Selection techniques for bearings in machine tool design

Reasonable selection of bearings not only prolongs the service life of the machine, but also reduces the machine failure rate, Industrial Bearings Inc improves the use efficiency, and reduces maintenance costs, which is an important driving force for improving the production efficiency and productivity of the enterprise.

1 Reasonable configuration of spindle rolling bearings

1.1 Two-bearing spindle bearing configuration

The selection and configuration of the spindle bearings are mainly determined according to the working tasks and structural characteristics of the spindle components. At the same time, it must also take into account the experience accumulated by the manufacturer for long-term use of certain types of bearings and the flexible supply conditions of the bearings. The machine tool spindle has two front and rear supports and three front, middle and rear supports. The former is more common. The configuration of the two-bearing spindle bearings, including the selection, combination and arrangement of the spindle bearings, is mainly based on the requirements of the designed spindle components in terms of rotational speed, load carrying capacity, rigidity and accuracy. The following general principles should be followed when determining the two-bearing spindle bearing configuration:

(1) Adaptation to the requirements of stiffness and load carrying capacity: The choice of the configuration of the spindle bearing should first meet the required stiffness and load carrying capacity. There are multiple bearings in the support that are stiffer than only one bearing. Since the rigidity of the front support can be increased to effectively increase the rigidity of the main shaft assembly, the bearing with improved rigidity should be disposed on the front support.

(2) Adaptation speed requirements: The maximum speed allowed by bearings of different types, specifications and accuracy grades is different. Under the same conditions, the point contact is higher than the line contact; the cylindrical roller is higher than the tapered roller. Therefore, the bearing configuration should be selected considering the requirements of the stiffness and speed of the spindle assembly.

(3) Adaptation accuracy requirements: The thrust bearing configuration form of the spindle assembly that receives the axial force directly affects the axial position accuracy of the spindle. When the front end is positioned, the main shaft is extended by heat deformation and does not affect the machining accuracy, but the front support structure is complicated, the adjustment of the bearing clearance is inconvenient, and the front support heat is large. The characteristics of the backend positioning are opposite to the above. When the two ends are positioned, the axial clearance of the bearing changes greatly when the spindle is heated and extended.

1.2 Three-bearing spindle assembly

Due to the structural design reasons of some machine tools, the length of the headstock is long, and the bearing span between the two bearings of the main shaft is much larger than the optimal span. In this case, the intermediate support should be considered to increase the rigidity of the spindle assembly. Vibration resistance. Due to manufacturing limitations, it is not possible to completely coaxial the centers of the three spindle support seats in the cabinet. In order to ensure the rigidity and rotation accuracy of the main shaft assembly, usually only two supports play a major role, while the other support plays an auxiliary role. The auxiliary support often adopts a bearing with less rigidity and load carrying capacity, and the ratio of the outer ring to the bearing seat hole The main support is loose from 1 to 2, ensuring a certain gap to solve the problem of three holes with different axes.

1.3 Adjustment and preload of bearing clearance

Proper bearing clearance or proper preload (negative clearance) has a significant impact on the performance of the spindle assembly and the life of the bearing. In addition to the amount of clearance required to ensure the manufacture of certain special bearings, the general spindle assembly should be structurally guaranteed to adjust the clearance of the bearing. The method of tightening the nut or grinding the gasket is usually used to adjust the bearing clearance on the machine tool. Usually the roller bearing is smaller than the preload applied by the ball bearing. The higher the bearing accuracy, the smaller the preload required to achieve the same stiffness. The higher the speed, the lower the bearing accuracy and the greater the clearance required for normal operation.

1.4 Lubrication of spindle bearings

Lubrication has a large impact on the performance of the spindle assembly and the life of the bearing. Unreasonable lubrication may cause an increase in heat generation, reduce spindle work accuracy, and accelerate bearing wear. Lubricants for rolling bearings can be divided into two categories, namely grease lubricants and liquid lubricants. The choice of the lubrication method of the rolling bearing depends on the bearing speed, load, allowable temperature and bearing type. Since the temperature rise of the bearing is usually proportional to the speed factor (dn value or dmn) of the bearing, the lubrication method can often be selected according to the dn value of the bearing or dmn.

2 spindle sliding bearing

Sliding bearings are used in high-speed or low-speed precision and high-precision CNC machine tools because of their good vibration resistance, high rotation accuracy and smooth motion. The main shaft sliding bearing can be divided into dynamic pressure bearing and hydrostatic bearing according to the way of producing oil film. According to different fluid media, it can be divided into liquid sliding bearing and gas sliding bearing.

2.1 hydrodynamic bearing

The dynamic pressure bearing is a small oil flowing from the gap to the small gap when the main shaft rotates at a certain rotation speed to form a pressure oil film to float the main shaft and support the load. A single oil wedge dynamic pressure bearing that produces only one pressure oil film in the

bearing. When the working conditions such as load and rotation speed change, the oil film thickness and position of the single-oil wedge dynamic pressure bearing also change, which makes the axial line float and reduces the rotation precision and the movement stability. Due to the existence of several independent oil films, the oil film bearing supports the journal in several directions, and the axial position is stable, and the vibration resistance and impact resistance are good.
When the main shaft rotates at a certain speed, several pressure oil wedges can be formed around the journal to push the journal toward the center, so that the centripetality of the main shaft is good. When the main shaft is subjected to an external load, the journal is slightly eccentric, the load gap is reduced and the pressure is increased, and the gap in the opposite direction is increased and the pressure is lowered, forming a new balance. At this time, the oil film pressure in the bearing direction will be higher than that of the ordinary single oil wedge bearing. The higher the oil film pressure and the thinner the oil film, the greater the rigidity. Therefore, the multi-oil wedge bearing can meet the requirements of the spindle assembly. The bearing capacity of the oil film is related to the working conditions, such as speed, viscosity of the lubricating oil, and oil wedge structure. The higher the speed, the smaller the gap and the greater the load carrying capacity of the oil film. Dynamic pressure sliding bearings must produce a pressure film at a certain operating speed. Therefore, it is not suitable for spindles with low speed or high speed range and low speed. Therefore, it is generally not suitable for use in machining center spindle assemblies.

2.2 Hydrostatic bearing

The hydrostatic bearing consists of a special oil supply system, a throttle and a bearing. The hydrostatic bearing is supplied with a certain pressure oil from the oil supply system and is fed into the gap between the shaft and the bearing. The static pressure of the oil is used to support the load, and the journal always floats in the pressure oil. Therefore, the bearing oil film pressure is independent of the spindle speed, and the bearing capacity does not change with the rotational speed. Compared with dynamic pressure bearings, hydrostatic bearings have the following advantages: high bearing capacity, high rotation precision, oil film homogenization error, improved machining accuracy, good vibration resistance, stable operation, and can work at very low speeds. It can also work at very high speeds, with low friction and long bearing life. The main disadvantage of hydrostatic bearings is the need for a special oil supply equipment. The bearing manufacturing process is complex and costly.

2.3 Hydrostatic bearing

Hydrostatic bearings that use air as a medium are called hydrostatic bearings, also known as air bearing or air bearings, and operate in the same way as hydrostatic bearings. Because the viscosity of air is much smaller than that of liquid, the friction is small, the power loss is small, it can work at very high speed or very low temperature, the vibration and noise are very small, the rotation precision is high, the service life is long, and basically no maintenance is needed. High-speed, ultra-high-speed, high-precision CNC machine tool spindle assembly.

2.4 Magnetic bearing

Magnetic bearing is a new type of high performance bearing with special properties that cannot be compared with various conventional bearings. The magnetic bearing does not contact the surface of

the journal, there is no mechanical friction and wear, no lubrication and sealing, low temperature rise, small thermal deformation, high speed, long life and low energy consumption. The basic electromagnetic force feedback control system of the magnetic bearing guarantees the spindle. The rotation precision, stiffness and damping can be adjusted to eliminate the vibration caused by the rotor mass imbalance, which can realize self-balancing under high-speed rotation. The rotation characteristics can be obtained by sensors and control systems, which is convenient for condition monitoring and diagnosis. Magnetic bearings are mainly used in the spindle assembly of the machining center.