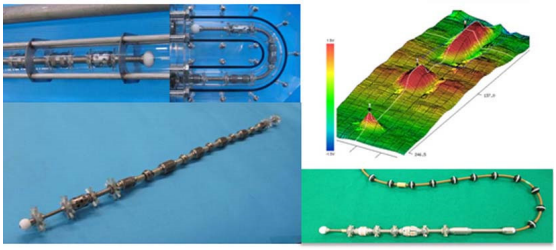
Non Destructive Inspection Technology for Thermal Power Plants



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In boiler facilities for thermal power plants, various types of damage may occur from rapid load change or as a result of the operation mode. Therefore, Mitsubishi Hitachi Power Systems, Ltd. has developed non-destructive inspection technologies which enable the accurate and timely detection of damage and has been promoting the application of these technologies to maintenance work for actual boiler facilities. In this article, the outlines of the following developed inspection technologies and the future prospects are described: thickness measuring technique by inner UT/cable-less inner UT, corrosion thinning part inspection technique using tube-inserted ECT, creep damage detection technique using phased-array UT, and thickness monitoring technique using thin film UT.

1. Introduction

Boiler facilities for thermal power plants are necessarily operated for long periods in high temperature and high pressure states, and there are concerns that each facility may be damaged due to aging and deterioration such as wear, corrosion and creep. Therefore, on top of daily maintenance inspection, it is important to conduct inspections with due consideration given to various forms of damage. In addition, since maintenance budgets are being reduced along with the deregulation of electric utilities, more reasonable and higher-precision inspection methods are required.

As such, we have developed, as non-destructive inspection technologies for the accurate and timely detection of damage, inner UT/cable-less inner UT, phased-array UT, thin film UT monitoring, ECT (Eddy Current Testing) technology, etc., and have been promoting their application to maintenance work for actual boiler facilities. In this article, the outlines of the developed non-destructive inspection technologies and the future prospects are described.

2. Boiler damage and non-destructive inspection technologies

In boiler facilities, various types of damage may occur from rapid load change or as a result of the operation mode. Non-destructive inspection technologies for detecting damage must be developed with full knowledge of the forms of damage and the structures of target facilities. **Figure 1** shows damage to boiler facilities and the non-destructive inspection technologies we have developed. First, there are concerns that on the outer surfaces of heat transfer tubes such as economizer and reheater tubes, local erosion thinning or wide-area thinning may occur. In many cases, it is difficult to measure the wall thickness from the outside of tubes with a high degree of precision, and depending on where damage occurs, a significant amount of supplementary work is required. Therefore, inner UT [(1)] and cable-less inner UT, which are ultrasonic immersion methods for measuring thickness from inside a tube, are effective. In addition, on the inner surface of a heat transfer tube, corrosion thinning due to oxygen corrosion, alkali corrosion, etc., occurs, which generates corrosion products (scale), resulting in difficulty in measurement using inner UT. In

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addition, inspection over a wide area becomes necessary, and so tube-inserted ECT technology, which is barely affected by scale, is effective. On the other hand, at welds of large-diameter pipes such as header and main steam pipes, creep damage occurs due to the many hours of use at high temperatures. Therefore, the detection of the congestion state of creep voids, which are pre-cracking, enables the execution of appropriate maintenance, and so the application of the phased-array UT technique is effective. Furthermore, the application of the thin film UT technique in which the state of damage due to the present thinning can be monitored during operation, enabling the prevention of problems such as steam leaks.

As described above, we have developed various non-destructive inspection technologies for boiler facilities and damage. The following section describes the outline of each non-destructive inspection technology.

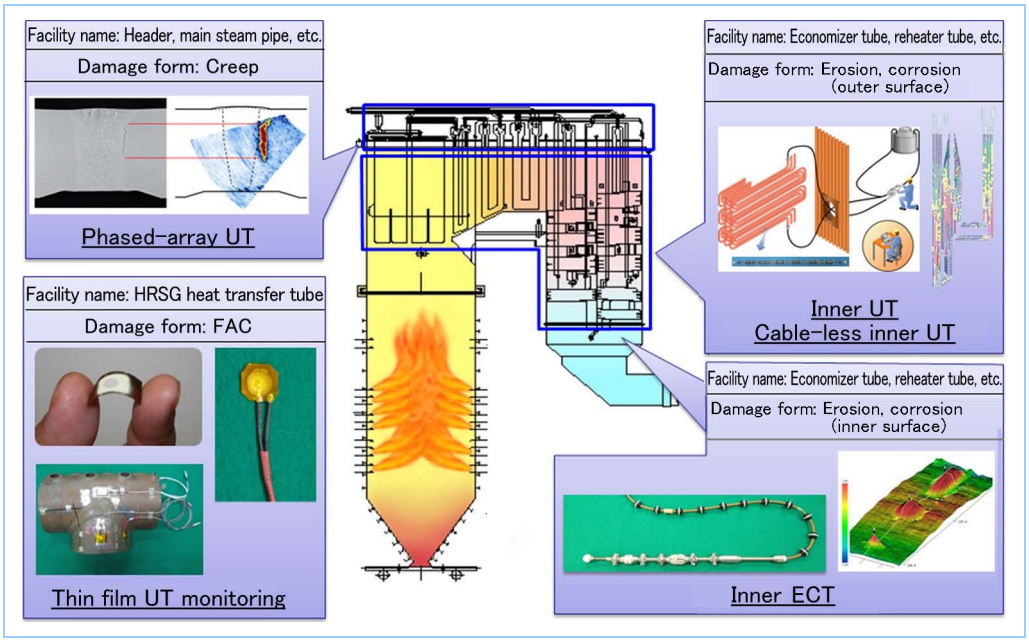

Figure 1 Damage to boiler facilities and non-destructive inspection technologies

3. Outline of various non-destructive inspection technologies

3.1 Thickness measuring technique by inner UT/cable-less inner UT system

Figure 2 shows the outlines of the inner UT system and the cable-less inner UT system. The inner UT system is comprised of an ultrasonic sensor with long lengths of signal cables, an ultrasonic thickness gauge, a cable feeder and a large pump. The inlet side and the outlet side of the heat transfer tube are cut, to which the cable feeding nozzle is attached and the cable guide hose is connected. Then, using pressurized water and a cable feeding unit, the thickness of the heat transfer tube is measured over the length while inserting the ultrasonic sensor into the heat transfer tube. Inner UT has been applied to inspection work for over 290 tubes so far and has proved highly reliable. At present, the application performance remains solid.

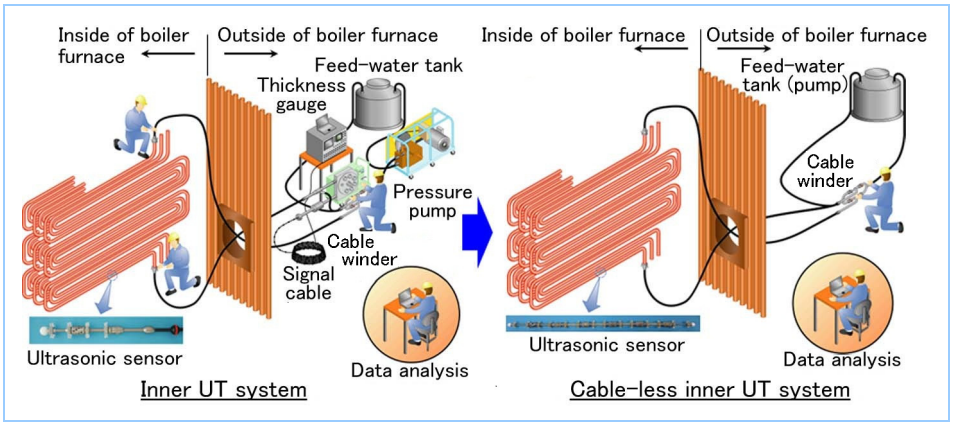

Figure 2 Outlines of the inner UT system and the cable-less inner UT system

In addition, aiming for the further high efficiency of the measurement of wall thickness of heat transfer tubes, we developed the cable-less inner UT system by making the conventional inner UT technology compact and increased the measuring speed. The cable-less inner UT system is a small ultrasonic sensor comprised of various electronic circuits which are made small enough to be inserted into the heat transfer tube, and it is inserted into the heat transfer tube to measure the thickness along the periphery and the length of the heat transfer tube while moving with the use of water pressure. Since it has no signal cable, no large cable feeder or pressure pump is required and the total weight is reduced by about 90% compared with the conventional one, achieving a substantial size reduction of the system. **Figure 3** shows the ultra-small ultrasonic sensor we have developed. The ultra-small ultrasonic sensor is comprised of a multi-channel ultrasonic probe with the same structure as the conventional inner UT system, an ultra-small pulser receiver, memory for recording measured values, an electronic circuit for controlling the devices and a battery. Measured values are transferred to a PC via USB connection, are imaged by our proprietary data processing system and can be output as a thinning state map.

Figure 3 Ultra-small ultrasonic sensor for Cable-less inner UT system

Table 1 shows a comparison between the conventional inner UT system and the cable-less inner UT system. While the cable-less inner UT system has a thickness measuring precision equal to that of the conventional system, its total weight is reduced by 90% compared with the conventional system. In addition, it has been proved by the actual heat transfer tube inspection that the cable-less inner UT system can measure the thickness at a speed about twice as high as the conventional system. Therefore, it is expected that the inspection process can be shortened.

Table 2 shows the scopes of the application of the conventional inner UT and cable-less inner UT. The cable-less inner UT system is applicable to the measurement of the thickness of a heat transfer tube with an inner diameter of 32 mm or more. The future development challenge is to make it applicable to a heat transfer tube with a smaller inner diameter and bend radius.

Table 1 Comparison of results

	Conventional inner UT	Cable-less inner UT	Comparison result
Measuring precision	±0.1mm	±0.1mm	Equal
Measuring speed	Average 100 to 150mm/s (Max. 200mm/s)	Average 200 to 280mm/s (Max. 300mm/s)	Double in time
Total weight	1200kg	120kg	90% reduction
Preparation time at site	2days	1day	50% reduction

Table 2 Scope of application

	Conventional inner UT	Cable-less inner UT
Thickness of heat transfer tube	1.5mm to 20mm	1.5mm to 20mm
Inner diameter of heat transfer tube	22 to 60mm	32 to 60mm
Bend radius of heat transfer tube	≧35mm	≧50mm
Target heat-transfer-tube panel type	Horizontally installed, hanging	Horizontally installed only

3.2 Corrosion thinning part inspection technique by tube-inserted ECT

There are concerns that on the inner surface of boiler heat transfer tubes, corrosion thinning due to oxygen corrosion, alkali corrosion, etc., can occur. Depending on where the corrosion occurs, it may be difficult to measure the thickness from outside the tube. Therefore, it is desirable to apply a high efficiency inspection technology such as inner UT. At corrosion thinning parts, however, scale is produced in association with corrosion reaction. If ultrasonic waves are applied from inside a tube, the ultrasonic waves may scatter at scaled parts, and as a result, it becomes impossible to measure the thickness. Therefore, at present, the presence or absence of thinning or abnormalities are evaluated by cutting part of the tube, inserting a fiber scope in the tube, and observing the state of the deposition of surface scale. But the evaluation by visual inspection is qualitative and it is difficult to quantitatively evaluate the thinning rate.

Accordingly, we developed a tube-inserted ECT sensor which enables the measurement of corrosion thinning depth of the inner surface of the tube. ECT is a technology for detecting surface flaws on specimen by generating the eddy current on the electrically conductive specimen and observing changes in the eddy current. Since ECT is a detection method using electromagnetic reaction, it is barely affected by scale. Using this characteristic of ECT, corrosion thinning part of the inner surface of heat transfer tubes, which couldn't be detected so far, can be detected, and thinning depth can be quantitatively evaluated. **Figure 4** shows the appearance of the developed ECT sensor and the evaluation example of simulated thinning defect. The ECT sensor adopts a multi-channel system in which a plurality of small coils are arranged to prevent thinning from being overlooked and can detect both local and wide-area thinning without missing. In addition, the depth of detected thinning part can be measured within the range of error of ±0.3 mm. In the future, we are going to conduct verification with actual heat transfer tubes toward full-scale application to actual facilities.

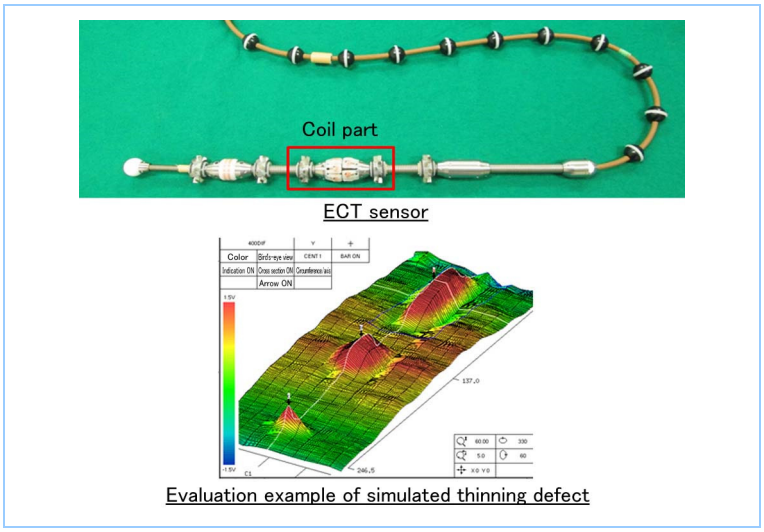

Figure 4 Appearance of the inner ECT sensor and the evaluation example of simulated thinning defect

3.3 Creep damage detection technique by phased-array UT

On large-diameter pipes such as boiler header and main steam pipe, creep damage occurs at parts affected by welding heat in long hours of use at high temperatures. Creep damage generate a significant amount of creep voids at grain boundary. The creep voids are congested and connected, and then, they become cracks, and finally penetrate wall thickness, causing a leakage. In order to prevent creep fracture and conduct maintenance as planned, it is desirable to detect creep voids before they become cracks. Therefore, we developed the creep damage detection technology using the phased-array method which is one of the ultrasonic flaw detection methods.

Figure 5 shows the phased-array probe we have developed. This probe was designed with the optimum probe conditions found from the supersonic simulation to detect the congestion state of creep voids. **Figure 6** shows the comparison between the flaw detection result and the cross sectional state on the actual pipe. This shows that with the developed phased-array probe, the congestion state of creep voids can be detected.

On the actual boiler pipe, the inspection was conducted using a dedicated scanner in order to improve the data reliability and the workability. The operation time was reduced to about 50% of that of the conventional method. Thus, the application of this technology enables the early detection of creep damage, prevention of serious problems such as steam leaks and implementation of effective maintenance as planned.

Figure 5 Phased-array probe

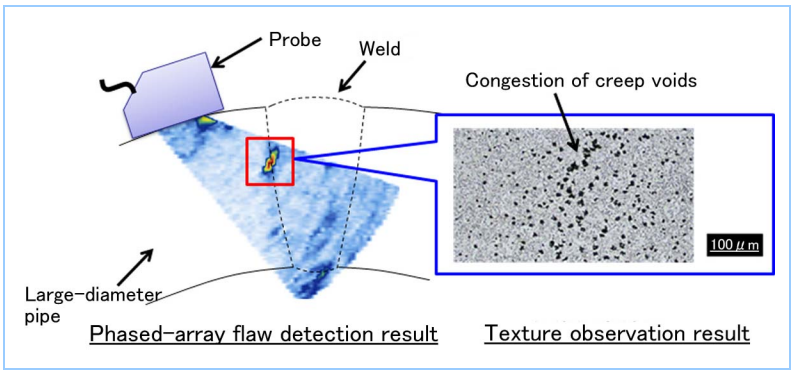

Figure 6 Comparison between the result of flaw detection by phased-array UT and the state of the actual pipe

3.4 Thickness monitoring technique by thin film UT

For boiler heat transfer tubes and pipes, the state of thinning is managed by periodical thickness measurement. On HRSG heat transfer tubes, FAC (flow accelerated corrosion) which causes thinning at a relatively high-speed has been observed. As such, thickness management is important. With the conventional method, supplementary work such as the removal/restoration of thermal insulation, setting-up of scaffolding and the polishing of the tubes is required, and the workability and reliability of inspection are degraded at narrow portions. As a result, there has been a need to develop a method to solve these problems. Therefore, we have developed a thin film UT sensor [(2)] with great flexibility that enables highly reliable thickness monitoring at low cost.

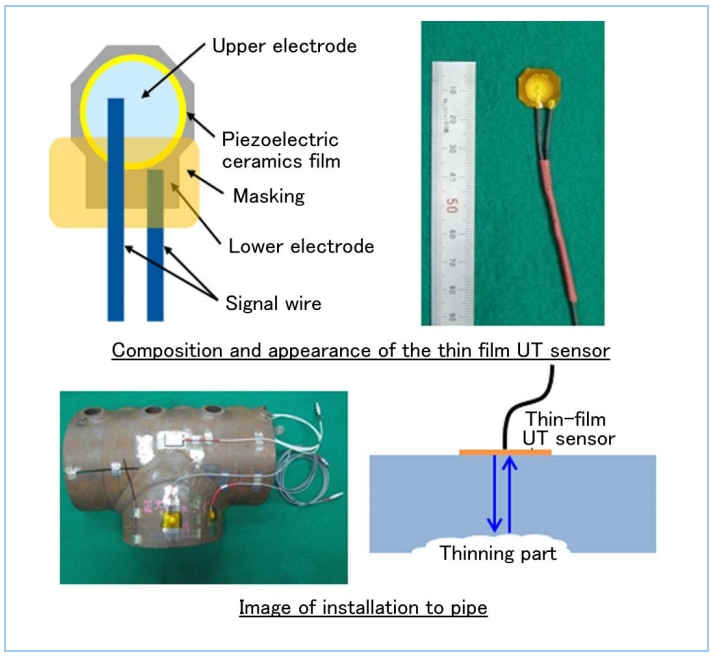

Figure 7 Outline of the thin film UT sensor

Figure 7 shows an outline of the thin film UT sensor. The sensor is comprised of upper and lower electrodes, piezoelectric film and signal wires, and it is a thin film with a thickness of 1.0 mm or less with great flexibility, and has a heat resistance of up to about 300℃. After the part for which the thickness is measured is polished, the sensor is fixed by adhesive curing, so that the thickness can be monitored in the state with thermal insulation restored. Therefore, no supplementary work such as the setting-up of scaffolding is required, resulting in the substantial reduction of long-term maintenance costs. In addition, by continuous monitoring, the tendency of

thinning can be understood, and the method is expected to be effective for thickness management especially of FAC, which has a relatively high thinning speed. Furthermore, since it has flexibility, the thickness of part near the weld toe, which was difficult to measure using the conventional UT and other methods, can be measured, and it is expected that highly reliable maintenance can be implemented. In the future, application to complex shapes and actual verification tests will be continued toward full-scale application.

4. Conclusion

We have been making efforts to develop various inspection techniques for boiler parts/forms of damage in order to improve the operation rate of thermal power plant boiler facilities. In this article, inner UT/cable-less inner UT technology, which is a thickness measuring technology for boiler heat transfer tubes, tube-inserted ECT technology which enables the detection of corrosion thinning of the inner surface of tubes phased-array flaw detection technology which enables the detection of creep damage at large-diameter piping welds and thin film UT technology, which enables the monitoring of thinning, were introduced. We will continue the application of these technologies to actual facilities and also promote further upgrades in order to contribute to the improvement of the operation rate of thermal power plant boiler facilities. The inspection technologies introduced here will be applied not only to boiler facilities, but also to chemical plants and various piping facilities.

References

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