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Analysis Of Indexable Insert Cutting Tool With Reverse Engineering

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ABSTRACT

Reverse engineering plays a major role in generating digitized data from a complex component with intricate shape. This paper deals with the modeling and analysis of an indexable insert cutting tool. The design data of cutting tool is obtained using reverse engineering technique. The cutting tool is analyzed at varying cutting forces, temperatures and the stresses induced are found. Coupled field analysis is carried out to investigate the combined effect of temperature and structural cutting forces. The cutting tool is modeled from cloud points obtained from reverse engineering technique. The points are obtained by "surface reconstruction digitization technique". The points are joined by lines and then creating bounding areas and filling the volume. The side cutting edge which makes contact with the work piece is subjected to a normal load along the edge, Stress distribution for the tool assuming to be a cantilever are obtained.

KEY WORDS: *Reverse Engineering, Digitization Technique, Surface Reconstruction, Surface Modeling, Indexable Insert Cutting Tools.*

1. INTRODUCTION

Geometric modeling of physical objects from point samples of existing artifacts is a rapidly surfacing discipline, also referred as reverse engineering. The applications of this relatively new discipline of technology are encouraging. Current state of the art of modeling from point cloud offers simple point cloud processing and single surface fitting with interactive help. Segmenting the point cloud that can collectively represent a single surface and selecting the parameters for surface model to fair the point data still remain a difficult task and the users iteratively assess the model before a final solution is obtained. The problems become more difficult as well as computationally expensive due to the noise, randomness introduced during data acquisition and when the parts scanned are partially damaged or worn out.

Reverse engineering technology can be used to aid in manufacturing of spare parts when original part's inventories are exhausted. For mechanical parts the process involves sensing the geometry and then passing the sensed data to an appropriate CAD/CAM system for manufacturing. Reverse engineering of mechanical parts require extraction of information about an instance of the particular part sufficient to replicate the part using appropriate fabrication techniques. The resulting models can be directly imported into feature based CAD system without loss of semantics and topological information inherent in the feature based representation.

2. SINGLE POINT CUTTING TOOLS FOR TURNING

In terms of annual budget spent, machining is the most important of the manufacturing processes. In the present context, machining is necessary where tight tolerances on dimensions and finishes are required. Turning is one of the basic machining processes, produces solids of revolution which can be tightly toleranced because of the specialized nature of the operation. There are many types of cutting tools for different operations, performed for turning. Cutting tools have distinct advantages such as low cost, do not require the space that a mechanical tool holder does, and can be ganged in tooling devices where crowded conditions exist. The selection of tool for turning depends on many variable factors such as the work piece material, the machine tool, setup, the amount of material to be removed, the power available at the machine, and the operation.

3. LITERATURE REVIEW

Y. M. Chiang, F. L. Chen [1] proposes a new architecture based on look-up table that keeps the estimated normal vectors of the measured data to refine the data points digitized by CMM. The digitized data are first fitted into several NURBS curves by interpolation. Chang-Xue Feng and Shang Xiao [2] presents a Computer Aided Reverse Engineering (CARE) approach. In this approach, a CMM is used to digitize an existing mechanical object, and then a piece of software called

ScanPak is used to generate the *IGES* files of the point cloud data from CMM digitization. Pro/Engineer is used to create the solid model of the object and finally the laminated object manufacturing process is used to duplicate the object. T. Shen, J. Huang, and C-H Menq[3] the development of a multiple-sensor coordinate measuring system and its applications to automated part localization and rapid surface digitization. C.X. Feng presents the methodology of Internet-based reverse engineering with a case study illustrating its applications in integrating CAD and CAM [4]. Yin Zhongwei and Jiang Shouwei [5] reports on the automatic segmentation and approximation of three-dimensional digitized points for reverse engineering. Based on an innovation that uses the properties of a Non-Uniform Rational B-Spline (NURBS) or B-spline and makes ordered digitized points, which takes less computation time than traditional algorithms in calculating surface normals and curvatures at digitized points, an algorithm was developed for automatic segmentation and NURBS surfaces fitting for digitized points.

4. REVERSE ENGINEERING PROCESS

If only one original part is available and it has to be handled with utmost care during the process as the original part is crucial for validation. The component is studied thoroughly and the prominence of every feature affecting the working of that component must be estimated also the feature which can be measured manually must be identified. Such features encompass prismatic, geometric shapes. All other features like free-formed surfaces and complex contours and 3D surfaces and to be measured through other techniques like scanning, acoustics and optical methods. All the dimensions which can be measured manually are taken with the help of available measuring devices like vernier calipers, height gauge, etc. The features, which cannot be measured manually, can be obtained through any available digitization techniques.

The typical Reverse engineering process can be summarized in sequence as under

1. Physical model which needs to be redesigned or to be used as the base for new product.
2. Scanning the physical model to get the point cloud. The scanning can be done using various scanners available in the market.
3. Processing the points cloud includes merging of points cloud if the part is scanned in several settings. The outlines and noise is eliminated. If too many points are collected then sampling of the points should be possible.
4. To create the polygon model and prepare *.stl* files for rapid prototyping.
5. To prepare the surface model to be sent to CAD/CAM packages for analysis.
6. Tool path generation with CAM package for suitable CNC machine manufacturing of final part on the CNC machine.

4.1 Digitization

Digitization is the process of capturing the data of the physical model and converting it into digital form. However, with the introduction of new technologies the term digitizing is used as the generic description for the process of acquiring data from undefined surfaces out of which a complete CAD model of the part is made, to facilitate analysis and to incorporate changes easily. The part is studied in detail, an idea of the probable manufacturing process helps in identification of the proper strategy for the digitizing. Higher the accuracy required higher will be the cost; hence one must strike the balance between the desired accuracy and the cost incurred. Use of Coordinate Measuring Machine (CMM) which can be attributed as semi automatic digitization technique is justified in cases, where 3D surfaces and holes are to be considered. The features to be scanned are identified and appropriate sections are made on the part. In the vicinity where there is a sudden change in profile maximum number of sections are to be made. Then scanning is done along the predetermined sections and the point cloud data obtained from the parts. The data is normally in the form of a point cloud containing the X, Y, and Z coordinates. This digital data in general, can be used for generation of surface models or *.stl* files. This data can also be used for inspection purposes where the point cloud is superimposed on the CAD model and calculate the deviation at the respective points on the component with respect to CAD model. There should be a powerful package which can handle the collected point cloud to form the files for Rapid prototyping or for any CAD application.

4.2 Surface Reconstruction

Two main categories in surface reconstruction are *free form* fittings and *quadric* fitting. The surface meshes generated in these approaches are inadequate for current CAD/CAM software which typically require surface to be represented in the Non Uniform Rational B-Splines (NURBS) form. CAD model has the flexibility of incorporating changes and interfacing with CAM. Thus through a CAD, one can achieve faster production rates. Surface Modeling and Solid Modeling of the part is done from the cloud point data using modeling packages like Pro-E and CATIA.

5. The Present Work

Indexable insert cutting tools are considered for the present study. The considered tools are worn out, not in use and available in the shop floor. The tools are studied to identify the features for digitizing. The tool can be divided in to two main sections the tool tip section and shank section. The tip has more contours housing different cutting angles.

5.1 Digitizing of single point cutting tool

The following procedure followed to obtain the coordinate point data.

i. Select the suitable probe (straight probe of 0.5 mm diameter) depending on the geometry of cutting tool.
ii. Clamp the cutting tool with magnetic clamping (Fig.1. a & b) to restrict the degrees of freedom.

Fig. 1(a)

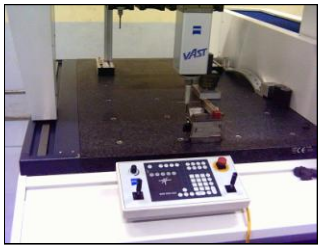

Fig. 1(b)

iii. All surfaces are probed (Fig.3 a & b) separately and patches are created for each surface.

iv. The surfaces and patches created in step 3, in *IGES* format, directly imported to 'CATIA' to create the solid model.

v. Using the patches full extended surfaces are obtained for each face of the tool by extrapolating, extending, blending, intersecting and trimming operations of wire frame and surface design module of CATIA to create a closed surface model (Fig.4 a & b).

vi. The 3D Solid model of the tool is then created from closed surface model, and is imported to ANSYS (Fig.5).

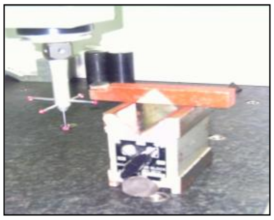

Fig.3(a)

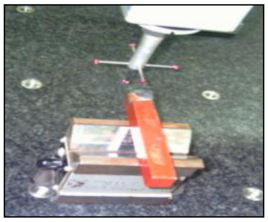

Fig.3(b)

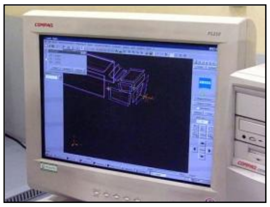

Fig.4(a)

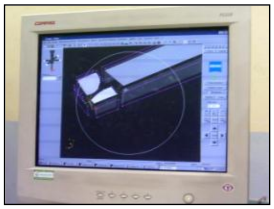

Fig.4(b)

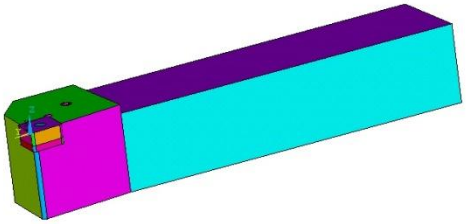

Fig. 5

6. ANALYSIS OF CUTTING TOOL

The cutting tool is subjected to both thermal and structural loads. Coupled field analysis has been carried out to analyse the effect of maximum temperature generated at the tool tip as well as cutting forces applied. To conduct coupled field analysis, thermal analysis should be carried out first. The solid model of the cutting tool is meshed with 3D 10-node tetrahedron thermal elements. The maximum temperature is applied on tool tip as the remaining surfaces are maintained at ambient air temperature. The obtained results are applied as an input to structural analysis. In structural analysis the tool is considered as a cantilever beam and the cutting forces measured by lathe tool dynamometer in F_x, F_y and F_Z directions are applied at and near the tool tip evenly (Table.1 a & b)for different spindle speeds and feeds.

Table.1 (a) Dynamometer Observations
(Depth of cut=0.5mm, Feed=0.86mm/rev)

S. No.	Speed (RPM)	Cutting force (Fz)kg	Feed force (Fx)kg	Thrust force (Fy)kg
1	33	34	10.3	27.4
2	51	30.3	8.3	24.1
3	82	27.2	4.1	19.4
4	123	27.4	3.0	19.0
5	163	19.9	1.8	20.5
6	246	19.6	2.3	19.8
7	399	20.1	2.5	19.5
8	598	34	3.4	21.6

6. RESULTS AND DISCUSSION

The maximum stresses induced in the tool tip are presented in Table.2 (a) (Depth of cut=0.5mm, Feed=0.86mm) and 2(b) (Spindle speed=246 RPM, Depth of cut=0.5mm). There is a little variation in shear stresses as the depth of cut is kept low at 0.5mm.

Table.1 (b) Dynamometer Observations
(Spindle speed=246 RPM, Depth of cut=0.5mm)

S.No	Feed (mm/rev)	Cutting force (Fz)kg	Feed force (Fx)kg	Thrust force (Fy)kg
1	0.86	14.2	1.4	20.5
2	0.74	14.6	1.3	21.7
3	0.72	14.6	1.3	22.7
4	0.67	15.5	1.3	21.9
5	0.61	35.5	1.3	24.6
6	0.59	38.8	1.3	26.6
7	0.52	39.9	1.3	27.3
8	0.47	40.3	1.3	29.8

There exists low shearing of metal, except rubbing forces on the job surface. The sudden drop in the von mises and principal stresses can be observed in the beginning i.e. with increase of spindle speed, and they are stable for a period (spindle speeds 200-400 RPM) and gradually raised with high spindle speeds. But with increase of feed sudden increase in these stresses can be observed. This can be attributed to low cutting forces at high feed.

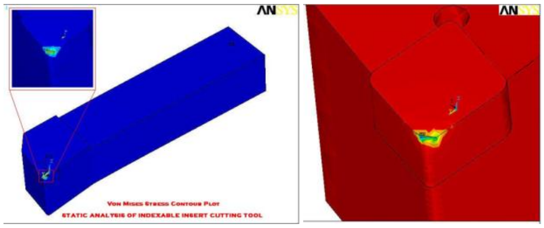

Fig. 6 Contour Plots of Stress Distribution

Table 2(a).Static Analysis of Cutting Tool – Maximum Stresses (When Depth of cut=0.5mm, Feed=0.86mm)

Speed RPM	Maximum Stress in N/mm^2			
	Von-mises	Shear	Principal	Thrust direction
33	134.10	23.38	50.55	39.44
51	131.45	21.83	86.34	36.21
82	115.87	16.50	70.26	34.98
123	110.00	15.44	54.25	31.75
163	88.68	21.34	44.75	14.63
246	82.10	19.27	42.39	15.27
399	89.86	19.26	47.97	16.83
598	139.66	19.94	69.28	41.67

Table 2(b). Static Analysis of Cutting Tool – Maximum Stresses(When Spindle speed=246 RPM, Depth of cut=0.5mm)

Feed mm/rev	Maximum Stress in N/mm^2			
	Von-mises	Shear	Principal	Thrust direction
0.86	77.92	21.63	36.87	11.55
0.74	83.58	24.57	40.48	12.51
0.72	84.95	23.66	40.67	12.71
0.67	99.47	24.31	48.14	15.59
0.61	137.25	21.11	66.51	38.75
0.59	150.39	22.40	71.52	42.60
0.52	155.62	21.87	74.47	43.88
0.47	152.00	25.66	76.66	41.60

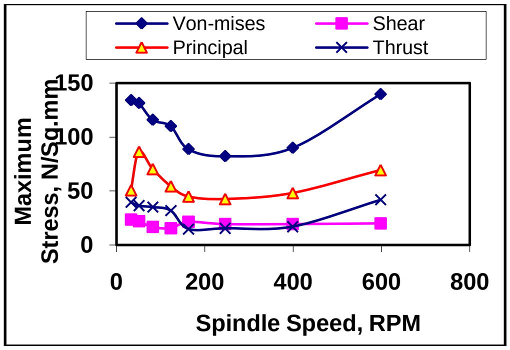

Fig. 7(a) Maximum Stresses at Depth of -cut = 0.5mm, Feed=0.86mm

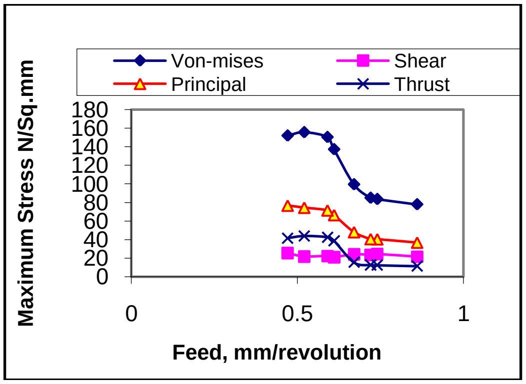

Fig.7(b) Maximum Stresses at Spindle speed=246 RPM, Depth of cut=0.5mm

8. CONCLUSIONS AND FUTURE SCOPE

The rise in induced stresses observed in case of high spindle speeds are well within the safe limits. These stresses are stable at spindle speeds from 200-400RPM, and at feed range 0.74-0.86 mm/rev. For a smooth metal cutting operation on mild steel with cutting tools these ranges are to be maintained.

The obtained CAD model can be used to get the automatic NC code for the manufacture of cutting tools as further work with CAD/CAM integration. This project can be extended to validation of component, material analysis and manufacturing methodologies of the component. The work can be extended for various materials, type of tools with complex geometry in different applications.

9. ACKNOWLEDGEMENTS

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10. REFERENCES

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