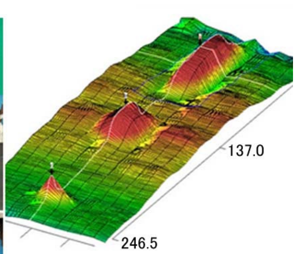
High-efficiency Inspection Technology for Inner Surface Corrosion of Lengthy Tubes by ECT



MIKIYASU URATA[*1] KIYOTAKA AOKI[*2]
NAOYA URATA[*3] TAKEHIKO YAMAGUCHI[*4]
KENTARO JINNO[*4] SHINTARO MATSUMOTO[*5]

In boiler heat transfer tubes for thermal power plants, corrosion thinning caused by caustic gouging may occur on the tube inner surface. Mitsubishi Heavy Industries, Ltd. (MHI) and Mitsubishi Hitachi Power Systems, Ltd. have established inner UT technologies using the ultrasonic method for continuous thickness measurement of heat transfer tubes, but they are affected by scale which is comprised of rust and deposits produced by corrosion, resulting in difficulty in the detection of thinning of the tube inner surface. The author et al. studied the application of ECT (Eddy Current Testing) as a method of inspecting the overall length/circumference of the tube without being affected by scale, extracted the flaw detection conditions for detecting thinning parts through electromagnetic field simulation and developed a special ECT probe.

1. Introduction

In boiler heat transfer tubes for thermal power plants, corrosion thinning may occur on the tube inner surface caused by caustic gouging, etc. (**Figure 1**). Boiler heat transfer tubes, however, are densely installed to form tube banks. Therefore, in many cases, thinning parts cannot be easily accessed depending on their locations. We have established inner UT technologies using the ultrasonic method for continuous thickness measurement of heat transfer tubes, but the effect of scale produced by corrosion has made it difficult to detect thinning of the tube inner surface. Furthermore, it is impossible to inspect finned tubes from the outer surface. Therefore, conventionally, a part of the tube was cut and a borescope, etc., was inserted and the state of the deposition of surface scale was observed to evaluate the presence or absence of thinning or abnormalities. This evaluation by visual inspection is qualitative, however, and it was difficult to quantitatively evaluate thinning.

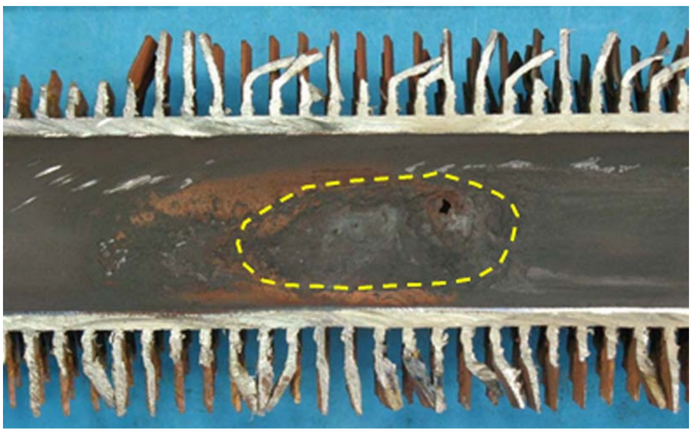


Figure 1 Example of caustic gouging

*1 Materials Research Department, Research & Innovation Center
*2 Chief Staff Manager, Materials Research Department, Research & Innovation Center
*3 Nagasaki Power Systems Service Department, Power Systems Service Headquarters, Mitsubishi Hitachi Power Systems, Ltd.
*4 Electricity & Applied physics Research Departmen, Research & Innovation Center
*5 Manager, Nagasaki Power Systems Service Department, Power Systems Service Headquarters, Mitsubishi Hitachi Power Systems, Ltd.

For corrosion thinning which occurs on the inner surface of boiler heat transfer tubes, we studied the application of ECT (Eddy Current Testing) to inspect the overall length/circumference of the tube without being affected by scale produced as a result of corrosion. In this report, the ECT probe and the inspection system that were developed based on electromagnetic field simulation and the actual boiler heat transfer tubes are introduced, and the results of the verification of the detectability of caustic gouging thinning and the practicality of the inspection system are described.

2. Development of ECT inspection system

Figure 2 shows the developed tube-inserted ECT inspection system. In this system, the developed ECT probe is inserted into the heat transfer tube to inspect thinning over the circumference and length of the tube while being moved by the driving force of a cable conveying device and hydraulic pressure. In ECT, eddy current is generated in a test specimen that has electrical conductivity, and from the change of the eddy current, flaws on the surface of the test specimen are detected. It is a detection method using electromagnetic reaction and is hardly affected by scale. The use of this feature enables the detection of corrosion thinning of the inner surface over the length/circumference of the heat transfer tube and quantitative evaluation of thinning depth, which were previously impossible.

Figure 3 shows the developed ECT probe. There are various types of sensor coil, and this probe adopts the differential coil method in which the effect of the magnetic properties and noise generated by the sensor tilt are small and the defect detectability is high. This means that to detect the difference between the signal components in the tube circumferential direction and in the tube axial direction, noise can be reduced while signals generated by defects are maintained. In addition, a float structure was incorporated in the signal cable, improving the driving force and allowing passage through a tube with a long length.

Figure 4 indicates the state of the eddy current generated on the thinning part in an electromagnetic field simulation. In the simulation, local thinning and relatively wide-ranging thinning were simulated, and the distribution of the eddy current in a single coil was evaluated. Based on these results, the arrangement of a small-sized coil was optimized and a multi-channel structured probe which allows the detection of thinning over the tube circumference without missing anything was designed. The coil part of this probe has a flexible structure, which allows it to pass smoothly through discontinuous portions such as welding penetrations or tube bends.

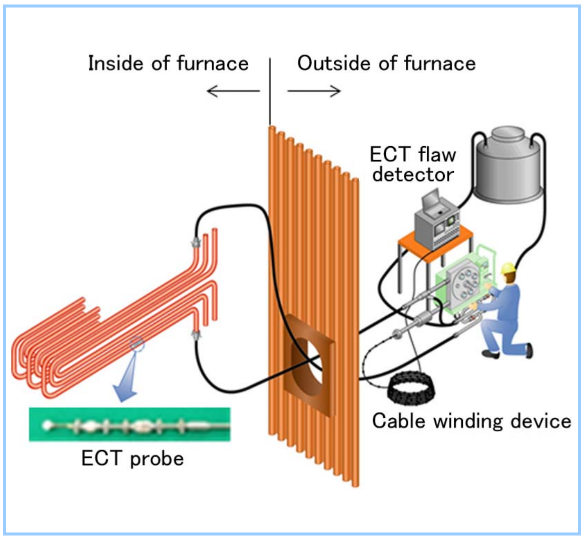


Figure 2 ECT inspection system

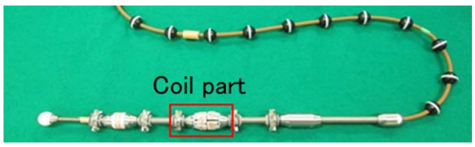


Figure 3 Developed ECT probe

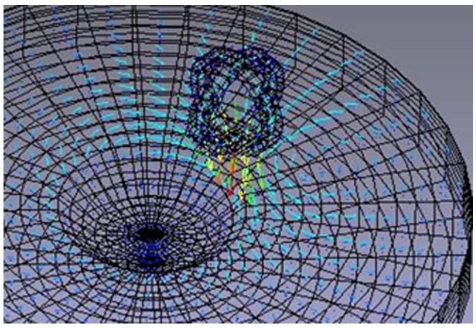


Figure 4 Electromagnetic field simulation

3. Detected state of thinning part

To evaluate the thinning detectability of the developed ECT probe, a verification test was conducted using a sample with artificial flaws processed on the tube inner surface. **Figure 5** shows the detected state of the artificial flaws. The artificial flaws had the same depth (0.5 mm) and varied in width and length. The developed ECT probe was able to detect all the artificial flaws.

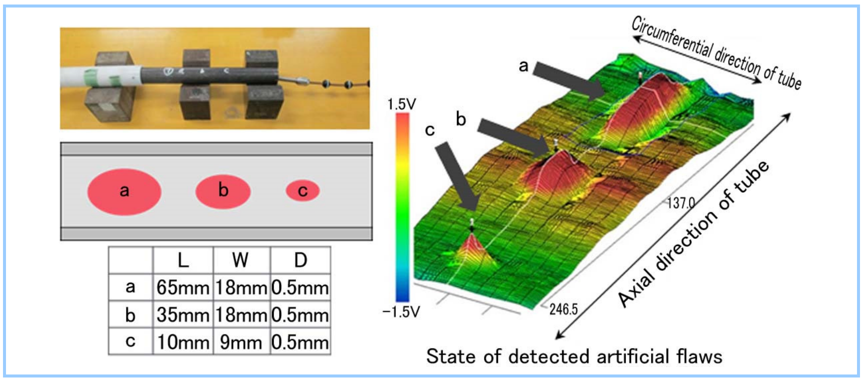


Figure 5 Example of detection of artificial flaws

Figure 6 shows the inspection results of the boiler heat transfer tube obtained in the trial operation of the actual unit and the investigation results for the cross section. The developed ECT probe was able to detect the corrosion thinning part of the actual boiler tube inner surface with deposited scale. In the investigation of the cross section, corrosion thinning that was 1.8 mm in depth was observed at a point at the thinning depth of 1.6 mm evaluated by ECT. **Figure 7** provides the comparison results of the thinning depth evaluation value by ECT and the thinning depth value measured by the investigation of the cross section. The error in the thinning depth evaluation by ECT was ±0.3 mm, and it shows that among the measurement techniques using electromagnetic reaction, this method allows a relatively high-precision evaluation of thinning depth. In this system, the inspection results are displayed with a color view of the tube inner surface developed by the original analysis system, enabling the thinning distribution to be visually understood. Furthermore, the thinning depth is evaluated from the obtained signal amplitude, etc.

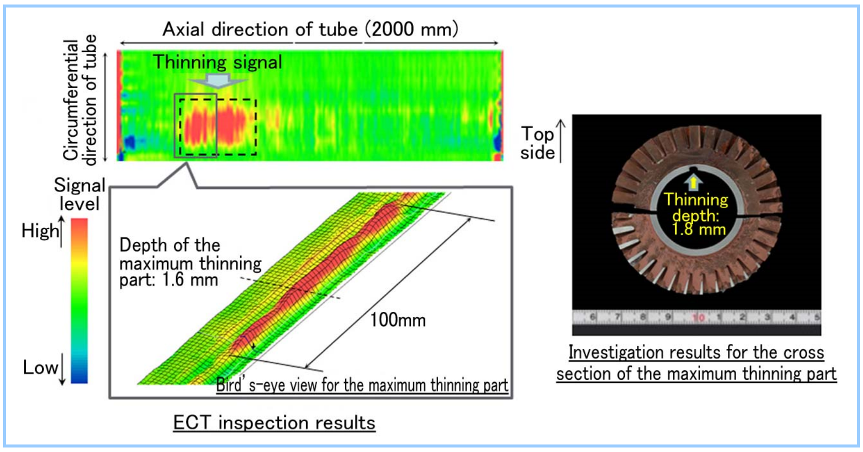


Figure 6 State of corrosion thinning detected on the actual tube

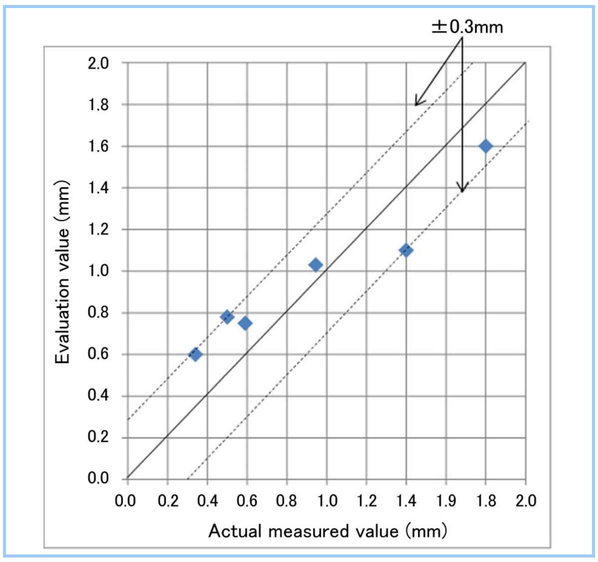


Figure 7 Evaluation precision for thinning depth

4. Conclusion

An outline of the tube-inserted ECT inspection system, which allows the inspection of corrosion thinning of the inner surface of boiler heat transfer tubes over the tube length and the circumference and a quantitative evaluation of the thinning depth, was presented. This system is our original inspection technology which enables a quantitative evaluation of corrosion thinning generated on the inner surface of magnetic material tubes without removing scale and is applicable to an actual plant. This system has already been applied to two plants and its effectiveness has been verified. However, this technology adopts a hydraulic system, and therefore, the size of the system is large and a great deal of time is required for preparation for inspection, such as the transport and installation of a large-sized pump and water storage tank. Therefore, the adoption of a pneumatic transfer system instead of a hydraulic system is currently under study. Through substitution with a pneumatic transfer system, the device can be installed inside a boiler furnace and an increase in work efficiency and labor saving can be expected. In the future, we will continuously conduct verification tests to increase the practicability of the technology.