Study of the Test Methods of Emission Rates in Different Ambient Temperature Fields

Xia Zhao\textsuperscript{1}, Xin Jia\textsuperscript{2*}, Lining Pei\textsuperscript{1}, Qufei Shi\textsuperscript{1} and Jian Wu\textsuperscript{1}

\textsuperscript{1} Temperature and Humidity Laboratory, Beijing Institute of Metrology, Beijing 100029, China
\textsuperscript{2} Frontier Science Metrology Centre Department, National Institute of Metrology, Beijing 100029, China
Email: *995531040@qq.com.

Abstract. With the wide application and rapid development of infrared temperature measurement, which has attracted widespread interest in the field of non-contact temperature measurement due to its unique advantages. Measurement of the real temperature of the measured object is an important task in many disciplines, especially critical and difficult for the non-contact measurement. However, the accuracy of the infrared thermography technique is difficult to reach a satisfactory level, and cannot meet the requirements of high accuracy, due to the emissivity cannot be determined in outdoor environments. It is very meaningful to determine the emissivity and accurate temperature of the object in outdoor heterogeneous environments. The influence of external environmental factors on the object surface emissivity are analyzed in this study, which is very important to improve the measurement accuracy of the infrared thermal imaging instrument. This study reveals that the increased temperature will lead in the increase of the emissivity of nonmetallic materials first and then decreases slowly. In addition, as the ambient temperature higher, the emission rate of non-metallic object becomes smaller.

Keywords. Ambient temperature; emissivity; infrared temperature measurement.

1. Introduction

With the wide application and rapid development of infrared temperature measurement, which has attracted widespread interest in the field of non-contact temperature measurement because it has a lot of incomparable advantages, such as no damage to the temperature field, visualization of the measurements, no environmental harm and low consumption [1-3]. The true temperature of the measured object tested is an important task in many disciplines, especially critical and difficult for the non-contact measurement. However, infrared temperature measurement accuracy of the measured object is difficult to reach a satisfactory level, and cannot meet high accuracy use requirements, due to the emissivity cannot be determined in outdoor environments [4-5], which lead to the limitations on the application of infrared thermal imaging technology [6-7]. Meanwhile, the emissivity of the measured object has a very close relationship with the true temperature of the measured object. Emissivity refers to the ratio of the electromagnetic energy emitted by an object outward to the electromagnetic energy emitted by a blackbody with the emissivity of 1 under the same conditions. This is the parameter to evaluate the radiation energy of an object, and its value varies between 0 and 1. Because the emissivity depends largely on the surface properties of the object, the emissivity of objects is unreliable due to unstable environmental factors in the outdoor practical measurement. At
present, the direct measurement method is mainly used to measure the emissivity of the target and needs to be carried out without atmosphere, environmental factors and under conditions of constant temperature of the object itself, which is only suitable for laboratory measurement, but the emissivity measurement of target in the outdoor field is meaningless. Nevertheless, infrared temperature measurement technology is an irreplaceable role in all walks of life [8-10]. It is very meaningful to determinate the emissivity and accurate temperature of the object in outdoor heterogeneous environments.

Therefore, it is very important to research the influence of changes in the external environment on the emission coefficients of object, which is very important to improve the measurement accuracy of the infrared thermal imaging instrument.

2. Methods

2.1. Theoretical Method

In practical infrared thermographic techniques, infrared radiation is roughly divided into three parts: the target radiation, environmental reflection and atmospheric transmission, and infrared expression can be written in the following form:

\[ T_R = \tau_a \varepsilon T_0 + (1-a)I(T_U) + \varepsilon_a T_a \]  

(1)

\( T_R, T_0, T_U, \) and \( T_a \) are all of the radiation temperature, radiation temperature of the measured object, environmental radiation temperature and atmospheric transmission rate temperature. \( \varepsilon \) is target emissivity. \( a \) is target absorption rate, however in short distance measurements, \( a \) is target emission rate, \( \tau_a \) is atmospheric absorption rate, \( \varepsilon_a \) is the target absorption rate of the surrounding objects. In the short-distance measurements, \( a=\varepsilon \), equation (1) can be simplified as follows:

\[ I(T_R) = \varepsilon [I(T_0) - I(T_U)] + I(T_U) \]  

(2)

According to equation (2), it can be obtained as follows:

\[ \varepsilon = \frac{I(T_R) - I(T_U)}{I(T_0) - I(T_U)} \]  

(3)

Based on equation (3), the relationship of the emissivity and the environmental factors can be obtained.

2.2. Experimental Method

In this study, four samples of graphite, steel, copper, silicon are selected as the test objects, shown in figure 1. The four samples are polished smooth by sandpaper.

(a) Flume heater.  
(b) Temperature and humidity box.  
(c) Four samples of graphite, steel, copper, silicon.

Figure 1. Sample, flume heater and temperature and humidity box used in the experiment.
3. Results

3.1. Emissivity Results at the Different Heating Temperature

Figure 2 shows the change trend of emissivity of graphite, silicon, steel and copper at different temperatures. Shown in figure 2a, with the increase of temperature from 40°C to 90°C, sample curve shows a large increase in graphite emissivity, but more than 100°C, graphite emissivity shows a slow downward trend, this is because the emissivity of non-metal appears a slow downward trend with the increase of temperature to some extent. Similarly, in figure 2b, a rapid increase in the emissivity of silicon appears in the range of 40°C-100°C, however, as the temperature continues to increase, the emissivity of silicon decreases rapidly. Compared with graphite, the emissivity of silicon decreases seriously with increasing temperature.

Shown in figure 2c, both methods show that as the temperature increases from 40°C to 100°C, the emissivity of steel increases rapidly, when the temperature is greater than 100°C, the emissivity of the steel no longer increases as the temperature continues to increase. Shown in figure 2d, the same change rule can be seen on the emissivity of copper, the two methods also show that the emissivity of copper increases continuously with the increase of temperature. However, when the temperature over 100°C, the copper trend does not continue to increase, which may be due to the possibility of partial oxidation on the surface. Both copper and iron conform to the rule that the emissivity of metals increases with the increase of temperature.

![Graph of emissivity results](image)

(a) (b) (c) (d)

Figure 2. Emissivity of four samples at different temperatures.
3.2. Emissivity Results in Non-uniform Temperature Field

In order to analyze the effect of different ambient temperature on the emissivity obtained by using the new method, so after the sample is heated at different temperature, then placed in an adjustable temperature box and adjust temperature from 25°C to 60°C, then measure these temperatures of four samples. When the four samples are heated to 100°C (The temperature is very different from the ambient temperature), the experimental results are tested to check the variation of emissivity with time under different ambient temperature fields.

![Graphs showing emissivity results](image_url1)

**Figure 3.** The change of emissivity at inhomogeneous temperature field.

Shown in figure 3, a continuous increase in the ambient temperature can cause the silicon emission rate to decrease slowly. Figure 3b indicates that the emissivity of silicon decreases rapidly with the increase of ambient temperature. Shown in figures 3c-3d, the increase of ambient temperature will lead to the emissivity of steel and copper higher.

4. Conclusion

The real emissivity non-metallic and metallic materials of four samples are determined in this study. The interrelationship between the emissivity of measured temperature and the measured temperature is analyzed in experiments. As the measuring temperature increase, the emissivity of non-metallic measured object increases first and then decreases slowly. In addition, the increased of ambient temperature cause a smaller in the emission rate of non-metallic materials. And the greater the
emission rate, the measurement accuracy will decrease smaller. But for metal materials, the increase of environmental temperature will lead to the emission rate of metal materials small, the smaller the emission rate rise rate, the greater the measurement accuracy.

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