Thickness Measurement Technology using Cable-less Inner UT for Boiler Heat Exchanger Tube

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Heat exchanger tubes in the main equipment of thermal power plant boilers, such as economizers and reheaters, have concerns about the occurrence of local thinning caused by wear of the external surface and widespread corrosion thinning. As a technology for the accurate detection of such damage, Mitsubishi Heavy Industries, Ltd. (MHI) and Mitsubishi Hitachi Power Systems, Ltd. developed the cable-less inner UT system, which is an ultrasonic water immersion method that can measure tube thickness from inside the tube. This paper describes a summary of the cable-less inner UT system and an example case of heat exchanger tube thickness measurement performed on an actual boiler.

1. Introduction

It is important for the enhancement of the operating ratio of thermal power plant boiler equipment to perform inspection sufficiently taking into consideration the form of damage occurring depending on the operation mode such as frequent starts/stops and quick load changes, as well as daily maintenance. In addition, more reasonable and higher-precision inspection has been required because of the reduction in maintenance budgets resulting from the liberalization of the electricity market.

Heat exchanger tubes in the main equipment of thermal power plant boilers, such as economizers and reheaters, have concerns about the occurrence of local thinning caused by wear and widespread corrosion thinning. As a technology for the accurate detection of such damage, MHI and Mitsubishi Hitachi Power Systems, Ltd. developed inner UT technology[(1)], which can measure the tube thickness from inside the tube. Inner UT technology has been applied to many inspection works and users have gained confidence in the technology, and the number of cases where inner UT technology is used has been steadily increasing. With such a background, we developed a cable-less inner UT system that enables a smaller size and a higher measurement speed than conventional inner UT technology, with the aim of further enhancing the efficiency of heat exchanger tube thickness measurement. A summary of the developed cable-less inner UT system and an example case of heat exchanger tube thickness measurement performed on an actual boiler are described below.

2. Cable-less inner UT system

Figure 1 shows the schematic diagrams of the conventional inner UT system and the cable-less inner UT system. The cable-less inner UT system is a small ultrasonic sensor that can be inserted into a heat exchanger tube. The cable-less inner UT system can measure the tube thickness over the whole circumference and the full length while traveling with the use of water pressure. Because the cable-less inner UT system requires no signal cable, the large cable feeding device and

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pressure pump could be eliminated, and thus the total weight of the system was reduced by 90% in comparison with the conventional system. In this manner, the size of the system has been significantly reduced.

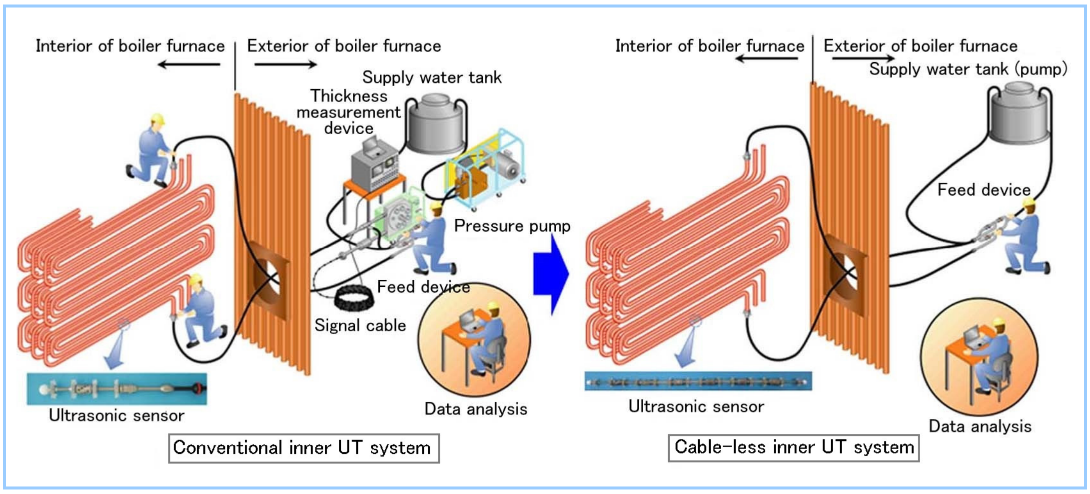

Figure 1 Schematic diagram of conventional inner UT system and cable-less inner UT system

Figure 2 shows the developed small ultrasonic sensor. The small ultrasonic sensor is reduced in size according to the limitation imposed by the pipe inner diameter and consists of the ultrasonic probe, a very small pulser-receiver, a memory device for recording of measured values, and an electronic circuit and a battery for the control of such components. The measured values can be sent to a computer through a USB connection after inspection, and then MHI's unique data processing system can visualize the measured waveforms and output as a thinning state diagram. The system adopts multi-channel ultrasonic probes that are placed at equal intervals in the circumferential direction of the sensor. The number of channels (number of probes) used is selected depending on the tube inner diameter.

Figure 2 Ultrasonic sensor for Cableless Inner UT system

In this manner, the cable-less inner UT system can measure the tube thickness from the inner surface and therefore needs no tube grinding work or scaffolding, in contrast to general thickness measurement technologies that measure the tube thickness from the outer surface. Therefore, the cable-less inner UT system can efficiently measure the thickness of the tubes entirely in a boiler heat exchanger tube consisting of a tube bundle. The cable-less inner UT system can also be used for finned tubes, which allows tube thickness measurement of almost all of our boiler heat exchanger tubes.

3. Case examples of tube thickness measurement

3.1 Case example of mockup panel measurement

Figure 3 shows an external view of a mockup panel that simulates a boiler heat exchanger tube. The mockup panel consists of a tube with an inner diameter of 34 mm and a bending radius of 57.5 mm. Several parts of the tube are artificially thinned to make thinning flaws. The minimum thickness values of the thinning flaws are 2.0 mm, 2.7 mm and 3.8 mm. **Table 1** and **Figure 4** shows the measurement results. Figure 4 shows the analysis results of measurement data with the use of a data processing system and the minimum thickness values are indicated as a chart. It was confirmed in Table 1 that thinning parts can be detected and the tube thickness can be measured at an accuracy of +/-0.1 mm against the actual thickness measured from the outer surface of the tube. **Figure 5** shows the traveling state of the small ultrasonic sensor. It was confirmed that the small ultrasonic sensor can smoothly pass through the tube and bends that have a bending radius of 57.5 mm.

Figure 3 External view of mockup panel

Table 1 Thickness measurement results

	Thinning A	Thinning B	Thinning C
Actual measured value	2.0mm	1.5mm	2.9mm
Measured value	2.0mm	1.5mm	3.0mm

Actual measured value: Thickness measurement value obtained by cross sectional inspection
Measured value: Thickness measurement value obtained with cable-less inner UT

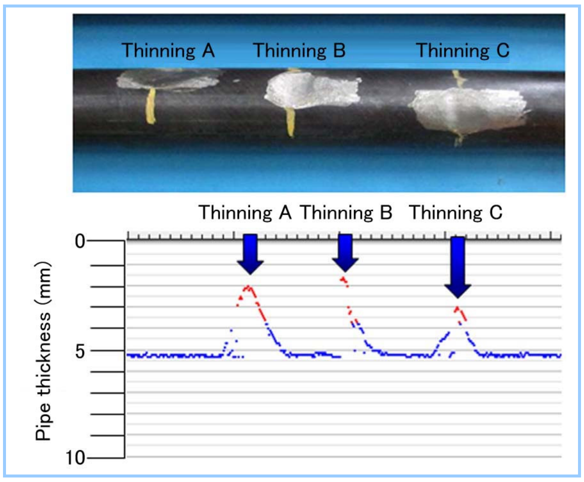

Figure 4 Thickness measurement results (chart diagram)

Figure 5 Passage situation of sensor

3.2 Case example of measurement of heat exchanger tube in actual boiler

A verification test was performed during a scheduled inspection of an actual boiler in order to evaluate the practicability of the cable-less inner UT system. The verified panel was a reheater tube with a minimum inner diameter of 57 mm and a minimum bending radius of 50 mm. **Figure 6 to Figure 8** show the measurement results. The validity of the measurement values was evaluated by comparing them with the measurement values obtained by the conventional inner UT system that has been used for many applications.

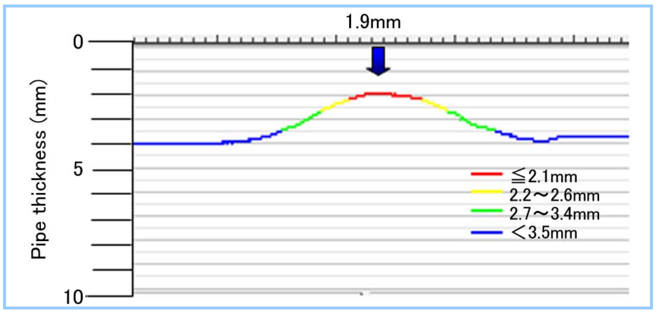

Figure 6 Measurement results of maximum thinning part (conventional inner UT system)

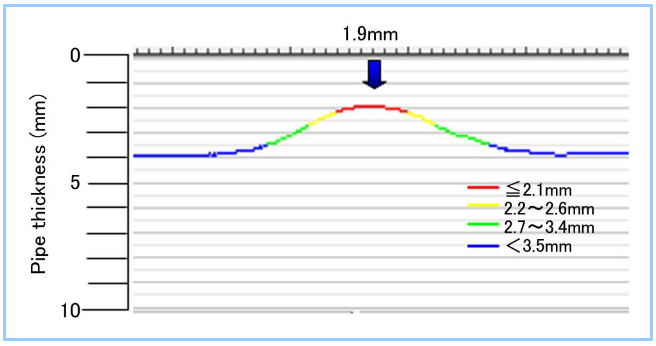

Figure 7 Measurement results of maximum thinning part (cable-less inner UT system)

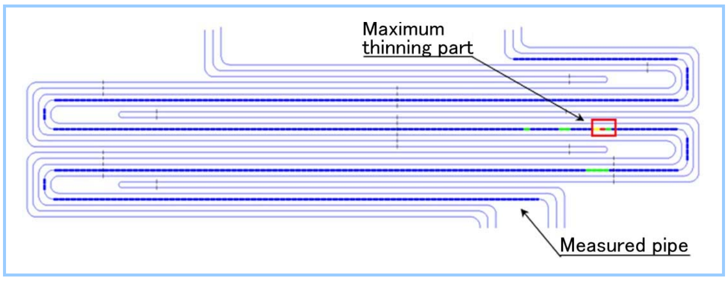

Figure 8 Measurement results (panel diagram)

As a result of verification, both the minimum measurement value of the conventional inner UT system and that of the cable-less inner UT system were 1.9 mm, and the cable-less UT system can measure the tube thickness at an accuracy equivalent to the conventional inner UT system even on an actual boiler, as shown in Figure 6 and Figure 7. In addition, the cable-less UT system can analyze the measurement data with the use of the data processing system that can display the minimum thickness value for every 100 mm section using different colors on a panel drawing as shown in Figure 8. It was confirmed that the thinning position detected by the cable-less UT system corresponds with that detected by the conventional inner UT system. Moreover, the sensor of the cable-less UT system could pass through both straight tubes and bent tubes smoothly, and therefore perform tube thickness measurement at a speed about twice that of the conventional inner UT system.

4. Performance comparison and applicable scope

Table 2 shows the results of a comparison between the conventional inner UT system and the cable-less inner UT system. The cable-less inner UT system successfully reduces the total weight by 90% in comparison with the conventional inner UT system, while maintaining tube thickness measurement accuracy equivalent to the conventional system. It can also shorten the time required for preparation for an inspection. It was also verified, in an actual heat exchanger tube inspection, that the cable-less inner UT system can measure a tube thickness at a speed about twice that of the conventional inner UT system, and therefore it is expected that the cable-less inner UT system can shorten the inspection process.

Table 2 Comparison results of conventional inner UT system and cable-less inner UT system

	Conventional inner UT system	Cable-less inner UT system	Evaluation
Thickness measurement accuracy	±0.1 mm	±0.1 mm	Equivalent
Positioning accuracy	±100 mm	±100 mm	Equivalent
Measurement speed	Normal inspection: 100 to 150 mm/s (Max. 200 mm/s)	Normal inspection: 200 to 280 mm/s (Max. 300 mm/s)	Approximately double
On-site preparation time	2 days	1 day	Reduced by 50%

Table 3 compares the applicable scope between the conventional inner UT system and the cable-less inner UT system, and **Figure 9** shows the correlation between the passable tube inner diameter for the sensor used and the tube bending radius. The minimum passable bending radius of

the sensor of the cable-less inner UT system is 35 mm when the tube inner diameter is 30 mm, with a minimum tube inner diameter of 25 mm. Due to development of the small sensor, almost all of our boiler heat exchanger tubes can be measured.

Table 4 shows the standard inspection process. In contrast to the conventional inner UT system that takes seven days to complete the whole process, the cable-less inner UT system can shorten the period by three days, and therefore it is estimated that measurement can be performed in four days including the preparation and withdrawal of the equipment. In this manner, the cable-less inner UT system is expected to shorten the inspection process due to the simplification of the equipment components and the increase in measurement speed.

Table 3 Applicable scope of conventional inner UT system and cable-less inner UT system

	Conventional inner UT system	Cable-less inner UT system
Heat exchanger tube thickness	1.5 mm – 20 mm	1.5 mm – 20 mm
Heat exchanger tube inner diameter	22 mm – 60 mm	25 mm – 60 mm
Heat exchanger tube curvature radius	≧35 mm	≧35 mm
Objective panel type	Horizontal type and hanging type	Horizontal type

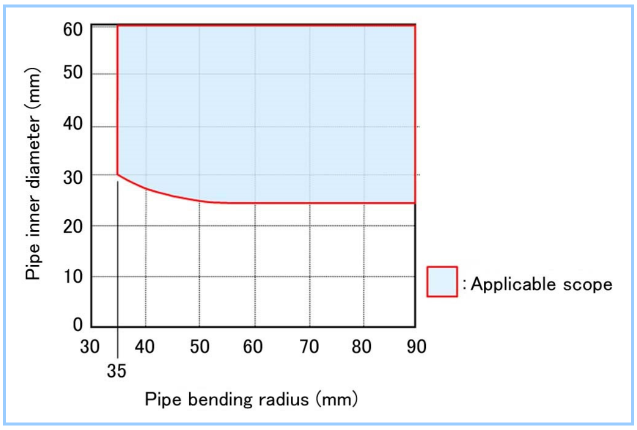

Figure 9 Applicable conditions of tube inner diameter and tube bending radius

Table 4 Inspection process

Work item \ Day	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8
Setup and adjustment of equipment								
Measurement								
Disassembly and removal of equipment								

Reduced by 1
Reduced by 1.5 days
Reduced by 0.5 day
: Conventional inner UT system
: Cable-less inner UT system

5. Conclusion

MHI has been working on the development of various inspection technologies according to the form of various parts and different types of damage to boilers in order to enhance the operating ratio of thermal power generation plant boiler equipment. This paper presented the cable-less inner UT system, which is a measurement technology for boiler heat exchanger tube thickness. Among many boiler heat exchanger tube thickness measurement technologies, this technology is the only high-efficiency technology that can perform thickness measurement of an entire heat exchanger tube at a high speed and with high accuracy, and is expected to significantly contribute to improvement in the operating ratio of boilers. MHI will continue to work on the enhancement of such systems in the future.

References

1. Urata, M. et al., Nondestrusctive Inspection Technology of Heat Exchanger Tube by INNER UT, The Japan Society of Mechanical Engineers