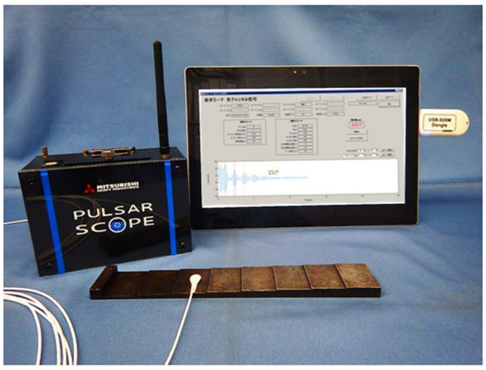
Development of Remote Monitoring System for Operating Power Plants Using Thin-film UT Sensors



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Mitsubishi Heavy Industries, Ltd. (MHI) has developed an ultrasonic pulsar receiver with a radio communication function that allows wireless transmission of measurement data obtained by an ultrasonic sensor such as a thin-film UT sensor to a remote location. The ultrasonic pulsar receiver, in combination with a thin-film UT sensor, is installed in piping, etc., thereby realizing continuous remote monitoring of the high-temperature piping during operation. The developed ultrasonic pulsar receiver is driven by dry cells so that it can be used in locations where there is no power supply and is miniaturized to palm size so that it can be installed anywhere. This report describes the technical specifications of the developed ultrasonic pulsar receiver and the development of the application of the remote monitoring system in combination with the thin-film UT sensor.

1. Introduction

In power plants, pipe wall thinning due to corrosion during system operation is a well-known issue, and it is important to monitor the state of pipe wall thinning in order to increase the efficiency of replacement plans for maintaining the soundness of facilities. Under present circumstances, fixed-point measurements of pipe wall thickness are carried out regularly at many plants in accordance with guidelines and standards. In some cases, in addition to the measurement of pipe wall thickness, the measurement of the water level in a horizontal pipe is conducted regularly to detect air pockets in pipes in the system. In such regular measurements, it is difficult to find any significant wall thinning or air pockets immediately by just a single measurement, and it is necessary to increase the frequency of regular measurements in order to detect any abnormalities before pipe wall thinning or air pockets adversely affect facilities. But the pipe temperature is high during system operation, and it is difficult to conduct continuous measurements using a general UT (Ultrasonic Testing) sensor. For measurement during operation halts when the pipe temperature becomes normal, the included work such as the installation and removal of heat insulation materials and temporary scaffolding are required at each measurement, and the increase in the frequency of measurement results in an increase in inspection cost. In order to solve these problems, a monitoring system[2] was developed, in which a thin-film UT sensor[1] which can be continuously used at high temperature and an ultrasonic pulsar receiver with a radio communication function are combined. In this report, the outline of the monitoring system, the features of the thin-film UT sensor and the ultrasonic pulsar receiver with a radio communication function, as well as the development of the application of the monitoring system, are described.

2. Outline of the monitoring system

The configuration of the developed monitoring system is shown in **Figure 1**. This monitoring system is comprised of the thin-film UT sensor, the ultrasonic pulsar receiver with a radio communication function (hereinafter referred to as the pulsar receiver), a PC for the collection of

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data and a PC for monitoring. Since the thin-film UT sensor is thin and flexible and can be continuously used in a high-temperature environment, it is used in a state of being permanently installed inside of a heat insulating material even during system operation. The heat-resistant cable drawn out from the thin-film UT sensor through the inside of the heat insulating material is connected to the pulsar receiver installed in the vicinity of the pipe, etc., to be measured. Using this pulsar receiver, UT data can be obtained from multiple sensors at a specified frequency. It is assumed that this monitoring system is used by the two methods described below (**Figure 2**), and the data acquisition mode can be selected according to the operating conditions such as the use or non-use of radio communication and PC installation location.

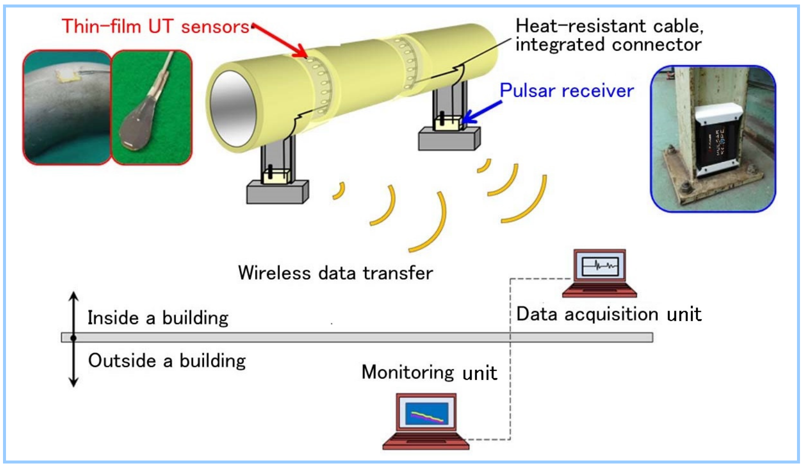

Figure 1 Configuration of the monitoring system

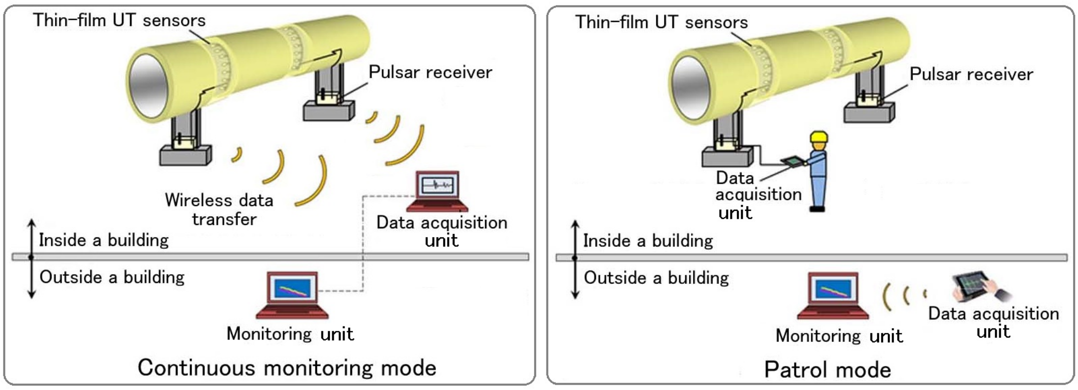

Figure 2 Operation modes of the monitoring system

(A) Continuous monitoring mode

The UT data acquired by the thin-film UT sensor is wirelessly transferred to a data acquisition PC which is setup in a building. On the data collecting PC, the UT data may be checked or analyzed, but access from the monitoring PC connected by LAN line, etc., to the data acquisition PC enables remote checking or analysis of the UT data. It is assumed that the monitoring PC is setup at a distant location such as outside of the building, and this configuration realizes continuous remote monitoring.

(B) Patrol mode

When the monitoring system is used in an environment where radio communication cannot be used because it may affect existing equipment, etc., the UT data acquired by the thin-film UT sensor is recorded in the memory of the pulsar receiver in advance, and the data acquisition PC that is carried on regular field patrols, etc., is directly connected to the pulsar receiver to collect the UT data recorded in the memory. The collected UT data can be checked or analyzed on the data acquisition PC or the monitoring PC in the same way as in continuous monitoring mode. Although real-time monitoring cannot be conducted in patrol mode, included work such as heat insulating material work is not required and UT data during system operation can be the obtained. Therefore, the frequency of measurement can be increased while reducing costs.

With one data acquisition PC, multiple pulsar receivers can be set and data from several pulsar receivers can be collected, which allows the monitoring of a plurality of sections to be measured in a building. In addition, UT data collection parameters such as gain and frequency during continuous measurement can be changed on the data acquisition PC without direct operation of the pulsar receiver, and even in the case where it is difficult to access a measuring site, continuous monitoring can be realized.

3. Features of the thin-film UT sensor

The outline of the thin-film UT sensor has already been reported(1), and this report describes the latest state of the continuous heating test which has been continuously implemented for the verification of durability. In the simulation of the measurement of the wall thickness of a pipe which reaches high temperature, the heating test has been conducted with a specimen of the thin-film UT sensor installed on a test body pipe. An electric furnace is used for heating to keep the temperature constant, and the UT data of wall thickness measurement is obtained regularly from the outside of the electric furnace. In this test, the wall thickness of the test body pipe is not reduced, and it has been continuously observed that a constant wall thickness value is exhibited and there is no substantial change in signal sensibility or fluctuation of the waveform.

Using the thin-film UT sensor with the material of the piezoelectric element changed according to the test temperature, continuous heating tests have been conducted at constant temperatures of 200°C, 300°C and 450°C. The cumulative number of days when heating has been conducted since the start of the heating and the results of the measurement of the pipe wall thickness are given in **Figure 3**. At the right of the graph, one example of signal waveform during continuous heating is shown. As can be seen in Figure 3, the signal waveform showing that the pipe wall thickness can be stably measured at the time when 1500 days – the longest duration – has elapsed at the temperature of 300°C was obtained, and a constant wall thickness value has been acquired except for variations due to temporary changes in measurement conditions. During this test, there were temperature drops due to several power failures, but no effect of these temperature changes on the signal was observed. This continuous heating test will be continued to accumulate the actual continuous heating data.

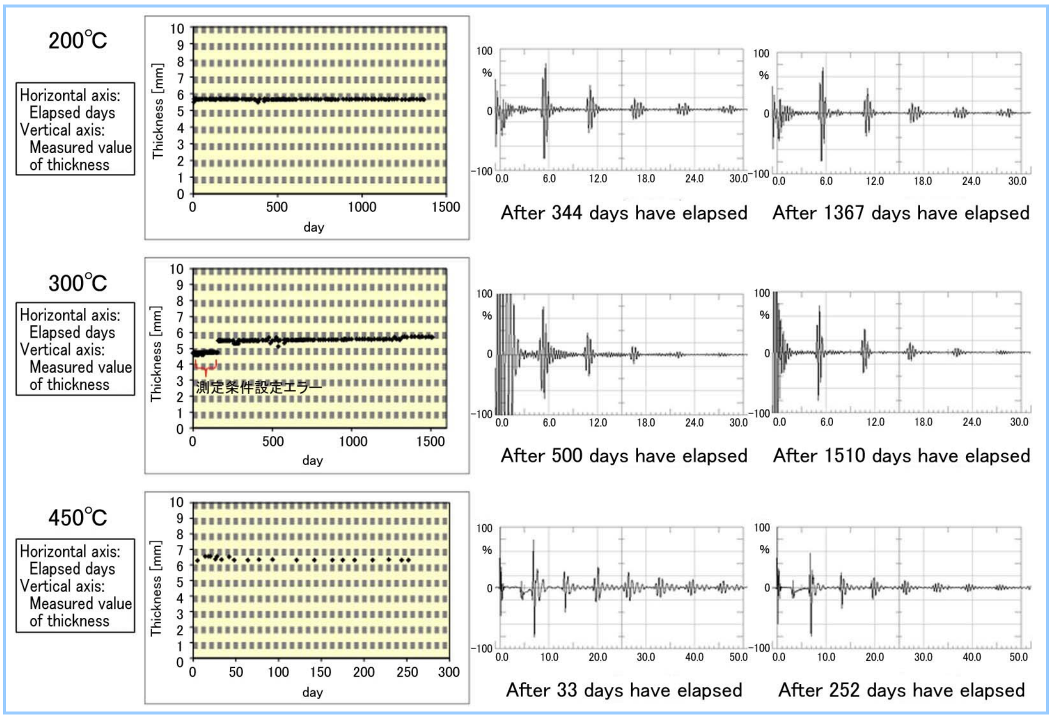

Figure 3 Result of continuous heating tests for the thin-film UT sensor

Based on the results of the in-house tests described above, the thin-film UT sensor has been installed in power plant facilities under operation for trial operation with actual units, and the signals have been regularly acquired. For the thin-film UT sensor installed in a steam system pipe (thickness: about 6 mm, system temperature: about 150°C) at a nuclear power plant, the signal waveform showing that the pipe wall thickness can be stably measured was obtained after about 800 days of system operation, and for the thin-film UT sensor installed in an exhaust heat recovery boiler pipe (thickness: about 5 mm, surface temperature: about 170°C) at a thermal power plant, the signal waveform was obtained after about 300 days of system operation. We will continuously conduct these measurements, and based on the results of the trials with actual units, not only will the performance and the durability of the sensor itself be validated, but the installation performance in the field, etc., will also be improved.

4. Characteristics of the ultrasonic pulsar receiver

Assuming that the developed pulsar receiver is installed in the environment of a plant building where it is planned to be installed or is additionally installed in an existing facility, it was designed with the following concepts:

(a) The power supply is driven by a battery and data is wirelessly transmitted so that it can be installed in locations where existing infrastructural facilities such as power sources are not available.
(b) A multi-channel type, by which multiple UT sensors can be connected at the same time, is adopted so that one pulsar receiver can monitor several portions.
(c) It is designed for low power consumption so that the replacement of the battery is minimized during long-term use.
(d) Data can be temporarily recorded in the pulsar receiver main unit so that it can be used in an environment where radio communication is not available.
(e) The enclosure is miniaturized so that it can be installed in narrow spaces around pipe support structures.

The appearance of the pulsar receiver developed that satisfies the above concepts is illustrated in **Figure 4** and the specifications are provided in **Table 1**. At some plant sites where the pulsar receiver has been introduced, EMC (Electro Magnetic Compatibility) performance is required. Therefore, for operation in the actual environment, additional installation of a filter, ferrite beads, etc., and the strengthening of grounding were implemented as EMC measures in the design of the substrate. After the development, the EMC test for this pulsar receiver was conducted at a specialized agency with ISO/IEC17025 laboratory accreditation, and it was confirmed that this pulsar receiver satisfies the EMC requirements defined by CISPR-11 (the international standards referred to in Japan and the EU) and FCC Part 18 (U.S. standards).

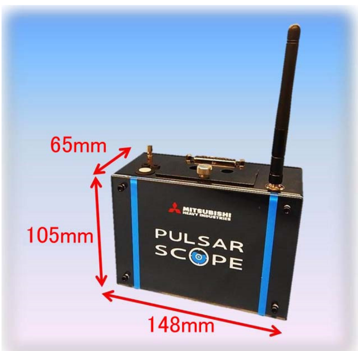

Figure 4 Appearance of the developed pulsar receiver

Table 1 Specifications of the developed pulsar receiver

Item	Specifications
Number of channels	8 channels
Power supply	Four AA alkaline batteries
Battery life	1 year In the case of measurement once a day for 8ch, 2000 samples
Communications system with PC	Wireless or wired
Dimensions of the main unit	100×150×75mm

5. Development of application of the monitoring system

The combination of the thin-film UT sensor and the pulsar receiver allows the realization of various kinds of UT monitoring. Some examples are descried below.

(1) Wall thickness monitoring (**Figure 5**)

As a measure for reducing pipe wall thinning due to flow-accelerated corrosion, water quality and operating conditions have been improved. The thin-film UT sensor is installed in locations where significant wall thinning is observed to obtain data at high frequency using the pulsar receiver, thereby enabling an understanding of changes in the wall thinning state in real time when water quality or operating conditions change, as well as the optimization of the water quality and operating conditions for the reduction of wall thinning.

(2) Water level monitoring (**Figure 6**)

The thin-film UT sensor is installed in equipment where air pockets may exist to obtain UT data at a given frequency, thereby enabling the monitoring of the water level. Through the early detection of abnormal water levels, it becomes possible to prevent water hammer events, abnormal vibrations of the pump, etc., toward the improvement of the safety of the equipment. This monitoring system can be also used for the verification of the air vent effect of a vent line.

In fact, in the corrosion wall thinning verification test implemented at an outside laboratory, this monitoring system was applied and the wall thickness of a pipe which was heated to 200°C or higher was continuously measured for over 1500 hours. The wall thickness measurement values obtained by the pulsar receiver and the actual values measured after the test showed a similar wall thinning state. It was verified that this system can monitor wall thinning during heating.

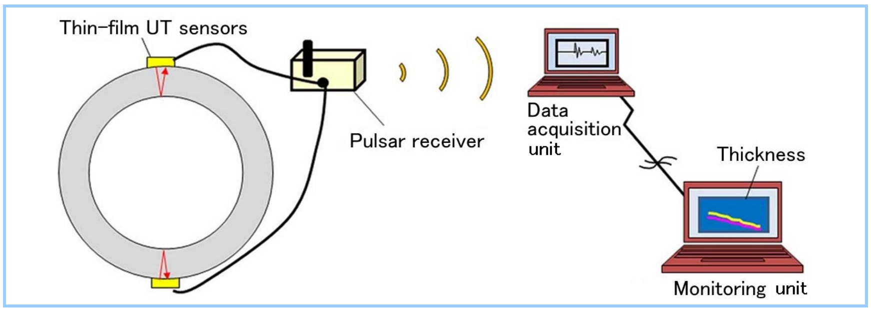

Figure 5 Wall thickness monitoring

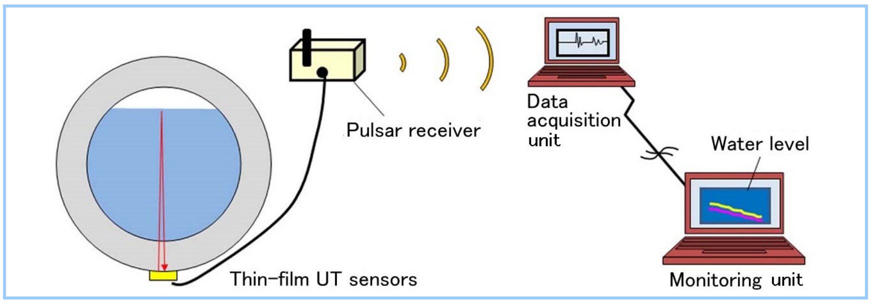

Figure 6 Water level monitoring

6. Conclusion

As an alternative to regular wall thickness measurement using a portable measuring apparatus, which was conventionally conducted at power plants, MHI has developed the UT monitoring system in which a thin-film UT sensor that can be permanently installed in a pipe to be measured and a pulsar receiver driven by a battery and that has a radio communication function are combined. Through the application of this monitoring system, the accuracy of thickness evaluation is improved by an increase in data acquisition frequency, and the wall thinning state can be observed in real time. Therefore, it can be expected that inspection costs can be reduced through the reduction of included work. This monitoring system can be used not only for the monitoring of pipe wall thinning, but also for the monitoring of air pockets by measuring the water level in a pipe.

In the future, we will further expand the application of this technology to actual plants and contribute to the increased safety, reliability and economic efficiency of plants. Wide-ranging application to UT monitoring needs other than the monitoring of pipe wall thinning and air pockets will be also studied.

References

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