Teaching Reform of NC Programming for Complex Parts in the Course of NC Technology

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Abstract. In the process of experiment and practice teaching of numerical control technology course, the characteristics of common numerical control programming methods need to be understood and mastered by students so that they can be flexibly applied in production practice. The programming method for a certain rotary part is taken as the research object of this paper. Manual programming and computer-aided programming are adopted respectively during the process of NC programming. Based on the analysis of the implementation process of various programming methods, the applicable conditions of manual and computer-aided programming methods are analyzed, and the contents that should be emphasized in the course teaching are finally determined.

Introduction

With the increasing proportion of CNC machine tools in machine manufacture, the requirement of NC programming and operation level of NC machine tools is also increasing. The combination of theory and practice needs to be applied to complete the learning and application of numerical control technology, in order to better learn the basic theory and programming level of CNC machine tools. The basic principle of numerical control technology is mainly explained in the theoretical teaching of numerical control technology, through which the basic working principle of numerical control equipment can be mastered. The main problems in the actual operation of CNC machine tools are mainly explained in the experimental teaching.

With the popularization of CNC machine tools, CNC technology has become a necessary course for mechanical engineering and related majors. The basic knowledge of working principle, basic operation and programming of CNC machine tools can be well learned through relevant theoretical and experimental teaching. In the learning process of numerical control technology, the practical ability and basic theoretical level of students are required to be higher. The method of combining theory and experiment teaching should be applied to complete the teaching.

In the process of theoretical and experimental teaching of NC technology, the ability of students to operate numerically controlled machine tools and the ability of NC programming should be strengthened so as to enhance students’ innovative spirit and practical ability. Experimental teaching can help students understand the law of movement, learn experimental knowledge and ability, improve creative and comprehensive hands-on ability and cultivate academic and practical literacy. Experimental teaching is an important means to cultivate innovative spirit and practical ability. It is of great significance to expand the scope and depth of experimental teaching content for improving the level of experimental teaching. The laboratory of mechanical engineering and automation has constructed many types of CNC machine tools in recent years, and all the devices play an important role in the experimental and practical teaching of numerical control technology.

In this paper, the NC programming and implementation process of complex revolving parts are taken as the research object. The manual programming and automatic programming are respectively used to realize the NC programming of parts. The characteristics and main application occasions of various programming methods are analyzed, and then the key points and main directions of
experimental teaching contents are determined, so as to promote students’ in-depth understanding of the basic concepts of NC programming, NC programming and machine tool operation, and enhance students’ practical ability and innovation ability.

Manual Programming of Complex Parts

According to the complexity of rotating parts, different programming methods are needed. The commonly used programming methods are mainly manual programming and computer-aided programming. Manual programming means that every step of the NC machining program is completed by workers manually, which is mainly used for point and position machining or the NC programming of simple geometric parts. Computer-aided programming refers to the use of computer-aided to complete the main calculation work, except that the analysis of part drawings and the formulation of process planning are completed manually. Automatic programming mainly includes the generation of cutting location data and post-processing. For graphic interactive automatic programming, the generation of cutting location data is to use three-dimensional modeling technology to generate the cutting location data file, and can use simulation software to evaluate the correctness of numerical control program quickly. The main function of post processing is to convert the cutter location data into the NC machining program suitable for specific NC machine tools.

In this paper, the rotating part as shown in Fig. 1 is taken as the research object. The methods of manual programming and automatic programming are used to realize the NC programming of parts. The program is used in htc1635i CNC lathe, the numerical control system of the machine tool is FUNAC 0i-T.

![Figure 1. Parts drawing of NC programming.](image)

Manual programming mainly includes single instruction and compound cycle instruction programming. Single instruction programming mainly refers to the use of instructions such as G00, G01, G02 and G03 for programming. Single instruction is helpful for programmers to better understand the movement path of the cutter in the process of machining. Compound cycle instruction programming mainly refers to the instruction programming such as G70, G71, G73 and G76. In the compound cycle instruction, only the necessary parameters such as cutting depth, finishing allowance, etc. need to be set, and the CNC system will automatically repeat cutting according to the tool path of the circular instruction until the machining is completed.

Before manual programming, process analysis is needed, including blank cutter selection, machining steps and cutting parameters determination. The cylinder with a diameter of 78mm and a length of 95 mm is selected as the blank. Four turning cutters have been installed on the lathe, including the external turning cutter, the grooving cutter, the 60 thread cutter and the end turning cutter. The parts are installed and positioned with hydraulic three jaw chuck. The tool offset of the tool used in the machining process is set. Considering the shape of the blank, G73 circular machining
instruction is used to realize the rough machining of the contour, and G76 circular machining instruction is used to complete the NC machining program of the thread. The NC programs of the part are as follows.

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O1234
N10 G50 X100.00 Z100.0
N20 T0101
N30 M03 S1000
N40 G00 X80.0 Z5.0
N50 G73 U18.0 W0 R12;
N60 G73 P70 Q210 U0.4 W0.2 F0.1
N70 G01 X46.0 F0.1
N80 Z0
N90 X50.0 Z-2.0
... ... ... ... ...
N220 G70 P70 Q210
N230 G00 X100.0 Z100.0
N240 T0505
N250 G00 X52.0 Z2.0
N260 G76 P30160 Q80 R0.1
N270 G76 X48.052 Z-19.0 R0 P974 Q400 F2
N280 G00 X100.0 Z100.0
N290 M05
N300 M30
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### Automatic Programming of Complex Parts

With the rapid development of manufacturing industry, more and more parts with complex shapes can be seen everywhere. It is difficult to calculate the mathematical expression of curve by hand. Automatic programming can realize the programming of complex parts. Making full use of the automatic programming software can not only reduce a lot of calculation, but also fully demonstrate the important role of simulation technology in the teaching process of NC programming for complex rotating parts, so that students can deeply understand the whole process of part modeling, programming, simulation and actual machining.

The realization of automatic programming requires 3D modeling, the generation of cutter location data and post-processing. First of all, it is necessary to establish the 3D model of the machining part in the CAD/CAM software. Then select turning in the application module to enter the machining environment, create geometry, machine coordinate system, turning workpiece and avoidance geometry, create various cutters according to the actual cutters used, and then create the program according to the specified part machining process. The generated rough and finish turning cutters locations are shown in Fig. 2.

![Figure 2. NC machining path generated by CAM software.](image)

(a) Roughing tool path  (b) Finishing tool path

The generated cutter location data need to be post processed to generate NC machining programs suitable for specific CNC machine tools. By modifying the parameters of CAM post-processing constructor module, the post-processing configuration file is generated, and the NC code generated by the newly generated post-processing file can be directly used for part processing. Select the post-processing file modified by the post-processing constructor to generate the post-processing G code program as follows.
Analysis of NC Programming Result of Complex Parts

Manual and automatic programming methods are used to realize the NC programming of the parts as shown in Figure 1. When the finish machining path of parts is relatively simple, the compound cycle instruction programming can achieve good results. When the finish machining path of parts is more complex, it is difficult to realize the NC programming by using the manual programming method. For the selected parts in this paper, it is more suitable to use the manual programming method.

The automatic programming tool is used for NC programming of complex parts. The programming tool provides templates for various processing methods. The programmers can select appropriate processing methods by selecting templates for various processing methods. In addition, the automatic programming system is generally equipped with the cutter location simulation function, which is convenient for programmers to judge the rationality of the programs. For complex parts, the programming time of automatic programming is much less than that of manual programming.

In the process of NC programming, programmers often need to consider the problem of path interference, whether the new tool path interferes with the machined surface, etc. Through the application of computer-aided programming tools, programmers can check the correctness of the program in time, greatly reduce the programming time, and solve many problems of complex parts that can't be solved by manual programming. Manual and computer-aided programming methods have their own advantages. In order to shorten the cycle period of NC programming and improve the efficiency, computer-aided programming is recommended for complex rotating parts.

Conclusion

At present, in the teaching process of numerical control programming of numerical control technology, the manual programming method is mainly explained. In consideration of the actual situation of the NC programming method used in the actual production, it is necessary to adjust the focus of the course content. In the explanation process of manual programming method, the compound cycle instructions should be emphasized. The compound cycle instructions are the instructions which are closest to the automatic programming idea in the manual programming instruction. Some programming tools provided by numerical control system, such as shop mill and shop lathe provided by Siemens numerical control system, should be strengthened in the teaching process. In the process of teaching and practice, NC automatic programming and its related contents should be added. So that students can master the key technologies that affect the application of NC automatic programming, and adapt to the needs of NC talents in the new era and new engineering.

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