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REVERSE ENGINEERING: POINT CLOUD GENERATION WITH CMM FOR PART MODELING AND ERROR ANALYSIS

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ABSTRACT

From many decades reverse engineering (RE) has been used to make duplicate parts and part drawing prints in military and defence sectors. Scientific literature presents many different approaches for implementation of reverse engineering. Most of the studies are based on the analysis of point clouds acquired through coordinate measuring devices, such as, Coordinate Measuring Machines (CMMs), Optical Scanners or Interferometric Systems [2]. In recent years, the development of computer technology resulted in the integration of design and manufacturing systems and automated inspection/gauging systems in manufacturing engineering applications. Geometrical information of a product is obtained directly from a physical shape by a digitizing device, from this complete 5-axis tool-path is obtained [1]. Duplicating the part is done with the help of CMM and CAD/CAM software like Mastercam, ProEngineer etc. CMM is used to digitize the mechanical object. Taking coordinates (scan data) of the various points on the surface of the object and converting it into IGES file and using the same in the CAD/CAM software with required interfacing creates a surface or solid model of the object. Finally this solid model is used to generate CNC part program to manufacture the part on CNC Machining center.

Keywords: reverse engineering, modeling, coordinate measuring, CNC, machine, point cloud, computer aided inspection.

INTRODUCTION

Reverse engineering is a process of reproducing the geometry of an available physical object. The method of reverse engineering is either manual or computer aided system. In both the cases it requires extraction of information about geometry to develop the part drawing for duplication and manufacture. Machine vision system is capable of creating a contour CAD drawing for various flat sheet metal components which are typically used in the aerospace industry. The process of image acquisition is accomplished by the integration of a CNC machine and a CCD line scan camera [4]. With reconstruction technique, surfaces are automatically created directly from a digitized data points file, from one or with millions of points [6]. Comparison of two free-form surfaces based on discrete data points is very important for reverse engineering digitized data. It can be used to assess the accuracy of the reconstructed surfaces and to quantify the difference between two such surfaces. The entire process involves three main steps: data acquisition, 3D feature localization and quantitative comparison [7].

In the manual methods the drawing prints of CSG objects are easy to make using metrology. Copying method is not useful for damaged and broken objects and hence can not be used to make prints. Computer based method with CMM is used to digitize the object having complicated shapes, profiles and surfaces other than CSG and is also economical.

Applications of reverse engineering are:

1. Old and overseas products which are not having prints and documentations can be produced, like replacing the molds and dies due to wear and damages.
2. Automated inspection, the manufactured part is automatically inspected after a successful prototype is produced.
3. To understand the manufacturing process of components of competitors in markets.
4. Design reuse, to design a new product, the manufacturer incorporates the 2D drawings into a new design. Reverse engineering is used to take advantage of information of existing parts, including cost, geometry, calculator, assembly steps and CNC codes to produce a new part in minimum time and cost.
5. 3D digitizers capture organic objects used by video and production experts. Reverse engineering is to be practiced in India in the area of tomography (X-ray and sketches provided by the surgeons).

METHODOLOGY

In reverse engineering, digitization and collection of coordinates of every point of contact of probe with the part surface is the point cloud data of the part/product. There are two types of collecting this data (i) contact type (mechanical type) and (ii) non-contact type (optical type). In mechanical, the data is collected from mechanical probes touching the surface at various points on part profile i.e. coordinate points xyz. This process is very slow to collect enormous points for cloud of points. This method is most useful for inspection purpose. It has high accuracy compared to all other mechanical methods.

The second method in mechanical process is scanning. In this the probe is drawn along the surface of the object. There are manual scanning and automated scanning. In the manual scanning the accuracy depends on skill of the scanner. The automated scanning is more accurate than manual scanning. However, the scanning method is slightly less accurate than individual point method. The sequential steps of the CMM data are to first convert the points in to Lines, Arcs, Curves, and Surfaces. After manipulating, the data collected is converted into surface model or a solid model. This solid model is used for down stream operations such as analysis, Mass properties, CNC program generation etc.

Figure-1. CMM, TESA micro-hite 3D Swiss made.

The data conversion depends on software availability in the CMM. Some of the CMM softwares convert the data into CAD format, (DXF, DWG), IGES and other forms. The CMM used here is TESA micro-hite 3D Swiss made. It has a Reflex Scan pack for converting the data into polyline IGES format as small segments depending on pitch. The polylines are generated into curves/splines manually. Some of the scan packs convert the data into curves/splines and will reduce the curve generating process.

The scan pack software of Reflex Scan pack, Switzerland is capable of capturing the coordinates of points into a file.

The captured point file (notepad xyz co-ordinates) is converted into polylines IGES file. Style of Probe used for scanning is 90 degrees. The IGES file is transferred to ProE / Mastercam. The data available in the IGES is line segments. The segments are converted in to datum curves by using **create / datum curves / through points**. It is a tedious process and is one of the disadvantages, due to the limitations of the software used in CMM. All the datum curves are converted into surfaces, manipulating the patches by trimming and extending surface. Finally the model is converted into solid.

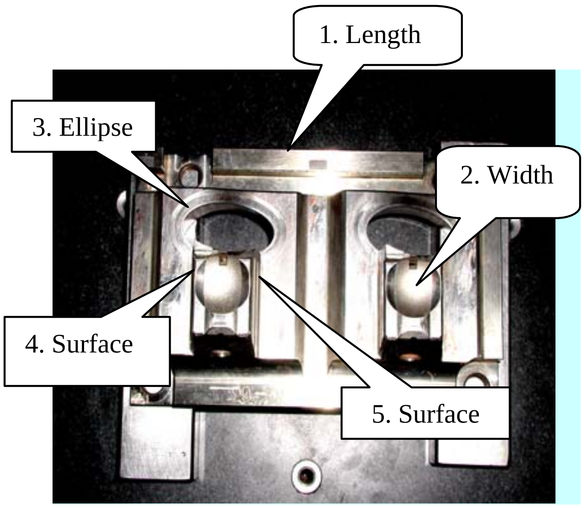

Figure-2. Existing part, injection mould.

CASE STUDY

The object we reversed in this case study is injection mould with two damaged cavities in the part, without any drawing prints. Using CMM and CAD software point cloud files are created. Parameters selected for CMM for effective collection of data points are given below:

Probe diameter:	6.294 mm
Pitch of scan points:	0.1 mm
Probe orientation:	90 degrees
Operation mode:	Manual scanning

The probe diameter is calibrated manually with standard Gauge/spherical object.

Time analysis	Hours-Minutes
1. Probe calibration and Setting	00.15
2. File conversion in to IGES	00.02
3. Scanning	00.45
4. Loading in to CAD and Conversion into curves	04.40
5. Creation of Surfaces	01.55
6. Inspection and comparison	01.00

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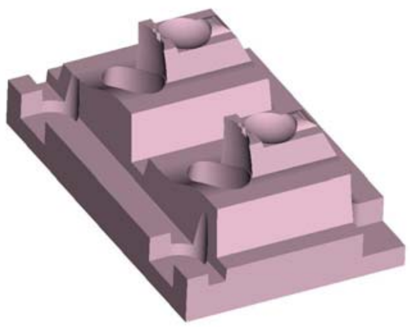

Figure-3. ProE model of Injection mould.

CONCLUSIONS

- If scanning data is converted into datum curves/curves (Blend) scanning itself, 50% of manual work can be reduced.
- Scanning along and across directions in surface scanning will improve the accuracy of surfaces.
- Accuracy in surfaces will depend on complexity of shape.
- The accuracy of surfaces will increase by manipulation of surfaces.

Table-1. Comparison of error in ProE model generated from point cloud with actual Part feature.

ERROR ANALYSIS OF FEATURE PROFILE/SURFACE -5 BY COMPARING PRO/e MODEL

	Feature surface/profile 5			Pro/e Model			
sl.no	X	Y	Z	X	Y	Z	ERROR IN 'Z'
1	126.719	102.446	-17.717	126.719	102.446	-17.744	0.027
2	134.689	104.197	-17.895	134.689	104.197	-17.911	0.016
3	147.671	105.504	-20.457	147.671	105.504	-20.505	0.048
4	156.994	104.833	-24.38	156.994	104.833	-24.387	0.007
5	167.927	105.611	-28.269	167.927	105.611	-28.296	0.027
6	178.589	105.219	-30.157	178.589	105.219	-30.071	0.086
7	188.261	105.028	-30.25	188.261	105.028	-30.272	0.022
						Total error	0.233
						Average Error in 'Z' axis	0.033286

ERROR ANALYSIS OF FEATURE PROFILE/SURFACE -4 BY COMPARING PRO/e MODEL

	Feature surface/profile 4			Pro/e Model			
sl.no.	X	Y	Z	X	Y	Z	ERROR IN 'Z'
1	61.124	65.592	-5.759	61.124	65.592	-5.709	-0.05
2	59.069	58.398	-7.695	59.069	58.398	-7.653	-0.042
3	54.832	57.757	-8.016	54.832	57.757	-7.985	-0.031
4	48.19	64.838	-5.844	48.19	64.838	-5.816	-0.028
5	47.74	57.433	-7.029	47.74	57.433	-6.998	-0.031
6	48.048	49.252	-5.714	48.048	49.252	-5.671	-0.043
7	61.74	49.805	-5.981	61.74	49.805	-5.925	-0.056
8	54.379	49.388	-6.733	54.379	49.388	-6.671	-0.062
						Total error	-0.343
						Average Error in 'Z' axis	-0.042875

ERROR ANALYSIS OF FEATURE ELLIPSE -3 BY COMPARING PRO/e MODEL

	Feature ellipse 3			Pro/e Model			
sl.no.	X	Y	Z	X	Y	Z	ERROR IN 'Y'
1	152.957	101.123	-24.031	152.957	101.269	-24.031	0.146
2	143.004	99.062	-20.121	143.004	99.116	-20.121	0.054
3	132.57	91.625	-19.306	132.57	91.967	-19.396	0.342
4	132.194	89.136	-18.571	132.194	89.126	-18.571	0.01
5	178.912	90.636	-30.629	178.912	90.63	-30.629	0.006
6	176.878	94.346	-30.613	176.878	94.225	-30.613	0.121
7	155.775	101.188	-25.185	155.775	101.285	-25.185	0.097
						Total error	0.776
						Average Error in 'Z' axis	0.110857

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