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Simulation of a workpiece in CNC milling machine on the basis of G and M code based NC programming

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ABSTRACT
The assisting technology of CNC milling machine is inaugurating the virtual machining platform, correcting NC program and process simulation and optimization, which can fabricate the efficient machine technology come true. The paper represents the G and M code based numerical control (NC) programming and real time 3D virtual simulation of workpiece in CNC milling machine (DENFORD MICROMILL, 2000), by using machine simulator. Machine simulators namely Denford Virtual Reality CNC milling.micromill and CncSimulator Pro. are used. The workpiece is designed through the MasterCAM (QuickCam) software (CAD/CAM Family) which reflects a milling process, setting all the movement trajectory of cutting tool over that workpiece using polynomial interpolation. Intelligent CAD/CAM generates NC program for a particular case along with a G and M code based NC program is also developed for a separate workpiece. The simulators used enable development of complex machine troubleshooting scenarios that are not feasible on real equipment.

Keywords: G and M code, Simulation, CNC Milling machine, MasterCAM, CncSimulator Pro.

1. Introduction

Modern manufacturing system and industrial robots are advanced automation systems that utilized computers as an intelligent division of their control, where an innovative organization of intelligent CAD/CAM (CAD – Computer Aided Design / CAM – Computer Aided Manufacturing) is implied, which can able to design the contours of workpiece, can easily be transferred it to the machine software for real time simulation, then manufacturing.

There exist many commercial software for NC machining simulation and verification in the market and verity of CAD/CAM software, which methodologies are mainly underlying either object-based, image-based or solid-based method and object-based simulation often adopt Z-Map method, which is most commonly used in machining simulation. There were many successful attempts for machine simulation and troubleshooting analysis. Ding [1] simulated the machining of flat-end and ball-end mill. For a 5-axis solid milling simulation Du et al. [2] used the envelope theory and swept volume generation method. Based on Z-Map method, Yun et al [3, 4] predicted cutting force for the initial transient toolpath and the stable middle toolpath of flat-end milling tool, which deals with the feature of machining simulation integrated with cutting force estimation. With the help of machine software Heidenhain iTNC 530, Gjelaj A. [5] shows the spline interpolation for simulation of workpiece.

This paper focused on the G and M code based programming for a workpiece simulation, individually for Denford Micromill-2000, along with the virtual milling environment analysis of a workpiece with the help of CncSimulator Pro. software. Programming command used for various geometric interpolation approach such as linier interpolation, circular interpolation, spline interpolation, which represents exactly in the simulated environment, for the tools trajectory.

Denford Micromill-2000 is a classic CNC milling machine, quite an accurate one, which working environments is simulated through Denford Virtual Reality CNC milling software. CncSimulator Pro. is another efficient CNC simulation software.

2. Mathematical Model of Geometric Interpolation for Programming Command

To fulfill the requirements of NC-machining, in a workpart dimensioning all coordinates should be specified that are necessary in conformity with G-code (DIN 66025 used in Germany) for programming the terminal point of a straight course or a circular arc, or of the circle center [6]. As a matter of fact, workshop drawings of workpart often lack some of the requisite dimensions. This can lead to extensive mathematical calculation in establishing the coordinates. In such cases the programming can be much facilitated by using the so-called programming of contour strings (also known as segment contour programming).

Different address code used for different interpolation.
G01 Linear Interpolation (for Contour String Programming G71)
G02 Circular Interpolation: Clockwise (for Contour String Programming G72)
G03 Circular Interpolation: Counterclockwise (for Contour String Programming G73) [8].

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The following combinations are possible:

1. line – line
2. line – arc
3. arc – line
4. arc – arc

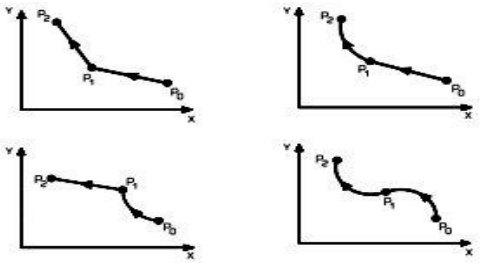

Figure 1. Three-Point-Strings

There is a spline interpolation function with a third degree polynomial, where manufacturing can be accomplished with two, three, four or five axes of the machine. Simulation processes have Spline interpolation sentences after third degree polynomial.

Therefore, the general mathematical model is given:

$$\begin{aligned} X(t) &= K_3X.t^3 + K_2X.t^2 + K_1X.t + X \\ Y(t) &= K_3Y.t^3 + K_2Y.t^2 + K_1Y.t + Y \\ Z(t) &= K_3Z.t^3 + K_2Z.t^2 + K_1Z.t + Z \\ I(t) &= K_3I.t^3 + K_2I.t^2 + K_1I.t + I \\ J(t) &= K_3J.t^3 + K_2J.t^2 + K_1J.t + J \end{aligned} \qquad (1)$$

Each detail of the coordinates in last command should be programmed as Spline interpolation parameter - K3 to K1. t is depended on feed rate and varies from 0 to 1 [6,5].

NC-Block G01 [X...] [Y...] [Z...] [F...] [S...]
[T...] [M...]
NC-Block G02 [X...] [Y...] [Z...] [I...] [J...]
[F...] [S...] [T...] [M...]
NC-Block G03 [X...] [Y...] [Z...] [I...] [J...]
[F...] [S...] [T...] [M...]

Optional Addresses

X	X-Coordinate of the target point
Y	Y-Coordinate of the target point
Z	Z-Coordinate of the target point
I	Circle Centre Incremental (distance between the starting position and the circle Centre in the X-direction).
J	Circle Centre Incremental (distance between the starting position and the circle Centre in the Y-direction).

When I or J (as defined above) are not programmed, the respective Centre coordinate is set to zero.

F	Feed rate (mm/min)
S	Spindle Speed (RPM)
T	Tool Change
M	Additional Function

3. Programming and simulation of workpiece

As an advanced simulation software for CNC milling, can be used to verify the collision, interference, over-cut, owse-cutting, and unreasonable cutting parameters which may arise in programs, and has been widely used the companies which using multi-axis CNC machining. The programming and simulation are analyzed by using the DENFORD MICROMILL, 2000, where master CAM (QuickCAM, CAD/CAM family) is used to make a design which produced the NC programming code by synchronizing with the Denford Virtual Reality CNC milling.micromill [7]. Intelligent CAD/CAM system have similar efficacy and functions based on common logarithms, but it lacks features for machining feed, speed and efficacy. MasterCAM can generate almost same NC code for a particular workpiece, along with MasterCAM generated code, required specific NC codes can be plugged to the CncSimulator Pro. (Ver: 1.0.5.2 beta) which gives an accurate real time simulated environment for particular workpiece.

So the machining simulation environment is completed by transferring G and M code based NC program, loading the control system, setting the machine parameters and structural variables, and by customizing special instructions.

3.1 Simulation approach with the Denford Virtual Reality CNC milling.micromill:

Dimension and design of the workpiece are made by using the QuickCam, which helps to realize the workpiece.

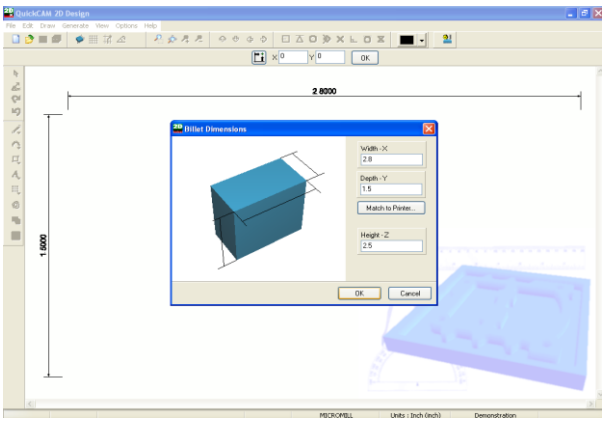

Figure 2. Dimensions of the workpiece

Machine simulators, Denford Virtual Reality CNC milling.micromill compiles with the MasterCAM designs and generates required G and M codes for the workpiece, which shows the real time machining of workpiece in a virtual environment. The design of the workpiece can be changed according to the observations.

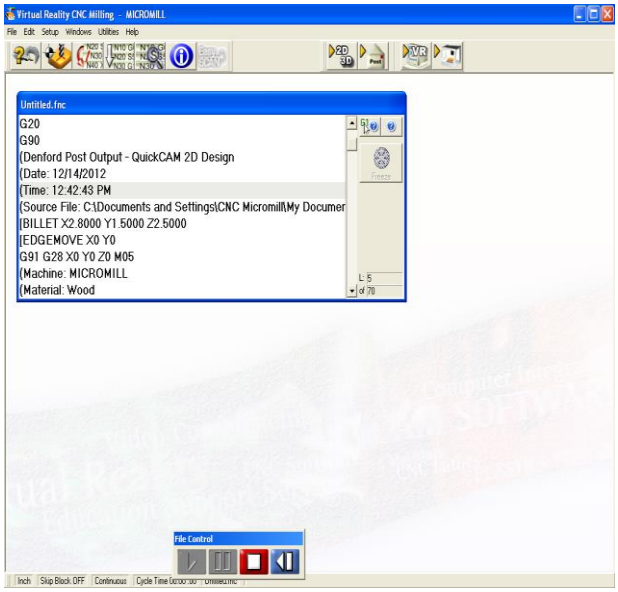

Figure 3. Generated NC program

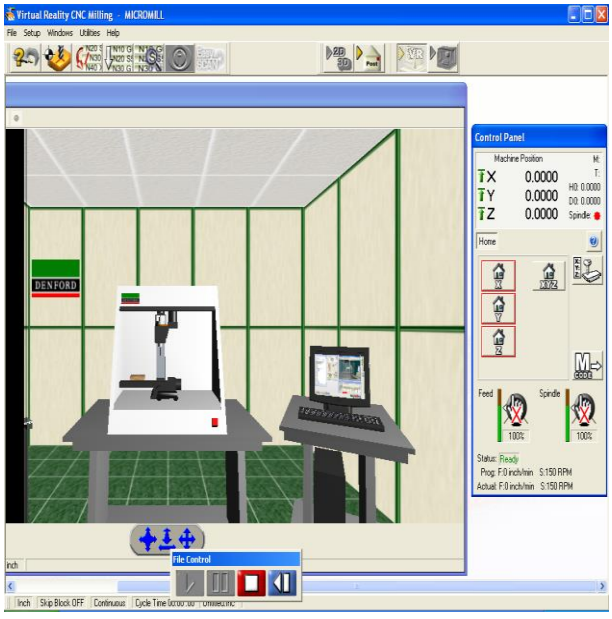

Figure 4. Machine Simulated environment

Simulated environment of the milling process of the workpiece, enables the operators to analyze the total process including the feed rate analysis, cutting speed and process and others which indicate the forecast for the real time troubleshooting.

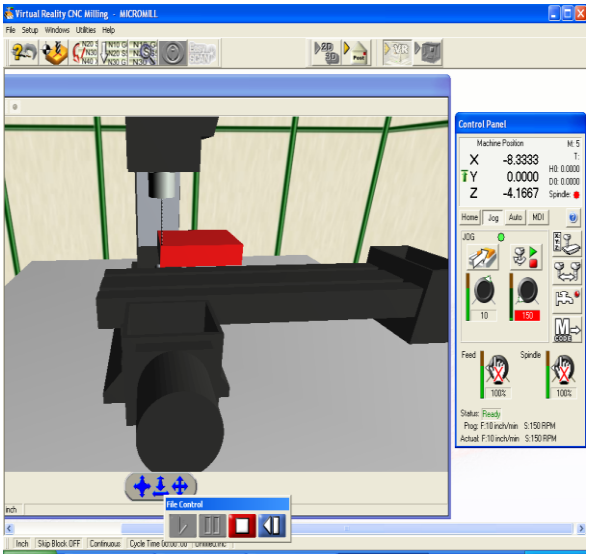

Figure 5. State of a virtual milling

3.2 Programming and simulation of workpiece in CNC milling machine with the help of CncSimulator Pro. (Ver: 1.0.5.2beta):

CncSimulator Pro. is an efficient machine simulator, which deals with DIN 66025 types machine language(G & M code) [8].

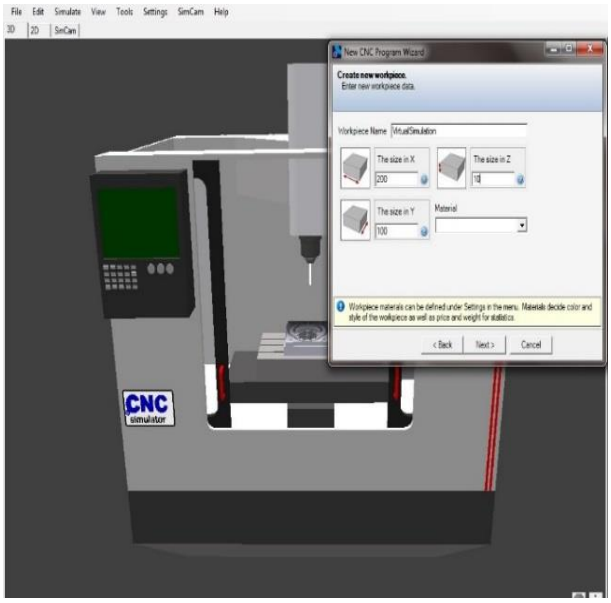

Figure 6. Virtual job setup

Software like CncSimulator Pro. is quit efficient one, used for 3D simulation, certainly helps for manufacturing forecast and for reducing errors. The process of the job setup and tool setup can be visualized in a virtual environment, this feature deals with the proper tool selection process for making a workpiece.

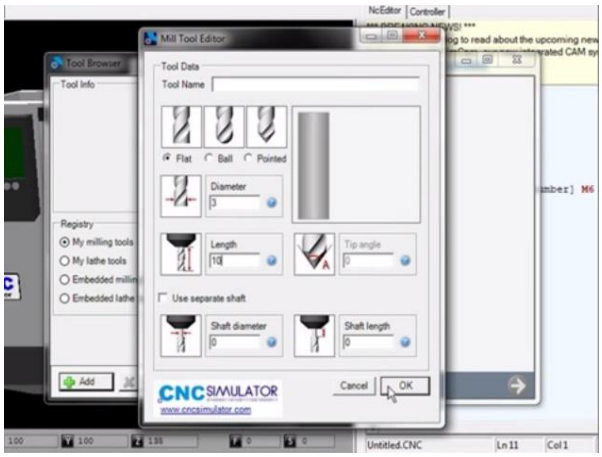

Figure 7. Virtual tool setup.

A G and M code based machine programming for a workpiece can be plugged in externally for checking the error in the code by observing the virtual simulation of workpiece.

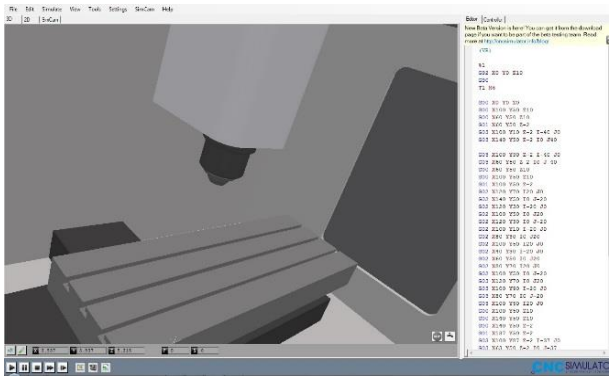

Figure 8. Plugging NC program code with the CncSimulator Pro.

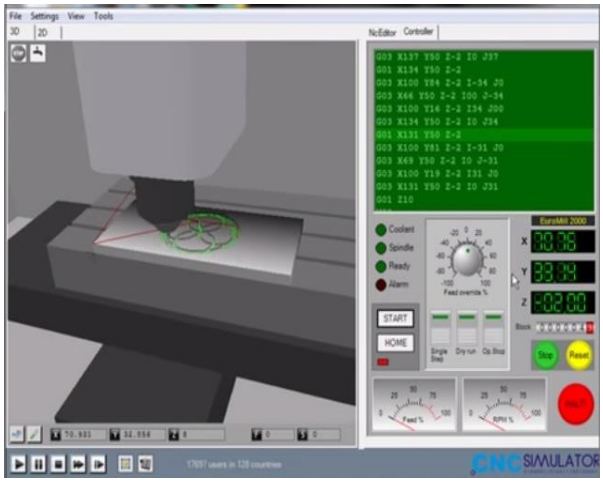

Figure 9. Simulation of cutting process

By utilizing real time virtual simulation of the machining process, engineers drastically can reduce the number of production errors which may be advised in case of settlement of tolerance. With this software we have slimmed down production costs and save material from errors during the fabrication operation.

3.3 The G and M code that using for the simulation of a workpiece with CncSimulator Pro. (Ver: 1.0.5.2 beta) is given below [8]:

G92 X0 Y0 Z10
G90
T1 M6

G00 X0 Y0 Z0
G00 X100 Y50 Z10
G00 X60 Y50 Z10
G01 X60 Y50 Z-2
G03 X100 Y10 Z-2 I-40 J0
G03 X140 Y50 Z-2 I0 J40

G03 X100 Y90 Z-2 I-40 J0
G03 X60 Y50 Z-2 I0 J-40
G00 X60 Y50 Z10
G00 X100 Y50 Z10
G01 X100 Y50 Z-2
G02 X120 Y70 I20 J0
G02 X140 Y50 I0 J-20
G02 X120 Y30 I-20 J0
G02 X100 Y50 I0 J20
G02 X120 Y30 I0 J-20
G02 X100 Y10 I-20 J0
G02 X80 Y30 I0 J20
G02 X100 Y50 I20 J0
G02 X40 Y30 I-20 J0
G02 X60 Y50 I0 J20
G02 X80 Y70 I20 J0
G02 X100 Y50 I0 J-20
G03 X120 Y70 I0 J20
G03 X100 Y90 I-20 J0
G03 X80 Y70 I0 J-20
G03 X100 Y50 I20 J0
G00 X100 Y50 Z10
G00 X140 Y50 Z10
G00 X140 Y50 Z-2
G01 X137 Y50 Z-2
G03 X100 Y87 Z-2 I-37 J0
G03 X63 Y50 Z-2 I0 J-37
G03 X100 Y13 Z-2 I37 J0
G03 X137 Y50 Z-2 I0 J37
G01 X134 Y50 Z-2
G03 X100 Y84 Z-2 I-34 J0
G03 X166 Y50 Z-2 I00 J-34

G03 X100 Y16 Z-2 I34 J00
G03 X134 Y50 Z-2 I0 J34
G01 X131 Y50 Z-2
G03 X100 Y81 Z-2 I-31 J0
G03 X69 Y50 Z-2 I0 J-31
G03 X100 Y19 Z-2 I31 J0
G03 X131 Y50 Z-2 I0 J-31
G01 Z10

M30

4. Conclusion:

An important direction to elevate the performance and efficiency of a CNC milling machine is to install a virtual machining system. By using MasterCAM (CAD/CAM system) the processing and manufacturing of a workpiece can be understood easily by comparison to the manual approach. Simulators can compile with MasterCAM, generates requisite NC programs of workpiece, in some extent, this is a frugal approach which saves time. A written NC program code of a workpiece can be tested accurately through the real time virtual simulation, consequently, improved efficiency, flexibility, productivity and manufacturing process are achieved, along with complex machine trouble shooting become feasible.

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