Quality Control Method of Machine Tool Spindles

Abstract: the quality control of machine tool spindles is one of the important quality control requirements of a series of machine tools. This article mainly discusses the quality control methods of spindles from the aspects of spindle rotation accuracy, stiffness, earthquake resistance, temperature rise, thermal deformation and wear resistance, to provide a reference for the guidance of process schemes in the field of quality control of machine tool spindles.

Keywords: rotation accuracy, stiffness, earthquake resistance, temperature rise, thermal deformation, wear resistance

Introduction

The quality of a machine tool spindle directly determines the quality of a machine tool. So, how to distinguish whether the machine tool spindle is good or not? It depends on the following aspects:

A measure of spindle rotation accuracy is the runout of the spindle, which directly determines the working accuracy and stability of the machine tool. Taking the lathe as an example, if the runout of the lathe spindle is 0.01mm, the size of the machined parts will be at least 0.01mm larger or oval. If this runout is allowed to expand, it will affect the processing quality of machined parts. In serious cases, it will lead to quality accidents.

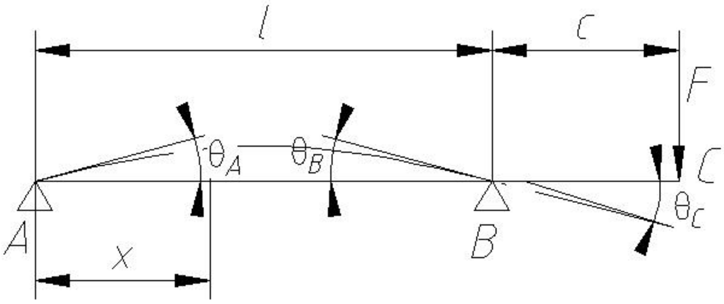
On the one hand, the runout of the spindle depends on the machining progress of the spindle itself; On the other hand, the inappropriate assembly of the spindle will also lead to excessive runout of the spindle. Of course, such excessive runout caused by such assembly may arise from the unreasonable design of the assembly structure or the assembly not following technical requirements.

Spindle stiffness refers to the anti-deformation ability when external forces act on the spindle, such as the turning force on the lathe, and the ability that the spindle can still maintain a certain working accuracy. If the stiffness of the spindle is insufficient, it will not only affect the accuracy and surface quality of the machined parts but also cause vibration. Therefore, in the design, the working state of the spindle should be fully considered in detail, and whether its stiffness meets the machining requirements should be calculated in advance.

How to calculate the bending stiffness of the spindle?

The evaluation of the bending stiffness of the spindle mainly includes deflection and deflection angle. If these two values are calculated, we can know whether the bending stiffness of the spindle meets the design requirements.

It is generally calculated as a double fulcrum beam, for example:



Deflection angle

$$\theta_A = \frac{Fcl}{6 \times 10^4 d_{v2}^4}$$

$$\theta_B = -\frac{Fcl}{3 \times 10^4 d_{v2}^4} = -2\theta_A$$

$$\theta_C = \theta_B - \frac{Fc^2}{2 \times 10^4 d_{v2}^4} \qquad \theta_x = \theta_A\,[1 - 3(\frac{x}{l})^2]$$ (在 A — B 段) (At section A-B)

Deflection

$$y_c = \theta_B c - \frac{Fc^3}{3 \times 10^4 d_{v2}^4}$$

$$y_x = \theta_A x\,[1 - (\frac{x}{l})^2]$$ (在 A — B 段) (At section A-B)

$$y_{max} = \frac{Fc^2}{9\sqrt{3} \times 10^4 d_{v2}^4} \approx 0.384 l \theta_A$$

(在 $x = \frac{l}{\sqrt{3}} \approx 0.577l$) (At $x = \frac{l}{\sqrt{3}} \approx 0.577l$)

Allowable deflection and deflection angle of spindle

condition	y_p deflection	condition	deflection angle
General-purpose spindle	$y_{maxp} = (0.0003{\sim}0.0005)l$	Sliding bearing	$\theta_p = 0.001$
Metal cutting machine tool spindle	$y_{maxp} = 0.0002l$	Centripetal ball bearing	$\theta_p = 0.005$

	(l—span between supports)	Centripetal spherical bearing	$\theta_p = 0.05$
Installation of gear	$y_p = (0.01\sim0.03)m_n$	Cylindrical roller bearing	$\theta_p = 0.0025$
Installation of worm gear	$y_p = (0.02\sim0.05)m_t$ (m_n,m_t—span between supports)	Tapered roller bearing	$\theta_p = 0.0016$
		Install the gear	$\theta_p = 0.001\sim0.002$

Note: (from the tenth edition of mechanical design manual)

Vibration resistance of spindle

It refers to the ability of the spindle to resist forced vibration and self-excited vibration and maintain stable operation during operation. Spindle vibration resistance directly affects the surface quality and productivity of machined parts.

To improve the seismic resistance of the spindle, pay attention to the following aspects:

First, installation of the machine tool. The machine tool should be installed on solid ground and firmly fixed by anchor bolts or embedded machine feet. The machine tool must be installed in strict accordance with the installation requirements of the manufacturer;

The second is the installation site. The machine tool should be installed far away from other vibration sources;

The third is the structural design of the machine tool. In the structural design of the machine tool, the spindle vibration should be fully considered to take certain measures to reduce or even eliminate the negative impact of vibration. For example, the base and frame of the machine tool are generally made of cast iron because the cast iron is rigid, thick and stable, and can resist the diffusion of vibration sources; In addition, an elastic coupling will be used between the spindle and its driving motor, which can avoid the transmission and diffusion of vibration to a certain extent.

Temperature rise and thermal deformation of spindle

When turning parts, the machine tool will produce large heat, which will lead to temperature rise. The temperature rise will cause thermal deformation of machine tool parts, change the relative position of the spindle rotation center and affect the machining accuracy. The too high temperature will also change the clearance of components such as bearings, destroy lubrication conditions, accelerate wear and even hold the spindle.

Generally, the temperature rise parts of a lathe are mainly concentrated in turning parts and spindle bearings. The temperature control means of turning is generally to spray coolant; When the temperature at the spindle bearing is too high, forced lubrication or forced cooling is generally used to reduce the temperature.

Wear resistance

The wear resistance of the spindle refers to the ability to maintain the original accuracy for a long time.

The wear resistance of the spindle mainly depends on the heat treatment of material, bearing type and lubrication mode.

Reasonable design can greatly improve the wear resistance of the spindle, thus improving the service life.

Conclusion

The spindle function, performance and purpose of various types of machine tools are different, but the theoretical basis for the design of spindle is in common. This article mainly discusses the rotation accuracy, stiffness, seismic resistance, temperature rise, thermal deformation and wear resistance of machine tool spindles, to provide reference opinions for the initial design and calculation of various types of machine tool spindles, and provide a certain degree of theoretical basis for spindle structure and installation technology.