

Application of Infrared Thermography in Building Energy Efficiency

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Abstract: Based on experience, the paper introduces the key issues during the use of infrared thermography in building energy efficiency. In order to get a more useful thermal infrared spectrum, we must correct the operating apparatus and measure more environmental parameters. This includes selecting the temperature range, setting emissivity values, setting the number of averaged frames, selecting auto or manual focus adjustment and temperature tracking, recording thermographic image and measuring position of equipment, visible light photo, temperature of appointment, outdoor temperature, outdoor air speed, and the angle of gradient.

Key words: infrared thermography; building energy efficiency; application

1. INTRODUCTION

At present, China is pushing forward with the building energy conservation, including the implementation of energy conservation reconstruction of existing residential buildings. During the reconstruction, energy conservation testing is a system work. We can get to know the heat defect of building envelope including Cold Bridge or Heat Bridge and so on according to the building envelope surface temperature distribution, so it's very important. This testing is an in-field work, and we can't damage the existing residential buildings during the testing.

With the development of testing technology, the infrared thermography is applied in the building field. It has the virtues of great speed and large range of tested temperature, and has non-contact surface temperature measurement. It specially adapts for testing the building envelope surface temperature

distribution ^[1, 2]. According to the testing result, we can observe building envelope heat defect including cold bridge or heat bridge and so on.

2. PRINCIPLE AND APPLICATION OF INFRARED THERMOGRAPHY

According to the Planck's radiation law (equation 1), radiometric force of common object has the biquadratic direct proportion with the absolute temperature of its surface. Infrared ray belongs to the electromagnetic wave, which also goes by the name of bolometric radiation. Any object has radiation output because of molecular thermal motion as long as its temperature is beyond the absolute temperature. The infrared thermography tests the surface temperature with the use of infrared detector according to infrared radiation law.

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

Where

E — radiometric force, W/m²

ε — emissivity

σ — the constant of radiation = 5.67×10^{-8} , W/(m²·K⁴)

T — the absolute temperature of the surface, K

For the testing of the heat defect of building envelope, the infrared thermography's color monitor presents a temperature distribution image (thermographic image) of the building envelope, it is the effective and visualized model. We can quickly identify the heat defect of building envelope, so enhances the work.

For the building envelope, the heat flow comes into being when there has the large temperature difference between indoor and outdoor. Whether any structure type and building materials, the surface

temperature of the building envelope is different because of the heat defect. Judging from the temperature difference, we can get the heat defect of building envelope including Cold Bridge or Heat Bridge and so on (shown in Fig.1 and Fig.2). In the thermographic image, the low temperature indoor area pointed the heat defect in winter, and the high temperature outdoor area pointed the heat defect in winter.

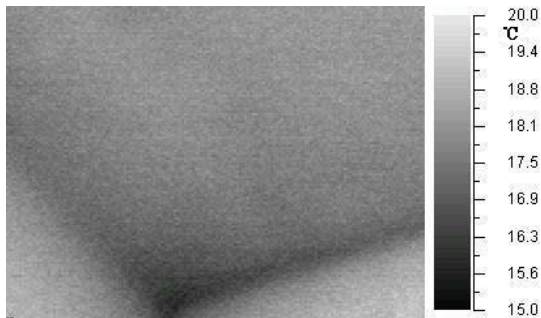


Fig.1 The thermographic image of indoor corner

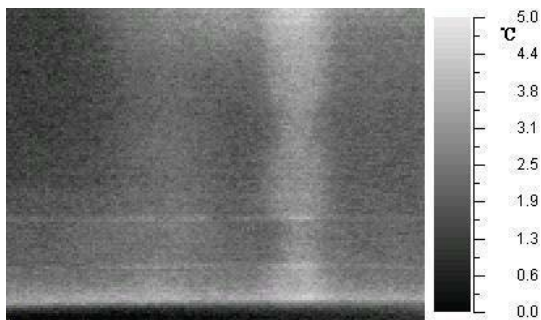


Fig.2 The thermographic image of building envelope

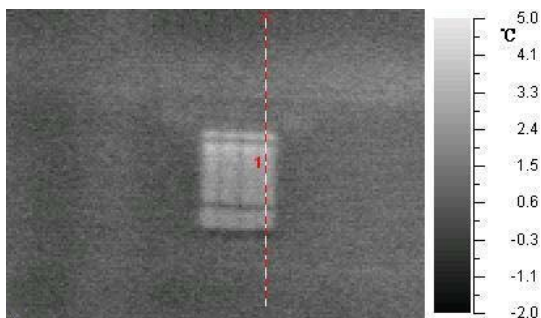


Fig.3 The thermographic image of exterior window

With the development of the technology, the modern infrared thermography is designed to make non-contact surface temperature measurement of an object observation. Its LCD color monitor presents a temperature distribution image of the object. Capable of observing the object at a rate of 24 frames per second, it allows the user to acquire and record thermal phenomena of the object with high fidelity.

The user can conduct temperature measurement while carrying about it. Also, through digital processing, it permits image quality improvement, automatic temperature tracking, and recording/playing back of thermographic images to/from floppy disk. Furthermore, the user can record thermographic images on VTR/photograph with a peripheral device or perform thermographic image data analysis with a personal computer (shown in Fig.3 to Fig.6).



Fig.4 The correspondence photo with the thermographic image

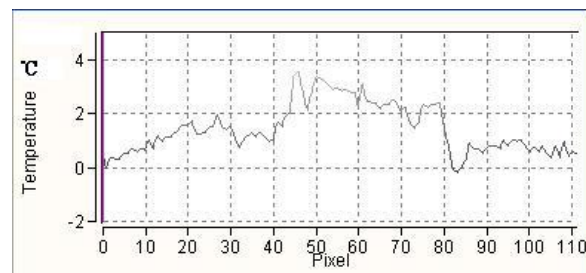


Fig.5 The temperature in pointed line

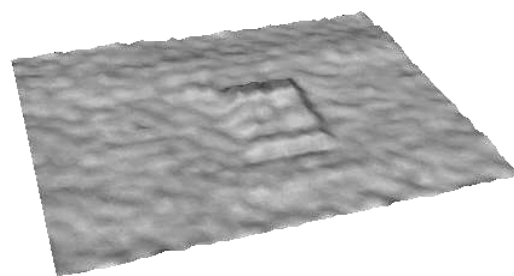


Fig.6 The three-dimensional thermographic image

3. OPERATING STEPS OF THE INFRARED THERMOGRAPHY

Modern infrared thermography has more functions. The major key includes manual focus adjustment key, auto focusing key, manual temperature tracking key, auto temperature tracking key, freeze thermographic image key, recording thermographic image key and so on. When in use, we

must set the temperature range and the emissivity of the surface. Here, we introduce above functions based on the experience.

3.1 Temperature Range Setting

Two or three kinds of measurement temperature ranges are available on most infrared thermography, we must select the right one. When used in building field, generally, we select the low temperature range (-20°C to 120°C), otherwise, we can not get the right result.

3.2 Emissivity Setting

Temperature measurement can be carried out according to a preset emissivity value which in a range of 1.00 to 0.10.

Emissivity is the difference between an object's apparent radiation output and its ideal output, the output of a perfect radiator (blackbody) at the same temperature. Using the following equation, it can be seen that emissivity is the remaining component of radiation after transmissivity and reflectivity are taken into account. In other words, the emissivity factor is the portion of a target's radiation that is due to its own heat content.

$$\varepsilon = 1 - (\tau + \rho) \quad (2)$$

Where

τ — transmissivity

ρ — reflectivity

When the substance to be imaged is known, emissivity tables may be used to directly determine the emissivity. Surface conditions such as oxidation, coating crystallization, or presence of impurities can have a large effect on 'true' emissivity. Also the angle of incidence (imager angle relative to the target) can have an effect^[3,4]. Emissivity can also be determined empirically. Temperature sensing devices can be used to determine actual target surface temperatures, then emissivity settings can be adjusted to produce the 'correct' temperature. Drawbacks of this method usually relate to the effect the measurement devices have on the target.

Emissivity value of the common building materials in a range of 0.7 to 0.95, the emissivity value of cement is higher than brick. We can set an

approximate emissivity value in advance when measure, although emissivity value is not correct, it does not effect the last test result. Because emissivity value can be modified by means of software, and we can get the correct test result after adjusting, this can economize in-field work time.

3.3 Image Quality Improvement (Averaging) Setting

For relative noise reduction, the input image data and the data stored in memory are added a ratio specified with a weighted constant value. This averaging function is effective when measuring object's temperature that varies delicately. When used in building field, this is very efficiency because of the steady heat transfer of the building.

3.4 Focus Control Setting

The infrared thermography is similar in focusing function to the general camera, the main portion is adjusting the optical system to get sharply focused image. This is very important not only to improve image quality, but also to measure temperature. In general, manual focus control and automatic focus control are available.

It expends a long time to execute automatic focus control of the infrared thermography, and user can not break it. Sometimes, the time span of automatic focus control is beyond one minute in field usage, it is unfavorable for batter-powered during outdoor work. For increasing test efficiency and adapting to the general testing on the building envelope, we recommend select the manual focus control after have some experience. When we adjust focus control in manual mode, we can look for the identifiable figure or form of the surface, it is useful to get the best articulation of the thermographic image, outline and border is also useful.

3.5 Temperature Tracking Setting

Use the automatic temperature tracking function in case that a temperature of the object is unknown. When this function is turned on, the temperature setting is automatically adjusted according to object's temperature, which includes the setting of the upper limit temperature and the lower limit temperature on screen. Thus, a proper thermographic image can be

attained. We had better adapt narrow interval of temperature span because there are much color that show small temperature spots.

Commonly, the thermographic image has the functions of automatic temperature tracking and manual adjustment. When testing the building envelope surface temperature distribution, we had better primarily choose automatic temperature tracking because temperature surge is small and temperature difference of the surface is small. After getting the probable temperature range, we manually set the upper limit temperature value and the lower limit temperature value. Then, we can test extensively. This can save much in-field work time and capacity of battery.

3.6 Thermographic Image Recording

The response time of the infrared thermography is slow due to its principle. Ghost image can be brought into being by the shock which be made by operator or the change of ambient conditions. Therefore, firstly we use the freeze function to get a still thermography image, recording it after we check the monitor and affirm the correct thermographic image is in still.

4. TESTING OF OTHER PARAMETER

Because infrared thermography is designed to make non-contact surface temperature measurement of an object under observation, we must prevent parasitic light and heat emission entering exploring instrument directly or through reflection. We still consider the effect of environmental impact upon heat emission.

For the measurement of the building envelope, we need notice several facts: the surface temperature of the object under observation, emissivity value, instrument position, ambient temperature, humidity (which is measured indoor), wind velocity, direct light, thermal source which is related to measured surface, and so on.

Because of solar radiation interferes with infrared imaging system, we can't put up infrared detection when the surface is shot at direct light^[5,6]. By day, heat emission which is reflected by the opposite building can cause unsafe thermographic

image on the back side of building, we shoot thermographic image at night. According to Fig.7, outdoor temperature is relative stabilization during 7:00 pm to 9:00 pm, the average temperature fluctuation is less than 1.5 , contemporaneous indoor temperature change, the average temperature fluctuation is less than 0.5 . During this time, we put up infrared detection of the building envelope surface temperature distribution, this can avoid the interference from sunshine, and indoor and outdoor temperature is relative stabilization, test environment is relative stabilization.

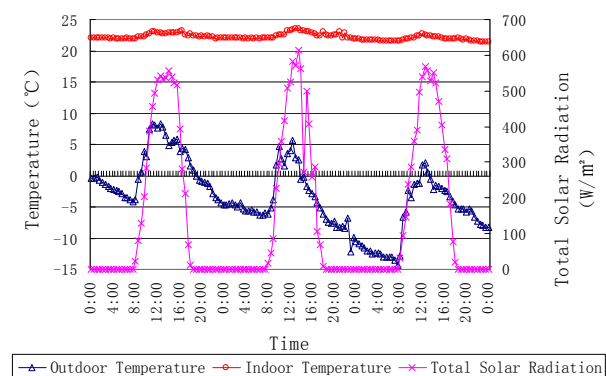


Fig.7 The indoor and outdoor temperature in three days

During the testing, for increasing the accuracy we need to put up multiple single-point modified test. We must record the point temperature measured by other thermometer, location of spot measurement correctly, number of thermographic image and corresponding location in the thermographic image.

Based on low of imagery, we can calculate the real area which thermographic image shows by focal length of lens and imaging distance when we know the distance between infrared thermography and measured surface, new generation of infrared software has the function. Thus, we must record the position of infrared thermography in testing, it is favorable for post treatment of thermographic image and joint of several images, and useful for census of the heat defect of building envelope. We need record the angle of gradient of instrument when shooting upper part, generally the angle of gradient is less than 15°. For high-rise building, we get correct test area through post analysis.

For the detail analysis of thermographic image, during the infrared detection we need to record

environmental parameter, such as outdoor temperature, wind velocity and so on. We also need to shoot the correspondence photo with the thermographic image if possible, which is favorable for visual localization and analysis. Fig.3 shows a thermographic image of exterior window, we have recorded specific position of thermographic image in testing. But after we get the visual photo (shown in Fig.4), visual result of the window is shown immediately, the heat defect of building envelope which is brought by unstructured defect also can be shown.

5. CONCLUSION

Infrared thermography is the major equipment to test the heat defect of building envelope, it will greatly enhance in-field test technology in building energy conservation.

Based on the practical application, we generalize the following experience for existing residential buildings: start the testing after 7:00 pm; considering the change of environmental condition, spend short time shooting the building; record the position of instrument; the corresponding photo with the thermographic image; single-point modified temperature; outdoor temperature; wind velocity and so on, and record the angle of gradient of instrument when shooting upper part.

ACKNOWLEDGEMENT

The work of this paper is supported by Funding Project for Academic Human Resources

Development in Institutions of Higher Learning under the Jurisdiction of Beijing Municipality (BJE10016200511).

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