Proceedings of MARTEC 2010
The International Conference on Marine Technology
11-12 December 2010, BUET, Dhaka, Bangladesh

DEVELOPMENT OF G-CODE FROM CAD MODEL FOR ROTATIONAL PARTS

Md. Deloyer Jahan[1]

[1]Department of Industrial and Production Engineering,
Bangladesh University of Engineering and Technology, Bangladesh
E-mail: mdjahan.mpe@aust.edu

ABSTRACT

Throughout the life cycle of engineering products, computers have a prominent, often central role. In the process of product design and manufacturing and its interface; process plans, this role becoming increasingly important as competitive pressure call for improvements in product performance and quality and for reduction in development time-scales. Computer aided process planning engineers to improve the productivity with which they carry out their work. Feature extraction and classification is considered as the bridge between Computer-Aided Design (CAD) and Computer-Aided Process Planning (CAPP). This paper proposes a method that can extract and classify for rotational parts taking a 2D data file as input. In addition, feature interactions are also taken into consideration in this methodology. The proposed feature extraction and classification method consists of three basic procedures. First, polyline of desired profile for certain object is drawn in certain manner and saved in DXF format of AutoCAD. Second, feature is extracted from the 2D CAD DXF data file. Third, G-Code compatible for CNC machine is generated using several logics. A sample application description is presented for demonstration purposes. The system has been implemented in Visual Studio (Visual C++) on a PC-based system.

Key words: CAD, CAPP, CAM, DXF, Process plans, Data Extraction, Feature Recognition, Tool Path Planning, Part Program, G-Code.

1. INTRODUCTION

Process planning translates design information into the process steps and instructions to efficiently and effectively manufacture products. As the design process is supported by many computer-aided tools, computer-aided process planning (CAPP) has evolved to simplify and improve process planning and achieve more effective use of manufacturing resources. Process planning encompasses the activities and functions to prepare a detailed set of plans and instructions to produce a part. The planning begins with engineering drawings, specifications, parts or material lists and a forecast of demand. A computer-aided process planning system has various modules such as for shape recognition, costing and process database etc. Each module may require execution several times in order' to obtain the optimum process plan. The input to the system will most probably be a 3-D wire frame or solid model from a CAD data base or a 2-D model. The process plan after generation and validation can then be routed directly to the production planning system and production control system.

2. FEATURE BASED CAM SYSTEM

An intelligent interface between CAD and CAPP systems is imperative because the CAPP systems depend on correct data obtained from CAD systems to perform precise process planning. Feature recognition techniques provide such a connection between CAD and CAPP. CNC part programs are derived automatically using automatic feature recognition from 2D drawings in this system. The CAD model of the component including half of the 2D upper profile to be turned has to be designed in any CAD environment and be converted to DXF data structure to accomplish the feature recognition process of the system. Part programs have been derived appropriate to the Fanuc O-T control system. This system was prepared using Delphi version 7. In addition, the system is supported with material and cutting tool database prepared according to the Sandvik Coromant catalogue [1, 9]. The system is composed of three important modules, file reading, feature recognition and tool path planning. The General structure of the system is shown in Figure 1.

2.1 File Reading System

After data input into the system using DXF format a set of processes is done automatically according to a specific hierarchy. Firstly, the features in the drawing are found and defined to the system. In this stage, the coordinates of the start and end points of arc features which is not obtained directly from DXF database are found using trigonometric equations and all of feature coordinates are modified from right to left and from below to above. These processes provide the precise feasibility of the sequencing process to be done in the following stages. It may be possible that the drawing could have been constructed anywhere in the CAD environment according to the Cartesian coordinate system. In that case all of the feature coordinates of the design are modified according to the quadrant II (x<0,y>0) of the coordinate system because of the fact that tool paths, according to the absolute dimension system, are formed by generally taking the face of the component in the manufacturing of cylindrical components. After these processes, all coordinates of the features are sequenced according to their start points and transferred to the origin. Finally the shape of the work piece is drawn with the program with its sub symmetry [2, 10].

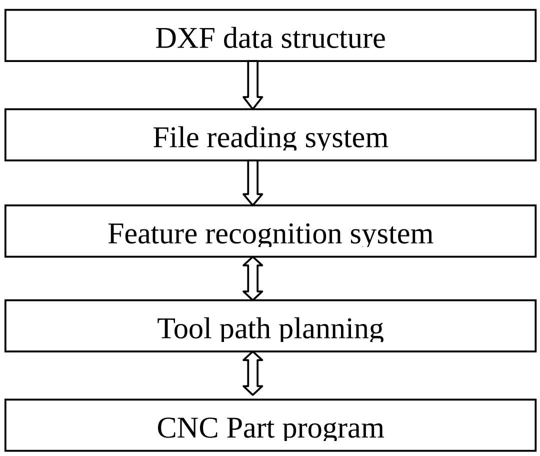


Figure 1: Structure of the system

3. DATA EXTRACTION

3.1 Data Extraction from the CAD File

It is difficult for the end user to interpret or alter the databases used by different CAD packages. Commercial CAD package developers designed their CAD system for design purpose only, not for manufacturing systems. As stated earlier, one CAD, CAM or CAPP system cannot completely understand a design file created by different software and for this reason, it is not possible for a third party to develop a CAPP system that will completely compatible with other CAD systems i.e. understand and extract all the information kept in a design file. To resolve the problem some standard formats like Initial Graphics Exchange Specification (IGES), Data Interchange Format (DXF) are being used for transferring design information from one CAD system to another CAD, CAM or CAPP system. In this research work, Data Interchange Format (DXF) is used for its rigidly defined structure. It is also easy to write programs to extract data from these files. [3, 11].

3.2 Structure of the DXF file

There are six sections in a DXF file. They are: HEADER, CLASSES, BLOCKS, TABLES, OBJECT and ENTITIES. Among them, only ENTITIES section contains geometric information regarding any object drawn in the design file. So, part feature information is extracted from the section. Geometric information regarding each entity is stored after different DXF numbers or codes in the ENTITIES section. In actual DXF file all data (DXF codes and respective values) are in a single column one after another. DXF code ‘0’ in the first row of the first column indicates that a new section is started. Similarly name of an entity (‘POLYLINE’), handle number (BC), name of the layer (‘0’) are after DXF code ‘0’, ‘5’ and ‘8’. X, Y, and Z coordinate values of different points are available after DXF code 10, 20 and 30 respectively. . The ending of the current (‘ENTITIES’) section is identified by ‘SEQEND’. Similarly ‘ENDSEC’ is for ending of all six section of the DXF file. [7]. Detail structure, DXF code and their description are available in AutoCAD online help. [4, 12].

3.3 Part Data Extraction

In this work, a visual C/C++ program is used to extract the information from the DXF file. As already mentioned in a DXF file data is stored in a single column. So, the program opens the DXF file and search ‘ENTITIES’ section line by line until a match is found because data regarding the part geometry is available in this section. As the profile of the part is drawn by a polyline, when the program reaches the ‘ENTITIES’ section it searches for ‘POLYLINE’. After this, X and Y coordinates of each ‘VERTEX’ which represents a point in the profile are collected following DXF code 10 and 20 respectively from the entire ‘ENTITIES’ section. To know whether the line between two points is curved or not, the program search DXF code 40 after DXF code 10, 20, and 30 for individual vertex. DXF code 40 indicates that line between the current point and the next point is curved.The program continues until it reaches ‘ENDSEQ’, i.e. the end of the entity section. [5, 13, 16]

3.4 Vertex Coordinate Extraction

The vertex coordinate extraction algorithm utilizes headers and flags used in DXF files to identify coordinate values. The VERTEX header, for instance, indicates the beginning of vertex coordinates of edges. All X and Y coordinates are placed under specific flags following this header. The 10 flag precedes an X coordinate value, whereas the 20 flag precedes a Y coordinate value. The flow chart of the algorithm is given in Figure 2. As illustrated in the figure, the coordinates that represent the part are identified and stored into the Vertex Coordinate Array (VCA). Other attributes, such as the X and Y coordinates of fillet beginning, sweeping and beginning angle of the fillet and fillet radius, are extracted and stored into the Fillet Array (FA). Both arrays are saved for further processing.

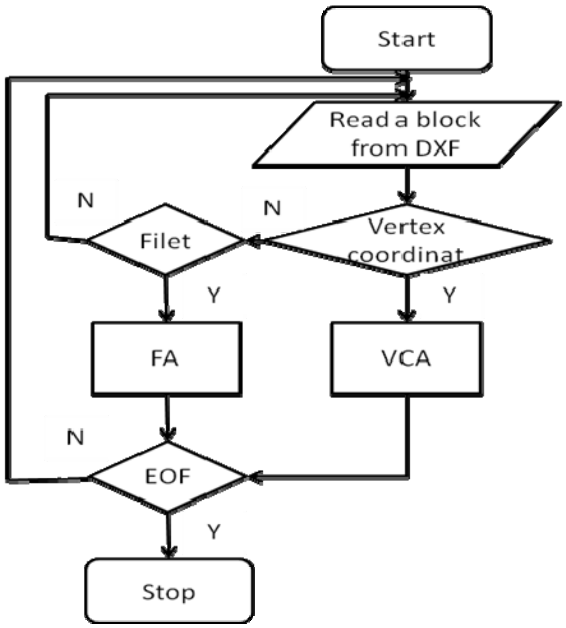


Figure 2: Extraction algorithm for coordinates

4. PROCESS PLANS FOR ROTATIONAL PARTS

Computer aided process planning is done in this study by generating G-CODE for CNC machine for rotational parts. A sample shape is studied here featured with fillet. First of all it is needed to understand what G-code is. G-Code, or preparatory code or function, are functions in the Numerical control programming language. The G-codes are the codes that position the tool and do the actual work. The programming language of Numerical Control (NC) is sometimes informally called G-code. But in actuality, G-codes are only a part of the NC-programming language that controls NC and CNC machine tools. Today, the main manufacturers of CNC control systems are GE Fanuc Automation (joint venture of General Electric and Fanuc), Siemens, Mitsubishi, and Heidenhain, but there still exist many smaller and/or older controller systems.

G-codes are also called preparatory codes, and are any word in a CNC program that begins with the letter 'G'. Generally it is a code telling the machine tool what type of action to perform, such as:

G0 rapid positioning
G1 linear interpolation
G2 circular/helical interpolation (clockwise)
G3 circular/helical interpolation (c-clockwise)
G4 dwell
G10 coordinate system origin setting
G17 xy plane selection
G18 xz plane selection
G19 yz plane selection
G20 inch system selection
G21 millimeter system selection
G40 cancel cutter diameter compensation
G41 start cutter diameter compensation left
G42 start cutter diameter compensation right
G43 tool length offset (plus)
G49 cancel tool length offset
G53 motion in machine coordinate system
G54 use preset work coordinate system 1
G55 use preset work coordinate system 2
G56 use preset work coordinate system 3
G57 use preset work coordinate system 4
G58 use preset work coordinate system 5
G59 use preset work coordinate system 6
G59.1 use preset work coordinate system 7
G59.2 use preset work coordinate system 8
G59.3 use preset work coordinate system 9
G80 cancel motion mode (includes canned)
G81 drilling canned cycle
G82 drilling with dwell canned cycle
G83 chip-breaking drilling canned cycle
G84 right hand tapping canned cycle
G85 boring, no dwell, feed out canned cycle
G86 boring, spindle stop, rapid out canned
G87 back boring canned cycle
G88 boring, spindle stop, manual out canned
G89 boring, dwell, feed out canned cycle
G90 absolute distance mode
G91 incremental distance mode
G92 offset coordinate systems
G92.2 cancel offset coordinate systems
G93 inverse time feed mode
G94 feed per minute mode
G98 initial level return in canned cycles

4.1 Profile With Fillet:

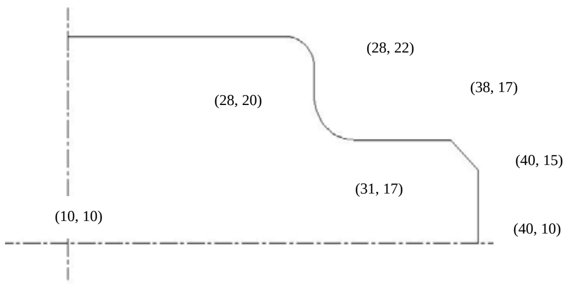
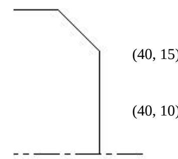


Figure 3: Profile of rotational parts

For this profile first part zero is determined. Here part zero is at point (10, 10). Then for absolute positioning other points are determined from the vertex coordinate system. Points found from vertex coordinate system are (40, 10), (40, 15), (38, 17), (31, 17), (28, 20), (28, 22), (26, 24), (10, 24) From those points least value of X coordinate and least value of Y coordinate is determined which is found to be (10, 10) So by subtracting the value of X and Y from all the coordinates' conversion from global to local system is made. Profile with fillet needs to consider extra features. For those features extra calculation and idea is generated. [6]

Steps to generate G-Code from DXF file format:

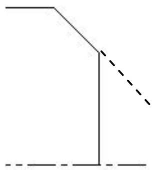
1. Drawing is saved in DXF format.
2. From large list of data ENTITIES is to be found. [8, 17, 18]
3. From ENTITIES several features are identified
4. Every line is start with AcDbLine and ends with a character 0
5. X_{start} is shown by 10 and Y_{start} is by 20
6. X_{end} is shown by 11 and Y_{end} is by 21
7. Lowest value of X and Y is determined and is set to origin of the coordinate by subtrac1ting them from all the coordinates.
8. Generation of G-Code is executed from the highest value of x at which the value of Y is no equal to the value of coordinate origin value of Y there is such one point, in this case this value is (40, 15)




```
ENTITIES
  0
LINE
  5
89
330
1F
100
AcDbEntity
  8
0
100
AcDbLine
 10
40.0
 20
10.0
 30
0.0
 11
40.0
 21
15.0
 31
0.0
  0
LINE
  5
8A
330
1F
100
AcDbEntity
  80
100
AcDbLine
 10
40.0
 20
15.0
 30
0.0
11
38.0
21
17.0
 31
0.0
  0
LINE
  5
8B
330
1F
100
AcDbEntity
  8
0
100
AcDbLine
 10
38.0
 2017.0
 30
0.0
 11
31.0
 21
17.0
 31
0.0
  0
LINE
  5
8C
330
1F
100
AcDbEntity
  8
0
100
AcDbLine
10
28.0
 20
20.0
 30
0.011
28.0
2122.0
 31
0.0
  0
LINE
  5
8D
330
1F
100
AcDbEntity
  8
0
100
AcDbLine
 10
26.0
 20
24.0
300.0
 11
10.0
 21
24.0
31
0.0
  0
ARC
  5
8E
330
1F100
AcDbEntity
  8
0
100
AcDbCircle
 10
31.0
 20
20.0
 30
0.0
 40
3.0
100
 AcDbArc
 50
180.051
270.0
  0
ARC
  5
8F
330
1F
100
AcDbEntity
  8
0
10022.0
 30
0.0
 40
2.0
100
AcDbArc
50
0.0
 51
90.0
  0
ENDSEC
  0
AcDbCircle
 10
26.0
 20
```

Figure 4: DXF for the profile

9. As cutting is starting from some far from the workpiece thus for rapid positioning cutting tool is positioned in the position at +2 in X axis and -2 in y axis from the first point(in this case (40, 15)).
10. For this case starting point is (42, 13).



(42, 13)

11. For G-Code representation X axis of the coordinate system is represented as Z and Y axis of coordinate system is as X. The Codes used is elaborated later in the chapter. So for initial rapid positioning G-code is G00. The formulae used to define is as following

    $(X-X_{origin}) = X_{start}$

    Represented as Z….

    $(Y-Y_{origin}) \times 2 = \text{diameter}$

    Represented as X…

    So after rapid positioning first line become

    G 00 Z 32 X 6

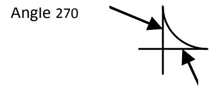
12. Then linear interpolation is made with respect to descending order of X axis coordinate in the DXF file 10, 11 commands. So next line in G-code become

    G 01 Z 28 X 14

13. Another type of feature include in the profile is fillet. To represent fillet circular interpolation is necessary. When AcDbCircle is found in the DXF file it implies there is some circular shape.

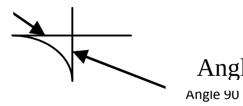
14. For circular shape 10, 20 imply coordinate of center of the circle and 40 implies radius of the circle. One important measure is either the circle is clockwise or anticlockwise. 50, 51 imply the starting angle and ending angle. If 50 and 51 range from 0 to 179 degree then the circular shape is clockwise and if range of 50, 51 is 180 to 359 then circular shape is counter clockwise.

Angle 270



Angle 180

Angle 0



Angle 90

15. So for corresponding G-code for clockwise circular interpolation is G02 and for counterclockwise circular interpolation is G03.
16. For this sample problem for first fillet which is clockwise and following G-code is obtained for the input of DXF file.

    G02 Z18 X20 R 3

17. For this sample problem for second fillet which is counterclockwise and following G-code is obtained for the input of DXF file.

    G03 Z16 X28 R 2

    After linear interpolation when there is some gap program understand it as fillet and by the descending order of X coordinate it arrange the G-code command. Similarly circular interpolation is done for all AcDbCircle command.

5. IMPLEMENTATION

The intended use for this G-Code operation is to enable specialist machine builders to use for Motion Coordination. It provides solutions for the control of X, Y axes where the motion program source is from a CAD/CAM program that outputs G-Code sequences. This G-Code implementation is not intended to replace full functioning CNC controllers on sophisticated metal turning machines. G-Code processing has been implemented on Motion Coordinator system software's. The system allows up to 2 axes to be controlled by a sequence of G-Code commands that are resident in one or more of the programs can be saved to the Motion Coordinator. This will be implemented to aid flexibility of CNC operation. A typical application would require a startup program, written in BASIC and the G-Code dispatcher program which is also a BASIC language program. [19] G-Code programs can be loaded into the memory and can be selected for running as required.

6. CONCLUSION

Computer-Integrated Manufacturing has gained recognition as a most effective tool in increasing manufacturing competitiveness. In this work, the work provides a rigorous method for the understanding of process planning of rotational parts and the development of effective and efficient Computer-Aided Process Planning systems. The main contribution of this paper is to develop CAPP module based on G-Code that has been conceived and realized for the manufacturing of data transmissions in an integrated production system. Realizing the CAPP module for data transmissions has led to an increase of the flexibility and correctness of the technological planning, having favorable influences on the manufacturing costs.

ACKNOWLEDGMENT

This work would not have been possible without the support and encouragement of my thesis supervisor, Dr. Nafis Ahmad, under whose supervision I chose this topic and began the thesis. I would also like to thank the department of industrial and production engineering, BUET for supporting me during my one year of study and research on this topic by providing full access of their capacity. I would like to give special thanks to Md. Shihabuddin (B.Sc. In Computer Science and Technology, BUET) for helping me to make the program for my work. I cannot end without thanking my family, on whose constant encouragement and love I have relied throughout my time at the academy.

REFERENCES

[1] Gindy, N. N. Z.,"A hierarchical structure for form features", International Journal of Production Research, Vol. 27, No. 12, pp. 2089-2103

[2] Jaekoo, J., et. Al., "Efficient feature-based process planning for sculpture pocket machining", Computers and Industrial Engineering,

[3] Li, R. K and Adiga, S.,"Part feature recognition system- A vital link in the integration of CAD and CAM", Proceedings of the IXth ICPR, pp-198-205

[4] Auto CAD online help. Version 2000, 2004, 2007.

[5] Tr. J. of Engineering and Environmental Science 23 (1999) , 339 { 347. (c) TUBITAK

[6] Ahmad, N., "A dynamic model of Computer Aided Process Planning for rotational components". M.Engg. thesis, BUET, 2001

[7] Online help AutoCAD 2007, Autodesk Inc.

[8] Hill, A.E. and Pilkington, R.D.,"A Completed

[9] AutoCAD Databook", Prentice Hall Inc (UK) ltd

[10] IJCSNS International Journal of Computer Science and Network Security, VOL.10 No.2, February 2010 vol. 27(4), pp. 148-154.

[11] Alam, M. R., Lee, K. S., Rahman, M. and Zhang, Y. F., (2000), "Automated process planning for the manufacture of sliders", *Computers in Industry*, vol. 43, pp. 249-262.

[12] Aslan, E., Seker, U and Alpdemir, N., (1999), "Data extraction from CAD model for rotational parts to be machined at turning centres", *Journal of Engineering and Environmental Science*, vol. 23, pp. 339-347. Atkinson, A., (1991), "Manufacturing parts features: CIM's technological common denominator", *Integrated Production Systems – Design, Planning, Control and Scheduling*, fourth edition, Institute of Industrial Engineers, Norcross, Georgia.

[13] Cay, F. and Chassapis, C., (1997), "An IT view on perspectives of computer aided process planning research", *Computers in Industry*, vol. 34, pp. 307 337.

[14] ElMaraghy, H. A., (1993), "Evolution and future perspectives of CAPP", *Annals of CIRP*, vol. 42(2), pp. 1-13

[15] int. j. Computer Integrated Manufacturing, 1997, vol. 10, no. 1-4, 266± 280

[16] Asmundsson, J., Rardin, R.L. and Uzsoy, R., Tractable non-linear capacity models for aggregate production planning. Technical Report IN 47907 1287, Purdue University, School of Industrial Engineering, West Lafayette, 2003

[17] Han, J. H., Pratt, M. and Regli, W. C., (2000), "Manufacturing feature recognition from solid models: a status report", *IEEE Transactions on Robotics and Automation*, vol. 16, no. 6, December. [18]. J. Rossignac and A. Requicha, "Solid modeling", in the Encyclopedia of Electrical and Electronics Engineering, Ed. J. Webster, John Wiley & Sons, 1999.

[18] Hayong Shin, "Classification of geometric model", IE752 geometric modeling class in KAIST, 2002

[19] http://www.triomotion.com/upload/AN-208%20Using%20GCODE.pdf