Study on the Dynamic Characteristics of Tool

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Abstract

Tool vibration is an important factor affecting machining efficiency and surface quality. Considering turning tool as the research object, the variation trend of the natural frequency and mode of the tool is revealed by modal analysi. Combined with the experimental method, the tool vibration dynamic diagram was obtained by modeling percussion test.the results showed that the stability between the tool theory and the actual mode was compared, and the theory and test method can be used to provide reference for the structure parameters of cutting tools in metal machining. In the cutting process, the vibration frequency caused by the tool and the vibration source to determine the foundation, to suppress the bad phenomenon brought by the vibration.

Keywords

Modal analysis, tool vibration, sensor, vibation response.

1. Introduction

In metal machining processing, vibration will cause relative changes in the position of the workpiece and the tool.These vibrations are not suppressed, they will greatly affect the machining accuracy and efficiency of turning[1].Taking the tool as the research object, it is necessary to analyze the dynamic response of the tool. To Reduce unfavorable factors caused by resonance in the cutting process of the tool or close to the cutting frequency, and analyze and study the dynamic characteristics of the tool system, test and predict the results, and then improve the structure of the tool itself to achieve better processing. Hao et al. [2] established the tool model of the shield hob to compare finite element analysis and hammering modal test method. The results showed that by changing the parameters of the tool, the natural frequency of the tool and the anti-vibration performance of the tool are improved. Xu et al. [3] studied the problems of diamond tools in the machining process, and the dynamic mechanical properties through the modal test method. They found that modal test is an effective means to understand the dynamic characteristics of the structure in the machining state, and the data obtained provides data support for the diamond tool. Shen et al. [4] used ABAQUS finite element to analyze the milling cutter, and optimize the structure of the milling cutter through modal analysis. The results indicated that increasing the thickness of the milling cutter shaft hole and the diameter of the shaft hole improves the natural frequency of the milling cutter and can effectively suppress vibration. Ji et al. [5] researched stiffness and strength of the tool , and carried out modal analysis of the tool holder. The experiment verified that the design of the tool and the tool holder is reasonable, and provided a basis for the dynamics. Pham et al. [6] conducted experiments of high-speed face milling of A6061 aluminum alloy under dry cutting conditions, they thought that the increasing cutting speed reduced the tool-chip contact length,vibration and surface roughness. When the rise in cutting depth and feed rate,the tool-chip contact length, the workpiece vibration, and the surface roughness were all increased. Jauregui et al. [7] carried out the analysis of cutting force and vibration to monitor tool conditon, the results showed that tool wear brought about the variations in the dominant frequencies. The two process signals provide more reliable results and improve the sensing bandwidth.

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Arslan et al. [8]studied vibration and tool wear to explore the relationship between vibration and tool wear with tool vibration signals. They concluded that RMS value of tool vibration in cutting process can obtain the link for tool wear and surface roughness. Abainia et al. [9] conducted experiments to study the effect of tool geometry parameters on tool vibrations and cutting forces. It was concluded that positive values of the γp angle reduced cutting forces and tool vibration (ay).

Therefore, the dynamic characteristics of the cutting tool can effectively avoid the resonance phenomenon by optimizing the structure itself and suppressing the vibration of the vibration source during the cutting process, which is of great significance for obtaining better surface quality of the workpiece.

2. Modal theory

2.1. Modal Analysis Theory

During the machining process, when excited by the cutting force,the excitation frequency of the cutting process is close to or equal to that of the tool, the object will resonate.But resonance will aggravate the deterioration of the surface quality of the workpiece and generate noise [10]. Mode is the natural vibration characteristic of a mechanical structure, which refers to the dynamic response of the structure at various frequencies. The dynamic response of a system is the synthesis of its several modes. For a general multi-degree-of-freedom system, motion can be synthesized by its vibration mode. The modal analysis of finite element is the process of establishing the model modal for numerical analysis, and its differential equation of motion is shown in formula 1. For a free system without damping and vibration, both the damping term and the external force term are zero, so the above differential equation can be reduced to formula 2. By formula 3, the natural frequency and mode shape of the i-th order of the turning tool can be obtained.

$$[m]\ddot{x}(t)+[c]\dot{x}(t)+[k]x(t)=f(t) \tag{1}$$

$$[m]x(t)+[k]x(t)=0 \tag{2}$$

$$[k]-w^2[m]=0 \tag{3}$$

Where ‘m’ is the mass matrix; ‘c’ is the damping matrix; ‘k’ is stiffness matrix; ‘x(t)’ is the displacement response vector of each point of the system; ‘f (t)’ is the excitation force vector at each point of the system.

2.2. The Finite Element Analysis

The actual size of the tool in the turning process was used to build the 3D model of the tool in SolidWorks. The 3D tool model is shown in Figure 1. Importing the 3D model of turning tool into ANSYSWorkbench software for modeling and simulation. The physical parameters of the tool are as follows: Elastic modulus (E1) is 211Gpa; Poisson's ratio (u) is 0.28; density (p) is 7850 kg/mm3. In ANSYSWorkbench, setting material properties, mesh generation and constraints, and analysis options (modal analysis).Because the tool is constrained by the bolts on the tool holder in the actual machining process. During ANSYS simulation, it is fixed completely one end of the turning tool. The meshing model of the tool is shown in Figure 1 (b). Through the ANSYS modal analysis module, the natural frequency, mode shape of the tool and the third-order mode is obtainde. The third-order mode under modal analysis is obtained, as shown in Figure 2.

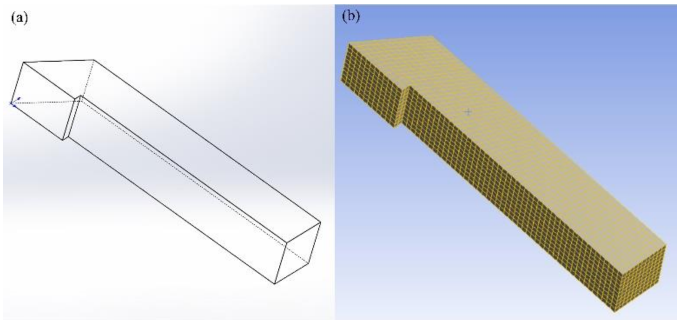

Figure 1. (a) Tool 3D model; (b) Meshing diagram

It can be seen from Figure 2 that in the first-order mode the turning tool mainly swings up and down on the tool plane, and the deformation of the tool head and the front end of the tool bar is the largest. In the second-order mode, the tool bar is the same as the first-order mode. In the third-order mode, In the third-order mode, the tool bar mainly swings in an S-shape in the plane. The main deformation occurs behind the cutter head.

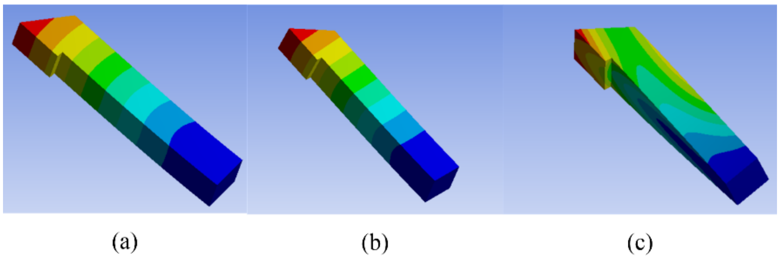

Figure 2. Step 3 Mode diagram

3. Test Analysis and Results

3.1. Equipment and Solutions

The instruments and equipment used in this modal test including DH5922N collector, charge amplifier, DHDAS (analysis software), impact hammer (LC-02A), force sensor (CL-YD-312A), DH131 piezoelectric sensor, etc. The experimental setup is shown in Figure 3. To study the natural frequency of the tool itself and the natural frequency of the clamping in the actual machining process, the excitation method of the tool structure is used for hammer excitation, which does not affect the dynamic characteristics of the tool. The tool is simplified into a slender rod, and its modal model is established.

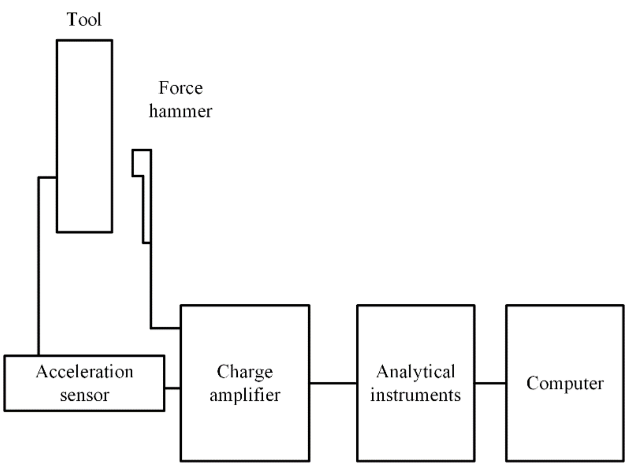

Figure 3. The experiment of vibration test

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Using a single-point pick-up method, the hammer sensor is connected to the first channel of the signal detection system, and the acceleration sensor is connected to the second channel of the signal detection system. The specific parameters of DHDAS vibration signal analysis software are set to sampling frequency of 5.12 KHz; sampling mode is transient; trigger mode is signal trigger; trigger level is 10%; delay points are -100; frequency resolution is 0.313; linear average is adopted Method, the average number of times is 3; the filtering method is manual confirmation. From the first measuring point, using a hammer hits the measuring points to save 3 test data at each measuring point position, and changes the measuring point and measure in turn. In the experiment, the force signal and the response signal of the time domain signal are transmitted to DH5922N at the same time, Then DHDAS vibration signal analysis software analyzes the collected data.

The tool is subjected to vibration test in the free state of the tool and in the clamping state, and the modal frequencies under the two working conditions are obtained. In the free state of the tool, the suspension method suspends the tool in the air. A total of 5 knocking points are arranged on the tool. the numbers are 1-5 from the end of the tool to the tip of the tool. Each measurement point only measures the response of the tool in one direction, and the layout of the test tapping point is shown in Figure 4. Through the feedback of the tool's actual tapping point to DHDAS software, it is found that the main deformation also occurs at the head. In the free state, the first natural frequency of tool reaches 6989HZ.

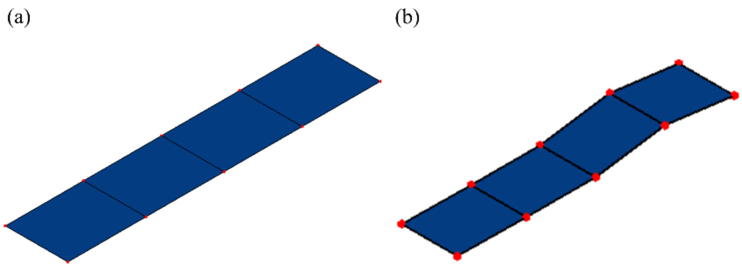

Figure 4. (a) Measuring point arrangement; (b) Tool deformation.

4. Conclusion

The vibration modes of the tool in 3 order modes was obtained by using finite element analysis, and the deformation area are analyzed. It was found that the main deformation of the cutting tool occurs in the cutting head through the comparison of theory and experimental simulation, the feasibility of the test is verified. The results provide a basis for controlling the adverse effects of tool vibration in the future machining process.

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