Modeling and Simulation of K2x8 Five Axis Machine Tool Based on VERICUT 8.0

Xuanlin Ye1,*, Jingjie Yin1, Jin Cai1 and Lianjiang Xu1

1College of Mechanical and Electrical Engineering, Yunnan Open University, Chenggong University City, Kunming City, Yunnan Province

*Corresponding author email: 190516046@qq.com

Abstract. Taking the VERICUT 8.0 software as the platform and k2x8 five axis machine as an example, this paper expounds the method and steps of constructing non orthogonal five axis machine simulation machine. The key technologies such as the modeling of machine tool, the construction of machine tool kinematic chain, collision detection and stroke setting, the configuration of control system and simulation are introduced in detail. And the impeller is used as a sample for numerical control simulation processing, which verifies the correctness and effectiveness of the simulation platform, and provides a useful reference for other five axis machine simulation platform configuration.

Keywords: Vericut 8.0, Machine tool modeling, Five axis simulation machining.

1. Introduction

In the process of five axis machine tool machining, especially the five axis linkage, it is easy to produce interference or collision, resulting in damage to the machine tool and workpiece. In addition, the five axis machine tool is expensive, high maintenance cost and long cycle, so it is very important to avoid interference and collision. VERICUT is a machining simulation software developed by CGTech company of the United States. The software can simulate the NC machining process by setting up a virtual machine prototype, setting up blanks and cutting tools, and running NC programs. It is convenient for programmers to observe the machining state and compare the machining results, so as to effectively avoid collision and provide a strong guarantee for safe production [1-2]. At present, many scholars have carried out some research on the simulation technology of machine tools based on VERICUT, including the simulation technology of vertical three-axis machining machine tools, the simulation technology of orthogonal turntable and cycloid five axis machine tools [3]. However, the research on non orthogonal five axis machine tools, especially the five axis machine tools with space vector axis as the rotating axis, is very rare.

2. Construction of Machine Simulation Platform

2.1. 3D Modeling of Machine Parts

Due to the limitation of the modeling function of VERICUT 8.0 software, this paper uses Siemens NX10.0 software to build the machine model, and then saves it as STL file format to import into VERICUT 8.0 software. The prototype of the machine tool is k2x8five, a non orthogonal five axis linkage machine tool produced by French Union Huron company. The numerical control system is Siemens 840D system. The spindle speed is 24000rpm, the table size is φ 500mm, the feed speed of X, Y and Z axes is 50m / min, and the feed speed of A and C axes is 50rpm. See Table 1 for the travel of each
axis of the machine tool. According to the actual size and stroke of each axis of the machine tool, a new machine model file is created in NX10.0 software. When modeling, "WCS" coordinate system shall have the same axis orientation with the actual machine tool, and the origin of "WCS" coordinate shall be the intersection of the rotation center of axis A and axis C and the center of the spindle end face. Starting from the origin of "WCS", according to the relative position relationship between the components, the base, X-axis, Y-axis, Z-axis, Spindle, A-axis, C-axis components and pallet fixture are drawn in turn. After the modeling, the machine model is as shown in Figure 1. When modeling, the component model of each axis is an independent individual. After modeling, the components of each axis are exported to STL format files.

| Serial number | parameter       | data        |
|---------------|-----------------|-------------|
| 1             | X axis stroke   | 650mm       |
| 2             | Y axis stroke   | 700mm       |
| 3             | Z axis stroke   | 450mm       |
| 4             | A axis stroke   | -180° ~+45° |
| 5             | C axis stroke   | 360°        |

Table 1. Travel schedule of k2x8 five axis machine tool.

![Figure 1. Machine model after modelling.](image)

![Figure 2. The kinematic chain of Huron k2x8.](image)

2.2. Set up Machine Tool Component Tree and Machine Tool Configuration
When building the component tree of the machine tool, the key is to grasp the kinematic chain of Huron k2x8 five axis machine tool. The machine tool mainly has two kinematic chains, as shown in Figure 2. One is the kinematic chain of "Base → Y axis → A axis → C axis → Fixture → Workpiece", and the other is the kinematic chain of "Base → X axis → Z axis → Main axis → Cutter". These two kinematic chains constitute the basic model of the machine tool.

Start VERICUT 8.0 software and create a "new project". According to the kinematic chain relationship as shown in Figure 2, add each axis component under the project tree. Under the bed "base" of the machine tool, there are two components with the same logical status: X axis and Y axis, Add Z-axis under the X-axis, and add spindle under the Z-axis. When configuring the spindle component, it is necessary to move the coordinate system of the spindle component to the spindle end face, in the "coordinate system" option under the "configuration component" column, change the position of "relative to parent component position" from (0,0,0) to (335,350,450), and add tools under the spindle. Add axis a under axis Y (the rotation vector of axis A is 45° angle of axis X and Z), the rotation center of axis A is the center of cylindrical end face of axis y, and measure the distance from the center of cylindrical end face of axis y to the origin of machine tool (-126.5718,0,-198.6967). When configuring axis a components, in the "coordinate system" option under the "configuration components" column, change the position of "relative to superior components" from (0, 0, 0) is changed to (-126.5718,0,-198.6967), and the angle is changed from (0,0,0) to (0,-45,0). C-axis is added under
A-axis. When adding C-axis, since C-axis inherits A-axis, when configuring C-axis components, in the "coordinate system" option under the "configuration components" column, change "machine base point relative to coordinate system" from (-126.5718,0,-198.6967) to (0,0,0), change the angle from (0,-45,0) to (0,0,0), add "accessories" under the C axis, add fixtures and blanks under "accessories", and change the position of "relative to superior component position" from (0,0,0) to (0,0,43.5) in the "coordinate system" option under the "configuration component" column when configuring blanks. After the logical relationship of each component is established, the corresponding "STL" model needs to be added to each component. Since the initial state is that the rotation center of axis A and axis C and the end face center of the spindle converge to the origin of "WCS", the initial position of axis X, Y and axis Z components needs to be adjusted according to the stroke of each axis in Table 1. In order to distinguish each component visually and change the color of each component, after adding all components, add "Siemens 840D" numerical control system in the "library". The component tree of the machine tool is shown in Figure 3, and the model files of axes X, Y, Z and axes A and C are added. After configuration, the machine tool model is shown in Figure 4.

Figure 3. Machine tool component tree.  
Figure 4. Huron k2x8 simulation model.

2.3. Machine Settings and Control Settings
The setting of machine tool includes the setting of "collision check", "table" and "travel limit". In five axis machining, the main concern is the collision between Z axis, Spindle, Tool and A axis, C axis, fixture. Therefore, when setting collision check, these items can be set. The specific setting of machine tool collision check is shown in Figure 5. Select "machine zero" for "offset name" in "table", and the setting of "travel limit" shall be consistent with the actual situation of the machine, and the specific value setting is shown in Figure 6. In the "control setting", the setting of the "rotation" parameter is more critical, mainly because of the rotation direction of the c axis in the five axis linkage machining. If this setting is not correct, it may cause the simulation distortion and cause the collision, which should be reasonably set according to the actual machine tool and NC program instructions [4], and the control setting is shown in Figure 7.

Figure 5. Machine collision check settings.  
Figure 6. Machine travel limit setting.
3. Tool and Blank Adding and Coordinate System Setting

3.1. Tool Adding and Setting
In the "project tree", under "machining tool", select "Tool Manager", and create the required tool in "Tool Manager". The "clamping point" is the joint point between the tool handle and the spindle end face, which should be set in the center of the top surface of the tool handle, "tool setting point" is the point of the tool tip, which should be selected in the position of the tool tip. The set tool is shown in Figure 8.

3.2. Blank Adding and Coordinate System Setting
Add a blank model file under stock in the project tree. After the blank model is added, the position of the blank can be moved to keep the preset position relationship between the blank and the fixture. At the same time, the setting of the blank should be consistent with the clamping position of the actual blank on the machine tool. After setting the blank, add "csys1" coordinate system in the "coordinate system" of the "project tree", rename it to "G54", and "attach coordinate system" to "stock". When configuring "G54", you need to change the moved menu position from the original (0,0,0) to (0,0,-16.5), adjust its position so that the coordinate origin is at the center of the lower surface of the blank, as shown in Figure 9. For the "G code offset" in the "project tree", set the offset name to "program zero point", and "component" from "Spindle" to "G54". The sub register number shall be consistent with the register number specified by the machine and program.

4. Simulation and Verification
In this paper, the impeller processing as a sample for simulation. The NC program after post-processing is added to the "NC program" in the "project tree" in turn according to the processing order, and the simulation can be carried out by resetting the machine tool and running the program. If there is a collision in the simulation process, the collision part will display different colors (usually the default is red), and the collision and other details, such as tool path name, error, warning, machining times, will be displayed in the "VERICUT 8.0" logger. In order to better compare the over cutting or under cutting situation, add the impeller workpiece model file under "stock", and simulate the impeller workpiece as a blank, so that the over cutting or under cutting situation can be clearly observed in the simulation process. Through the above information analysis, the correctness of NC program can be verified, problems can
be found and corrected in time before actual processing, which shortens the development cycle of new products and improves the processing efficiency. The simulation results of impeller parts are shown in Figure 10, and the simulation results of impeller machine cutting are shown in Figure 11. Upload the NC program of simulation machining to k2x8 five axis CNC machining center for actual machining. In the actual machining, the machining process is basically consistent with the simulation situation. The results show that the correctness of tool path file is verified by numerical control simulation, various possible collisions in numerical control machining are detected, and machining efficiency is improved. It is a multi axis linkage CNC machine tool. The actual machining results are shown in Figure 12.

Figure 11. Machining simulation of impeller with machine tool.

Figure 12. Actual machining of impeller.

5. Conclusion
This paper analyzes the structural characteristics of Huron k2x8 non orthogonal five axis linkage machine tool [5], and reasonably formulates the model construction and simulation processing scheme of Huron k2x8 machine tool, that is, using NX10.0 software to Huron The parts of k2x8 machine tool are modeled and assembled, and then imported into VERICUT 8.0 software to build simulation platform, including the creation of machine tool parts model, the construction of motion relationship, collision detection and stroke setting, and the configuration of control system. After the VERICUT 8.0 simulation platform is built, the machining of impeller is simulated as a sample, and the actual machining of impeller is carried out. The results show that the simulation machining is consistent with the actual machining, which verifies the correctness of the scheme, and provides a useful reference for the configuration of five axis machine simulation system of related structures.

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