Research and Practice of Intelligent Tool Setting Device for CNC Milling Machine

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Abstract. The utilization of intelligent tool setting device of CNC milling machine can reduce the probability of tool setting error, better guarantee the normal operation of CNC milling machine and the safety of relevant operators, and avoid unnecessary losses. Based on this, this paper first analyses the coordinate system of CNC milling machine and the concept of tool setting, then studies the operation method of tool setting device of CNC milling machine, and finally gives the design and practice of intelligent tool setting device of CNC milling machine.

Keywords: Intelligent Tool Setting Device, Milling Machine, CNC

1. Introduction

The continuous progress and amelioration of social mass production put forward higher requirements for intelligent production equipment. In this context, a large number of CNC intelligent equipment are put into commercial operation, which not only greatly ameliorates the production efficiency, but also brings new challenges to the operator's professional quality and info tech skills. As an important supporting force of equipment manufacturing, CNC production equipment has greatly changed the traditional processing mode in the process of improving and releasing productivity and production efficiency. In particular, the deep utilization of intelligent equipment represented by CNC milling machine in the field of processing and manufacturing represented by mold manufacturing effectively accelerates the development of industrial production [1]. As a key part of CNC milling machine operation, its tool operation skills have high requirements for machine tool operators. If it cannot be carried out according to the standard requirements, it is easy to affect the machining accuracy and cause accidents.

With the transformation and upgrading of China's manufacturing industry, intelligent CNC equipment is more and more widely used, especially the utilization of CNC milling machine in the field of abrasive processing, which has an important guarantee for the subsequent processing [2]. The research goal of intelligent tool setting device of CNC milling machine is to reduce the complexity and difficulty of tool setting process, so as to reduce the probability of tool setting error, to better protect the normal operation of CNC milling machine and the safety of relevant operators, and to further avoid unnecessary loss. As an important operation skill of CNC milling machine, tool setting operation is to make the tool position coincide with the origin of workpiece coordinate system. In this process, it is
necessary to accurately measure and control the offset between the origin of workpiece coordinate system and the origin of machine tool.

In short, the tool setting environment of CNC milling machine is often more complex, and the commonly used tool setting methods have some shortcomings, such as poor environmental adaptability, high operation difficulty and low degree of intelligence, which urgently need to be reformed and optimized. The utilization of intelligent tool setting device in CNC milling machine can not only effectively reduce the difficulty of tool setting operation, more calmly deal with the processing of parts with special material, shape and volume, but also make the processing of workpieces with special requirements for datum position more smooth. The tool setting device of CNC milling machine has a high marketing effect on the accuracy and efficiency of the processed products. It needs to focus on ensuring the standardization and stability of the tool setting operation procedure. Therefore, it is of great practical value to carry out the practical research on the intelligent tool setting device of CNC milling machine.

2. Coordinate system and tool setting concept of CNC milling machine

2.1. Specification of coordinate and movement direction of NC milling machine

In order to realize and control the tool movement in data milling machine, it is necessary to know the tool movement position, that is, the coordinate system direction of CNC milling machine [3]. On the one hand, the operator of CNC milling machine should have a complete and correct understanding of the coordinate system of CNC milling machine, so as to avoid the confusion of programming and operation accidents; On the other hand, in order to describe the motion of the milling machine when programming, it is necessary to further simplify the programming method and ensure the interchangeability of the recorded data, so as to make the CNC system open [4]. At present, the coordinate and movement direction of CNC milling machine have been standardized. In the coordinate system of milling machine, it is relative to the work piece, and because the work piece is static, in the CNC program, the recorded tool path is the path of tool movement. As long as it is based on the part drawing, the CNC program of recording tool movement can be programmed.

In addition, at the level of determining the coordinate axis of CNC milling machine, the rectangular coordinate system is mostly used to represent the shape and size of the workpiece. Correspondingly, CNC milling machine also uses rectangular coordinates to calibrate the axial direction [5]. When determining the coordinate axis of the milling machine, usually first determine the Z axis, then determine the X axis and Y axis, and finally determine other axes. The coordinate system of the vertical CNC milling machine is shown in Figure 1 below.

![Figure 1. The coordinate system of the vertical CNC milling machine](image-url)
2.2. Coordinate system and origin of CNC milling machine
Coordinate system is the basic coordinate system of CNC milling machine, and its orientation is determined by referring to some datum on the machine. There are some fixed datum lines on the machine tool. The coordinate system of the machine tool is not used for programming, but is often used to determine the workpiece coordinate system. The origin of the workpiece coordinate system is determined by tool setting. The origin of the machine tool is a fixed limit point set on the machine tool to determine the origin of the machine tool coordinate system [6]. It has been set up when the machine tool is assembled and debugged. Generally, the operator is not allowed to change it by himself. The origin of the machine tool is also the reference point of the machining movement of the NC machine tool. The origin is generally set at the limit point where the tool is far away from the workpiece.

For NC programming and NC machining, workpiece origin is the origin of coordinate system used in NC machining program. Numerical control program is based on the part drawing; usually the origin of the program is set on the design basis of the part drawing, which is not only convenient for size calculation, but also conducive to ensure the machining accuracy [7]. In programming, select a point on the workpiece or fixture as the programming zero point, and take this point as the zero point to establish a coordinate system to determine the programming and calculation origin of the workpiece contour, which is called the workpiece coordinate system origin. When machining a part, only choose the corresponding workpiece coordinate system to program. Therefore, the workpiece coordinate system should be set at the beginning of each program. The establishment of the workpiece coordinate system is shown in Figure 2 below.

![Figure 2. Establishment of workpiece coordinate system](image)

3. Operation method of tool setting device of CNC milling machine

3.1. Function and principle of tool setting device
After the NC machine tool is programmed and the workpiece or fixture and cutter are clamped to the machine tool, it is necessary to first set the workpiece origin, determine the position of the workpiece origin in the machine coordinate system, and then determine and input the cutter parameters. Only in this way can the NC milling machine be started for operation. For the specific workpiece processed on the vertical CNC milling machine, it is necessary to reflect the machine coordinate value of the origin of the workpiece coordinate system [8]. This process is called tool setting. The machine coordinate system is the only datum of the milling machine, and the determination of the program origin position in the mechanical coordinate system needs to be completed in the process of tool setting.

The plane linear interpolator of NC milling machine is composed of two digital integrators, each of which is composed of accumulator and integrand function register. The working principle of DDA linear interpolator is shown in the following equation 1. Each interpolation iteration pulse is sent to
make $kx_e$ and $ky_e$ accumulate once in their respective accumulators. Whether there is overflow pulse in the accumulation result depends on the capacity of the accumulator and the size of $kx_e$ and $ky_e$.

$$
\begin{align*}
  x &= k \sum_{i=1}^{m} x_e \Delta t = k \sum_{i=1}^{m} x_e = knx_e = x_e \\
  y &= k \sum_{r=1}^{m} y_e \Delta t = k \sum_{r=1}^{m} y_e = kny_e = y_e
\end{align*}
\Rightarrow nk = 1 \quad (1)
$$

According to the coordinate data in the workpiece coordinate system, the programmer compiles the running track of the tool center. The tool setting point can be set on the part to be processed, or on a certain position of the fixture which has a fixed dimension connection with the positioning datum of the part. In tool setting, the tool location should be consistent with the tool setting point, for opposite milling cutter, that is, the intersection of tool axis and tool bottom; For ball end milling cutter, that is the ball center of ball end cutter.

3.2. Operation method of tool setting device of CNC milling machine

The tool setting point of CNC milling machine is mainly selected at the origin of workpiece coordinate system to ensure the tool setting accuracy and reduce the tool setting error. Secondly, the tool setting point or tool setting datum can be set on the fixture positioning element, and the positioning element can be directly used as the tool setting datum for tool setting, which is conducive to the accuracy of workpiece coordinate system position in batch processing [9]. In the process of tool setting in milling, the intersection of the spindle axis and the end face of the tool are taken as the tool point, so that the intersection of the spindle axis and the end face of the tool coincide with the tool point. Among them, the tool setting with edge finder mainly uses the potential difference between the handle and the contact of the photoelectric edge finder to form a loop current when the contact contacts the surface of the workpiece and establish the photoelectric signal. In addition, when the tool setting point of workpiece coordinate system is the intersection point of mutually perpendicular lines, tool touching or standard spindle and block gauge are often used for tool setting.

4. Design and practice of intelligent tool setting device for CNC milling machine

4.1. Design of intelligent tool setting device for CNC milling machine

In this paper, the intelligent tool setting device of CNC milling machine is designed to accurately measure the distance between the tool and the workpiece in the process of ultrasonic tool setting. The clamping mechanism is mainly used to adjust the distance between the device and the tool. In the aspect of hardware design, it mainly includes ultrasonic transmitting circuit and receiving circuit. The former drives the transmitting device by means of the signal amplifying circuit; the latter uses integrated circuit to ameliorate gain effect and anti-interference ability [10]. At the design level of the main control system, it integrates control module, ultrasonic sending and receiving module and distance lifting module. In addition, at the software design level of the tool setting device of the control system, it mainly realizes power on reset, ultrasonic transmission and reception, measurement distance calculation, comparison judgment feedback and prompts device work, etc., and its workflow is shown in Figure 3 below.
4.2. Practice of intelligent tool setting device for CNC milling machine
The practice of intelligent tool setting device of CNC milling machine is mainly aimed at the large amount of blank, forming surface, circular workpiece and tool setting under special circumstances. Among them, the tool setting of large amount of blank should ensure that the rough area not machined is not left on the final product and the tool cuts to the lowest position on the surface of the blank. Tool setting of forming surface mainly includes tool setting with paper, tool or tool holder. Secondly, for the tool setting of circular workpiece, it is mainly for the cylindrical workpiece with large allowance and low accuracy requirements, and the tool setting of circular workpiece by using lever dial indicator. In addition, tool setting in special cases is mainly for special-shaped parts and multiple workpieces to be processed.

5. Conclusion
In summary, the tool setting device of CNC milling machine has a high marketing effect on the accuracy and efficiency of the processed products. It needs to focus on ensuring the standardization and stability of the tool setting operation procedure. In this paper, through the analysis of the coordinate system and the concept of tool setting of CNC milling machine, the coordinate system and origin of CNC milling machine are studied. Through the research on the operation method of tool setting device of CNC milling machine, this paper analyzes the function and principle of tool setting device, and studies the design and practice of intelligent tool setting device of CNC milling machine.

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References
[1] Chen Shiping, Li Yan. Tool setting method in NC machining [J]. Modular machine tool and automatic machining tech, 2004 (12): 101-102.
[2] Ding Haiping, Gu Jianfeng. Common tool setting method and its utilization in CNC machining center [J]. Guangxi light industry, 2017 (8): 51-53.
[3] Han Hongling, Cui Zhiheng. Experimental research on mobile robot based on MCU [J]. Experimental tech and management, 2012, 29 (8): 43-46.
[4] Jiang Huiming. Several tool setting methods in the utilization of CNC milling machine [J]. Guizhou: modern machinery, 2011 (6): 98-103.
[5] Liang Xiaoliu, Chen Bingsen, Liang Jianhe. Design of automobile anti-collision radar system based on AT89S52 [J]. Mechanical and electrical engineering tech, 2011, 40 (1): 49-51.
[6] Qian Yuanping. Selection and analysis of tool setting method on CNC milling machine machining center [J]. Development and innovation of electrical products, 2015, 28 (3): 135-137.
[7] Tang Qingchun, Zhang Renbin, He Jun, et al. Research on post processing of five axis machining center based on vbbv100 [J]. Mechanical design and manufacturing, 2012 (2): 73-
75.

[8] Yang Cuili, Bao Yuhua. Design and utilization of tool setting block in NC machining [J]. Vocational tech, 2010 (10): 89.

[9] Zhang Xiaobing, Song Aiguo, Tang Hongru. Ultrasonic multi-target ranging based on single receiver [J]. Journal of sensing tech, 2007, 20 (5): 1167-1170.

[10] Zhou Zhiping, Chen Yong. Tool setting principle of CNC machine tools and tool setting skills in machining [J]. Mechanical manufacturing, 2019, 47 (6): 36-39.