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Integration of Scientific Research and Teaching in Course of Fundamentals of Mechanical Measurement Technology

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Abstract: Fundamentals of Mechanical Engineering Testing Technology is a basic theoretical course for mechanical majors, mainly designing the basic theories and methods of mechanical engineering testing technology. In the field of engineering technology, product development, manufacturing, quality control and performance experiments are inseparable from testing technology. In order to deepen the students' understanding of the theoretical knowledge of testing technology, this paper puts forward the application of the basic theory of testing based on the cutting force sensor. The content includes the working principle of cutting force sensor, signal processing and installation.

1. Introduction

Mechanical measurement technology is to extract useful information from objective things so as to realize the purpose of understanding things and mastering the law of development of things. The measurement technology refers to the measurement theory, measurement method and measurement equipment involved in the process of testing, which are widely used in industrial and agricultural production, scientific research, national defense construction, transportation, medical and health care, environmental protection and people's life, and are playing an increasingly important role in them. It has become an essential basic technology for national economic development and social progress. Therefore, this paper proposes how to promote absorption of theoretical knowledge through scientific research projects in course of “Fundamentals of Mechanical Measurement Technology”.

2. Explaining the basic components of the measurement system using cutting force sensor

2.1 Test system composition

The test system refers to the whole system composed of related devices, instruments and test devices, which has the function of obtaining certain information. Fig. 1 shows the composition diagram of the test system [1].

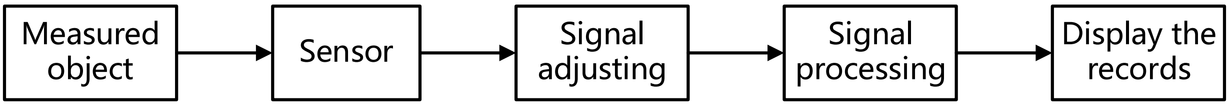


Figure 1 Test system composition

The information of a measured object is always expressed by a certain physical quantity, namely signal. The sensor is the device that converts the measured information into some electrical signal. The signal conditioning step is to convert the signal from the sensor into a form more suitable for further transmission and processing [2]. Most of this signal conversion is the conversion between electrical signals, such as amplitude amplification, impedance changes into voltage changes or frequency changes, etc. Signal processing is the signal from the signal conditioning link to carry out a variety of calculation, filtering and analysis [3]. Signal display and recording link is to display or store test results in a form easy for observers to observe signals from signal processing link, such as local instrument display record, and remote display record through the network.

2.2 Cutting force sensor

Force sensor is a device or device that can sense force signals and convert force signals into usable output electrical signals according to certain rules. According to the different structure and principle, it can be divided into: strain type, piezoresistive type, capacitance type, piezoelectric type and so on. Piezoelectric force sensor is a piezoelectric element as the conversion element, the output charge is proportional to the force, the force changes into electricity measurement device, such as some cutting force sensor.

The principle of piezoelectric force sensor is mainly based on the piezoelectric effect. If pressure is applied to the piezoelectric material, it will produce potential difference, which is the positive piezoelectric effect [4]. Conversely, the voltage is applied, which produces mechanical stress with the negative voltage electric effect. If the pressure is a high-frequency vibration, it produces a high-frequency current. When a high-frequency electrical signal is applied to the piezoelectric material, it produces a high-frequency acoustic signal (mechanical vibration).

At present, metal cutting remains the most important process, providing the basis for all technological products and the basis for the manufacture of various technical products. In order to ensure certain product quality, while taking into account the cost effectiveness of finished products, the industry to the cutting technology requirements is increasing. In the cutting process, the tool is subjected to high mechanical, thermal and chemical pressure, which affects the cutting process and tool life. Only by ensuring accurate measurement in the tool development process can we achieve process reliability and avoid defective products. Therefore, it is very important to apply cutting force measurement to advanced programming of NC machine tools and construct intelligent machining strategy. Cutting force signals can also be connected to machine tools in a variety of ways to improve cutting processes, improve traceability and ensure sustainable machining operations.

2.3 Principle of cutting force test system

Cutting force measurement is one of the important parts of mechanical measurement. So the cutting force measurement system is a necessary basic instrument to study the cutting process. The measurement system is generally composed of dynamometer, signal amplifier, data acquisition system and laptop computer, etc. Taking the cutting force sensor of Kistler Company as an example, the specific composition of the measurement system can be referred to Figure 2.

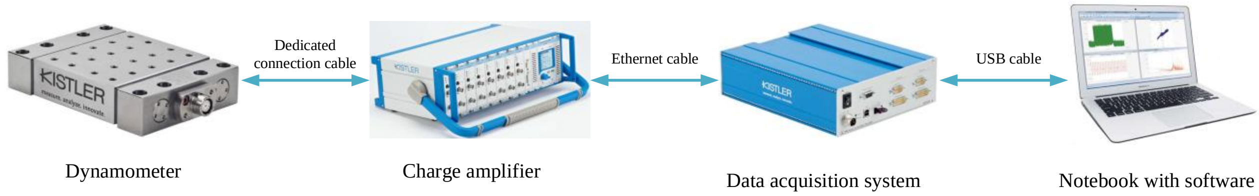


Figure 2 Composition of cutting force measurement system

The dynamometer is usually mounted between the machine table and the workpiece, which is fixed to the dynamometer and can measure the reaction force during milling, drilling, etc. Different dynamometers have different structures. Some use one or more multicomponent force sensors to measure the force produced. The dynamometer outputs a signal as an electric charge through a plug.

The dynamometer used is in the three-component form, which has the significant advantage of being used as either a three-component dynamometer or a six-component dynamometer. There are four three-component force sensors inside the dynamometer. The function can be switched according to the situation. The structure of the dynamometer can be referred to Fig. 3. F_x, F_y and F_z are directly measured, while the moments M_x, M_y and M_z are calculated with the help of the component forces and sensor spacing. The dynamometer can be mounted on the milling table and lathe turret with suitable adapters. The dynamometer is composed of multiple force sensors, which are installed between the two bottom plates and the top plate through high preload, and the friction force can be transferred after preloading. There are various mounting holes and threaded holes on the cover plate, which can realize a variety of clamping installation methods.

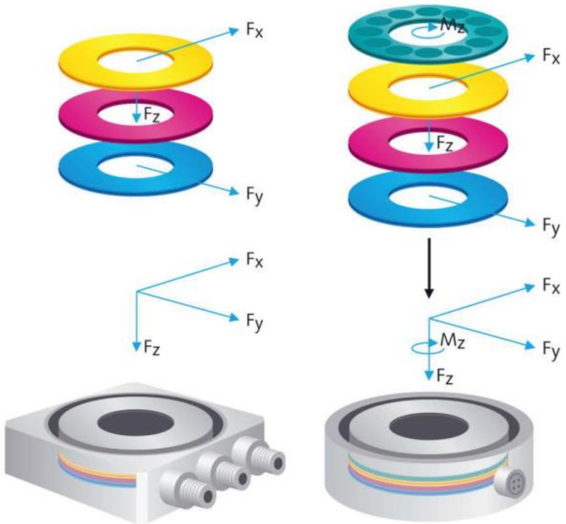


Figure 3 The structure of the dynamometer

For dynamometer collected information, the data acquisition system and charge amplifier will be charge signal into voltage, and analog signal to digital signal conversion, the end user can view the cutting force related data signal on the software, save the data, complete the cutting force measurement.

3. Example of milling

Milling process refers to the use of rotary multi-edge cutter on the machine tools. When milling, each tooth in turn and cut out the workpiece, the formation of intermittent cutting, and the cutting thickness of each tool tooth is changed. So that the cutting force changes, the workpiece and the tool teeth are subjected to periodic impact and vibration. Due to milling is in vibration and unstable state, it is necessary to measure cutting force in milling process. Fig. 4 shows the cutting force measurement diagram. Fig. 5 shows the installation and fixing of each part in the actual measurement process. The dynamometer is fixed with the bottom plate through bolted connection. The whole machine is installed on the workbench through the fixture, and the workpiece is also placed on the measuring platform. In order to reduce the mass on the dynamometer and thus minimize the negative impact on its dynamic performance, the workpiece can be bolted directly to the dynamometer.

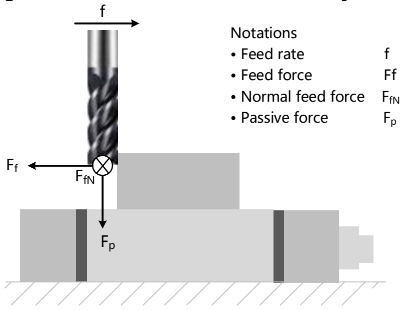


Figure 4 Simple structure of cutting force sensor

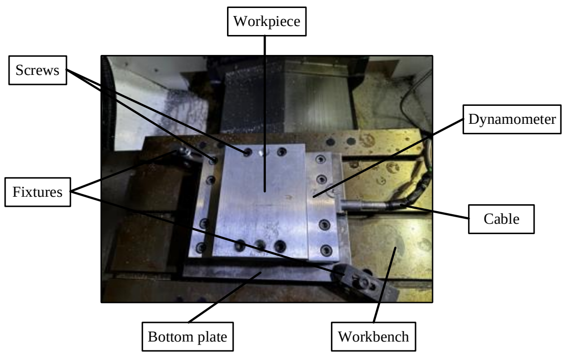
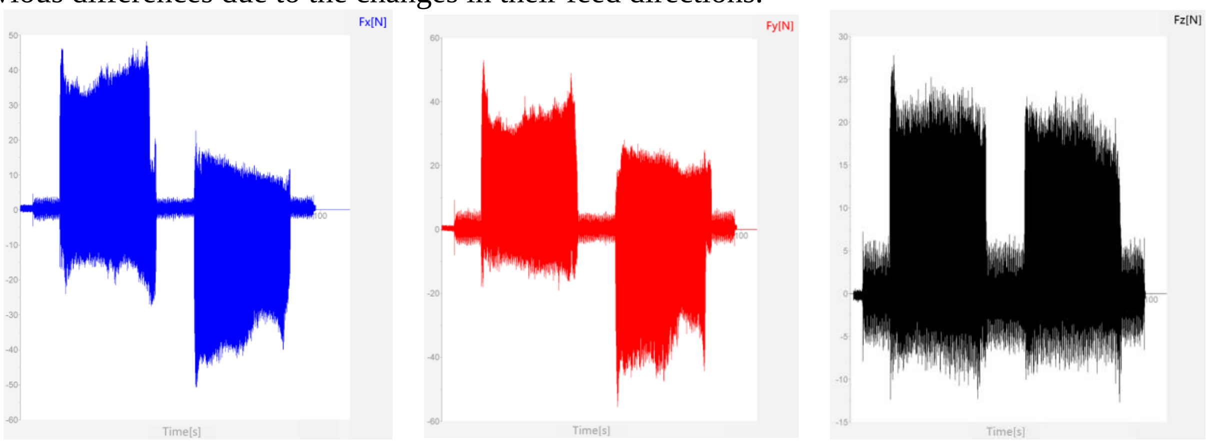


Figure 5 Installation of dynamometer in machining

In view of the above measurement system, data collection of cutting force signals of up-milling and up-milling is carried out on the workpiece surface. As shown in Figure 6, the two sections clearly separated in the data signal are the up-milling and up-milling processes. Great changes have taken place in the value of signals collected in the cutting process. It can be obtained that the cutting force signals in the F_z direction have little difference, while the signals in the F_x and F_y directions have obvious differences due to the changes in their feed directions.



(a) F_x direction (b) F_y direction (c) F_z direction

Figure 6 Cutting force signal during milling

To sum up, the force signal can be collected by the cutting force sensor. The accurate cutting force value can be obtained by processing the signal, which can be used for the research of cutting technology and tool wear.

4. Conclusion

In this paper, the cutting force sensor is taken as an example to analyze the composition of testing system and engineering application method, deepen the understanding of testing technology and practical application.

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References

[1] Wen B., Shimizu Y., Matsukuma H., Tohyama K., Gao W. (2020). A differential strategy for measurement of a static force in a single point diamond cutting by a force-controlled fast tool servo. Measurement Science and Technology, 31(7).

[2] Marziani C. D., Urena J., Hernandez Garcia J. J., Alvarez F. J., Jimenez A., et al. (2012). Simultaneous round-trip time-of-flight measurements with encoded acoustic signals. IEEE Sensors Journal, 12(10), 2931-2940.

[3] Niessner S., Liewald M. (2020). Identification of methods for the in-situ measurement of cutting forces in a tool-bound punching machine. IOP Conference Series Materials Science and Engineering, 967, 012025.

[4] Patil R. A., Gombi S. L. (2020). Operational cutting force identification in end milling using inverse technique to predict the fatigue tool life. Iranian Journal of Science and Technology: Transactions of Mechanical Engineering, 46: 31–41.