Standard Research on Vertical Machining Center for "Made in Zhejiang"

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Abstract. “Made in Zhejiang” is famous for its high-quality concept. Its open certification system and “A-standard + B-standard” certification model are guiding enterprises and industries to the mid-to-high end of the value chain and industrial chain. The concept of “Made in Zhejiang” was conceived in 2003, and was officially recognized in 2013. In 2017, the international certification body joined the “Made in Zhejiang” alliance. In this process it gradually matures. The article will firstly understand the reliability status of China's vertical machining centers and the research done by domestic and foreign scholars on the reliability of CNC machine tools, and then analyze the effect of the concept of “Made in Zhejiang” on its reliability improvement from the aspect of reliability test standards. Then according to the main parameters of FEELER NPB-1100A (#40) vertical machining center, design the vertical machining center reliability test according to the concept and requirements of “Made in Zhejiang”. Finally, the design content is compared with the current relevant national standards, which proves that the content meets the relevant requirements of “Made in Zhejiang” and puts forward suggestions for further improvement.

Introduction

Computerized Numerical Control machine tools in industrialized countries were gradually popularized since the mid-1970s, but many of their faults have also emerged, which has attracted the attention of professionals in the industry. In China, around the 1980s, scholars began research on the reliability of Computerized Numerical Control machine tools. Later, domestic Computerized Numerical Control machine tools were gradually developed [1].

In order to establish a reliability model, Keller and other scholars in the United Kingdom have tracked 35 Computerized Numerical Control machine tools on site and obtained more than 300 reliability data [2]. Lapidus established the fault distribution law of Computerized Numerical Control machine tools by collecting on-site tracking data [3]. Yingzhi Zhang proposed a non-fatal shocked reliability model based on failure interaction to illustrate the internal law of failure [4]. From the law of the formation of Computerized Numerical Control machine tool failure, Qinzhi Zhao studied the rapid evaluation technology applicable to the reliability evaluation of new Computerized Numerical Control machine tools [5].

At present, there are few product reliability evaluation standards in China, and there is a lack of reliability evaluation models, techniques and evaluation methods. The reliability test is an important part of reliability evaluation, so it is necessary to promote the development of domestic reliability test standards through high requirements.

At the end of 2013, with the approval of Certification and Accreditation Administration of the People's Republic of China, Zhejiang Province used the certification and accreditation method to build the “Made in Zhejiang” brand. By the end of 2017, 11 certification bodies had joined, and they were supervised by companies that had obtained “Made in Zhejiang” certification in accordance with certification regulations. In the standard positioning, it stands out that it has reached the first-class level in China and reached the leading level in the world. In the standard design, the “Made in Zhejiang” standard puts strict technical and quality control requirements on the main components, which can effectively extend the service life and meet the requirements of German products for 10 years [8].
It can be seen that if the concept of “Made in Zhejiang” is incorporated into the design of the reliability test standard of the vertical machining center, it will greatly help the reliability improvement. In order to improve the reliability test standard level of vertical machining center, this paper takes FEELER NPB-1100A (#40) vertical machining center as an example, and refers to the above-mentioned domestic and foreign scholars’ research on the reliability test of vertical machining center, and adopts requirements and rules of “Made in Zhejiang” to design the reliability test process and acceptance rules for the vertical machining center.

Materials and Methods

The parameters of the FEELER NPB-1100A (#40) vertical machining center are given in the official website of Hangzhou Youjia Precision Machinery Co., Ltd, as shown in Table 1.[9]

First, we must set goals and develop a feasible design method. Then find and collect data according to the target and the research object, to understand the operation process of the FEELER NPB-1100A (#40) vertical machining center, to understand which of his indicators are related to its reliability, and to know the implementation process of reliability test, but also to master the relevant specifications of “Made in Zhejiang”. The final draft need to be compared with the vertical machining center standards at home and abroad to prove that it is higher than the national standard. The draft is not the final standard, and it is necessary to think about the recommendations for further research.

Table 1. Parameter list of FEELER NPB-1100A (#40) vertical machining center.

| Travel               | X axis travel | Y axis travel | Z axis travel |
|----------------------|---------------|---------------|---------------|
| Spindle              | Spindle speed | 50-10000 rpm  |
| Feed                 | Axis rapid traverse | 24 [m/min]    |
| Worktable            | Worktable area | 1300[mm]×600[mm] |
|                      | Max workbench load | 1300[kg]    |
|                      | T slot | 18×5×100 [mm] |
| Numerical control system | FANUC 0IMF   |
| Tool magazine        | Tool magazine capacity | 24 |
|                      | Maximum diameter of the tool | 80 [mm]    |
|                      | Maximum diameter of the tool (No adjacent knife) | 150 [mm]    |
|                      | Maximum length of tool | 300 [mm]    |
|                      | Maximum weight of the tool | 8[kg]    |
|                      | Tool change time | 2.2[s]    |
| Drive motor          | Spindle motor | 7.5/11[ kW] |
|                      | X, Y, Z-axis AC servo motor | 4.0 [kW] |

Result

The following are the reliability test contents designed with reference to the Chinese national standards and the requirements of “Made in Zhejiang”.

No-load Test of Machine Tool

Test methods and procedures:

1) Before the active mechanism of the machine tool starts running, measure the initial temperature near the spindle centering bearing.

2) The active mechanism starts from the minimum speed of 50 rpm, and sequentially increases the speed gear position. The running time of each gear speed is not less than two minutes. At the maximum speed of 10,000 rpm, the running time must not be less than one hour in order to achieve a stable temperature of the spindle bearings. Measure the temperature at this point near the spindle centering bearing and calculate the temperature rise.

3) Please measure product noise under no-load conditions, measure the power of the main drive system at this time under no-load conditions, and measure the speed and feed of the spindles at each level and calculate the deviation from the indicated value under no-load conditions.
Receiving rule:
1) After a certain period of idle operation, the spindle temperature should not exceed 50°C, the temperature rise should not exceed 20°C.
2) The sound pressure level of the whole machine should not exceed 75dB (A) during the test, and the noise measurement method should be carried out according to the GB/T 16769 standard.
3) Under no-load conditions, the spindle motor power is 7.5/11 kW.
4) The deviation of the speed of the main shaft and the feed of the spindle driven by the polar axis shall not exceed -1% to +3% of the indication value of the sign. The spindle speed and the actual deviation of the feed at each stage of the stepless drive must not exceed ± 8% of the indicated value.

Machine Tool Load Test
Test methods and procedures:
The maximum load operation test, the maximum torque test of the main drive system, the maximum cutting resistance and the maximum power test of the main drive system shall be carried out in accordance with JB/T 8801-2017.

According to the provisions of GB/T 9061-2006, Eq.1 is used to calculate the torque measured by the cutting dynamometer. Eq.2 is used to calculate the torque measured by the power meter (or ammeter and voltmeter) and tachometer. Eq.3 is used to calculate the main component force of the cutting resistance.

\[
T = F \times r
\]  
(1)
\[
T \approx \frac{9550(P-P_0)}{\pi n}
\]  
(2)
\[
T \approx \frac{9550(P-P_0)}{r \times n}
\]  
(3)

In Eq.1 and Eq.2, \(T\) is the torque. In Eq.1 and Eq.3, \(F\) is the cutting resistance measured by cutting dynamometer, and \(r\) is the cutting radius of the tool. In Eq.2 and Eq.3, \(P\) is the input power of the motor during cutting, and \(P_0\) is the no-load power when the tools are mounted on the machine, and \(n\) is spindle speed.

Receiving rule:
1) When carrying out the maximum load test, the machine tool should withstand 1300kg weight of the workpiece, running smoothly, no faults, no obvious creeping phenomenon.
2) When the maximum power test of the main drive system is carried out, the power of the spindle motor reaches 7.5/11 kW, and when the power of the X, Y, Z-axis AC servo motor reaches 4.0 kW.

Functional Test
The function test mainly checks whether the main parameters of the product (stroke, speed, rapid moving speed, spindle head type, size, etc.) meet the requirements of design documents, instructions for use, product nameplates, etc. The test procedure refers to clause 7.2 of JB/T 8801-2017.

Test methods and procedures:
1) The spindle performs more than 10 times of continuous operation of locking tool, loose tool and blowing. Let the spindle perform 15 consecutive forward, reverse, start, brake, and stop continuous movements under medium speed conditions, and specify the direction of motion. The spindle is tested in three low, medium and high speed positions with a spindle speed range of 20-10000 rpm.
2) The moving parts on the linear coordinates and the rotary coordinates are operated at the mid-speed feed speed, and the tests are performed including forward and reverse start, stop and brake, and each action is performed 15 times.
3) The feed system is operated for more than 15 times, and the gear positions are low speed, medium speed and high speed. Operate the indexing or CNC rotary table to perform more than 15 positioning and indexing tests. Operate the pallet to perform 6 exchange movements.
4) Use a tool with a weight of 8kg, a diameter of 150mm and a length of 300mm, and operate the tool magazine and the robot to change the tool.

Receiving rule:
1) The spindle, the linear coordinates, the moving parts on the swivel coordinates, the feed system, and the indexing device should always be flexible and free from sticking during each test.
2) The hydraulic system, cooling system and lubrication system should ensure the sealing is firm, the cooling function is good, the lubrication function is good, and there is no leakage. The specific requirements are in accordance with the provisions of 5.18 of GB/T 23572, GB 15760-2004 and GB/T 6576.

Discussion

Differences from Other Standards and the Reasons

The test procedures and acceptance rules for the three reliability tests designed above are based on relevant national standards. However, since this standard is for “Made in Zhejiang”, the requirements in the standard need to be “first-class in China”, so the receiving standards have been improved.

About the No-load Test of Machine Tool:
1) According to the provisions of 4.6.2 of GB/T 9061-2006, when the spindle reaches a stable temperature, the temperature value of the measurement does not rise more than 5 °C / h, at which time the temperature and temperature rise do not exceed the requirements of Table 2. This paper stipulates that the spindle temperature should not exceed 50 °C, the temperature rise should not exceed 20 °C, and the requirements are higher than the national standard.
2) According to the provisions of JB/T 8801-2017, the sound pressure level of the noise must not exceed 83 dB (A) in this experiment. The noise pressure level specified in this paper shall not exceed 75dB (A), which is more strict than the international standard.
3) According to the provisions of JB/T 8801-2017, the actual deviation of the speed and feed rate of the spindle with pole drive should not exceed -2% to +6% of the indication value of the sign, and the limit specified in this document shall not exceed -1% to +3%.
4) According to the JB/T 8801-2017, the tool change on the tool position is not less than 2 times and the automatic exchange of various pallets is not less than 5 times. However, in this paper, the number of tool changes is increased to 5 times, and the number of pallet exchanges is increased to 10 times.

Table 2. Table of requirements for bearing temperature and temperature rise in Chinese national standard.

| Bearing type  | Temperature value | Temperature rise |
|--------------|-------------------|------------------|
| Sliding bearing | 60 [°C]          | 30 [°C]          |
| Rolling bearing | 70 [°C]          | 40 [°C]          |

About Function test:
1) JB/T 8801-2017 stipulates that the series of lock, knives and blows of the spindle need to be carried out more than 5 times, and this paper increases it to more than 10 times. And the series of actions of the spindle at medium speed increased from 10 to 15 times.
2) The number of movements of moving parts on linear coordinates and swivel coordinates at medium speed was increased from 10 to 15 times.
3) The number of positioning and indexing tests of the indexing or numerical control rotary table was increased from 10 to 15 times.

Conclusion

Compared with the relevant national standards, it can be seen that the reliability test design draft of the FEELER NPB-1100A (#40) vertical machining center has been improved in some rules, and the requirements are more stringent. It conforms to the B standard in “Made in Zhejiang”, that is, “first-class in China”.

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The reliability test of the machining center is to induce and expose the failure of the machine tool product. The research on the reliability test technology of the machining center can help the machine tool enterprise to effectively expose and eliminate the early failure of the machine tool within a limited budget and test period \(^{[10]}\). Due to the large number of vertical machining centers, different types of vertical machining centers have different requirements for reliability, it is necessary to classify different types of equipment to further study the reliability standards of vertical machining centers.

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