Spinning is a mature technique with long history. In this paper, the stress applied to the bed is calculated by the stress on spinning roller in closing. A geometrical model of bed is built, and finite element analysis is conducted in ANSYS software to analyze the stress and deformation of bed in the process of closing. The analytical result will guide the process design of bed.

Keywords: Finite Element Analysis; Spinning Force; Bed Design

1. Introduction

Most high-pressure gas cylinders are made of steel in a working pressure of 10~30Mpa. They are widely applied to industrial and mining enterprises, medical, transportation and other departments. The hot spinning closing technique is usually adopted for high-pressure gas cylinders, which effectively improves the production efficiency, reduces the production cost, and also increases the pass rate of products. However, if the bed of closing equipment has insufficient rigidity, deformation may occur and cause bad effect on forming precision of products. By the finite element simulation technique, the bed stress can be calculated indirectly by the stress on spinning roller. A finite element analysis is done on the bed using ANSYS to analyze the deformation of bed in the stress process [1-3].

2. Stress Analysis

Till now, there is no stress calculation method specially-used for closing device both home and abroad. Therefore, the stress will be analyzed by stress calculation method for cones.
Before the calculation of spinning force on cone, the following assumptions are made:

1) The blank is even and isotropic.
2) The material has no volume change before and after the deformation.
3) The friction between spinning roller and blank can be ignored.
4) When the blank material under the spinning roller deforms, materials of other parts have no deformation.
5) The equipment and tool system are absolutely rigid during the deformation.
6) The material is considered as being plane deformation in the area of deformation.

Figure 1 is the deformation in power spinning. In this method, the deformation of cone in power spinning is assumed to be shearing deformation along the mandrel axis line, accompanied by bending and contra flexure deformation on RZ plane and around the R axis. On the blank, main deformation occurs after the line element AB in distance R away from the mandrel axis line reaches position A1B1 and contacts the spinning roller. Then,

\[ n_0 = \frac{r \cdot \text{ctg} \, \varphi}{f} \]  

(1)

![Fig.1. Deformation of Cone Blank in Power Spinning](image)

The deformation for each passing of spinning roller is composed by bending on Point P and contra flexure on point Q. As a result, the steps of calculating strain is to calculate the total actual strain of point P and Q firstly, then the total actual strain for each passing of spinning roller, and finally the total actual strain for n0 passing of spinning roller.
3. **Bed Design and Modeling**

The bed is an important component of spinning machine. In a spinning machine, the bed has just a few parts, but more than half of the whole weight. The bed structure is mainly affected by layout, force direction, force size and other factors. Gray pig iron is usually used as the material. A good bed provides sufficient rigidity, vibration resistance and abrasion resistance to the whole spinning machine. The gauge finder is mounted on the bed. The shape, dimension and precision of parts processed on the copying spinning machine have a great deal to do with the design, manufacturing and adjustment of copying system. The gauge finder is composed by leading-in, spinning and leading-out segments. The function of leading-in segment is to lead the spinning roller in before it contacts the work piece. At this moment, the spinning roller gradually closes the work piece from far away until they contact each other. Spinning segment refers to a gauge finder profile of spinning roller running from the starting point to the end point. It is a crucial segment in the gauge finder. The lead-out segment is to lead the spinning roller out of the work piece. In modern machine building industry, there are many methods of processing machinery parts, such as casting, forging, welding, cutting, and various special processing. The technical level of machine directly affects the product quality and labor productivity of machine building industry. Over the years, gray pig iron is always used for the material of machine building, because it has typical advantages as machine tool structure. It has good fluidity and small volume and linear shrinkages, which can produce casting in complicated shape. Adding a small amount of alloy elements in the casting can improve the abrasion resistance. Casting iron has good cutting performance, high processing precision, and mature processing technique. Through the unceasing study, various characteristics of gray pig iron are utilized almost to the extreme. In recent years, some shortcomings are exposed in machine bed made of cast iron, such as the failure of meeting requirements of controlling cost or special processing. Moreover, with the improvement of people's environmental protection awareness, green manufacturing has become the consensus of the people, and it has become a hotspot of research at home and abroad to replace the traditional iron and steel materials with non-metal materials or composite materials for batch production of the products. With the economic development of China, the requirements for
product quality and parts precision are improved in the automotive, energy, shipbuilding, aviation, railway and other fields closely related to the machine tool, thus the demand for high efficiency and precision machine tool is increasing, which puts forward higher requirements to the processing precision and precision maintenance of the machine. Most high-tech sophisticated CNC machine tools in China's national defense, aviation and other high-tech fields are imported. The dimension precision and its maintenance of machine bed are the bottleneck hindering the manufacturing of high-end CNC machine tool in China. The bed is the key component of machine, and its dimension precision and precision maintenance are important factors affecting the processing precision and stability of machine. The structure of the bed is generally characterized by the thicker and longer guide rail surface and thinner side face. The thermal stress, phase transformation stress, and structural stress produced in casting process easily cause tensile stress on the guide rail surface and compression stress on the side face. In the service, the release of residual stress easily leads to bending of guide rail, concave of guide rail surface and protruding on thin wall side face, affecting the dimensional accuracy seriously. The deformation and even cracking of the casting caused by the residual stress are common technical problems for the casting industry. Therefore, the chemical composition of bed casting should be selected reasonably to improve the alloy smelting and production technology level. As a result, the casting has high tensile strength and elastic modulus, but low residual stress. By this way, the rigidity and non-deformability of material are improved, preventing the casting deformation and crack, so as to ensure the excellent dimensional stability and reliability of the machine. The material used for manufacturing machine components must have the following characteristics: being suitable for structure needs; satisfying the rigidity, strength and stability requirements; having good abrasion resistance and corrosion resistance; having good thermal stability and dimensional stability.

As a tool of processing, the machine's precisions directly affect the quality and efficiency of processed work pieces. In order to guarantee the processing quality, in the design of machine, certain original precision must be maintained when the machine bears no load. That is to say, under certain static load and fixed cutting force, the deformation of machine will not exceed the allowable amount, so as to guarantee the processing precision and working conditions of main components after the load
is applied. In the action of external alternate load in certain frequency and amplitude, resonance will not occur on the machine, and the amplitude of vibration is within the limit. The machine in operation will not cause self-exited vibration of cutting, ensuring the processing precision and surface smoothness. The machine generates thermal deformation due to the thermal expansion cause by heat in operation, which affects the processing precision. The design should ensure the error caused by thermal deformation not exceeding allowable value. The abrasion performance and fatigue resistance should be studied to keep processing quality and working conditions in a long period of working. Moreover, the noise of machine should be dealt with to provide a quiet working environment to workers.

Firstly, the case wall thickness is calculated as per the design manual of machine:

\[ N = \frac{2l + B + H}{3000} \]  \hspace{1cm} (2)

\( L \) is the length of casting; \( B \) is the width of casting; \( H \) is the height of casting. Consider \( N = 3 \), look up the table to find the corresponding thickness of gray pig iron \( t = 20 \text{mm} \), rib thickness \( 0.7t = 0.7 \times 20 = 14 \), and take \( t = 15 \text{mm} \). The geometrical model of bed is built on ANSYS platform, as shown in Figure 2.

![Geometric model.](image)

Figure 2. Geometric model.

4. **Finite Element Analysis**

The units and materials are defined, and grids are divided on the model. Then, the model is constrained and loaded to analyze the stress on bed, as shown in Figure 3.
The analytic result of displacement is shown as Figure 4.

The analytic result shows that, the integral displacement is small, but the deformation on main spindle box is slightly larger. It proves the main spindle box has a larger stress.

5. Conclusion

According to the process requirements and stress characteristics of machine bed, this paper studies the design and manufacturing method of machine, and analyzes the
materials and bed properties using finite element software. The analysis on deformation of bed using ANSYS is helpful to understand the equipment performance, and therefore to lay foundation for further optimization of equipment.

References