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Studying the Design and Verification of 5-axis NC program under the Manufacturing System

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Abstract

NC programming, based on part profiles, is the conventional theory involved in the NC codes creating tasks; this is not wrong but far from satisfying the needs of the 5-axis NC cutting jobs. Viewing from the manufacturing system level and taking the transmission lower tank cut job on the 5-axis MC (machine center) as an example, the author deeply investigated and summarized the technique principles and algorithms of all works involved from a manufacturing system preparation to the 5-axis NC program verification with the help of computer aided technologies. The program design for the 5-axis NC machining is achieved with the CAM methods, and the correctness of the NC codes is guaranteed with the Post-NC verifying. All these principles and algorithms are general and practical, and can be applied by the 5-axis MC users to promote their production quality, efficiency and cost targets.

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Keywords*: 5-axis NC Machining, Programming Algorithm under the Manufacturing System, Manufacturing System in Verification, Physical Manufacturing Status*

1. Introduction

Traditionally, NC programming is emphasized in part profile or graphic driving cutter [1, 2]. However, the 5-axis NC machining is a complicated procedure, and the NC programming should be finished with a full consideration of the machine tool, CNC, cutters and fixtures, namely the design of NC program should be done under the manufacturing system environment. The 5-axis NC machining codes can be achieved by means of the Computed Aided Manufacturing—CAM technologies.

There are a lot of books and articles concerning the software operations for each CAM platform both at home and abroad, but there is a little comparative research on the integrating Post-NC verification into NC program design using CAM. For this reason, the author studied some popular CAM platform and Post-NC verification strategies, and dug out the algorithms of 5-axis NC machining codes design and verifying.

2. Algorithm of NC Program Design under the Manufacturing System

2.1. NC Programming Workflow

The NC programming workflow is shown in Figure 1. Every manufacturing system (Figure1, right side) component, such as the machine tool configuration (CNC and construction lay out), the cutters, and the fixture should be fully considered in each step. The operation inf. is called from the manufacturing system. The middle part of Figure 1 shows how the associated information is transferred from the manufacturing system step by step, and how the final correct NC codes are schemed out.

2.2. The Machining Tasks and Manufacturing System Involved

The discussed 5-axis NC machining tasks are the rough cutting of the low tank - rough finishing all surfaces and holes, as shown in Figure 2.

To accomplish the jobs, the manufacturing system is designed as follows: the 5-axis HMC (Horizontal Machine Center (refer to Figure 8)), the fixture (refer to Figure 9), and the cutters. All the operation specifications are expressed in a different technique doc.; for example, the operation sheets, the cutter list, machine tool regulation sheets [3].

3. CAM and its Postprocessor

3.1. Jobs in the First 5 Steps

As shown in Figure 1, the preparatory work is done in the step 1 and step 2, and the key jobs are the determination of the workpiece dimensional orientation and the setting of the program coordinate system (PCS). Figure 3 shows the PCS setting in the CREO/CAM and

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Catia/CAM [4, 5]. The greatest work capacity occurs in the 4th step: all the detailed operation specifications should be imported to CAM platform, such as the machining parameters, the cutters and their compensation codes, and the other specific work contents. The cutter vector driven mode should be carefully set up for the 5-axis NC machining in this stage. The result of the preceding step is testified in the 5th step; this is called 'pre-verification' before the NC cutting codes are created. Figure 4 shows the pre-verification circumstances (in CREO/CAM).

3.2. The Critical Tasks in the 6th Step

The NC codes are created by the postprocessor in the 6th stage. During this phase, the dedicated postprocessor must be created firstly, and it must then be called to generate the appropriate NC codes.

Three jobs are done during creating the postprocessor.

Firstly, the machine tool layout and technical specifications should be imported into the "Post Creator" (see the center in Figure1). The "PTC/GPost" [4] result is shown in Figure 5 and Figure 6. Secondly, the program format is to be set up, which involves the transformation of the cutter path into the CNC-based NC codes, for instance, the output format of RTCP (Rotation Tool Centre Point) in the 5-axis NC machining [6]. As for this research, the 5-axis HMC is equipped with Fanuc 15/16M which enables RTCP functions through the use of code G43.4 [7]. In the "Post Builder"[8] (as shown in Figure 7), a MOM (Manufacturing Output Manager) segment compiled with the TCL (Tool Command Language) is affixed to the "tool change block", because the code 'G43.4' should be called immediately after the cutter changing. Thirdly, the other specific settings (for example, the postprocessor register, the preserved directory, etc.) should be finished.

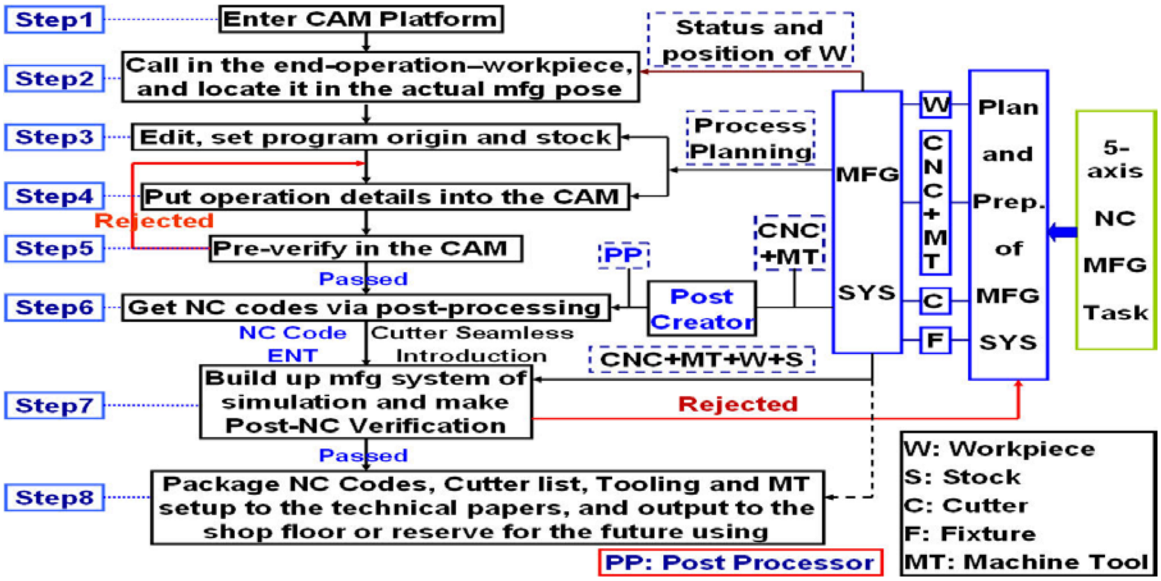

Figure 1. 5-Axis NC program design algorithm

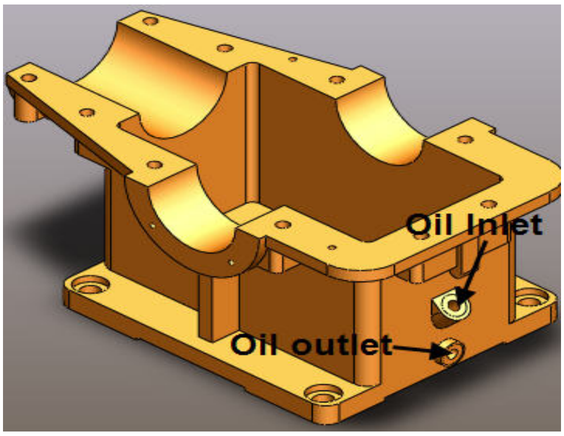

Figure 2. The lower tank of a transmission

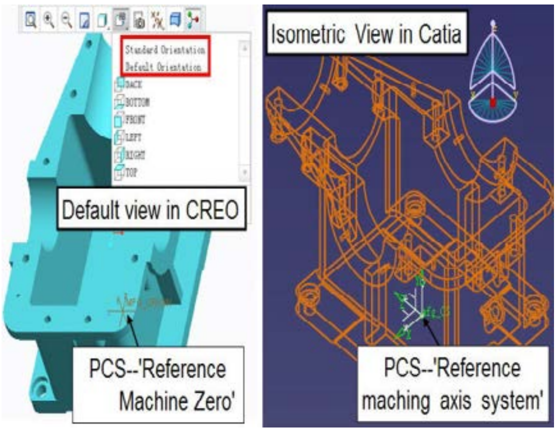

Figure 3. Setting of PCS in the 5-axis HMC

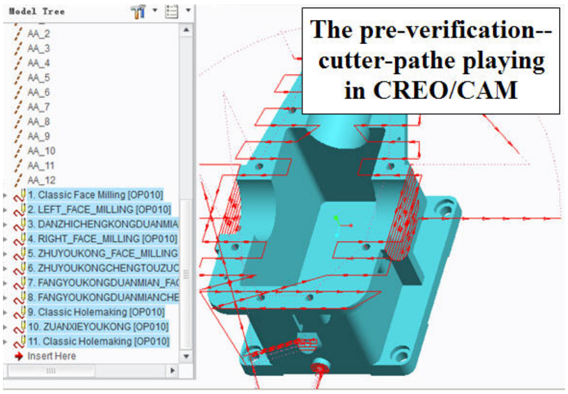

Figure 4. Pre-verification in CAM

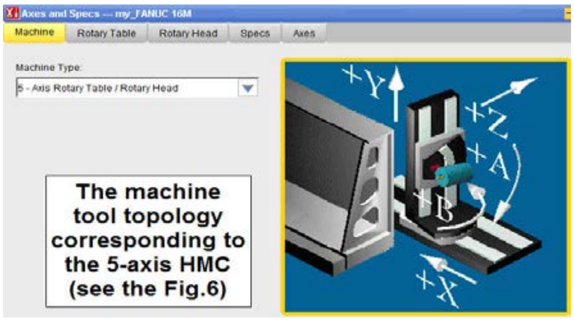

Figure5. Layout of the 5-axis HMC

4. Post-NC Verification under the Simulation Manufacturing System

4.1. Building up the Verification Manufacturing System

The certainty of the Post-NC verification is established on the fact that the "digital manufacturing system" totally represents the physical manufacturing status as much as possible. With the "manufacturing system", the inherent feature and interrelation (especially, the spatial and relative motion relationship) of every element could not vary with the research stages or issues. The manufacturing system's consistency throughout the different phases of the study is guaranteed by the bidirectional data transmission between the CAD/CAM platform and the verification package.

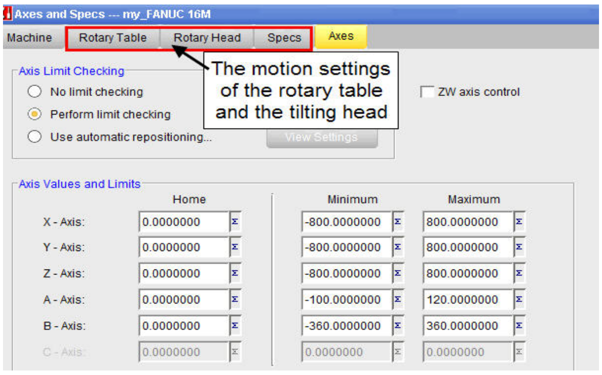

Figure 6. Technical specifications input

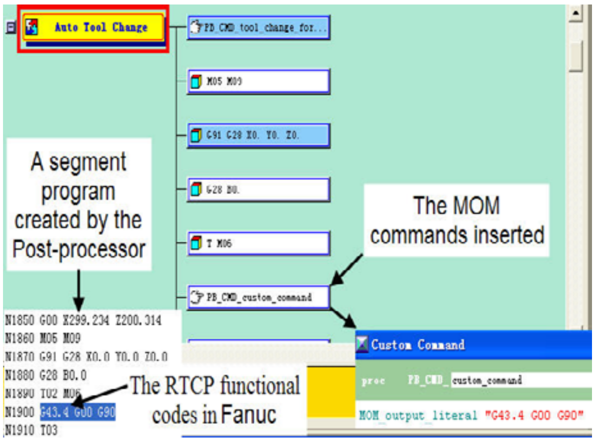

Figure 7. Output setting of the RTCP codes

The fixture and its interfacing with the worktable of a machine tool form into an "integrated manufacturing system". So, the fixture should be developed based on the worktable [9]. As a consequence, the manufacturing system feature-model, created in different CAD platform, has the unified spatial position with its verification-model. The primary construction of the 5-axis HMC is shown in Figure 8 [6]. The worktable's spatial relationship is shown in Figure 9 (left side). At the right side in Figure 9, there is the developed fixture with that associated worktable. Figure 10 shows the final manufacturing systems under the Post-NC verification platform-Vericut [10].

4.2. Start up the Manufacturing System and Execute the Verification

Several different running modes can be used to execute all kinds of simulations, such as uninterrupted running, pause at tool change, G codes running line-by-line, and so on. All the program errors could be checked out and eliminated by using a mix of these methods.

4.3. One Case of Postprocessor be Improved

In this research, the tool axis is on the slanting direction (45^0) when the oil inlet (see Figure 2) is being cut, and the Post-NC verification shows that: the cutter vector is on the correct orientation, but, it feeds in and out as a Z-shape movement which results in gouge. In order to solve this problem, the researcher employed the line-by-line simulation mode and read the NC codes. He found that the troubles occurred at the code translation fulfilled by the postprocessor in which the two dimensional coordinate of the base points ware represented into two program segments. The new code interpretation settings to the quick tool path are shown in Figure 11 (inside the "PTC/GPost"), and the NC codes, generated with the modified postprocessor, have proved to be of no kinematic errors in another Post-NC verification.

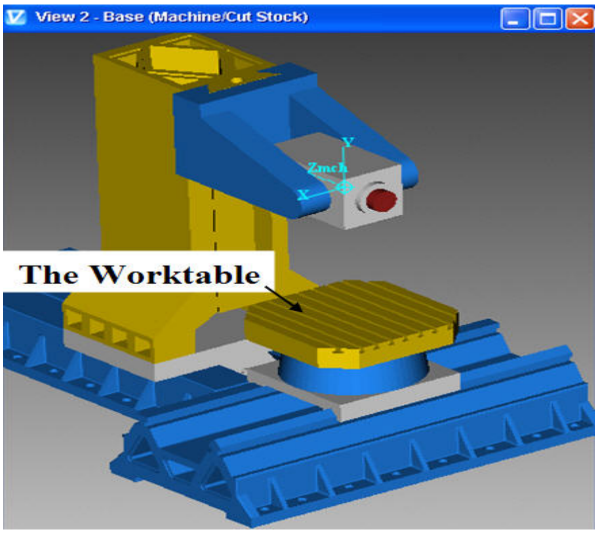

Figure 8. A 5-Axis HMC

4.4. One Case of Optimization to the NC Codes

In this study, when the top face and three side faces (refer to the Figure 2) are machined, the cutting and feeding parameters specified by the CAM are the fixed values, i.e., the machining parameters for all the 6 cut faces on the 4 different orientations (including the notches) are the constants. This will lead to extra machining time. When the NC programming is done based on the manufacturing system, the machine tool specifications, the workpiece materials, and the cutter materials have been considered. The "OptiPath" functional module of Vericut may be applied to resolve these problems [10], in which the empiric optimum cutting values about the materials of the cutter [11, 12], the materials of workpiece and the machine tool kinematic parameters are put into the module; the algorithm of "Volume Removal" or "Chips Thickness" is executed to obtain the optimum feed rates and spindle speeds, namely to get the optimum NC codes [13].

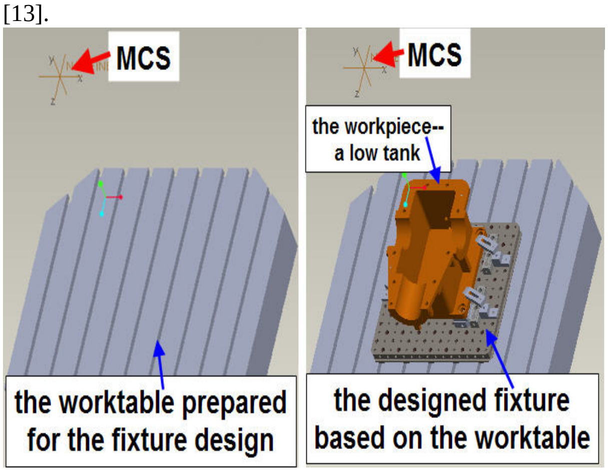

Figure 9. Worktable and designed fixture

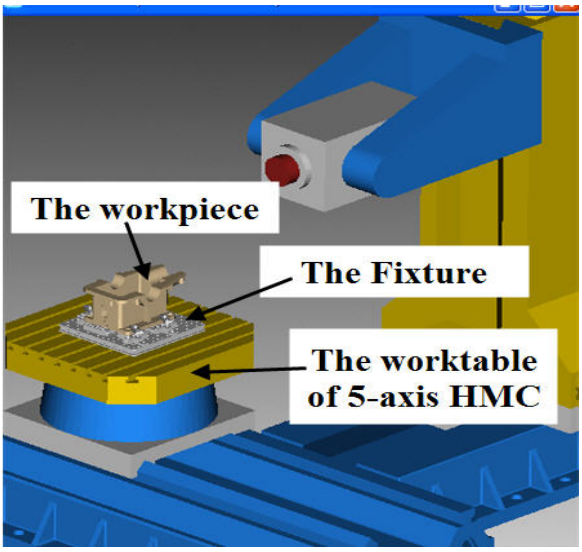

Figure 10. The final manufacturing systems

5. Summary

Taking the multi-directional machining on the 5-axis HMC as a case study and viewing from the manufacturing system, the researcher figured out the technical principles and algorithm involved in the program design and verification to the 5-axis NC machining. These approaches are of general purpose and can be applied to other types of 5-axis NC machining tasks. In addition, for the workpieces needing several set-ups, even requiring different machine tools to achieve multiple-operation, these principles and approaches can also be used to fulfill an integrated verification in order to estimate and correct all the potential design errors, which occur from the technological preparation to the field of machining. Moreover, the total manufacturing time may also be calculated out by the verification. All this effort contributes to the promotion of the quick response capability to market the modern enterprise.

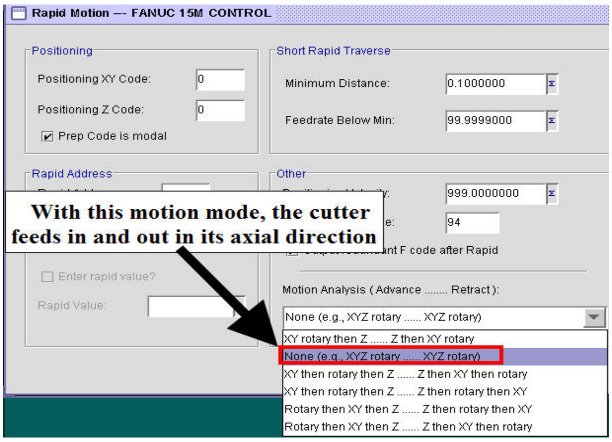

Figure 11. Appropriate setting of fast motion

Acknowledgment

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