Modal Analysis of a Sensing CBN Grinding Wheel

Lai Hu, Jun Zha, Zhenggang Chen, M. Bilal, Yaolong Chen*
School of Mechanical Engineering, Xi'an Jiaotong University, 28 Xianning Road, Xi'an, Shaanxi 710049, P.R. China.
**Correspondence: chenzwei@mail.xjtu.edu.cn;*

Abstract

Grinding is one of the high-speed and high-precision processes. In the grinding process, the instantaneous temperature and cutting force of the grinding wheel are two important factors that affect the grinding accuracy. In order to further improve the grinding accuracy, this study mainly designs a sensing grinding wheel. The original grinding wheel structure has been reformed. The temperature and force sensors are embedded into CBN grinding wheel to form sensing grinding wheel. In this paper, considering the influence of the basal body structure, the influence of the grinding accuracy is also very large. Therefore, the vibration frequency analysis of the basal body is also carried out. From the analysis of experimental data, the vibration frequency of the sensing grinding wheel basal body takes the first four orders, and the values are 292.469 Hz, 350.161 Hz, 386.639 Hz and 423.641 Hz, respectively. The vibration frequency ratios are 2.93%, 1.84%, 1.82% and 1.41%, respectively. This value absolutely meets the processing requirements. The idea of sensing grinding wheel lays a good foundation for the follow-up research of adaptive grinding.

Key words: Sensing grinding wheel, Temperature sensor; Force sensor; Vibration frequency

1 Introduction

The research on high-efficiency grinding technology has always been one of the engineering problems that is difficult to break through. The methods to improve grinding accuracy are basically to consider grinding force and grinding temperature. However, there are many researches on grinding accuracy. For example, early Hashimoto F et al. [1] developed an ultra-precision diamond forming grinder for diamond grinding wheels and a new type of diamond forming grinder to provide grinding accuracy and surface quality. Another example is Zhang X C et al. [2] who studied the micro-vibration phenomenon in grinding, established the mathematical model of aspheric spherical radius deviation caused by micro-vibration, and developed a dynamic high-precision micro-vibration measuring device with an accuracy of 0.02 μm. Zhang M et al. [3] developed an adaptive grinding method for precision casting blades with geometric deviation to improve the processing accuracy, efficiency and automation level. At the same time, some authors [4-5] have also carried out other grinding research. The main purpose is also to improve the grinding accuracy. In this paper, the structure of grinding wheel is innovatively designed. The temperature and force sensors are embedded in the grinding wheel basal body, and the grinding temperature and grinding force are collected. So as to analyze the relationship between temperature and force. This method is also to improve grinding accuracy and efficiency. This paper also analyzes the modal of this sensing grinding wheel basal body. The reliability and practicability of this design are verified again.

2 Structural development of sensing grinding wheel.

Based on the current situation of grinding wheels, this paper develops a sensing grinding wheel. In the grinding process, it is necessary to collect the grinding force and temperature and analyze the relationship between them. Therefore, it is necessary to use wireless transmission to collect force and temperature. The force sensor wireless transmission module is shown in figure 1. The sensing grinding wheel is shown in figure 2.

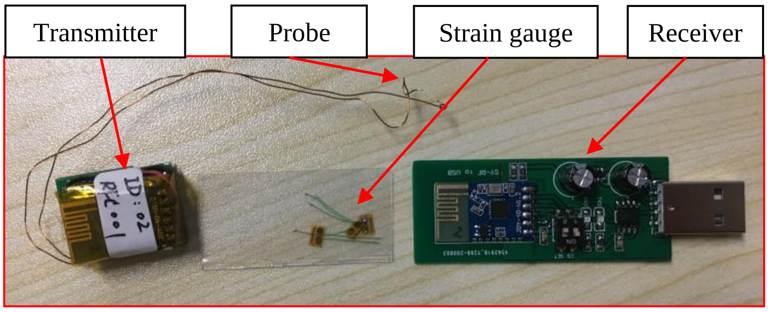

Figure 1: Force sensor wireless transmission module.

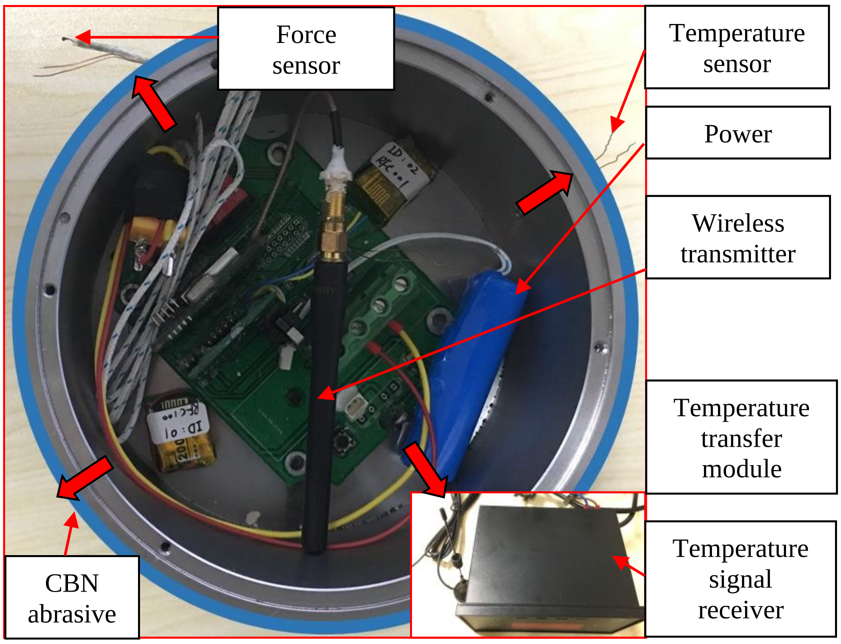

Figure 2: Sensing grinding wheel.

According to figure 1, the force sensor mainly uses strain gauges to measure grinding force. When the shape of the strain gauge changes, it is transmitted to the receiving end through the wireless transmitting end and processed by the signal.

The same transmission mode is used for temperature collection and analysis. As shown in figure 2, that CBN abrasive is adhere to the periphery of the maximum size of the grinding wheel substrate, with a thickness of about 5 mm and a width of about 25 mm. Simultaneously, four groups of holes are respectively opened in the basal body, which are distributed at 90°. The probes of the force sensor and temperature sensor across the holes for data collection. The force signal and temperature signal are actually received by an external wireless receiver. Finally, the two collected signals are processed to obtain the correlation between grinding force and temperature.

3 Vibration mode analysis of sensing grinding wheel basal body.

Before the sensing grinding wheel is used, the basal body needs to be analyzed. Because the structure of the basal body will have a great influence on the grinding accuracy. In the analysis of the basal body, this paper mainly analyzes its vibration frequency. The purpose is to analyze the relationship between the vibration frequency and the working frequency when the grinding wheel rotates.

So as to verify whether the design of the basal body structure is reasonable. First, let the basal body be in a free state and analyze its vibration frequency, as shown in figure 3.

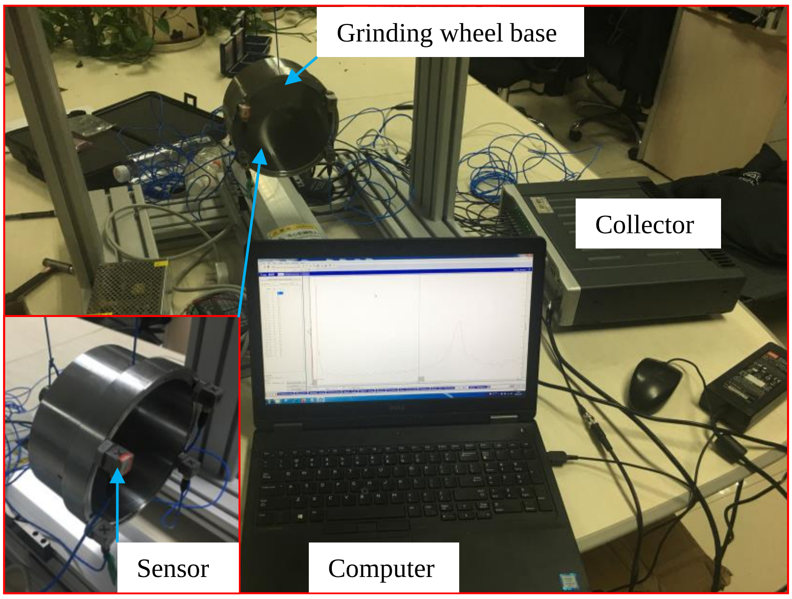

Figure 3: Vibration frequency analysis of sensing grinding wheel basal body.

As shown in figure 3, four sensors are simultaneously distributed on the basal body and tested in two groups. Take X + direction as the knocking point and carry out force hammer knocking. Thus, 8 sets of data and summed data are obtained, as shown in figures 4 and 5, respectively.

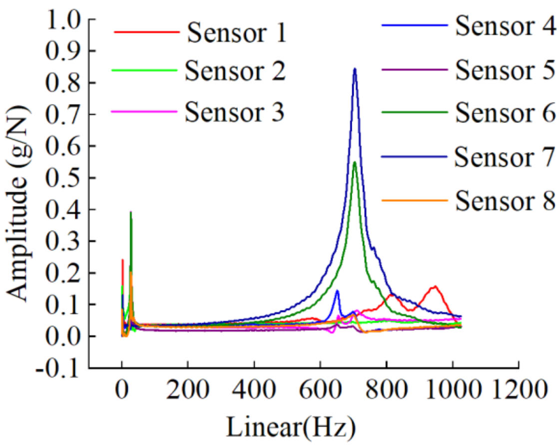

Figure 4: 8 sets of test data.

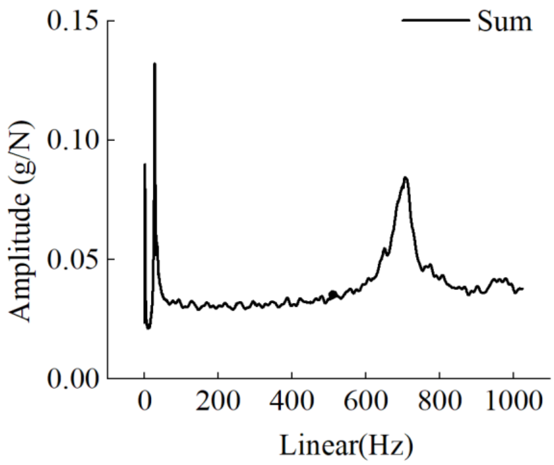

Figure 5: Summing data.

As shown in figures 4 and 5, a vibration frequency is desirable between that amplitude of 0-0.05 g/N. Therefore, the first four modal values are extracted: 292.469 Hz, 350.161 Hz, 386.639 Hz and 423.641 Hz. The vibration frequency ratios are also calculated, which are 2.93%, 1.84%, 1.82% and 1.41%, respectively. In the actual vibration frequency analysis, the first order is mainly analysed. From the equation n=60f, it is concluded that when f vibration frequency is 292.469 Hz, the grinding wheel rotation speed is about 17548 r/min. It can be inferred that the natural frequency of the grinding wheel will be greater than the working frequency only when the test speed of the sensing grinding wheel should be less than 17548 r/min. So that resonance does not occur. Because this study mainly tests the instantaneous temperature and force during grinding and analyzes the relationship between them. Therefore, it is not necessary to reach a very high speed. This shows that the design of sensing grinding wheel is reasonable and feasible.

4 Conclusion

This paper mainly makes innovations to the traditional grinding wheel. In order to further obtain the relationship between the instantaneous temperature and force, a sensing grinding wheel was developed. Temperature and force sensors are integrated inside the grinding wheel basal body. The vibration frequency of grinding wheel basal body is emphatically analyzed, and the first four modes are proposed for analysis. Taking the first order vibration frequency as a reference, reverse analysis shows that the test speed of sensing grinding wheel should be less than 17548 r/min. At the same time, the next step is to use this sensing grinding wheel to carry out mass grinding tests. On the contrary, the test data can be used to verify and optimize the sensing grinding wheel.

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