandrel geometry 8 different mandrel cross sections were scanned to get the final solid CAD. A bridge type CMM with Dea CW43 probe head having resolution of 0.36 arc sec was

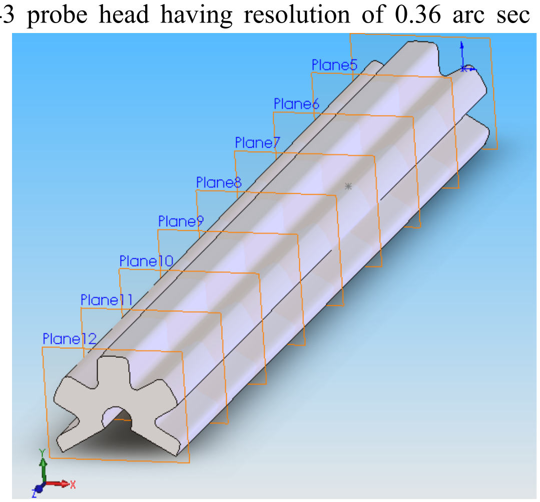

Fig.5. Generated CAD model from the scan data

used. A single probe of diameter 1.988 mm was attached to probe head and calibrated in auto mode for 20 different probe orientations. PCDIMS software was used to digitize data in open loop.

A small step size was used for scanning to capture the geometry. A 2D curvature based filter (figure 6.) was used to filter the data points with least curvature change (refer equation 1). Sectional profile was created in Auto CAD software using script file from scanned/ filtered data and methodology explained earlier was followed to create the solid model (figure 5.). Solid model was given to manufacturer to correct face taper in the rib segment (Figure 7.) in the mandrel. It was concluded from the CAD model that twist between the scanned X-section was not present in the mandrel. Solid model created from the scanned / filter data (figure 6) was compared with the actual scan data file using solid works macro (API) and the results are listed in Table 1.

Table 1. Deviation analysis for casting mandrel CAD model

Feature	Without filter (mm)		1% filter (mm)		2% filter (mm)	
	max	Stdev	max	Stdev	max	Stdev
Curve1	0.05	0.004	0.63	0.08	2.63	0.34
Curve2	0.16	0.017	0.92	0.12	3.02	0.40
Curve3	0.23	0.013	0.64	0.08	1.85	0.26
Curve4	0.05	0.004	0.61	0.07	1.28	0.19
Curve5	0.02	0.001	0.56	0.06	0.82	0.12
Curve6	0.03	0.003	0.11	0.01	1.29	0.16
Curve7	0.03	0.003	0.23	0.03	0.54	0.07
Curve8	0.01	0.001	0.15	0.02	0.65	0.07

4. EQUATIONS

Equations for 2D filter

$$\theta_{n-1} = (Y_n - Y_{n-1})/(X_n - X_{n-1}),\ \theta_{n-2} = (Y_{n-1} - Y_{n-2})/(X_{n-1} - X_{n-2})$$

$$\Delta\theta = 100*(\theta_{n-2} - \theta_{n-1})/\theta_{n-1} \quad \text{--------------------} \quad (1)$$

Fig. 6. a) Raw data b) filter data 1% c) filter data 5%

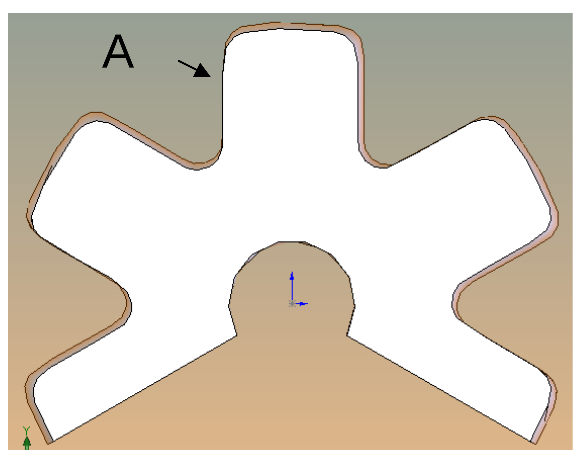

Figure 7. End view of mandrel CAD model

Face ‘A’ was found to be flat without required taper in the each rid segment and same pattern observed in each rib, which was later corrected on the basis Generated CAD model (view from smaller end and parallel to the mandrel axis).

5. CONCLUSIONS

This paper explained the concept of generating a solid CAD model using the CMM raw data out put and CAD software. Generated CAD model can be used as an input to the CNC machines for error correction in the object and it can be used as the critical design input for improving the system reliability simultaneously it overcomes the CMM software limitations and increases the capability of the CMM.

6. ACKNOWLEDGEMENT

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7. REFRENCES

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