Development of the magnetic inspection apparatus for detection of corrosion under insulation

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Abstract
The pipe under insulation which is used at plant consists of a pipe covered with thick insulation and the magnetic exterior plate, and there is no non-destructive inspection method for Corrosion Under Insulation (CUI). This is because there is a lift off caused by the insulation and the defect signal is attenuated by the magnetic exterior plate. Therefore, we developed a new pulsed remote field eddy current magnetic inspection apparatus which combines the pulse eddy current inspection and the remote field inspection, and the non-destructive inspection from outside of the pipe under insulation was performed. From the measured results, it is concluded that the developed new apparatus of pulsed remote field eddy current magnetic inspection can be applied for CUI.

Keywords: non-destructive inspection, magnetic inspection, eddy current, pipe, corrosion

1. Introduction
The pipe under insulation which is used at plant is widely used to transport variety of materials. The pipe under insulation consists of a pipe covered with thick insulation and the magnetic exterior plate. Corrosion Under Insulation (CUI) which is caused by standing water in the insulation is a big problem to operate the plant safety. Thus, a periodic inspection of pipe is necessary. Until now, various types of non-destructive inspection methods have been developed, for example, magnetic inspection and ultrasonic inspection, and so on. However, the magnetic inspection is difficult to inspect CUI because there is a lift off caused by the insulation and the defect signal is attenuated by the magnetic exterior plate. Also, the ultrasonic inspection is unsuitable for CUI because ultrasonic inspection is difficult to detect corrosion under multi layer construction. For these reasons, when we inspect CUI, we have to remove the insulation and the exterior plate. In addition, some methods require to eliminate the material flowing in the pipe and the operation of whole system related to the pipe should be stopped. These lead to that the inspection of CUI becomes high cost and needs long inspection time. Therefore, in this study, we investigated to detect CUI without removing the insulation and the exterior plate using magnetic inspection method. Although we tried the pulse eddy current inspection for CUI in the previous study, we could not inspect the defect under insulation with the exterior plate. To improve this problem, we developed a new pulse remote field eddy current magnetic inspection apparatus which combines the pulse eddy current inspection and the remote field inspection, and the non-destructive inspection from outside of the pipe under insulation was performed.

2. Developed pulse remote field eddy current magnetic inspection apparatus
Fig. 1 shows our developed system. First, we excited the pulse current (50 Hz, 4.5 A, Duty 25%) to the input coil by the transmitter and function generator. Then, two types of magnetic flux, direct and indirect magnetic flux, are generated. Here, the direct flux means that propagates the free space and the indirect flux means that propagates inside the pipe. When there is a defect on the pipe, the distribution of indirect magnetic flux changes and the indirect magnetic flux leaks through the insulation and exterior plate. This leaked indirect magnetic flux is detected by magnetic sensor, and we can detect the defect. When there is
distance between input and detection device, the indirect magnetic flux does not decay slightly while the direct magnetic field decays rapidly. For this reason, the remote field inspection is laid off input and detection device. The pulse method used in this study is some advantages that it has many frequencies leading to obtain many information from the detected signal and needs less electric power than sinusoidal current\cite{3} \cite{4}. As a magnetic sensor, Magneto Resistance (MR) sensor was used in this study because it can detect the direct magnetic field and has high sensitivity and resolution than the coil which has been used generally.

The measurement sample dimension used in this study is shown in Fig. 2. The sample length is 600 mm, diameter is 265 mm, the insulation thickness is 50 mm. We measured three samples which has three kinds of artificial slit defect in the centre of the pipe which assumes corrosion defect (non-defect, 25% defect, 50% defect). The picture of slit defect is shown in Fig. 3. The measurement was performed to the defect detection by measuring 200 mm of centre.

3. Result and Discussion

First, we removed the exterior plate and measured the magnetic signal on the insulation to clarify the influence of the insulation thickness. This result is shown in Fig. 4. The magnetic signal direction of Fig. 4 is

![Fig. 1. Schematic representation of developed pulse remote field inspection apparatus.](image1)

![Fig. 2. Cross-sectional view of the pipe with insulation and exterior plate.](image2)

![Fig. 3. Slit defect prepared on the outer surface of pipe.](image3)

![Fig. 4. Time waveform of magnetic signal without the exterior plate.](image4)

![Fig. 5. Normalized magnetic signal without the exterior plate.](image5)
Y axis shown in Fig. 1, because indirect magnetic flux and defect are verticality. As shown in

![Normalized signal](image1.png)

(a) The first measured point.

![Normalized signal](image2.png)

(b) The measured point at defect.

![Normalized signal](image3.png)

(c) The last measured point.

Fig. 6. Normalized magnetic signal with the insulation and exterior plate.

Fig. 4, the signal variation for the sample with 50% and 25% were almost the same while the non-defect sample was different in the time region of increasing and decreasing of pulse. In the pulse method, the signal which is caused by the deep position’s defect appears in the time region of decreasing pulse. Therefore, to compare the defect signal and normal signal easily, we normalized the peak signals and estimated the difference of signals. This result is shown in Fig. 5. As a result, it was found that the decrease rate of the detected magnetic signal was large when the pipe has defect. This is estimated that the residual time of eddy current changed because the pipe thickness changed by the defect.

Next, to investigate the influence of the magnetic exterior plate, we tried to the line measurement using the pipe with both insulation and exterior plate. This result is shown in Fig. 6. It was found from this result that the decrease rate of the detected magnetic signal showed a little difference in all experimental points when the pipe has defect. Moreover, the difference between the 50% and 25% signal was also observed. However, this difference was very small at each measured point. This is estimated that the detection area is large because probe is large and defect signal is attenuated by the magnetic exterior plate. From above results, the developed new apparatus of pulsed remote field eddy current magnetic inspection can inspect a defect without the influence of the exterior plate by evaluating the decrease rate of each pulse, and this apparatus can be applied for CUI detection.

4. Conclusion

We have developed the magnetic non-destructive inspection apparatus for detection of corrosion under insulation (CUI) from outside of the pipe under insulation. The signal intensity measured by the developed system depended on the defect size and this signal could be measured from outside of the pipe with insulation and exterior plate. Therefore, the
developed pulse remote field magnetic inspection can be applied for CUI. Using the new inspection apparatus, the measurement time and cost can be reduced, and also can enhance the safety because CUI inspection is very difficult.

References