Journal of Applied Sciences

ISSN 1812-5654

Journal of Applied Sciences 13 (10): 1710-1715, 2013
ISSN 1812-5654 / DOI: 10.3923/jas.2013.1710.1715

Analysis of Thermograph and Experimental Research Based on the Air Tightness Detection of Infrared Thermography

[1]Pengfei Tian, [1]Jiping Zhou, [1]Xinlong Zhu and [2]Jin Cao
[1]School of Mechanical Engineering, Yangzhou University, Yangzhou, Jiangsu, 225127, China
[2]Nantong Jianghua Thermal Power Machinery Co., Ltd., Nantong Jiangsu, 226300, China

Abstract: The airtight detection of sealed devices have been focused by many enterprises, which has been seen as an important technical index of quality. Thus, the airtight detection of sealed devices is very important. In recent years, the infrared thermography detection technology has been widely valued because of its advantages of the fast response speed, the wide measuring range and the non-contact measurement. But there is no study about its application and research in gas tightness detection technology. Through theoretical analysis and experimental research, a kind of gas tightness detection method based on infrared thermography is put forward, which is on the basis of the existing air tightness detection method and the analysis of its application. Fluent software is used to simulate the temperature field of the leak. In test, through the heat analysis of the measured container with a defect, the temperature field distribution of leak is obtained. The results of the test provide the basis for leakage of judgment based on infrared thermography.

Key words: Air tightness detection, infrared thermography, analysis of thermograph, test

INTRODUCTION

In recent years, the airtight detection of sealed devices have been focused by many enterprises, which has been seen as an important technical index of quality (Zhu, 2002; Li *et al*., 2001). If the sealing is not well, it is going to bring leakage, low efficiency and abnormal operation. Sometimes it can even bring environmental pollution problems and production safety problems (Suo *et al*., 2005; Fu *et al*., 2001). Thus, the airtight detection of sealed devices is very important. At present, the methods of air tightness detection contain water detecting method, flow method, direct pressure method, the differential pressure method, halogen method, helium method, ultrasonic method and so on (Gu and Huang, 2006; Miller *et al*., 1999). These methods have their own characteristics, but for mass production in the enterprise application, there are disadvantages such as the impossibility of achieving quantitative detection, the lack of high detection precision and the high cost (Lu, 2003). With the development of science and technology level and the increasing competition in the market, manufacturers need airtight detection equipments which are more efficient, convenient and intelligent. Therefore, at present, how to develop a more quick, convenient and efficient system of leak positioning device has become the hot topic in research institutions of airtight detection at home and abroad (Peng *et al*., 2008). In recent years, the infrared thermography detection technology has been widely valued because of its advantages of the fast response speed, the wide measuring range and the non-contact measurement. But there is no study about its application and research in gas tightness detection technology (Niong *et al*., 2009; Belikov and Enachescu, 2005). Through the early research and theory analysis, the research group of the author carried out experimental study of the air tightness detection based on infrared thermography.

BASIC PRINCIPLE OF INFRARED THERMOGRAPHY DETECTION

The infrared thermography detection is on the basis of infrared radiation principle, which can transform the surface temperature of the tested object into the directly perceived infrared heat maps through using the thermal imager to collect the infrared radiation of the surface of the object. All objects whose temperature are above absolute zero will continually launch the infrared radiation, which is a kind of electromagnetic wave and can't be seen by people. For the average gray body, the radiation intensity M (W/m^2) can use Stefan Boltzmann's law to represent:

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

Corresponding Authors: Pengfei Tian and Jiping Zhou, School of Mechanical Engineering, Yangzhou University, Yangzhou, Jiangsu, 225127, China

in the formula, ε is the emission rate of the gray body; σ is Stefan Boltzmann constant, whose value is 5.67×10^{-8} $W/m^2 \cdot K^4$; T is the absolute temperature.

Applying heat to the object, when a defect is an object's surface a defect, it will change the heat conduction of the object and make the surface temperature distribution different. According to Stefan Boltzmann's law, the thermal radiation on the surface of the object will have difference and the difference will be reflected on the infrared heat map. So, it can confirm the defect position of object through the observation of the infrared thermograph, still can make a further analysis and study on temperature field.

CONSTRUCTION OF THE SYSTEM OF DETECTION PRINCIPLE

It needs to meet the condition of thermal imaging when using infrared thermal imager to detect the air tightness of container. Only in the condition that it exists temperature difference inside and outside the airtight container can it forms thermal image for the analysis of the air tightness. Therefore, as shown in Fig. 1, a system about the analysis of principle and the study of experiment is built.

Gas with certain pressure produced by the compressed air generator is heated to a certain temperatureand then is filled to the sealed container to be tested. The infrared thermal imager collects heat maps of the container to be tested and transfers the signal to the computer. The signal is received by the analysis system of thermal imaging and the temperature field images of the tested container's surface are displayed on the green. These images are available for further analysis. If the container to be measured has leaks, then singular points or areas will appear on the temperature field images. It can achieve the singular points or areas by image analysis and processing technology and then it can distinguish the air tightness of the container to be tested and can further determine the location of the leak.

The system adopts infrared thermal imager of S680- DM60, the pixels are 384 ×288,the wavelength range is 8-14 and the thermal sensitivity is 0.08°C. The thermal imager and the computer are connected by Ethernet cable and the corresponding system of heat collection and analysis software of heat map are contained. Heat source is a heating device equipped with intelligent temperature controller of WK-SM3. Gas source is a Bosch silent air compressor. The containers to be tested are shown in Fig. 2. The container of I is made of plastic and there is a hole whose diameter is 1mm on it. The container of II is made of copper and there are two holes on it, one hole's diameter is 0.05 mm and the other is 1 mm.

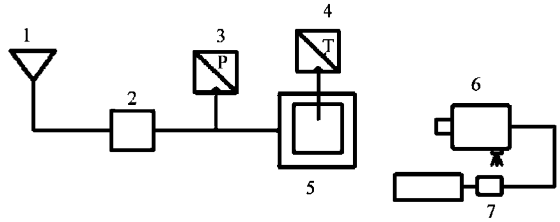

Fig. 1: System of the analysis and study of principle, (1) Compressed air generator, (2) Gas heating system, (3) Pressure sensor, (4) Temperature sensor, (5) The container to be tested, (6) Infrared thermal imager, (7) Thermal imaging analysis system

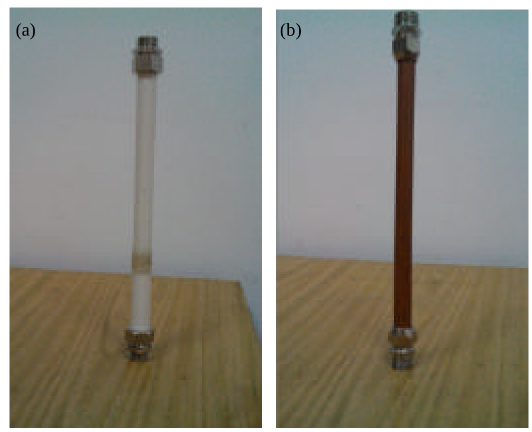

Fig. 2: Container to be tested

FLUENT SOFTWARE TO SIMULATE THE TEMPERATURE FIELD

The establishment of the model. Simulation model is established by using pretreatment software of Gambit. As is shown in Fig. 3, the red area is the fluid domain which is a cylinder of 9 mm in bottom radius and 90 mm in high. The green area is the solid domain which is a cylinder of 9 mm in bottom radius and 90 mm in high. At the same time, there is a inlet port 1 of 3 mm in bottom radius and 5 mm in deep and there is outlet port 2 of 1 mm in bottom radius.

Leakage simulation analysis: The model of the container to be tested is meshed and the parameters of boundary are set according to the actual situation, the pressure is 3 atmospheric pressure and the temperature is 50□. The result of Leakage simulation is shown in Fig. 4.

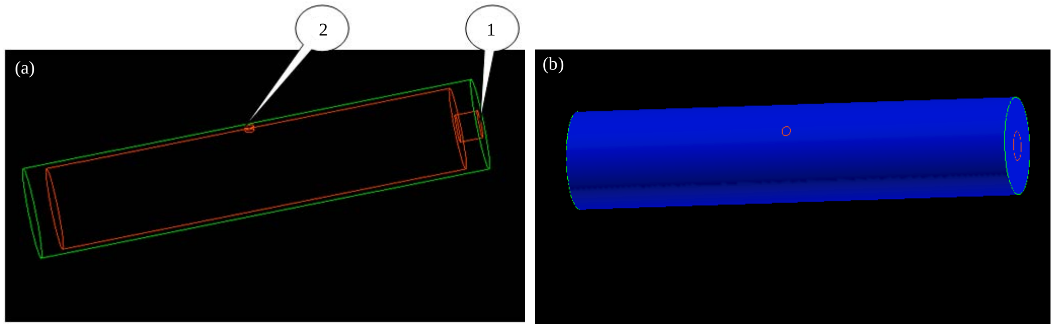

Fig. 3(a-b): Container model, (a) Wire frame model, (b) Entity model

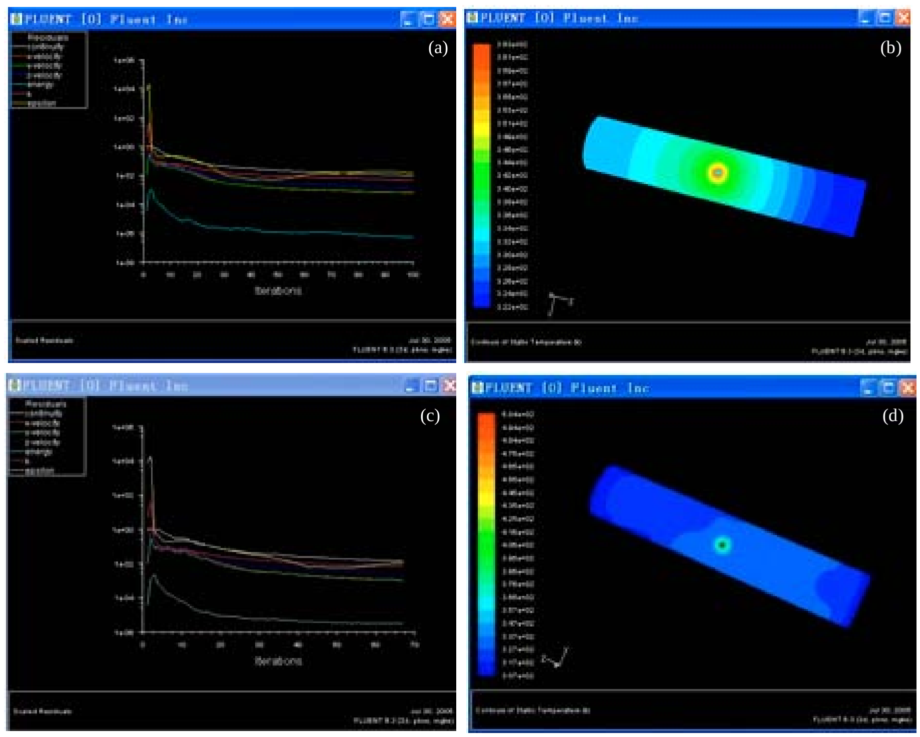

Fig. 4(a-d): The Leakage simulation, (a) The iteration result of steel, (b) The outer wall temperature field of steel, (c) The iteration result of plastic, (d) The outer wall temperature field of plastic

The Fig. 4b is the temperature field of steel material, the fig. 4d is the temperature field of plastic material. it can be seen from the two temperature field that the temperature in the leak mouth is in circular distribution and the temperature is gradually reduced from outside to inside. The temperature distribution of outer wall is different in 2 figures because of the different material properties. For the plastic material, due to the relatively small coefficient of thermal conductivity, the speed of wall heat transfer is slow, so the rise of temperature of the wall is lower than that of the Steel material in the same time.

AIR TIGHTNESS TEST OF INFRARED THERMOGRAPHY

Through the establishment of test environment and the setting of thermal imager parameters, the heat maps of the object to be measured are collected by using the built-in image acquisition system and then are analyzed.

Air tightness test of plastic containers: For the plastic containers I, the gas temperature is 50□, the pressure is 3 atmospheric pressure and the direction of the gas is from left to right. The Fig. 5a is the original heat map of the

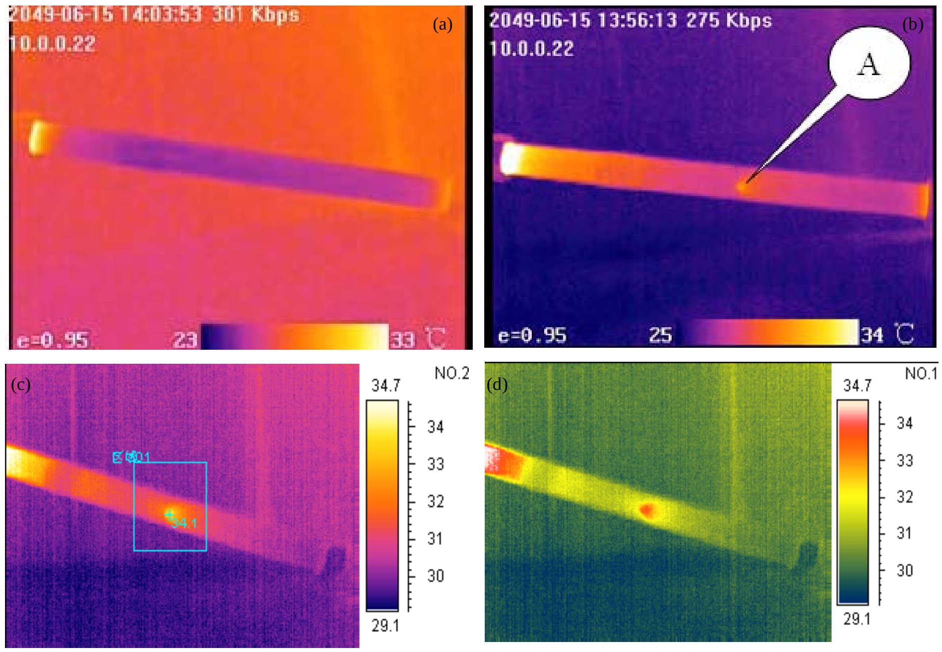

Fig. 5 (a-d): Heat maps of the plastic container, (a) The original heat map, (b)The heat map after filling gas, (c) Regional analysis, (d) Color scale adjustment

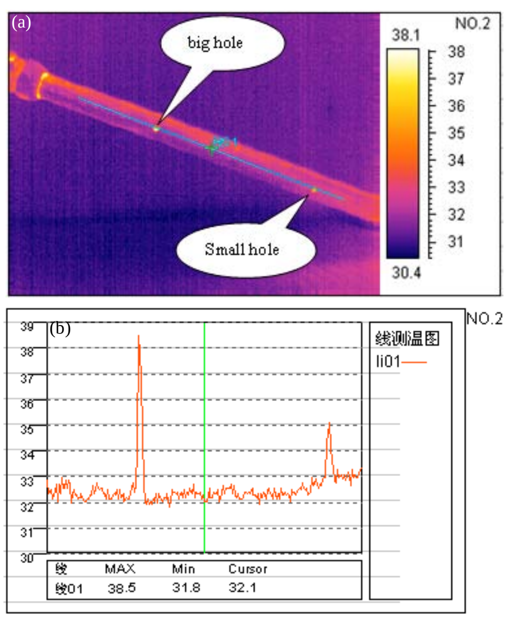

Fig. 6: Map of line temperature measurement from the big hole

plastic container I, the Fig. 5b is the heat map after filling the hot gas. In the Fig. 5b, we can clearly see a light point A, this point is the leakage point. As shown in Fig. 5c, using regional temperature analysis, demarcating a rectangular area and choosing the highest temperature in the Settings menu. We can clearly see that the highest temperature of 34.1□ is automatically identified, the point is the leakage point. By adjusting the temperature color label, the leak location can be found more obvious. As shown in Fig. 5d, the red area in the middle is the leak.

Air tightness test of bronze vessels: For the copper container II, the gas is filled from different directions in order to observe the temperature change of the leak. One is from the end of big hole, the other is from the end of small hole.

As shown in Fig. 6, the gas is filled from the end of big hole and a temperature measuring line is drawn through the two holes. In the chart, we can see that the temperature of the big hole and the small hole is high, the temperature of other points is almost the same and the big hole's temperature is greater than the small hole. As shown in Fig. 7, the gas is filled from the end of big hole a temperature measuring line is drawn through the two holes. In the chart of the online temperature measurement, we can see that the temperature of the big hole and the small hole is high, the temperature of other points is almost the same ,and the big hole's temperature is greater than the small hole. we can also see that the temperature difference between the big hole and the small hole in Fig. 6 is greater than that in Fig. 7.

In test, however the gas is filled from the end of the big hole or the small hole , the temperature of the big hole

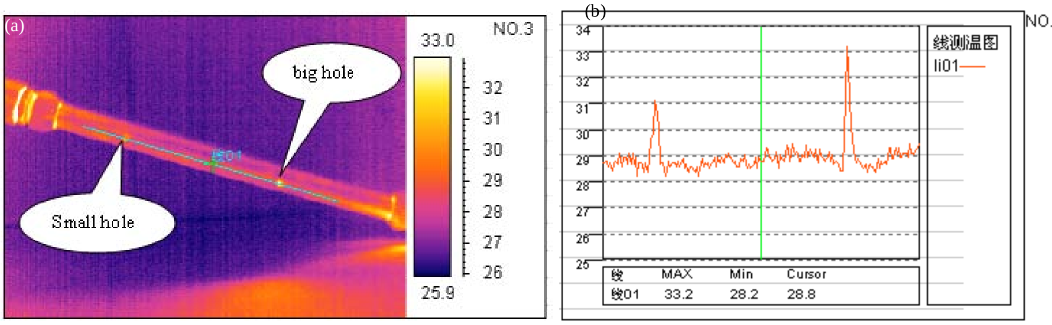

Fig. 7: Map of line temperature measurement from the small hole

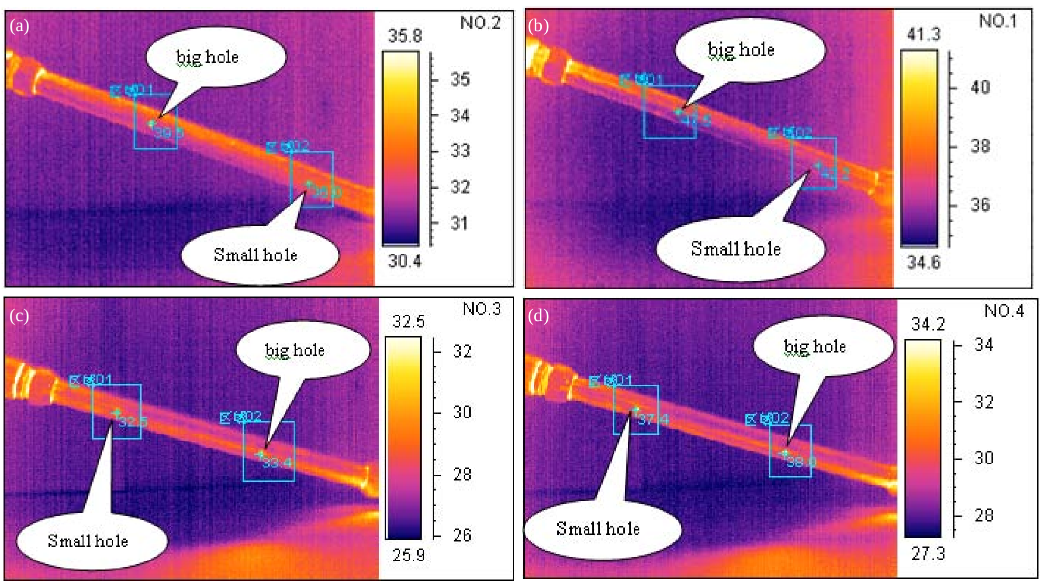

Fig. 8(a-d): Analysis of heat map in different temperature, (a) Gas of 50 filled from the big hole, (b) Gas of 60 filled from the big hole, (c) Gas of 40 filled from the small hole, (d) Gas of 50 filled from the small hole

is always higher than the small one. For this phenomenon, the different temperature of gas is filled to the container, using the method of regional temperature to see the temperature change. In Fig. 8a, the gas is filled from the end of the big hole and the temperature is 50, we can see that the temperature of the big hole is 39.5 and the temperature of the small hole is 36.0. In Fig. 8b, the gas is filled from the end of the big hole and the temperature is 60, we can see that the temperature of the big hole is 47.5 and the temperature of the small hole is 42.2. In Fig. 8c, the gas is filled from the end of the small hole and the temperature is 40, we can see that the temperature of the big hole is 33.4 and the temperature of the small hole is 32.5. In Fig. 8d, the gas is filled from the end of the small hole and the temperature is 50, we can see that the temperature of the big hole is 38.0 and the temperature of the small hole is 37.4.

From the Fig. 6, 8, however the gas is filled from the end of the big hole or the small hole, we can see that the temperature of the big hole is always greater than the temperature of the small hole. we can also see that ,when the gas is filled from the end of the big hole, the temperature difference between the big hole and the small hole is greater than that when the gas is filled from the end of the small hole.

CONCLUSION

By filling the gas to the container to be tested, using the technology of infrared thermography to test the container for air tightness, analyzing the collected infrared heat maps, we can get the following conclusions:

- The leak hole of container can be reflected in the infrared thermograph and bright spots appear, which indicates that the temperature of the leak is higher than the surrounding temperature

- The bigger the hole of container is, the greater the temperature of leak is. SO the big hole is easier to be detected
- When one container has two different size of leak hole, however, the gas is filled from the end of the big hole

REFERENCES

Belikov, S. and M. Enachescu, 2005. Methods and systems employing infrared thermography for defect detection and analysis. http://www.patentstorm.us/patents/6840666.html

Fu, D.M., X.G. Li and Z.H. Tang, 2001. The infrared diagnosis technology and its soft system of electrical equipment fault and its soft system development. Automation Electric Power Syst., 9: 55-57.

Gu, B.Q. and X.L. Huang, 2006. Investigation of leak detection method by means of measuring the pressure increment in vacuum. Vacuum, 80: 996-1002.

Li, F., L.X. Wan and W. Xin, 200l. The development of intelligent leak detection instrument of high precision and medium-pressure. Instrument Tech. Sen., 2: 21-23.

Lu, S., 2003. The intelligent detection method research of Seal air tightness. Automation Instruction, 5: 17-19.

Miller, R.K., A.A. Pollock, D.J. Watts, J.M. Carlyle, A.N. Tafuri and J.J. Yezzi Jr, 1999. A reference standard for the development of acoustic emission pipeline leak detection techniques. NDT E Inter., 32: 1-8.

Niong, S.C., C.J. Hu and J.D. Zhu, 2009. The development of the automatic detector of differential pressure air tightness based on volume compensation. Ind. Instrumentation Automation, 5: 46-49.

Peng, G.Z., C.H. Ji and N. Ge, 2008. The present situation and development trend of air tightness test technology. Hydromechatronics Eng., 36: 171-174.

Suo, X.L., D.D. Yu and T.Q. Duan, 2005. Capillary rheometer finite element analysis of temperature field. Mech. Eng., 12: 99-101.

Zhu, Z.D., 2002. The establishment and practice of the scientific and perfect leakage measurement system. Mod. Mach. Tool Automatic Manuf. Tech., 11: 4-6