Development of machining algorithm based on feature identification for three axis CNC lathe mill

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ABSTRACT

The demand for products having intricate features has increased dramatically so manufacturing industries have to find ways of supplying these products quickly to the costumers. Lot of research and work have been done on sculptured parts using CNC machines. However, there is an urgent need to machine and finish scallops using identification of features in order to reduce machining time. The stereo lithography (STL) file format which depicts data about part geometry is provided by any CAD package, is given as a primary input for generation of the tool path. The output data in the form of cutter location (CL) points is calculated through the machining algorithm by applying different checks such as triangle check, edge check and vertex check and considering various parameters such as depth of cut for roughing pass, side step for roughing and finishing operation. In the present work, features mainly cavities, protrusions and groves are machined in the last in order to save machining time.

Keywords: lathe mill CNC machine, tool path generation algorithm, feature identification, STL file.

1. INTRODUCTION

Computer Aided design (CAD) and Computer Aided Manufacturing (CAM) technologies have been around for decades to assist us with design and manufacturing of complex sculptured surfaces components. With CAD/CAM software, Computer Numeric Controlled (CNC) machines can machine intricate components with highest dimensional accuracy. CAD/CAM software simplifies the programming of CNC machines and helps improve their utilization. The complete CNC machining process is divided into three stages:

- Design phase
- Tool Path planning stage
- Verification and manufacturing stage

In the Design stage, a 3D Computer Aided Design (CAD) model for the design surface is created using the modeling capabilities of a CAD package. In the Planning stage, the cutter path is planned to produce the component from the CAD model within acceptable dimensional tolerances. In this stage, cutter location data that can be translated into G-Codes that can be understood by CNC machines is generated. In the Verification stage, the generated tool path is verified and checked in a simulator for machining errors or flaws before actually manufacturing the component. In the Manufacturing stage, the actual component is loaded on the machine and the machine tool reads the G & M codes generated during tool path planning stage to produce final product in its intended application.

Complex surfaces are machined in three sub-stages: Rough machining, finished machining and manual finishing. Conventionally, complex surfaces are machined using ball nose end milling cutter on 3-axis milling machines. CNC milling machines direct the tool via a computerized controller.

Tool path planning is the motion planning of machine tool and is one of the fundamental tasks in CNC machining. Tool path gives the trajectory followed by machine tool. Tool path gives information about surface topology because of scallops which are developed during machining. In the rough-cut stage, the tool path should be planned to maximize MRR (metal removal rate) by machining volumes of material in a slice by slice manner. However, in finish cutting, tool path should produce the desired surface finish and accuracy.

1.1 LATEST MACHINING APPROACHES

Gray et al. [1] proposed a new paradigm, in which the machine operates from simple PC. The work done by Bedi et al. [2] is an elaboration of such paradigm, and implements the paradigm that can be used to produce parts directly from the model. In order to make a part directly from the model, the information of CAD model is taken as STL (Stereo-lithography) file and tool path is directly generated from STL file, thus eliminating the need of postprocessor, in which is used to generate the G & M codes. Now the tool path is directly made without the conversion of part program into G & M codes. The present work also explores the tremendous capabilities of computer for the development of CAD-CAM integrated system. H. T. Yau et al. [3] proposed a model on Numerical control machining of triangulated sculptured surfaces in a stereo lithography format with a generalized cutter.

Manos et al. [2] developed the machine called single controlled axis lathe mill (SCALM) for machining intricate surfaces wherein a cutting tool is positioned using single axis of controlled motion. Machining complex sculptured surfaces out of wood is accomplished by mechanically linking two axes of motion which produce a fixed helical footprint of a tool path with constant step-over distance.

1.2 PROBLEM IDENTIFICATION

A tool path generation algorithm had been already developed for the three axis CNC milling lathe machine with ball nose end mill cutter [6]. Here tool path was generated which moves in the helical path with uniform side feed and varying radius of cutter for roughing and finishing passes. By taking the STL (Stereo-lithography) file as initial input from the CAD software, the computer program generates the cutter location (CL) points in a text file. Tool path generated is capable of generating all artistic features and complex parts other than making the simple turning parts. After this generalized tool path algorithm, it was identified that there was a need of feature based tool path planning algorithm which would identify the features like cavities, pockets, grooves etc. based on the x values generated in the text files obtained from the previous algorithm. Hence, a generalized algorithm for the cylindrical and conical geometries having distinct features such as cavities, pockets, grooves has to be developed.

1.3 PARAMETERS REQUIRED FOR GENERATING TOOL PATH

a) STL data for CAD model: The STL file [4] [5] is the first input to the tool path generation algorithm which discretizes the CAD model in small number of triangles known as facets. This STL can be made on any of the CAD model. The CREO has been used to make the .STL file for this research work. The STL standard includes ASCII data format.

ASCII file is human-readable and can be modified by a text editor if required, thus for this reason we are using the ASCII format.

b) Radius of roughing and finishing tool: The radius of roughing and finishing tool is the next input given by user. It gives user the ability to use the ball end tool for any radius.
c) Depth of cut for roughing: The depth of cut for roughing pass can be given by user as per requirements. The raw material generally is of much bigger size then the part dimensions to be manufactured. In case if the part dimensions are of much smaller in size, then the user has given independence to cut the raw material in multiple passes by giving depth of cut.
d) Finishing allowance: The another value which user inputs in the program is the finishing allowance which the roughing tool should leave for finishing tool. Generally it is kept 2mm but the user may enter another value if the part is not so complex or the tool used for finishing is of higher radius.
e) Side feed: The value of side feed is to be entered by the user. This value is kept large for roughing pass and small for finished passes.

1.4 BALL DROP METHOD

Kandarp patel [4] developed Drop the Ball method which could be used to machine a sculptured surface on 3 axis CNC lathes. This method can machine sculptures surface by dropping the ball nose cutter shaped like a sphere. The tool is dropped at each position, independent of the type of surface being machined which makes it efficient for machining complex surfaces. The tool is then moved over the fixed helical foot print to generate gouge- free tool path. The Drop the Ball method was developed and tested for machining complex sculptured surface on CNC lathes. This Drop the Ball method can machine sculptured surfaces efficiently but this method is limited for the use of ball nose end milling cutter with a fixed path along which cutter is moved.

In the present work, this method was selected for developing machining algorithm.

The entire work piece surface which is to be machined is mathematically represented by the triangle known as facets and surface normal called facet normal. In Dropping Method [7], for each cutter position the tool is dropped from a height along the tool axis at any particular position in X-Y plane. The cutter drops steadily along tool axis plane and would intersect one of the triangles representing the work piece surface. There are three possible scenarios for the point of contact between cutter and surface:

i. Contact on planar surface.
ii. Contact on edge.
iii. Contact on vertex.

The point of contact will be dependent of the topography of the surface. The tool path planning algorithm has been designed to check for the projection of the tool in a given position that the generic ball end milling cutter is touching with the part of the triangulated surface. The parameter u is set for the extreme position of the tool, and it keeps on decreasing as goes from Centre to the outer of the work piece. The tool projection may be inside the triangle or may touch triangle on edge or on vertices. The tool positioning strategy must stops the tool forward motion at the first contact of the tool with either of edge, triangle surface or vertex for which triangle, edge and vertex checks have been applied to extract the information about tool position along X-axis direction of the 3-axis CNC milling lathe.

After applying all these checks, the value of point of contact (P_c) is checked whether it is in the triangle or not and the appropriate value is stored and then tool is moved to another location. These values of P_c are stored in a file to retrieve for the next step.

Then tool path is generated for both roughing and finishing operation.

2. IDENTIFYING GEOMETRY AND FEATURE BASED TOOL PATH PLANNING

Based on the files generated from the generalized tool path algorithm, it can be identified by comparison of the x values that whether the geometry of work piece is cylindrical or conical. The present work is based on the identification of the geometry mainly cylindrical and conical geometry and then to identify what are the various features in these geometries like cavities, pockets, grooves etc. After identification of various features in a particular geometry, tool path planning strategy has to be adopted in such a way that first whole geometry is to be machined and features are skipped and saved in other files then feature based tool path planning has to done.

2.1 IDENTIFICATION OF CYLINDRICAL GEOMETRY

Cylinder can be identified based on the x values (final values as shown below) calculated from the roughing passes and finishing pass. If x values remains constant throughout i.e if we calculate the mean of all x values in the roughing passes as well in the finishing pass and it remains same as the integer values of x values then it is identified as cylinder.

0	0	15.6045
0	1	15.5661
0.002205	2	15.5269
0.0033075	3	15.4879
0.00441	4	15.4536
0.0055125	5	15.4238
0.006615	6	15.3984
0.007717	7	15.3776
0.00882	8	15.3612
0.0099225	9	15.3492
0.011025	10	15.3415
0.0121275	11	15.3383
0.01323	12	15.3394
0.0143325	13	15.3449
0.015435	14	15.3548
0.0165375	15	15.3691
0.01764	16	15.3878
0.0187425	17	15.4109
0.019845	18	15.4385
0.0209475	19	15.4707
0.02205	20	15.5074

2.2 IDENTIFICATION OF CONICAL GEOMETRY

Cone can be identified based on the x values (final values as shown below) calculated from the roughing passes and finishing pass. If x values follows a definite decremented pattern after a certain interval of time and decrement is constant throughout then it is identified as a cone.

8.23237	7467	14.0024
8.23347	7468	14.0376
8.23457	7469	14.0376
8.23568	7470	14.0376
8.23678	7471	14.0376
8.23788	7472	14.0288
8.23898	7473	13.9941
8.24009	7474	13.9635
8.24119	7475	13.9369
8.24229	7476	13.9145
8.24339	7477	13.896
8.2445	7478	13.8815
8.2456	7479	13.8709
8.2467	7480	13.8643
8.2478	7481	13.8616
8.24891	7482	13.8628
8.25001	7483	13.868
8.25111	7484	13.877
8.25221	7485	13.8901
8.25332	7486	13.9071
8.25442	7487	13.928
8.25552	7488	13.9531
8.25662	7489	13.9821

2.3 IDENTIFICATION OF FEATURES IN THE CYLINDRICAL AND CONICAL GEOMETRIES

If we have the combined geometry for both cone and cylinder then the tool path algorithm must verify whether first geometry is a cylinder or a cone then recognize the features in it and skip them and then go to other geometry and again recognize the features in it and skip them also and then in the last it would machine all the features separately in a single go

3. METHODOLOGY

A computer program has been developed for the mathematical procedure defined. The solution procedure for NC tool path generation for 3 axis NC milling lathe has been discussed stepwise as below:

1 The STL file is generated in CREO CAD modeling software.

2 The STL file is then send as input to the program and is made to run on the PC.

3 The STL data for the three dimensional CAD model of the part extracts the required dimensions of the part for the algorithm. Then facets which are not required are removed and others are saved during the program execution.

4 The execution of program starts only after user has provided inputs such as depth of cut for roughing pass, finishing allowance etc.

5 The maximum stock size is calculated to get the length of the work piece.

6 The program runs for the whole of the work piece. It checks the extreme tool position where the value of u is least at every point and after storing that value, it moves to next position.

7 The program then runs for the roughing passes. The calculation of roughing passes is done based on the depth of cut given by the user.

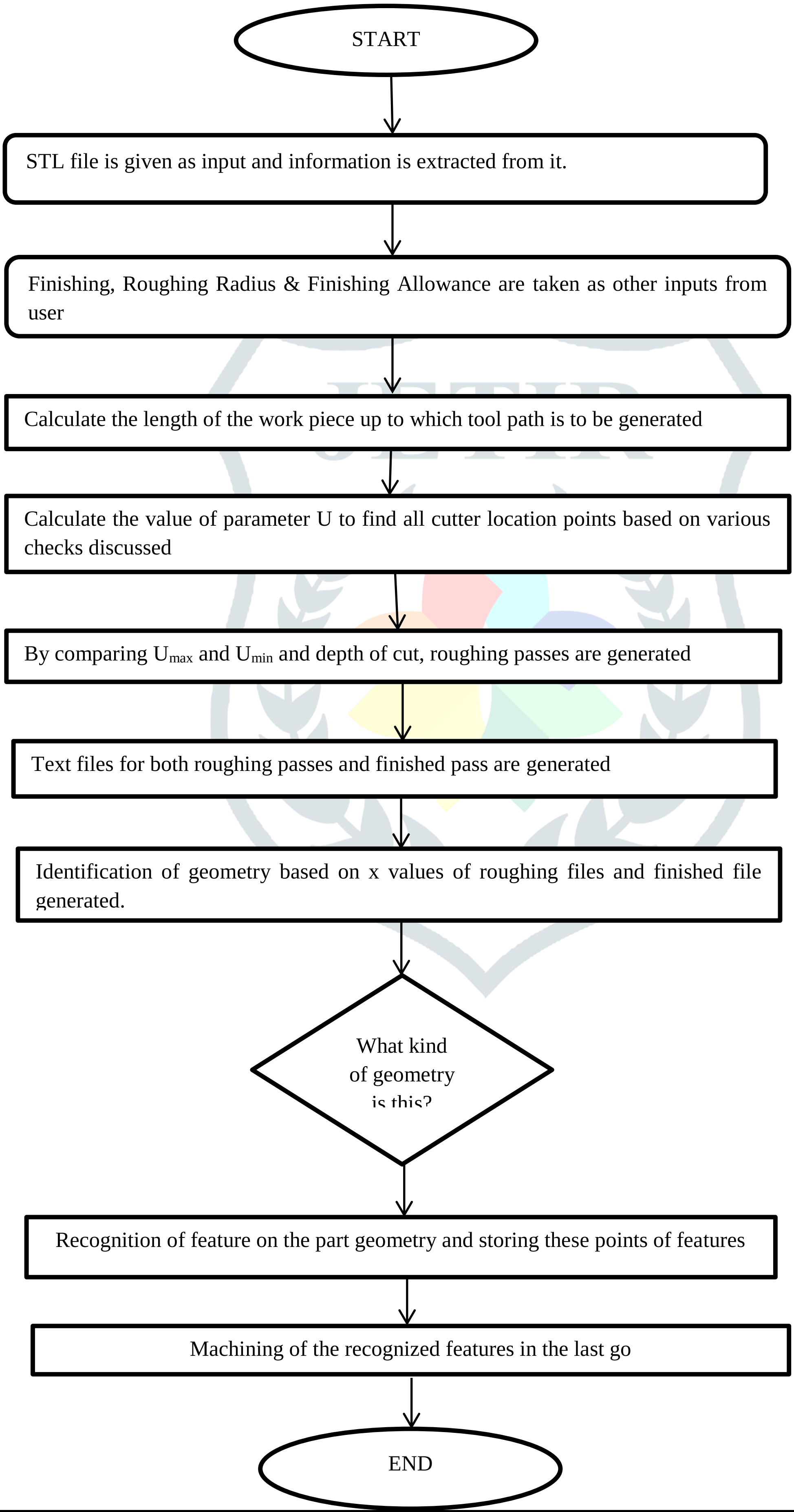
8 The program executes now for the last time for finishing pass after roughing passes are calculated. The finishing allowance is predefined in the algorithm. All Cutter Location (CL) points are saved in auto generated text files with different names for roughing passes and finishing pass.

9 After text files are generated for both roughing and finishing passes, based on the geometry of the work piece and various features incorporated in it, another algorithm is developed

10 In the next algorithm, roughing files and finished file both are processed based on the features identified in the work piece.

11 Here features are identified and then they are skipped in the machining and afterwards these features are separately machined in the last.

3.1 Flowchart



3.2 VALIDATION OF THE WORK

Tool path is tested on a Custom Simulator 'Tool Sim'. The validation is done by comparison of the STL file of the three dimensional geometry with the obj file of final machined geometry. Tool path have been prepared for different models like cylinder, cone and then various features are incorporated into these geometries like cavities, pockets and protrusions and these features are then machined in the last and tool path is validated by saving the stock as obj file and then validation of tool path algorithm is done by comparing obj file with STL file

4. CONCLUSION

In the present work, firstly tool path algorithm for the 3-axis lathe mill has been developed. Visual studio is used for programming purpose. Ball nose end mill cutter tool has been used in the algorithm. In the present work, tool of radius 6.35 mm has been used for roughing and 1.5875mm for finishing operations. Various checks have been applied to trace cutter contact point of contact with work piece. Tool and work piece moves in such a way that makes the helical tool path for machining. The accuracy of work piece depends upon the STL triangles, radius of tool for finishing and side feed for finishing pass. After generation of roughing files and finishing file then identification of the geometries have been done by developing geometry based algorithm and then various features like cavities, pocket, and grooves have been separately machined in the last step based on the algorithm developed.

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