Research of A Macro Program for Bolt Hole Patterns Based on EXCEL®

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Abstract: EXCEL® is a Microsoft Office software product, which has excellent numerical and logic calculation and analysis functions. The method of programming a CNC macro program using EXCEL® is being presented in this paper for the first time. By defining the locations of a hole pattern geometrically, and simulating the programming of a macro, it can be demonstrated that a CNC program using macros is simple and easy to understand, and the program is flexible, generic and portable.

1. Introduction

Macro program is a kind of extended function of numerical control system developed on the function platform. It can calculate and make decisions. In the process of program generation, constant is defined as variable, and mathematical functions and logical conditions are utilized for parametric programming. By modifying program parameters, the program can be used many times to meet the needs of one-time programming of similar parts, which can significantly improve the programming efficiency and processing efficiency rate, and the program is simple, less bytes with occupying small memory space[1]. However, some economic CNC systems or numerical simulation systems, which are widely used in enterprises, such as Prolight, Yulong version 3.7, do not support macro programming. Thanks to EXCEL®, one of the components of Microsoft office, which is the office software developed by Microsoft company. It has a large number of formula functions, which can execute numerical calculation, logical calculation, analysis, management and other operations, with complete functions, convenience and practicality. Thus, in this paper, according to the machining requirements of parts with hole groups from some enterprises and the actual processing function of CNC machine tool, the macro programming of economic CNC system realizes because of the calculation and decision-making function of macro program being carried out in EXCEL®, while the programming function of macro program being accomplished in Prolight CNC system.

2. Processing Requirements

The machining requirements of parts from an enterprise are: machining multiple bolt hole groups with circular uniform distribution on a large-scale flat plate, the quantity range of holes in the hole groups can be varied from 4 to 16, the hole diameter can be altered from 2 to 8, both the position and the
circular diameter of the hole groups can be changed arbitrarily, and the schematic distribution of the hole groups on the large-scale flat plate is shown in Figure 1.

![Fig. 1 Distribution of hole groups](image)

3. Macro Programming

3.1. Mathematical Model of Tool Path

Taking one of the hole groups as example. As illustrated in Figure 2, a coordinate system at the center of the uniformly distributed circle is established.

![Figure 2 mathematical model of single hole group](image)

The coordinates of each hole center are written as follows:

\[
X = R \cos(\alpha) = R \cos(\beta + \gamma) \\
Y = R \sin(\alpha) = R \sin(\beta + \gamma)
\]  

(1)

(2)

Considering the arbitrariness of the hole position, the coordinates of uniformly distributed circle center \(X_0\) and \(Y_0\) are added after the hole center coordinates, that is, the center coordinates of any hole are written as follows:

\[
X = R \cos(\alpha) + X_0 = R \cos(\beta + \gamma) + X_0 \\
Y = R \sin(\alpha) + Y_0 = R \sin(\beta + \gamma) + Y_0
\]  

(3)

(4)

Where \(\gamma\) is the initial uniform angle of the first hole, \(\beta\) is the angle between any two holes, and \(\alpha\) is the uniform angle of any hole.
3.2. Definition of Variables
The macro program variables are divided into local variables, public variables and system variables. The definition range of local variables is #1 - #33, which can be used freely by users; the definition range of public variables is #100~#199 and #500~#599, in which #100~#149 are automatically reset before the machine tool is started, and if the value in #500~#549 is not reassigned, the previous value \[2\] ~ \[3\] can still be maintained after power on again; the definition range of system variable is #1000~#5335. In this paper, the definition of variables is based on the "big" principle, that is, up to 16 holes are evenly distributed, and 54 variables are required, all of which are public variables. The definition is presented in Table 1.

![Table 1 definition of variables](image)

3.3. Data Structure in Program
The machining of hole groups includes not only the numerical information of hole coordinates, but also the information of logical positions and termination conditions between holes. The numerical information of hole coordinates is recorded by variables in macro program, and the information of logical positions and termination conditions between holes is achieved by functions in EXCEL®. The data structure of parts processing in this paper is described as follows.

(1) \(x = \cos \text{ (radians (angle))} \times \text{(radius)} + \text{x value of the center of a uniformly distributed circle;}
(2) \(y = \sin \text{ (radius (angle))} \times \text{(radius)} + \text{y value of uniformly distributed circle center;}
(3) \text{IF } SC12\leqSB3, \text{ THEN } \cos(\text{RADIANS}(SB12))\times(SB52/2)+SB56;
(4) \text{IF } SC12\leqSB3, \text{ THEN } \sin(\text{RADIANS}(SB12))\times(SB52/2)+SB77;
(5) \text{IF } F12="", \text{THEN CONCATENATE("X"}&amp; FIXED(F12,3));
(6) \text{IF } I12="", \text{THEN CONCATENATE("Y"}&amp; FIXED(I12,3)).

Among them, C12, B3, B12, B7, F12 and I12 are the row and column numbers of the cell in EXCEL®. The cell stores the hole number of the currently processed hole, the total number of holes, the X and Y coordinates of the uniformly distributed circle center, and the X and Y coordinates of the currently processed hole. If the numerical position of the input value in EXCEL® is different, the number will be different from the above. Adding "$" to the left of the row number of a cell means that only the value of the column in which the cell is located is taken, that is, the row number changes, and the column number remains unchanged. For example, $D means that the values of D1, D2, D3 in column D are taken; if "$" is added to the left and right sides of the cell row number, only the value in the current cell will be taken. For instance: $B $3 means that no matter how the cell row number and column number change, only the value in B3 will be taken. The concatenate() function is to convert the numerical value in EXCEL® into X and Y coordinates in CNC system. According to the above data structure, the information in the mathematical model of hole group in Figure 2 is input into.
EXCEL®. In order to facilitate tool setting, it is assumed that the coordinates of hole group uniform distribution center on the large plate are (0, 0), and the results are revealed in Figure 3.

![Figure 3 numerical and logical calculation results of hole group in Excel®](image)

3.4. Design of Processing Technology

The NC machining process design of parts includes the determination of machining content, the design of cutting path, the selection of cutting tools and cutting parameters [5] ~ [7]. In this paper, the object being discussed is a hole type part with simple process, which will not be described here. The flow chart of macro programming set according to the process is depicted in Figure 4.

![Figure 4 program flow chart](image)

3.5. Design of Processing Technology

In this paper, the NC machining program of the parts is compiled by utilizing the Prolight NC system, machining the hole groups shown in Figure 1, and the simulation results are illustrated in Figure 5. The X and Y coordinates of the holes in the program have been added with the coordinates of the evenly distributed circle center, and the program is Table 2.
Table 2 Program

| Program       | Description                                          |
|---------------|------------------------------------------------------|
| O1234         | Program name                                        |
| G17 G21 G40 G50 G90 | Set up initial machining environment               |
| T01M06        | Change tool 1                                       |
| G90 G43 H01 X220.803 Y57.586 Z3 | Establish tool length compensation and quickly locate to the first hole |
| G99 G81 Z-5 R3 F100 | First hole group machining with hole cycle          |
| X215.106 Y75.654 |                                                      |
| X200.077 Y87.186 |                                                      |
| X181.150 Y88.013 |                                                      |
| X165.173 Y77.834 |                                                      |
| X157.923 Y60.331 |                                                      |
| X162.023 Y41.836 |                                                      |
| X175.991 Y29.037 |                                                      |
| G98 X194.773 Y26.565 |                                                      |
| G80           | Cancel canned cycle                                |
| ...           |                                                      |
| M05           | Spindle stop                                        |
| M30           | The program ends and returns to the beginning of the program |

Figure 5 simulation results

4. Conclusion
In this paper, EXCEL® software is utilized to program NC macro program for the first time. From the analysis and compilation of the macro program above, it can be seen that the macro program itself is modular and flexible. The calculation decision and programming in the macro program are carried out separately in EXCEL® and NC system, which can further simplify the NC machining program, reduce the calculation and compilation time of the program, improve the processing efficiency, and expand the function of economical numerical control system. It has been proved by practice that the method proposed in this paper has portability and can also be used to program NC machining of non-circular curve contour parts such as ellipse and parabola.
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