Dynamic characteristic analysis of micro-hole gun drill based on ANSYS

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Abstract. This paper takes different material properties of gun drill as the research object. ANSYS software is used in the dynamic characteristic analysis of gun drills of different materials. According to modal analysis theory and experiment, the natural frequency and vibration mode of the drill are obtained. The analysis results show that the cemented carbide gun drill after the cubic boron nitride treatment can better withstand bending vibration and torsion during the working process. It is found that the natural frequency of the treated cemented carbide gun drill is very different from that of other materials. The performance micro-hole gun drill provides a certain theoretical basis, and at the same time provides a reference for reducing the vibration and deformation of the gun drill.

1. Introduction
In the field of deep hole drilling processing, the traditional gun drill design is basically a static design, and the study of dynamic characteristics is rarely involved. As a result, even though the static strength of the gun drill meets the requirements, cracks and fractures will still occur during use.

At present, the main methods of dynamic characteristics research are modal analysis, which is generally used to analyze the vibration characteristics of the designed part, that is, the natural frequency and vibration mode of the part; in the initial stage of gun drill design, the modal analysis is performed by using workbench. In order to avoid resonance of the gun drill during work. The natural frequencies and vibration modes of gun drills of different materials are compared, which provides a sufficient theoretical basis for the design and improvement of gun drills.

2. Establishment and Import of Finite Element Model for Gun Drill
The gun drill consists of a drill bit, a drill rod, and a drill shank. In the process of finite element analysis, a fixed constraint is imposed on the drill shank. The completion of gun drill modeling in 3D ug software is shown in Figure 1. The iges format is imported into the workbench, and the different material properties of the gun drill are defined as structural steel, titanium alloy, aluminum alloy and cemented carbide. The mesh is divided, and the finite element model is shown in Figure 2.
2.1. Analysis of Dynamic Characteristics of Gun Drill
With the emergence of difficult-to-process materials, higher requirements are now placed on the overall performance of gun drills. The modal analysis of the gun drill is to use the workbench to extract the natural frequency of the gun drill to prevent the gun drill from being close to the excitation frequency and causing fatigue failure due to resonance. In order to ensure that the calculation results can truly reflect the modal characteristics of the gun drill, the entire gun drill is used as the research image. The gun drills with different material properties of structural steel, titanium alloy, aluminum alloy, and cemented carbide are compared, and the different characteristics of gun drills under different material properties are studied.

2.2. Modal analysis of gun drills with different material properties
Do modal analysis of the gun drill through the default unit of Workbench and divide the mesh. The setting of boundary conditions: the connection between the drill shank and the drill pipe adopts a fastened FIX SUPPORT connection. The modal solution is solved, and the vibration modes of gun drills with different materials are shown in Figure 3–Figure 6.

Figure 3. Aluminum alloy gun drill
Figure 4. Titanium alloy Gun Drill

Figure 5. Structural steel gun drill

Figure 6. Cemented carbide gun drill
The vibration mode clearly reflects the displacement value of each node of the gun drill in a certain mode, and the manifestation of structural vibration can also be seen, as shown in Table 1.

1. Comparing the results of gun drill modal analysis of different materials, cemented carbide natural frequency > structural steel natural frequency > aluminum alloy natural frequency > titanium alloy natural frequency. It shows that the dynamic rigidity of cemented carbide > the dynamic rigidity of structural steel > the dynamic rigidity of aluminum alloy > the dynamic rigidity of titanium alloy; the dynamic rigidity of cemented carbide gun drill is much better than that of titanium alloy gun drill, so the cemented carbide gun drill is compared with other materials Gun drills will not resonate even at higher speed spindles.

2. Traditional cemented carbide gun drills usually wear out at a faster rate and require repeated re-grinding or replacement. This reduces productivity and increases costs. The weak places of the cemented carbide gun drill are treated with polycrystalline cubic boron nitride, so that the gun drill not only has a higher cutting speed, but also has the ability to reduce the drilling force, drilling torque and tool wear.

3. Experimental modal analysis of gun drills with different materials

3.1. Experimental equipment

1. The machine tool used in the experiment is a DH-1300 CNC deep hole machine tool, as shown in Figure 7. The speed of the machine tool is 6000r/min, the processing depth is 1300mm, the processing aperture is 2mm-38mm, the table size is 1500×900mm, and the table load is 11 tons.

2. Gun drills of different materials are structural steel gun drills, titanium alloy gun drills, aluminum alloy gun drills, and cemented carbide gun drills.

3. Vibration test equipment

In the modal experiment, DASP coinv high-performance data test and analysis system, three-way piezoelectric acceleration sensor, electromagnetic clutch vibrator, signal transmission line, PC monitor and other experimental equipment are used. The piezoelectric acceleration sensor is installed on the base, and the base is glued to the drill rod of the gun drill with strong glue to ensure that the sensor can effectively transmit the vibration signal of the drill rod. The vibration signal of the drill pipe and the electromagnetic clutch vibrator are captured by the piezoelectric acceleration sensor and the force sensor respectively, and reach the data testing and analysis system through the signal transmission line.

3.2. Modal analysis experiment scheme

Figure 8 shows the schematic diagram of the gun drill modal test system. According to the modal simulation analysis results of gun drills of different materials and the actual processing conditions of gun drills, 4 three-directional piezoelectric acceleration sensors are arranged at equal intervals from the tail of the gun drill rod, numbered 1, 2, 3, 4. The drill bit is struck by an electromagnetic clutch vibrator to vibrate the drill rod. The electromagnetic clutch excitation signal and drill pipe vibration signal reach the data acquisition system through the data transmission line. The signal waveform can be observed in real time through the computer.
3.3. Comparative analysis of experimental mode and simulation mode

Table 1. Comparison of frequency between simulated mode and experimental mode

| Order  | Structural steel simulation modal frequency (HZ) | Structural steel experimental modal frequency (HZ) | Titanium alloy simulation modal frequency (HZ) | Titanium alloy experimental modal frequency (HZ) | Aluminum alloy simulation modal frequency (HZ) | Aluminum alloy experimental modal frequency (HZ) | Cemented carbide simulation modal frequency (HZ) | Cemented carbide experimental modal frequency (HZ) | Average absolute error (HZ) | Average relative error (%) |
|--------|-------------------------------------------------|-------------------------------------------------|----------------------------------------------|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|--------------------------|--------------------------|
| Level one | 143.96                                         | 143.882                                         | 127.25                                       | 127.172                                       | 141.26                                       | 141.182                                       | 4944                                    | 4943.922                                       | 0.078                    | 0.054                    |
| Second order | 616.68                                         | 616.364                                         | 543.56                                       | 543.244                                       | 603.5                                        | 603.184                                       | 21126                                   | 21125.68                                       | 0.316                    | 0.051                    |
| Third order | 889.31                                         | 893.18                                         | 785.04                                       | 788.91                                        | 871.54                                       | 875.41                                        | 30508                                   | 30511.87                                       | 3.87                     | 0.43                     |
| Fourth order | 1707.3                                         | 1716.3                                         | 1495.5                                       | 1504.5                                        | 1660.4                                       | 1669.4                                        | 58123                                   | 58132                                           | 9                        | 0.53                     |
| Fifth order | 2450.4                                         | 2442.06                                        | 2157.1                                       | 2148.76                                       | 2395.2                                       | 2386.64                                       | 83856                                   | 83847.44                                       | 8.56                     | 0.35                     |

4. Results

In Table 1, the average relative error of the gun drill simulation mode and the experimental mode of different materials is within 1%, which is extremely consistent. The reason why gun drill simulation modal analysis and experimental modal analysis have a certain error is due to the difference between the gun drill simulation model and the real situation of the gun drill. In summary, it can be determined that the gun drill simulation modalities of different materials are well correlated with the experimental modalities, which further shows that the experimental data can truly reflect the natural frequencies of the gun drills of different materials, and confirms that the treated carbide gun drills compared with gun drills of other materials, the performance of treated carbide gun drills is better.
5. Conclusions
(1) The dynamic characteristics of gun drills of different materials are analyzed through workbench, and the natural frequency and vibration mode of gun drills are obtained, which effectively simulates the vibration and deformation of gun drills in the working process, and provides a strong theoretical basis for the design of new gun drills.

(2) From the results of modal analysis and experimental verification, it can be seen that the force of the gun drill is mainly concentrated on the drill bit and the shaft of the drill rod. When designing, not only the force and deformation of the drill bit, but also the torsional deformation of the shaft must be considered. The rigidity of the cemented carbide gun drill treated with cubic boron nitride is obviously better than that of the traditional alloy gun drill.

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