Stress based full field non-destructive evaluation for in-situ assessment

R.C. Tighe1, J.M. Dulieu-Barton1, J.P. Tyler2 and S. Lormor3

1 Engineering and the Environment, University of Southampton, UK, 2Enabling Process Technologies Ltd, Portishead, UK, 3EDF Energy, Cottam, UK.

Abstract. The present paper focusses on the development and onsite implementation of TSA as a new stress based non-destructive evaluation approach. On-site tests consisted of the inspection of several welds along thick walled high pressure steam drains during two scheduled outage periods at coal fired power stations. The initial visit found the inspection approach to be very efficient and robust in this environment with data collection and analysis taking a matter of minutes. Results identified stress concentrations however the second visit considered the issue of motion in the TSA data to enable a wider range of weld locations to be inspected.

Introduction

Phased array ultrasound (UT) [1] is the most common means of inspection of welds in the power industry. Currently, weld inspection is a laborious process involving comparison to a reference case and manual plotting of results, as such, only selected sites are inspected. Thermoelastic stress analysis (TSA) [2] is a thermographic non-destructive technique which uses an infrared (IR) detector to measure the surface temperatures of a component whilst it undergoes cyclic loading which are then used to create a map of the surface stresses. The results of TSA are presented as images, thus sizing of features can be done directly and the data can be stored. Typically TSA relies upon a servo-hydraulic test machine to apply the cyclic load to create the thermoelastic response; the current work investigates the use of vibration loading to create the strain change required for TSA. A portable pneumatic based loading system was developed that is capable of providing sufficient load to create a measurable thermoelastic response. The present paper focusses on the development and implementation of the portable TSA approach for stress based on-site non-destructive evaluation during two onsite inspections at EDF power stations. Initial trials are presented showing the inspection of several welds along thick walled high pressure steam drains during a scheduled outage period at a coal fired power station, EDF Energy, West Burton, UK. The second visit to EDF Energy, Cottam, UK, focusses on the refinement of the technique to take into account motion of the excited pipes to improve data fidelity.

Methodology

To facilitate TSA inspection it was necessary to prepare the surfaces of the pipes to remove corrosion. Such surface preparation is the same as that required for other inspection techniques, including ultrasound. A thin layer of matt black spray paint was then applied to the inspection areas to provide high and uniform emissivity for TSA. A pneumatic shaker, the GT35 from Vibtec, was used to provide excitation. The shaker runs using a standard workshop compressed air line which drives an eccentrically weighted turbine wheel that creates a rotating imbalance and hence vibration. In laboratory based TSA the signal from the load cell of the test machine which provides the loading is typically used as the reference signal for the lock-in processing. In the current case the excitation frequency was determined using a self-reference lock-in process. Self-referencing means the reference signal is taken from the collected infrared (IR) data. The reference signal is taken as the mean recorded value over an area of pixels from the surface of the component through time. The areas selected for obtaining the reference signal are close to the weld to ensure that the frequency of the local vibration of interest is used to process the data. To extract a frequency spectra a fast Fourier transformed (FFT) is applied to the reference data; the frequency component with the largest amplitude is used as the reference frequency for the lock-in processing. The current self-referencing approach is most suited where cyclic loading is applied however there are other self-referencing approaches in the literature, e.g. [3], suited to different loading conditions.

Figure 1a shows the pipes identified for on-site inspection during the West Burton visit, which provided a range of weld configurations to consider. Pipes 1-2 had an outer diameter 48 mm and a 600 mm long horizontal section joined a larger section of pipe creating a T-junction, numbered weld 1.1 and 2.1. The shaker was positioned on pipe 1 at the midpoint of the horizontal section, as shown in Figure 1b, and run at a pressure of 1.5 bar. Only data from pipe 1, weld 1.1 from the West Burton visit is presented in the current paper.
Results and discussion

The $\Delta T/T$ data and phase data [2] for weld 1.1 is presented in Figures 2a and 2b. Stress concentrations occur at the sides of the weld with a line of zero stress along the top of the pipe. The phase data shows the two halves of the pipe are out of phase with each other. This stress and phase distribution is attributed to the excited mode shape. To collect data from the full circumference of the weld several detector positions would be necessary although the loading could remain the same.

Motion assessment

Where welds are positioned towards the centre of pipes the effect of motion is much more apparent in the data. Motion manifests itself as blurring at the edges outlining the pipe in both the $\Delta T/T$ and phase data. Approaches to motion compensation including the addition of a white light camera, as in [4], or image processing solutions using only the collected IR data are evaluated. The second site visit to EDF Cottam uses the selected approaches to reduce the effect of motion to enable higher fidelity weld inspection throughout the length of pipes.

Conclusion

The present paper has shown TSA can be conducted with vibration loading and has been successfully applied on-site as an assessment approach for welds. The methodology was demonstrated on-site on thick walled stream drains. A second onsite assessment has been undertaken to implement methods of motion compensation and assess its feasibility for onsite deployment.

References