# The Frame Design of Desktop CNC Milling Machine Based on Finite Element

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**Abstract- machine tool is the machine of manufacturing machine, is an indispensable tool in industrial production. In order to reduce the high cost, large volume of traditional CNC machine tools and the cost of training related technical personnel for enterprises and schools, this paper designs a micro CNC milling machine with high integration, convenient operation, low cost and simple structure. Through the simulation module of Solidworks, the frame of the NC milling machine is simulated and analyzed, and the yield stress of the frame is 2.76 × 108 n. The test results show that the machining error of the micro milling machine is 0.6 ~ 0.8 mm when using the stand, which can meet the requirements of students' understanding and learning of CNC machine tools, and has the value of popularization and application. It is expected to contribute to the further development of CNC milling machine in China.**

**Key Words -Micro machinery, CNC machine tools, machining, CNC milling machine, micro milling machine**

## I. INTRODUCTION

Machine tool is a machine for manufacturing machines. It has been more than 270 years since it came to the stage of industry in 1774. At first, designers focused on the technical performance and functional performance of the machine tool, ignoring the appearance and human-computer interaction performance of the machine tool. As a result, many structural components are exposed and the safety performance is poor. After the frequent industrial accidents, the designers focused on the appearance of the machine tool. After that, the safety protection measures of the machine tool began to be reflected on the machine tool shell, and the optimization design of various parts of the machine tool began, but the volume was relatively large [1,2].

With the rapid development of science and technology, CNC milling machine is widely used in the field of machining [3,4], such as aviation, aerospace, automobile, microelectronics, medicine and national defense industry, which has become an important symbol to measure the level of a country's manufacturing industry [5 ~ 7]. Therefore, it is an urgent need for all countries to cultivate high-quality professional and technical personnel. However, the traditional industrial CNC milling machine has high cost, complex structure and large size. It is difficult to achieve large-scale popularization of equipment in Colleges and enterprises that cultivate relevant professional and technical personnel, which restricts the cultivation of professional and technical personnel of CNC milling machine [8 ~ 10]. Therefore, this paper designs a simple structure, easy to operate, low-cost teaching type micro CNC milling machine, so as to reduce the structural weight, improve the structural stiffness, and improve the product processing accuracy.

In recent years, with the rapid development of manufacturing industry, the demand for the operation efficiency and dynamic performance of CNC milling machine continues to improve. Only by continuous optimization and improvement, can the parts of CNC milling machine meet the processing requirements for different conditions and requirements [11 ~ 13]. The traditional optimization design method mostly improves the structural design of CNC machine tools with the help of experience,

which is difficult to meet the requirements of technical standards in terms of performance or overall structure, and the effect is usually not ideal [14]. For CNC machine tools, only continuous optimization design can fundamentally ensure the dynamic performance of the machine tool and improve the working speed and processing quality of the machine tool.

The frame is the main body of the micro CNC milling machine, which is mainly composed of the column and the base. It bears all the forces of the CNC milling machine and is an important guarantee for the accuracy of the milling machine. In this paper, the frame is optimized based on the finite element method, which provides a reference for the development of micro CNC milling machine.

## II.DESIGN REQUIREMENT

(1) Meet the requirements of CNC cutting, such as machining range, machining accuracy, etc.

(2) Ensure the relative position, relative accuracy and transmission efficiency of the workpiece and tool required by the established process method.

(3) Ensure that the lathe has the rigidity, vibration resistance, thermal deformation and noise level suitable for the required machining accuracy.

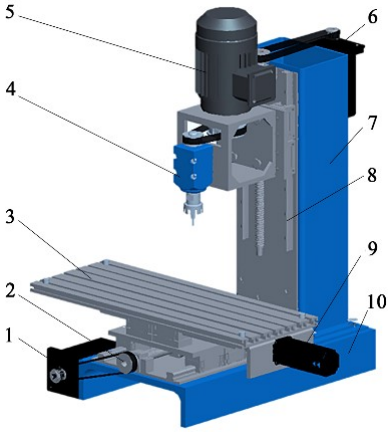
(4) It is easy to observe the machining process, easy to operate, adjust and maintain.

(5) The structure is simple, the disassembly is convenient, reasonable and reliable.

(6) Small size and light weight.

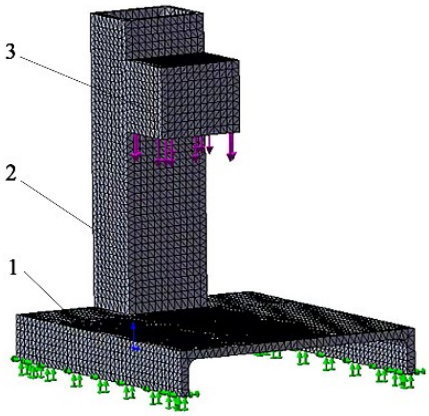
## III.STRUCTURE AND WORKING PRINCIPLE OF MACHINE TOOL

The micro CNC milling machine is a three-axis CNC milling machine, which is a simplified and reduced version of Industrial CNC milling machine. It is mainly composed of control system, guide rail, workbench, base, column, X, Y, Z three-axis and transmission system, as shown in Figure 1. The micro CNC milling machine is driven by a motor to move the worktable forward, backward, left and right, and to rotate the cutting tool and position it.




1. Y-axis motor; 2. Y-axis drive pulley; 3. Workbench; 4. Z-axis cutter installation device; 5. Z-axis motor; 6. Spindle moving motor; 7. Column; 8. Guide rail; 9. X-axis motor; 10. base

Fig 1 Micro CNC milling machine




1. Base; 2. Column; 3. Z-axis device

Fig 2 Framemodel

When working, first clamp the workpiece on the worktable, and at the same time, complete the tool installation and program preparation. Secondly, according to the tool setting method of the industrial CNC milling machine, find the origin of the tool setting relative to the workpiece. Finally, the X, Y, and Z axes are driven by manual operation method or numerical control system and run according to the path set by the processing program to complete the workpiece processing process. The codes used

by the CNC milling machine control system are internationally accepted G and M codes.

The dimensions of the machine are 700×600×750 mm, the three-axis strokes are 400×200×200 mm (X, Y, Z), the maximum power of the main shaft is 750 W, and the maximum speed is 6000 r/min.

## IV. FINITE ELEMENT ANALYSIS OF FRAME

SolidWorks software is used to establish the frame model of the micro CNC milling machine, as shown in Figure 2. The frame is welded with square tube. The model is meshed and applied with force. The z-axis device is a simplified figure, and its gravity is 500 n. The lower end of the base is fixed on the horizontal ground, and the simulation analysis is carried out in the simulation module of SolidWorks. The results are shown in Figure 3.

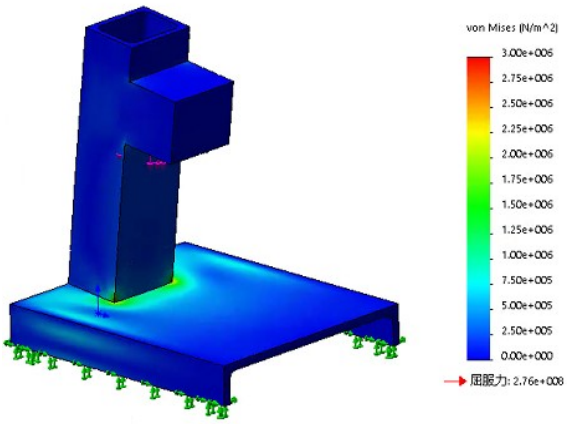



Fig 3 Stress cloud

According to Figure 3, the yield force of the frame is $2.76\times10^8$ N. When the stress exceeds the yield stress, the frame deforms greatly and the accuracy of the machine tool is greatly reduced. The maximum deformation position appears at the junction of the column and the base. The dead weight of the machine tool is much smaller than the yield stress. During the cutting process, the dynamic load is much smaller than the yield stress when operating in accordance with the specifications. Therefore, the frame structure is reasonably set and can meet the working requirements of a micro CNC milling machine. If overloading in special circumstances is considered, reinforcing ribs can be added at the junction of the column and the base to enhance the rigidity of the part.

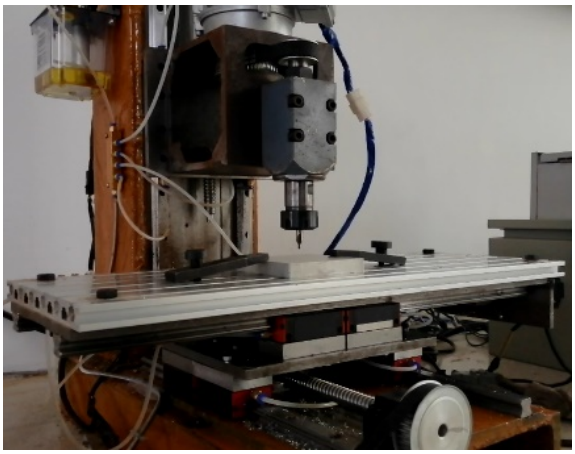


Fig 4 Test site

Fig 5 The shape to be machined

## V. Test study

In order to test the rationality of the rack design, the prototype test was carried out in the training center of Shaanxi national defense industry vocational and technical college on March 20, 2020. The test site is shown in Figure 4. The school emblem of Shaanxi national defense industry vocational and technical college is taken as the project, as shown in Figure 5. The pattern is more complex. In order to improve the programming efficiency, UG software is used to establish the digital model of the school emblem, as shown in Figure 6. Using UG NC processing module, the tool path of machining the pattern is generated and verified by simulation, and the corresponding processing program is obtained by post-processing.

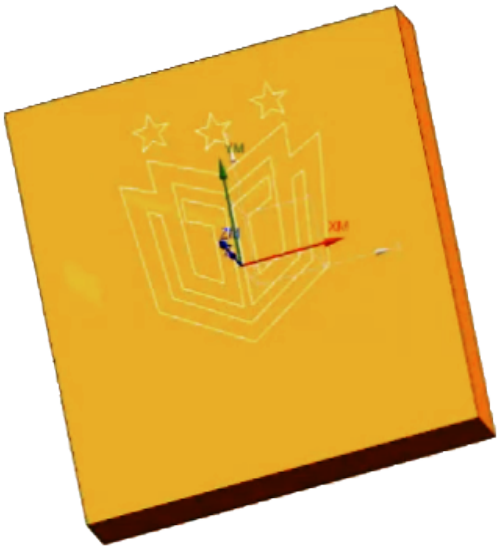


Fig 6 Digital model

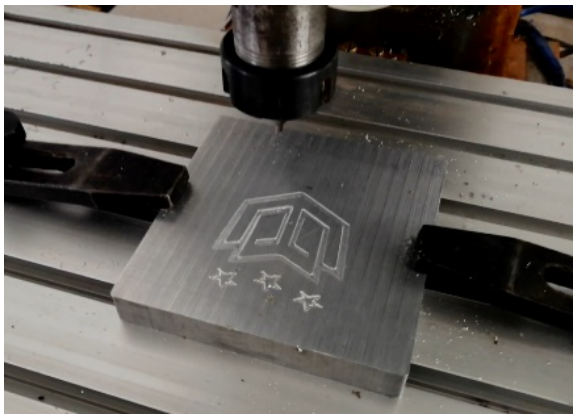


Fig 7Test result

After the tool setting is completed, switch to the automatic mode and start processing the outline of the school emblem of Shaanxi national defense industry vocational and technical college. After the processing of the school emblem is completed, the finished product is shown in Figure 7. The shape and size errors of the emblem contour are detected by using the contura G2 CMM. The measurement results show that the machining errors are concentrated in 0.6 ~ 0.8 mm, which means that the frame can meet the requirements of the micro CNC milling machine in the machining process. Therefore, the micro CNC milling machine can be used for students to understand the structure of CNC machine tools, to learn the working principle and to learn the basic processing operation, which has the value of popularization and application. It is expected to contribute to the further development of CNC milling machine in China.

## V.CONCLUSION

In this paper, a kind of Micro NC milling machine with high integration, simple structure, flexible operation and low cost for teaching is designed. The simulation results show that the yield stress of the frame is 2.76 × 108 n. The machining test of the micro milling machine is carried out. The test results show that the machining error of the micro milling machine is 0.6 ~ 0.8 mm when using the frame, which can meet the requirements of students' understanding and learning of NC milling machine, and has the value of popularization and application. It is expected that this research will contribute to the further development of CNC milling machine.

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