The Strength Analysis of CNC Machine Tool Hydraulic Automatic Centering Fixture

Hongwei Chen and Rongjie Wang

ABSTRACT:

CNC machine tool hydraulic automatic centering fixture is a kind of hydraulic automatic control fixtures, and installed on the tailstock inner clamp, have accurate and convenient clamping and good stability and high precision, suitable for excircle machining in long sleeve workpiece. In order to ensure the strength of the fixture meet the requirements, The force analysis on its structural analysis, applied mechanics method for strength calculation, and the use of Solidworks 3D Simulation software for finite element analysis, the results show that the clamp strength meet the design requirements.

INTRODUCTION

CNC machine tool hydraulic automatic centering fixture is a new type of fixture used for turning or grinding the outer circle of the long sleeve type parts of the NC machine tool. Because of a larger force on the fixture in use, so the strength of the calculation must be carried out in design. In this paper, the principle of Engineering Mechanics and finite element analysis method is applied to the theoretical analysis and Simulation of the strength of the fixture, and the results have certain guiding significance for the design of mechanical products.

Hongwei Chen, Department of Mechanical and Electrical Engineering, Longyan University, Longyan, Fujian, 364012, China
Rongjie Wang, Department of Mechanical and Electrical Engineering, Longyan University, Longyan, Fujian, 364012, China
THE STRUCTURE AND WORKING PRINCIPLE OF THE CNC MACHINE TOOLS HYDRAULIC AUTOMATIC CENTERING FIXTURE

Hydraulic Automatic Centering Fixture Structure

CNC machine tool hydraulic automatic centering fixture is an important accessory of CNC machine tool, mainly comprising the hydraulic device (cylinder head, cylinder, centering axle, etc.) and expansion device (sliding cone, expansion set, reset spring), bearing and lock nut, etc., as shown in Figure 1. It is mainly used for the positioning and clamping of the sleeve-type rotary workpiece in the CNC machine tool, and realize automatic centering and stable clamping in one time.

![Diagram of CNC machine tool hydraulic automatic centering fixture assembly drawing.](image)

The Working Principle of the CNC Machine Tools Hydraulic Automatic Centering Fixture

Hydraulic automatic centering fixture is fixed on the tailstock by Morse cone mandrel. The tailstock drives automatic centering for axial movement by the control of a hydraulic system in working, centering fixture is sheathed in the sleeve inner hole of the workpiece. Through the hydraulic oil into the joints, the hydraulic cylinder automatically moves in the axial direction of the workpiece according to the outer diameter of the workpiece, so as to expand the sleeve into three parts and set tight by the reset spring move radially and axially along the sliding cone, the inner hole of the workpiece is expanded, realize automatic and stable core jig coaxial connection; After processing in hydraulic control system, the hydraulic cylinder moves the expansion sleeve into the tailstock direction, because the reduction effect of the reset spring, the expansion sleeve slides along the radial and axial moving, relax the workpiece, the automatic centering fixture shifts out of the workpiece.
THE STRENGTH CALCULATION OF RHE HYDRAULIC AUTOMATIC CENTERING FIXTURE

Stress Analysis of Expansion Device

Expansion sleeve as the research object is done analysis of the force, as shown in Figure 2. \( F_{R1} \) and \( F_{N1} \) and \( F_{f1} \) are respectively Resultant force and surface normal force and friction force of outer surface expansion sleeve, \( F_{R2} \) and \( F_{N2} \) and \( F_{f2} \) are respectively Resultant force and surface normal force and friction force of inner surface expansion sleeve, \( F_t \) is tension on the expansion sleeve, \( \alpha \), \( \lambda \), \( f \) are respectively half cone angle and material equivalent friction angle and the friction coefficient of expansion sleeve.

The Strength Calculation of the Expansion Device

The sliding cone of the expansion device and the expansion sleeve are equivalent to the thick wall cylinder model, and the strength theory calculation is carried out by using the Lame formula.

The axial preload of the pre tightening expansion sleeve can be determined by the pressure of the hydraulic system of the automatic centering fixture of the CNC machine tool.

\[
F = p_e \times \frac{\pi}{4} \times (d_{hs}^2 - d_{hg}^2)
\]

Type (1): \( p_e \) — rated pressure of hydraulic system, 4MPa; \( d_{hs} \) , \( d_{hg} \) — I the hydraulic cylinder piston and piston rod diameter, mm. According to the analysis of the force of the expansion sleeve:

\[
\begin{align*}
F_{R1} \sin \lambda + F_{R2} \sin (\alpha + \lambda) &= F \\
F_t + F_{R1} \cos \lambda &= F_{R2} (\alpha + \lambda) \\
F_{N1} &= F_{R1} \cos \lambda \\
F_{N2} &= F_{R2} \cos \lambda
\end{align*}
\]

\[
\begin{align*}
p_1 &= \frac{F_t + F_{N1}}{\pi DB} \\
p_2 &= \frac{F_{N2}}{\pi d_m L} \\
d_m &= \frac{d_{\min} + d_{\max}}{2}
\end{align*}
\]

Type (2): \( p_1 \), \( p_2 \) — expansion sleeve outer ring and sleeve workpiece, average pressure between the inner ring and the sliding cone, MPa; \( B \), \( L \) — expansion sleeve width, inner loop of the expansion sleeve and the length of the indirect contact surface.
of the sliding cone, mm, see figure 3; \( d_m, d_{\text{min}}, d_{\text{max}}, D \)—the average diameter of D expansion sleeve expansion after the inner cone, small end diameter, large diameter and expansion sleeve outer ring diameter, mm, see figure 3;

According to the Lame formula, in the pressure distribution under the action of \( P_1 \) and \( P_2 \), At the diameter expansion point of the radial and circumferential stresses \( \sigma_r \) and \( \sigma_\theta \) were:

\[
\begin{align*}
\sigma_r &= \frac{p_2d_m^2 - p_1D^2}{D^2 - d_m^2} - \frac{(p_2 - p_1)d_m^2D^2}{(D^2 - d_m^2)d_r^2} \\
\sigma_\theta &= \frac{p_2d_m^2 - p_1D^2}{D^2 - d_m^2} + \frac{(p_2 - p_1)d_m^2D^2}{(D^2 - d_m^2)d_r^2}
\end{align*}
\]

(3)

According to the fourth strength theory, the equivalent stress is:

\[
\sigma_{eq} = \sqrt{\frac{1}{2} \left[ \sigma_r^2 + \sigma_\theta^2 + (\sigma_r - \sigma_\theta)^2 \right]}
\]

(4)

THE FINITE ELEMENT ANALYSIS OF THE HYAULIC AUTOMATIC CENTERING FIXTURE

Solidworks 3D Modeling of Hydraulic Automatic Centering Fixture

The use of Solidworks software, establish 3D model of CNC machine tool hydraulic mandrel and automatic centering clamp cylinder and hydraulic cylinder and sliding cone and expansion sleeve and a reset spring and a locking nut and shaft end ring, as shown in Figure 4.

Figure 4. 3D model of CNC machine tool hydraulic automatic centering fixture.
Equivalent Static Stress of Finite Element Analysis of Hydraulic Automatic Centering Fixture

Figure 5. equivalent static stress analysis of assembly. Figure 6. maximum equivalent stress of the sliding cone.

Figure 7. maximum equivalent stress of expansion sleeve. Figure 8. maximum equivalent stress of the sleeve.

Analysis of Figure.5, The static stress distribution of the assembly of the whole the expansion device is elementary symmetrical, maximum equivalent static stress is 16.733 MPa, occurred in the vicinity of the left side of the sliding cone hole at the shoulder (Figure 6). The maximum equivalent stress of the expansion sleeve is 16.29 MPa, occurred in the left end of expansion sleeve(Figure7); The maximum equivalent stress of sleeve workpiece is7.302 MPa, also occurs in nearly the sliding cone and the expansion sleeve. There maximum equivalent stress value of the finite element analysis are far less than their allowable strength value, it shall meet the strength requirements. There is a need to explain that equivalent static stress of finite element analysis is about 4 times larger than that obtained by using the theory of elastic mechanics, the main reason is that the torque function and the stress concentration problem of the structure are not considered in the theoretical calculation, therefore the finite element analysis method is used to analyze the strength and stress distribution of the parts is more accurate and more reliable than the traditional theory.

CONCLUSION

Engineering mechanics and elastic mechanics methods and finite element analysis methods are applied respectively, the results of stress analysis and strength calculation of the expansion sleeve parts are in agreement with the results of the stress distribution through the analysis of the mechanism of the hydraulic automatic centering fixture for NC machine tools. However, there are some differences in the value and location of
maximum stress, the analysis reason is the influence of stress concentration in the actual structure of the fixture. From the analysis results, the theoretical calculation is helpful to guide the design calculation from the principle, The finite element analysis method is more comprehensive, simple, accurate and practical.

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