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Application of infrared thermal imaging technology in measuring the temperature of metal cutting process

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Abstract

In this paper,I discuss the importance of infrared thermal imaging temperature measurement technology in measuring the cutting temperature,which for the study of the essence of metal cutting process and the advantages and disadvantages in infrared thermal imaging technology, as well as the improvement of emissivity, ambient temperature and other related variables. The setting of the infrared thermal imager should be more convincing in the measuring the temperature which in metal processing.

Keywords

Infrared thermal imaging, metal cutting, emissivity. ambient temperature.

1. Introduction

In the mechanical manufacturing industry, more than 90% of the machining of mechanical parts is made by cutting [1]. During the cutting process, the machine tool is converted into an equal amount of cutting heat, and the cutting heat is dissipated into the surrounding medium except for a small amount. 80% of the incoming chips [2], leaving the incoming tool and workpiece, the temperature rise of the tool will accelerate the wear of the tool, affecting the processing efficiency, so the appearance of infrared thermal imaging technology for the contact measurement of cutting temperature with thermocouple Further research on the nature of processing has important implications.

Cutting temperature is a very important physical quantity in the cutting process. Since the infrared camera can measure the surface temperature distribution of the target body non-contact and has the advantages of fast response speed and high measurement accuracy, it is widely used in many industrial fields. In recent years, it has also been introduced into the field of cutting machining research for cutting temperature detection. However, there are few applications in this area. One of the main reasons is that the workpieces and tool materials are many types and surface conditions are different. They are all unknown surfaces. The non-black body of the emissivity is not even gray, and the surface state may change greatly during the cutting process (for example, the steel is strongly oxidized at high cutting temperatures), thus causing the surface emissivity to be multiplied or changed by a factor of ten. This makes it possible to obtain the true surface of the tool and the workpiece during the cutting process from the infrared thermal image.

Infrared temperature measurement technology uses the energy value radiated from the surface area of the object and the surface emissivity of the measured object and the Stephen Boltzmann constant to calculate the surface temperature change of the object, ie

$$E=\varepsilon\sigma T^4 \qquad (1)$$

which in formula E---radiation energy per unit area of object radiating element (W/m^2)

ε --the surface emissivity of the object radiating element

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σ --Stephen-Boltzmann constant (σ=5.76 × 10-8W/m^2 ·K^4)

T --surface temperature of the object radiating element (K)

When cutting, the infrared camera detects the radiant energy of the surface radiating element of the workpiece (or tool) through the scanning mechanism of the optical machine, and converts the radiant energy of each radiating element into an electronic video signal, and processes the signal to obtain a visible image. The form is displayed, and the displayed thermal image represents the two-dimensional radiant energy field of the surface to be measured. If the surface emissivity of the radiating element is known, the temperature distribution field of the surface of the radiating element can be obtained by Stephen Boltzmann's law and Dynamic change [3]. Although the temperature measured by the infrared camera is relative temperature and lags behind the actual cutting temperature, the heat transfer reverse algorithm can accurately determine the temperature variation and dynamic distribution of the workpiece (or tool) during the cutting process. The infrared camera temperature measurement method is intuitive, simple, and can be used for long-distance non-contact monitoring. It has great advantages in measuring the surface temperature of objects in harsh environments.

2. Influence of two objective factors on temperature data during cutting process

2.1 Effect of surface emissivity of processed metal on measurement

The surface emissivity of materials is affected by many factors such as surface structure, color, shape and temperature and environmental conditions. The study of cutting temperature by infrared thermography has rarely been reported so far, and some literatures on infrared temperature measurement are not available. Referring to the tool, the surface emissivity of the workpiece material, such as DEWES et al [4], DINC et al [5] and Zhang et al [6] published cutting temperature research papers. Very few documents, such as KWON et al [3] on measurement Paper-to-chip interface temperature paper, Liu et al [7-8] paper on measuring tool temperature, although it involves the problem of surface emissivity of the tool or chip, but only given a certain condition (fixed temperature, surface shape) , the observation angle) of the surface emissivity, but the calibration method of its emissivity value is not introduced,as shown in figure 1 and table 1.

Carbon steel and die steel are the most common materials in cutting, but the surface emissivity of the two varies significantly with increasing temperature. Figure 1 shows the results of surface emissivity of 45 steel and 4Cr5MoSiV1 die steel at different temperatures. It can be seen from Fig. 1 that the mold steel 4Cr5MoSiV1 can maintain good oxidation resistance below 700 ℃, the surface structure and color have been relatively stable, so the surface emissivity is only slowly increased slightly; after 700 ℃, the mold steel material The oxidation resistance decreases rapidly, and the higher the temperature, the more severe the oxidation, so the surface emissivity increases rapidly or even several times. The surface emissivity of 45 steel at 450 ℃ or above, especially between 450 and 700 ℃, changes drastically, indicating a significant change in its surface structure. There is always an oxide film on the surface of the steel. The oxide film undergoes a phase transition at around 570 ℃. The two-layer structure of Fe_3O_4 and Fe_2O_3 is transformed into a three-layer structure of FeO, Fe_3O_4, and Fe_2O_3. FeO is a loose oxide film that gradually heats up. The rupture may occur, so the emissivity of the sample fluctuates in this temperature range, and then gradually increases due to the thickening of the oxide layer.

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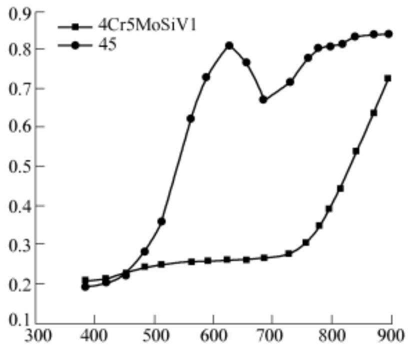

Figure 1 The change of emissivity of two samples at different temperatures

Table 1 45 steel and H13 composition table

	C	Si	Mn	Cr
45 # steel	0.42~0.50%	0.17~0.37%	0.50~0.80%	Cr:≤0.25%
H13 steel	0.32~0.45%	0.80~1.20%	0.20~0.50%	4.75~5.50

As can be seen in Figure 1, if the 45 °steel is used to measure the temperature of the cutting zone, the unstable rate of change will produce unreliable data; if 4Cr5MoSiV1 is used as the processing material, a reliable temperature will be obtained within 700 ℃.

2.2 The choice of workpiece processing method and the selection of the shooting angle of infrared thermal imager on temperature measurement

There have been many methods in the measurement of the temperature of the cutting zone. The existing methods for measuring the cutting temperature are mainly divided into two types: contact type and non-contact type.

Contact measurement is primarily the direct measurement of temperature using a thermocouple. For example, Lu et al. [9] used a wire-semi-artificial thermocouple to measure the milling temperature of the 508III steel workpiece away from the cutting side; Yuan et al [10] used a semi-manual thermocouple method to weld the constantan wire to the end face of the test piece. Thus measuring the temperature of the cutting area; Ma et al [11] designed a tool for embedded thin film thermocouple to measure the cutting temperature of the tool; congruent [7] developed a tool-based natural thermocouple in standing The mercury collecting current measuring system directly measures the temperature of the knife-work interface on the milling machine, and measures the temperature by measuring the tool potential signal. After congruent [8], the tool is slotted, and then the thermocouple is used to insert the thermocouple into the tool. However, during the measurement, the rubbing of the chip will cause the galvanic impact to leave the tool, and complete and accurate data cannot be obtained. Through these contact temperature measurements, the researchers can obtain the temperature of the workpiece or tool, but cannot measure the temperature of the chip. The chip temperature is not further explored.

Non-contact measurement is mainly based on the principle of infrared radiation temperature measurement. For example, Shi et al. [9] used infrared radiation pyrometer to obtain the distribution law of titanium alloy TC4 milling surface temperature field; Zhang et al [12] used infrared radiation temperature measurement technology to measure the temperature of milling aluminum alloy. This method of using infrared temperature measurement technology, because the experimenter did not consider the emissivity of the workpiece caused by the relative temperature change during the milling process, and also the temperature measurement of the workpiece surface, the measurement of the chip temperature remains to be determined Carry out.

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When the tool is in the process, the tool tip is always buried in the workpiece. The infrared thermal imager can't get the data. Therefore, the side milling method should be adopted, and the angle of the camera shooting is preferably obliquely above. This is beneficial to get the closest to the actual. Temperature data， as shown in Figure 2, 3

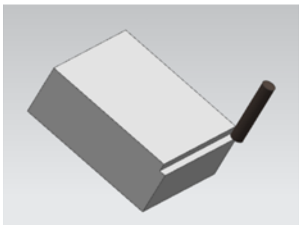

Figure3 Side milling processing

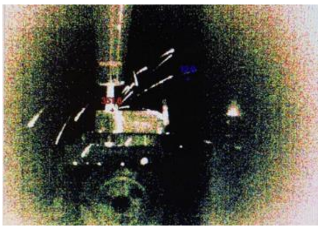

Figure3Typical infrared thermal imager temperature measurement scene

3. Conclusion

(1) The infrared thermal imager does not need to be in direct contact with the workpiece or directly contact with the tool, and can obtain real-time temperature data through high-speed shooting.

(2) It is necessary to know the emissivity of the machined workpiece or the emissivity of the tool surface using an infrared thermal imager, which is advantageous for measurement.

(3) The side milling method can be used to further measure the temperature change of the tool tip attachment during machining.

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