Design of a new type of deep hole boring device

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Abstract: When boring deep holes, as the workpiece hole becomes deeper and deeper, the size of the boring bar is large, the overhang is large, the vibration of the boring bar is large, and it is easy to deform, which makes the ordinary deep hole boring tool unable to meet the actual complex working conditions. In order to reduce the vibration and deformation of the boring bar and further improve the machining accuracy of the workpiece, a deep hole boring device with auxiliary support is designed. The adjustable support provided by the device can play a role of fixing and guiding during processing, thereby effectively reducing processing vibration and deformation and improving processing accuracy. And completed the trial production and processing experiment of the device prototype. The results show that the machining accuracy of the new cylindrical deep hole boring device is very high and meets the design requirements.

1. Introduction
At present, boring processing is one of the most widely used deep hole processing methods, and the workpieces obtained by boring processing have high precision and relatively low cost. Due to the long axial distance in the deep hole boring process, severe vibration, heat generation and deformation will significantly affect the dimensional accuracy and surface roughness of the processed workpiece.

In response to the above-mentioned problems, domestic and foreign researchers have conducted a lot of research and achieved some research results. Xianli Liu et al. designed a new type of boring bar with a variable stiffness dynamic damper (VSDVA), which can achieve the best damping performance by adjusting the stiffness of the VSDVA [1]. Qin Bai et al. designed a built-in dynamic vibration-damping boring bar to increase the dynamic stiffness of the boring device [2]. Liu Lijia and others designed a restrained damping damper that can adjust the stiffness of the boring device system, which provides a basis for the design of a new boring device [3]. Sentyakov Kirill et al. used a shock absorber to reduce the natural vibration amplitude of the boring mandrel under pulse action [4]. Ema S et al. tried to use an impact damper to improve the processing performance of the boring device and suppress vibration [5]. Although the above research can reduce vibration to a certain extent and improve boring machining accuracy, most of the structures are too complex to be widely used, so the machining accuracy in actual production still needs to be improved.

Based on this, this article designed a new type of deep hole boring device with support on the basis of the research of related researchers. The device uses increased support to fix and guide, reduce
boring vibration and deformation, and improve the processing accuracy of deep hole boring. And the experimental verification of the new type of deep hole boring device with support has been carried out. The experiment shows that the design of the new type of deep hole boring device is reasonable and has important reference value for the design of the new type of boring device in the future.

2. Design of new boring device

The structure diagram of the new type deep hole boring device is shown in Figure.1 and Figure.2. Its main feature is that a core rod with a tapered surface and two adjustable supports are installed inside the boring bar, and the tapered surface is used to control the radial movement of the adjustable support. At the same time, another core rod with a bevel is installed in front of the tool, and the horizontal movement of the bevel is controlled by the screw rod, thereby controlling the radial movement of the tool, which enables the tool to process workpieces with different aperture sizes. When the tool is retracted, it leaves the machined surface by rotating the screw to avoid scratching the machined surface and meet the quality requirements of workpiece roughness. Two adjustable supports are distributed in a straight line, sharing the radial and tangential cutting forces, and can reduce the bending and torsion deformation of the boring bar during the deep hole boring process. The spring can make the adjustable support always play a supporting role during the tool feed. Because one end of the adjustable support is in contact with the processed surface, it can be automatically guided to a certain extent, which is beneficial to improve the precision of deep hole boring.
3. Static analysis of boring bar system
When doing the static analysis of the boring bar system, the influence of factors such as speed and damping is generally not considered [6]. Use ANSYS Workbench to analyze and calculate the deformation of the boring bar system under the action of a fixed load. In order to reduce the amount of calculation, the model of the boring bar is appropriately simplified, and the core bar in the boring bar is removed, which has little influence on the analysis. The analysis model is established in ANSYS Workbench, the boring tool and the boring bar are set as a rigid connection, and the contact assembly is created by surface-to-surface contact [7].

After setting the properties of the raw material of the boring bar before the static analysis, customize the mesh, and the mesh unit size is 3mm. After the mesh is divided, the boring bar model of the new boring device is shown in Figure 3.

Select static analysis in Workbench to constrain the radial direction of the boring bar, but not the axial and rotation. Loads are applied to the ordinary boring bar and the boring bar of the new boring device. The main cutting force is 312N, the cutting resistance is 106N, and the feed force is 268N.

Using ANSYS Workbench for calculation, the deformation cloud diagram of the boring bar of the new boring device is obtained, as shown in Figure 4.

According to the deformation cloud map of the cylindrical deep hole boring device, it can be found that the new boring bar has excellent mechanical properties and can withstand large cutting forces.

4. Experimental verification
After the above simulation, the performance of the new type of deep hole boring device is qualified, and the following will be experimentally verified. According to the needs and actual conditions of the laboratory, processing experiments are carried out on the TS2150 deep hole drilling and boring machine. The workpiece is processed with the new supported deep hole boring device, the size of the processed workpiece is detected, and the performance is verified through actual use.

According to the technical requirements, two qualified workpieces are selected from the workpieces processed by the new boring device for inspection, the inner diameter of the workpiece is measured, and the surface roughness value of the inner hole is detected [8]. The measurement data of 2 points on the cross section 40mm, 120mm, 200mm, 280mm, 360mm, 440mm from the end face of the deep hole are as shown in the table.

| Table 1 The measurement data of the aperture at both ends of the workpiece processed by the new boring device (unit: mm) |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| 40mm            | 120mm           | 200mm           | 280mm           | 360mm           | 440mm           |
| 0°   | 90°   | 0°   | 90°   | 0°   | 90°   | 0°   | 90°   | 0°   | 90°   | 0°   | 90°   |
| Workpiece 1     | 60.03 | 60.02 | 60.01 | 60.03 | 60.02 | 60.02 | 60.01 | 60.01 | 60.04 | 60.02 | 60.01 | 60.01 |
| Workpiece 2     | 60.04 | 60.02 | 60.05 | 60.03 | 60.04 | 60.04 | 60.02 | 60.03 | 60.02 | 60.04 | 60.04 | 60.02 |

Calculate the residual error of each aperture measurement \( V_i = x_i - \bar{x} \); the standard deviation of the single measured value is:
\[
\sigma_1 = \sqrt{\frac{\sum_{i=1}^{N} V_i^2}{N - 1}} = \sqrt{\frac{0.0011}{11}} = 0.01 \text{mm} \quad (1)
\]
\[
\sigma_2 = \sqrt{\frac{\sum_{i=1}^{N} V_i^2}{N - 1}} = \sqrt{\frac{0.0012}{11}} \approx 0.01 \text{mm} \quad (2)
\]
\[3\sigma_1 = 3\sigma_2 = 0.03\]

It can be seen from Table 1 that the absolute value of the left end hole diameter and the right end hole diameter of the workpiece processed by the new cylindrical deep hole boring device does not exceed 0.03mm. The result proves that the machining accuracy of the cylindrical deep hole boring device with auxiliary support is very high. At the same time, the test results of the surface roughness detector show that the surface roughness value of the workpiece processed by the new supported boring device is less than Ra1.6. Both the aperture size and the surface roughness value meet the processing requirements, and the processing quality of the new boring device meets the design requirements.

5. Conclusion

Through the use of finite element analysis software to analyze the statics of the cylindrical deep hole boring device with auxiliary support, the dynamics analysis of the boring bar, and the performance comparison experiment of ordinary boring tool and new boring device, the following conclusions are drawn:

1. The cylindrical deep hole boring device system with auxiliary support produces little deformation under static load.

2. The trial production of the device prototype was completed, and the processing experiment was carried out. The results show that the machining performance of the cylindrical deep hole boring device with auxiliary support is excellent.

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