APPLICATION OF POTENTIAL DROP TECHNIQUE TO THE INSPECTION OF WELDED BOILER HIGH TEMPERATURE AND PRESSURE PARTS

Tomoki KUROIWA[1], Seiichi HAMADA[1], Yasuki OGAWA[1],
Hideo IIDA[1], Masahiko KUROKI[1], Manabu HAYAKAWA[1]
[1]Tokyo Electric Power Company, 1-3-1 Uchisaiwaicho Chiyoda-ku Tokyo Japan

ABSTRACT

In this paper, a practical method using the electrical potential drop technique was discussed to evaluate the creep damage accumulated in the welded power piping such as main steam pipe and hot reheat pipe. Round robin experimental measurements conducted by the authors et al. as academic activities in the Japanese Society for Non-destructive Inspection showed that the potential drop technique is effective for the application to the inspection of welded boiler pressure parts. The authors have conducted additional experimental and numerical studies for verification focusing on the application of the pulsed direct current potential drop technique. The authors have proposed technical requirements on the potential drop technique for the application to the inspection of welded power piping to be implemented in JSME Codes for Thermal Power Generation Facilities (2003 Edition) as a non-mandatory appendix JA. And the practical on-line measurement in the high temperature and high pressure burst test using the repair-welded power piping has been conducted. In this burst test, Tokyo Electric Power Company has tried to monitor the creep damage accumulated in the seam-welded area using the commercialized tool based on pulsed direct current potential drop technique.

1 INTRODUCTION

Since many of the current electric power fossil plants in Japan have been operated for more than 100,000 hours, it has been important to maintain these aged plants for safe and reliable operation. Therefore, the component life assessment of the high temperature and pressure parts of power boilers has become a significant problem.

Regarding the welded piping such as main steam pipe and hot reheat pipe, starting with the catastrophic failure of a seam-welded hot reheat pipe at the Mohave Power Station in 1985, numerous incidents of failures in high-energy piping systems have kept alive industry concerns regarding the safety of these systems [1]. Several research works showed that failure had occurred primarily as a result of in-service creep damage such as void formation and cracking in the heat affected zone (HAZ) of the weldment. Since detailed inspections have been required to assess the remaining lives for aged components, advanced ultrasonic methods such as time-of-flight diffraction (TOFD) and linear phased array techniques have been applied. Since flaws detected by the advanced ultrasonic methods may contain pre-service deficiencies such as material production flaws, welding related flaws, fabrication related flaws and heat treatment related flaws, the key decision that need to be made is whether the flaw is likely to progress in the future. However, it is difficult to distinguish some pre-service flaws from service induced damage.

Electrical potential drop procedure for crack size determination is generally applicable to conducting materials in wide range of environments including the high temperature condition. This method is expected to be applicable to the on-line monitoring procedure to determine the size of the crack in the welded piping. Round robin experimental measurements were proposed by the authors as academic activities in the workshop of the Japanese Society for Non-destructive Inspection (JSNDI) using several non-destructive techniques such as DC, pulsed DC and AC potential drop techniques to evaluate the sensitivity for detection of cracks introduced on the test piece. Results of the round robin measurements were summarized in the previous paper [2]. The round robin test showed that the potential drop technique is effective for the application to the inspection of welded boiler pressure parts. For the practical use in this application, measurement sensitivity to crack depth is strongly needed. Reviewing the results of the round robin tests, the authors have conducted additional studies detailed in the previous paper [2] focusing on the application of the pulsed direct current potential drop technique using a commercialized inspection tool known as FSM-IT developed by CorrOcean company in Norway. This tool can realize large current feeding, which is effective for the inspection of large thickness components such as welded power piping. The authors verified that this method based on pulsed DC technique is effective for the practical use.

2 APPLICATION TO THE BURST TEST MONITORING EXPERIMENTAL

Optimization of weld repair technologies can assist in reducing costs and lengthening the remaining life of welded pressure components such as main steam pipe and hot reheat pipe. For example, EPRI reported the cooperative program focused on the weld repair techniques employed in fossil power plants and examining methods and alternatives that can aid in extending the life of high temperature components [3]. Tokyo Electric Power Company (TEPCO) has been conducting a research program in cooperation with Mitsubishi Heavy Industries, ltd. (MHI) to verify the weld repair technologies employed in the seam-welded power piping. This cooperative program to be conducted in 2003 includes high temperature and high pressure burst test using the repair welded main steam pipe elbow. This elbow had been in operation in the TEPCO power plant for about 200,000 hours. The operating temperature and pressure in the burst test are 630C and 24.5MPa, respectively. In this burst test, TEPCO has planned to monitor the seam-welded area using the commercialized tool "FSM" mentioned above based on pulsed DC potential drop technique. FSM – the Field Signature Method – is a relatively new method for continuous monitoring of corrosion attacks and cracking of pipes, pressurized vessels and storage tanks [4]. FSM-IT measures each pair voltage to calculate the ppt value that expresses the voltage change relative to the signature value (initial value). The ppt value for measuring pair *A* at time *i* is defined as follows .

$$ppt_{Ai} = [1 - \{(B_i / A_i) / (B_S / A_S)\}] \cdot 1000 \quad (1)$$

where,

A: measuring pair

B: reference pair

A_S, B_S : signature value

Figure 1 shows the applied elbow to be set up in the test stand located in MHI Nagasaki laboratory. This elbow is to be enclosed by the electric heating furnace.

Figure 2 shows the sensing pin configuration installed on the elbow. A pair of current feeder pins was installed on the elbow in the circumferential direction. Each pins was connected to the elbow by welding.

Figure 3 shows the schematic diagram of the

Fig.1 Appearance of the elbow at the burst test stand

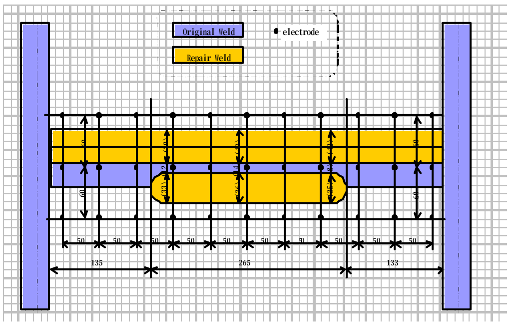

Fig.2 Schematic drawing of the sensing pin configuration

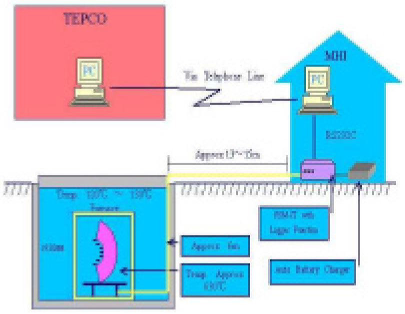

Fig.3 Schematic diagram of the monitoring system

monitoring system. Monitoring operation is remote controlled at the TEPCO headquarter office. Data logger is equipped at the test stand, and the measurement data is on-lined via telephone line. A typical monitoring data showing the crack propagation is shown in Figure 4. Judging from the monitoring data, the authors decided to stop the burst test and to conduct the intermediate inspection.

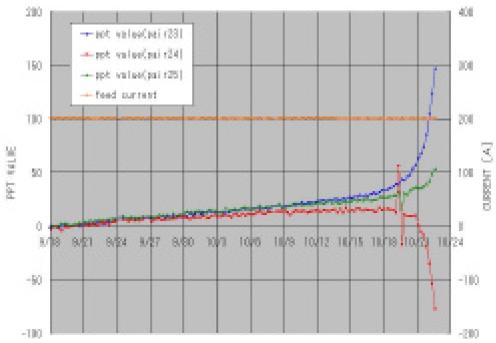

Fig.4 An example of monitoring test data(Before first intermediate inspection)

3 Numerical simulation

Before the burst test was started, it had been investigated on optimal monitoring system configuration and suitability for monitoring crack growth by numerical FEM (Finite Element Method) simulation.

The cracking areas were made as a finer element mesh, and placed in the center of the inner curve of the pipe bend. The cracks were simulated placed on the outside, inside and in the middle of the pipe wall. Simulations in various cases of the crack length, height, depth and location had been done.

The results indicated that the ppt value correlated with crack size and location. So, to presume size of a crack from measuring data, the authors made a master curve for size of a crack vs. ppt value (see Figure 5), assuming that the crack was in the outside of the wall and the ratio of crack height / length was 0.25.

Figure 5 shows the master curve for size of a crack assuming that the crack is in the outside of the pipe wall and the ratio of crack height / length is 0.25.

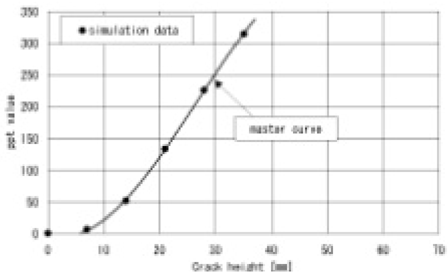

Fig.5 Master curve for size of a crack (height/length 0.25)

4 Discussion

Results of the first intermediate inspection were summarized as follows.

(1) Magnetic particle testing (MT) showed that the crack was on the outside of the pipe and about 150mm length along the repair welding line.

(2) Ultrasonic examination (TOFD) showed that the crack was about 16mm height.

Numerical simulations were conducted to various cases of a crack (not only in the middle of the wall, but also on the outside).

With the results of these simulations, it is able to presume the crack size on the outside wall from the measuring ppt data(see Figure 4). It is estimated that the ppt data before the first intermediate inspection correspond to about 19mm height assumed that the ratio of crack height / length is 0.25.

Figure 6 shows the monitoring data before the second intermediate inspection. It is estimated that the ppt data correspond to about 40 mm height.

Results of the second intermediate summarized as follows:

(3) MT showed that the crack was about 237 mm length

(4) TDFD showed that the crack was about 44mm height.

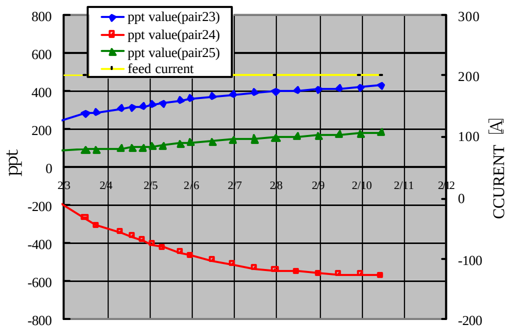

Fig.6 A monitoring data before the second intermediate inspection

These presumptions above indicate that the results of numerical simulations are corresponding with actual crack sizes and locations well.

5 Conclusions.

The authors reported the crack monitoring trial in the high temperature and high pressure burst test using the repair welded main steam pipe elbow. It was indicated by numerical simulation and intermediate non-destructive examination that it was possible to presume the crack size from measuring ppt data, assuming the crack location (on the outside or inside or in the middle of the wall) and the ratio of crack height / length.

REFERENCES

1.Guidelines for the Evaluation of Seam-Welded High-Energy Piping: An Executive Summary of Current Approaches, EPRI Report TR-111380 (1998)

2.Seiichi HAMADA, Hideo IIDA and Hiroshi OZAKI, Application of potential Drop Technique to the Inspection of Welded Boiler Pressure Parts, Proceedings of the International Conference on Power Engineering-03(ICOPE-03), November 9-13,2003,Kobe,Japan, Vol.1, pp.283-285

3.State-of-the-Art Weld Repair Technology for High Temperature and Pressure Parts: Volume 4: Weld Repair of Pipe/Header Girth Welds, EPRI Report TR-103592-V4 (1997)

4.Per Olav Gartland, Harald Horn, Kjell R. Wold and Tom Hallan, FSM Developments for Monitoring of Stress Corrosion Cracking in Ammonia Storage Tanks, Corrosion 95, NACE, Orlando, USA, March 1995.