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Vaccum Leak Detection Using Infrared Thermal Imaging for Detection of Failed Joints and Structural Integrity – Simulation and Experimental Study

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Abstract

Thermal Imaging is now being increasingly used as a non invasive NDE technique for leak detection of liquid and gaseous substances in oil and gas, refineries, petrochemicals and other industries. Apart from detection of the leaks, it also aids in measuring the leak through the changes in surface temperature. Nuclear industry has dense pipings and when leaks are minute and dispersed in such pipings, conventional leak testing methods prove inadequate. This paper focuses on a unique combination of conventional vacuum leak method with IR imaging for the location of leaks in piping. The study also highlights the simulation studies for understanding the temperature profiles around the leak region and the effect of leak diameter on the temperature pattern during the vacuum leak was also studied.

Introduction

Thermal imaging is very efficient and simple inspection tool for visualizing leaks. Apart from aiding in detection, it can also provide quantitative estimation through the changes in surface temperature that is being investigated. Extensive small diameter piping is an integral part of nuclear industry. Leaks occur in such systems at pipe flanges, threaded connections and welded points. If the leak rate is high, the leak can be easily detected through conventional leak testing methods including helium leak testing, bubble test or acoustic methods. However, when multiple small leaks are present, the use of HLT methods become difficult as the presence of number of minute leaks increases the background thereby making sniffing difficult. In this work, authors have combined in a unique way, the application of vacuum test technique with infrared imaging for detection of such minute leaks. Thermal imaging works on the principle of fluid flow affects surface temperature. As gas enters from atmospheric condition into a lower pressure reservoir such as vacuum condition, it expands, cools down and chills the leak point [1]. Hence, vacuum leak is recorded as cold spot in an IR thermal image. In this paper we discuss the application of full field IRT for visualization of leaks in engineering components such as complex pipelines and bellow system during vacuum leak testing. Detection of any leak in the welded region of the complex pipelines and other system are very crucial. In the present study, vacuum leak testing was carried out on two engineering components for evaluation of the nozzle welds and integrity of the system, during the testing an IR camera was used for mapping the surface temperature. To understand the temperature evolution during the vacuum leak in the component, simulation studies was carried out on the pipe structure using Finite Element Analysis.

Experimental and Simulation Studies

Leak detection was carried out using the infrared camera with focal plane array detector (320 x 256) and has Indium Antimonide (InSb) detector with stirling cooling system with a maximum achievable temperature resolution of 25 mK. It detects the infrared radiations in 3-5 µm region and a maximum frame rate of 176 Hz. ALTAIR software was used for acquiring and analyzing the images.

The pipe shown in the schematic drawing of Figure 1 was studied in this paper for simulation studies with defect using the ANSYS FEA code. The objective of the pipe simulation is to numerically establish the thermal signature of a pipe with defect. This is important for easy identification of changes that may occur in the temperature when leakage is introduced into the pipe. Pipe of dimension 200mm in length and 25mm in diameter was simulated with default mesh size of 0.125mm.

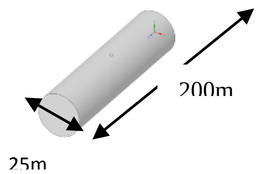

Figure 1. Schematic drawing of the pipe with a leakage which was used for the simulation studies

Results and Discussion

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Figure 3a and 3b shows the photograph and thermal image of complex pipelines during the vacuum leak. Thermal imaging clearly reveals the area where temperature drop has been observed. Temperature drop areas indicate the vacuum leaks from the systems due to failed nozzle joint in the complex pipeline system. Temperature contrast between the sound nozzle joint and failed nozzle joint clearly depicts the vacuum leak. Similarly leak in bellow system has been detected using the temperature difference generated on the leak region during the vacuum leak. To understand the temperature evolution during the vacuum leak in the component or system, simulation studies was carried out. Surface temperature on the pipe along the leak region can be successfully mapped in order to clearly identify and locate leakages of various diameters of 0.5mm, 1mm and 2mm. The simulation of temperature profile in the pipes with and without leakage has shown great potential in leakage detection in pipeline systems and can detect very small leaks of 0.5 mm diameter. The relationship of the leakage diameter to the temperature profile recorded over the leakage region has been studied. The identification of leakage in a pipe is intuitive from mere comparison of the temperature contrast generated of an intact pipe with that of a pipe with a leakage.

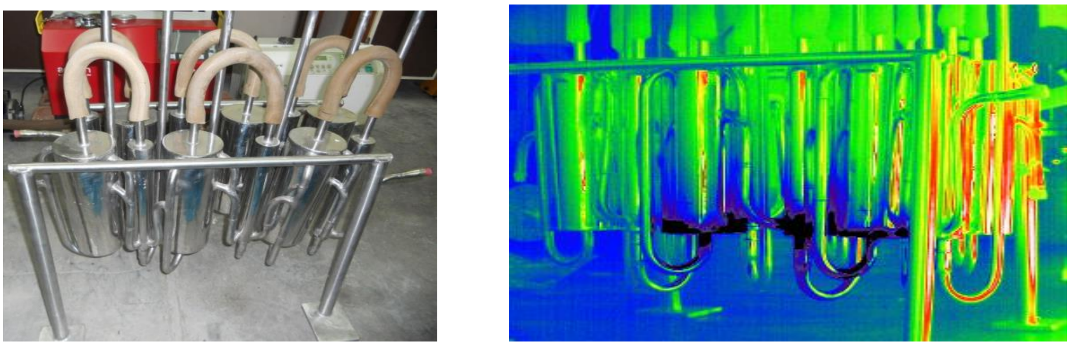

Figure 3. (a) Photograph of the complex pipeline system (b) Thermal image of complex pipeline system

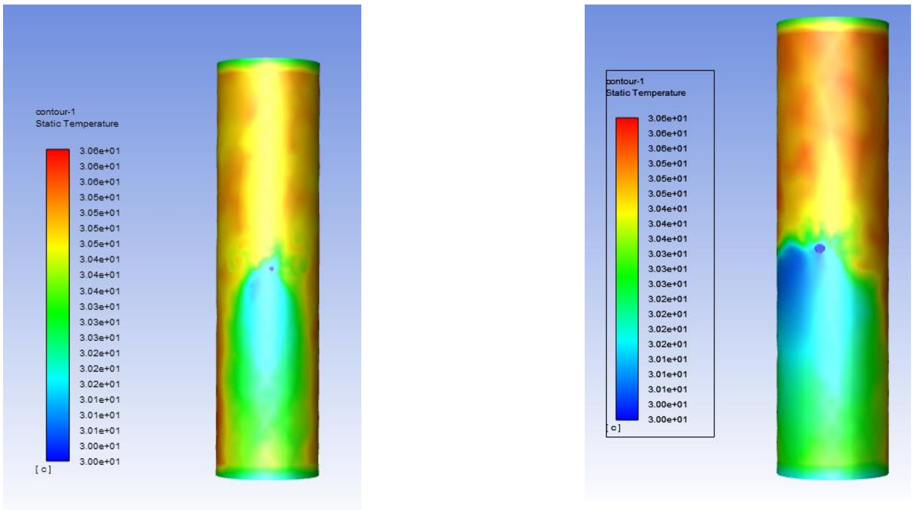

Figure 4. Simulated temperature distribution on the pipe along with the defect for 1mm and 2mm leak diameters

Conclusions: This study demonstrated the vacuum leak detection using IRT for evaluation of failed joints and structural integrity of engineering components. The simulation studies revealed the temperature distribution on the different leak diameters of 0.5mm, 1mm and 2mm. Further study has to be carried out to evaluate the lower limit of leak which can be detected using IRT.

References

1. A. Kroll, W. Baetz, and D. Peretzki. 2009. On autonomous detection of pressured air and gas leak using passive IR thermography for mobile robot application. In Robotics and Automation ICRA'09 IEEE International. pp. 921-926.