

# STEP-NC toolpath generation using IEC 61499 function block

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**ABSTRACT** – STEP-NC as a new interface for computer numerical control (CNC) system aims to overtake the drawback of existing CNC programming language, ISO 6983 (commonly known as G-code and M-code) bring comprehensive information for manufacturing such as geometry, workplan, machining strategy, and etcetera to CNC level. However, STEP-NC is a passive data model which does not contain any intelligent functionality. This paper presents the design and development one of module in intelligent STEP-NC/FB CNC controller system, which is a toolpath generation module. The generated output of the module, simulation and actual machining process are performed for validation purpose.

## 1. INTRODUCTION

One of the STEP-NC compliant CNC system key feature is the intelligent software in the machine controller that able to decode STEP-NC file, and then generating native information based on the capability and availability of manufacturing resources. In fact, most of the existing process planning systems are centralized in architecture and off-line in the data processing. In this case, it is difficult for a centralized off-line system to make adaptive decisions, in advance, without knowing actual runtime conditions on shop floors [1]. As a result, the evolution of CNC machines from ‘blind slave’ system into an integrated system with both decision-making and control abilities cannot be fully achieved.

To realize intelligent CNC controller, not only required a new data model and process planning approach, but the architecture of the controller should also be considered. Otherwise, the CNC controller will be remaining as an executor with no making-decision ability like before [2]. For that reason, this research proposes to incorporate three important techniques, which are layered architecture, distributed process planning (DPP), and distributed control system (DCS) concepts with intention to expand the automated and flexibility characteristics of CNC controller. In this research work, generic STEP-NC program uses an input. Then, based on availability and capability of manufacturing resources, proposed layered architecture of the CNC controller will generate native information for executing specific machine tools such as a cutting tool, machining parameter and toolpath. The detailed framework of this research work is already reported and

discussed in [3] and [4]. Here, only toolpath generation for round hole feature will be reported.

## 2. METHODOLOGY

The detail information of round hole feature is extracted from the STEP-NC example 1 sample NC program [5] by an interpreter module, and all the extracted information are summarised in Table 1.

Table 1 Round hole feature information extracted from STEP-NC Example 1 sample NC program

Diameter, D (mm)	Center Point (x,y,z)	Depth (z)	Bottom condition
22	(20.0,60.0,0.0)	(30)	Through _bottom _condition ()
(#17)	(#110)	(#83)	(#26)

Based on the feature information extracted and the availability of manufacturing resources. The type of operation, cutting tool diameter, feed-rate and spindle speed are determined by the native data generation modules based on embedded algorithms inside the related function block. For example, since the XY table milling machine using spindle motor ER20, the maximum size of the cutting tool can be attached 13mm. Thus, drilling type of operation cannot be used for creating a 22mm hole diameter. So, the system will automatically suggest the alternative solution and this time bottom and side milling are suggested to be used for machining this 22mm hole diameter. The detail parameter generated described in Table 2

Table 2 Machining condition generated by native planning module

Cutting Tool Diameter (mm)	Feed-rate (mm/min)	Spindle speed (RPM)	Machining strategy
13	480	1500	Contour parallel

Based on the data extracted and generated previously, RoundHole\_TPG FB (see Figure 1) will

generate the desired toolpath for completing round hole feature machining. Basically, for the 2D circular path, the toolpath motion can be represented by Equation (1) and Equation (2) for counterclockwise motion, and Equation (1) and Equation (3) for clockwise movement.

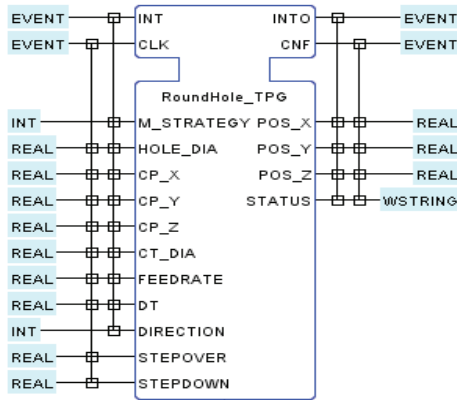


Figure 1 RoundHole\_TPG function block

$$x(t) = c_x + r \cos(\omega * t) \quad (1)$$

$$y(t) = c_y + r \sin(\omega * t) \quad (2)$$

$$y(t) = c_y - r \sin(\omega * t) \quad (3)$$

The angular velocity of the cutting tool motion expression is described by Equation (4).

$$\text{Angular velocity, } \omega = \frac{v}{r} \quad (4)$$

where  $\omega$  is the angular velocity (rad/s),  $v$  the feed-rate (mm/s) and  $r$  the circle radius (mm).

### 3. RESULT AND DISCUSSION

Based input information extracted by interpreter module, embedded algorithm inside RoundHole\_TPG FB will generate a set of position data for fabricating the input feature. Then, the output of this FB is simulated using CADCAMCONSys (see figure 3), and perform actual machining by XY table milling machine (see Figure 4) for validation purpose.

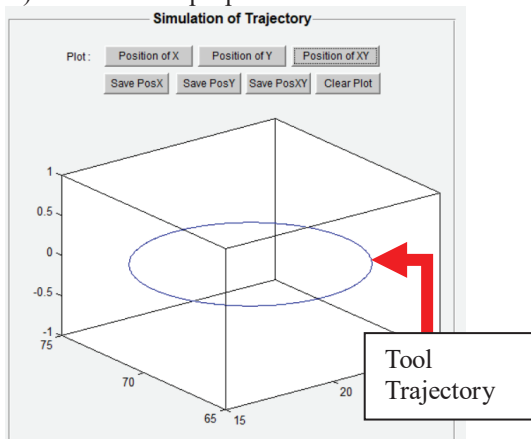


Figure 3 Simulation via CADCAMCONSys [6]

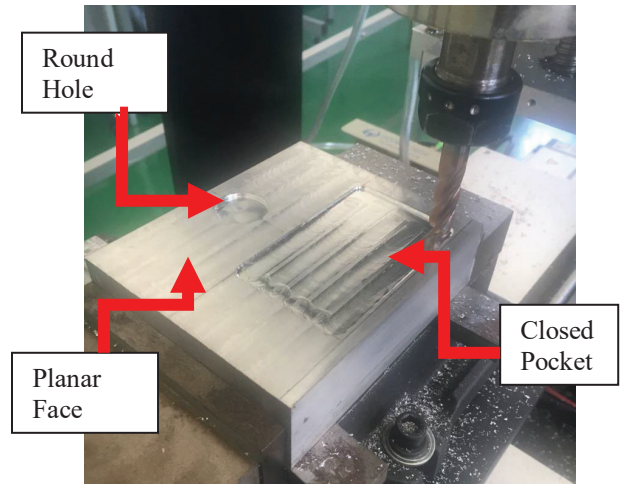


Figure 4 Actual machining testing result

### 4. SUMMARY

The manufacturing industry is constantly moving towards more customized components, driving the need for manufacturing systems that are more efficient in producing different parts with minimum effort required for re-planning, re-programming, and re-optimizing the process parameters. In the case of CNC machine tools, the proposed system enables to perform automatically native data generation by considering manufacturing resources availability autonomously.

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