Evaluation of Crack Location in Straight Pipe by Using Microwave

Abbasi KAVOOS, Department of QSE, Tohoku University — Non member
Ito SATOSHI, Department of QSE, Tohoku University — Non member
Hashizume HIDETOSHI, Department of QSE, Tohoku University — member

Abstract. A NDT method using electromagnetic waves has strong possibility for crack detection in large structure such as large pipes. In this study, electromagnetic wave with a TM_{01}-mode is used for detecting a circumferential crack and also time of flight (TOF) of the electromagnetic wave in several pipes is evaluated to determine the crack location.

Keywords: NDT, Electromagnetic wave method, Straight pipe, Mode converter, Time of Flight

1. Introduction

Piping system of nuclear power plants must be routinely inspected to guarantee the safety of operation. NDT methods with high speed and high accuracy must be developed to obtain both safeness and prolong operation availability. At present, typical NDT methods are eddy current testing (ECT) and ultrasonic technique (UT) [1]. These methods are unsuitable for the large pipe because it takes a long time to detect a crack or exciting coils must get larger. On the other hand the NDT method using electromagnetic waves has strong possibility to detect the crack in large structures because the electromagnetic wave can propagate through the pipe widely. Through previous studies [2, 3], it has been shown that the electromagnetic wave with a cylindrical TM_{01}-mode reflected or transmitted at the crack have some information of a circumferential crack. As a next step, time of flight (TOF) in several pipes is evaluated to determine the crack location in this study.

2. Experimental setup

The experimental system is shown in Fig.1. Electromagnetic waves with rectangular TE_{10}-mode, which are generated by the network analyzer, are converted to the cylindrical TM_{01}-mode by the mode converter. The electromagnetic waves are propagated into the inspected pipe with a circumferential crack whose width is 0.3mm or propagated in the pipes with a spacer who plays role as the circumferential crack. By changing plunger location which is distance between plunger and center of rectangular waveguide, it is possible to resonate electromagnetic wave inside the system. The electromagnetic waves are reflected and transmitted at the crack. The characteristics of the reflected and transmitted waves are measured by the network analyzer.

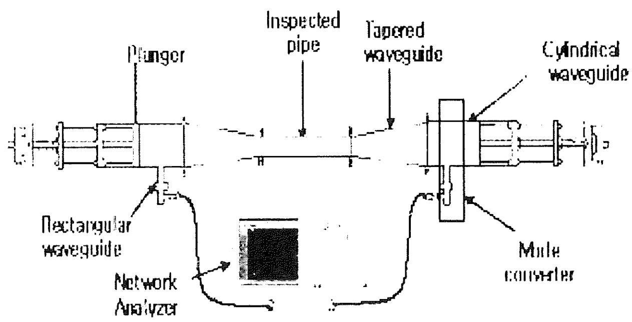

Fig.1. Experimental system

3. Results

In this study the experiment has been done by selecting

POC:Abbasi KAVOOS, Aramaki-Aza-Aoba, 6-6-01-2, Aoba-ku, Sendai, 980-8579, Tohoku University, Tel: 022-795-7906, e-mail:abbasi@karma.qse.tohoku.ac.jp

suitable frequency range (5GHz~15GHz) which is determined experimentally. Firstly, in order to estimate TOF clearly an aluminum foil is inserted in the circumferential crack to make high reflection. Circumferential crack was made by wire cutting and whose circumference is half of the circumference of pipe. Fig.2 to Fig.4 shows the difference of reflection coefficient in case between with and without the aluminum foil relative to time at the frequency range mentioned above. As the Fig.2 shows, there is a boarder between white and black area. This boarder shows the line of TOF for each plunger position. These TOFs agrees with calculated time which is 8.43 ns for L=90mm and 9.63 ns for L=180mm. In the fig.3 and fig.4 difference of reflection coefficient are shown for plunger position of 133mm. From the figures, high variation of the reflection coefficient begins at a specific time. This time show the TOF for each case. The calculated time is 9ns and 11.98 ns for crack located at 400mm and 800mm respectively. The crack location could be determined by evaluation of TOF.

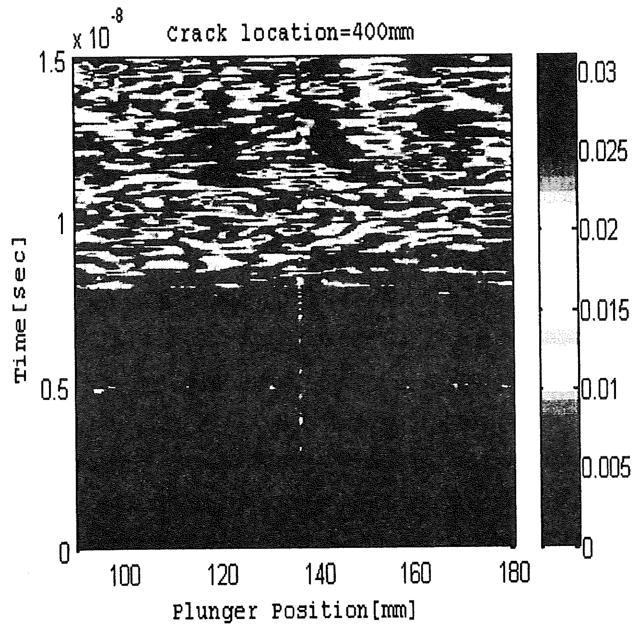

Fig.2 Difference of reflection coefficient in term of time and plunger position

Because of high reflection due to aluminum foil, reflections at another part of experimental system such as jointing point can be ignored, as it can be seen from Fig.3 and Fig.4.

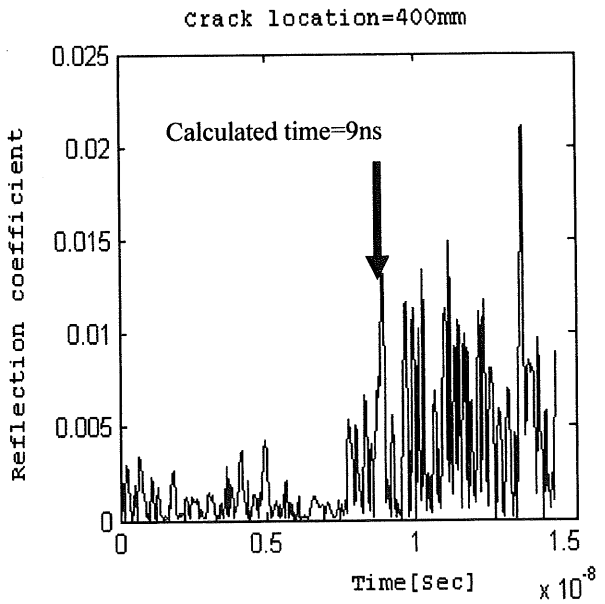

Fig.3. Variation of difference of reflection coefficient versus time for crack located at 400mm and plunger position of 133mm

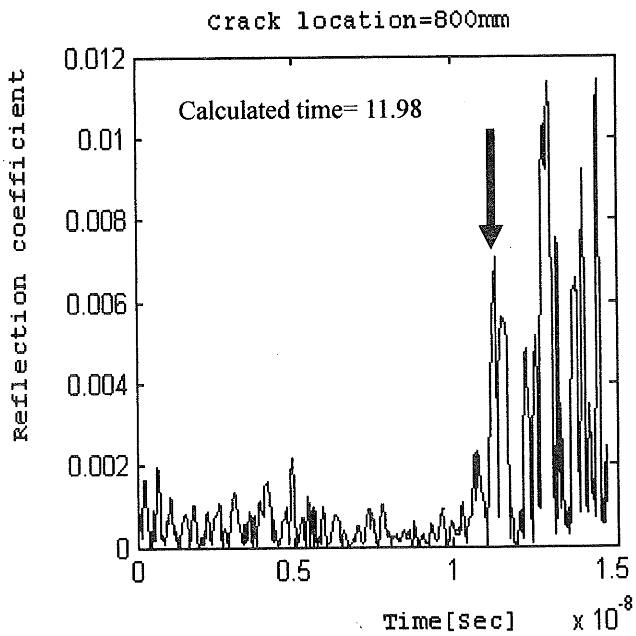

Fig.4 Variation of deference of reflection coefficient versus time for crack located at 800mm and plunger position of 133mm

In the second step, the spacer is used to make a crack. Diameter is greater than the diameter of inspected pipe. The spacer is inserted between two pipes instead of real crack.

The following results has been obtained for the spacer located at 600mm. Fig.5 and Fig.6 show the variation of reflection coefficient for the spacer width of 0.1mm and 0.5mm versus time. As the result shows there are three regions with highest reflection. The first maximum is due to jointing point of pipe with tapered waveguide and second one is due to the crack.

The calculated TOF for the first maximum is 4.68 ns and for the second maximum are 9.16 ns. Figure 7 shows the background which is reflection coefficient for this case when the spacer has been removed between two pipes. Comparing this figure with figures 5 and 6 shows clearly the response of the electromagnetic waves to the crack.

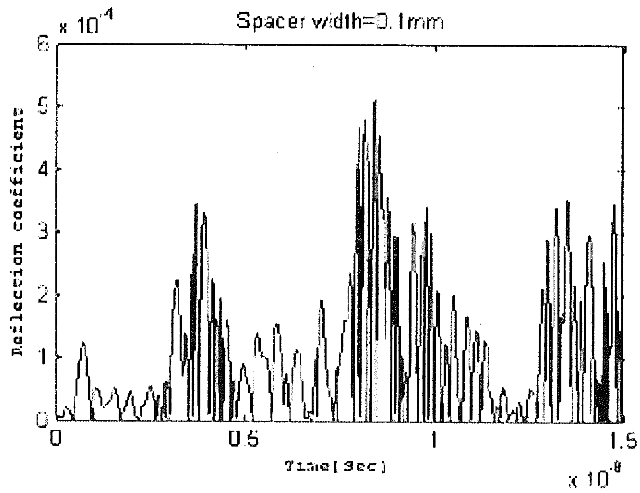

Fig.5. Variation of reflection coefficient versus time for spacer of 0.1mm width located at 600mm and plunger position of 133mm

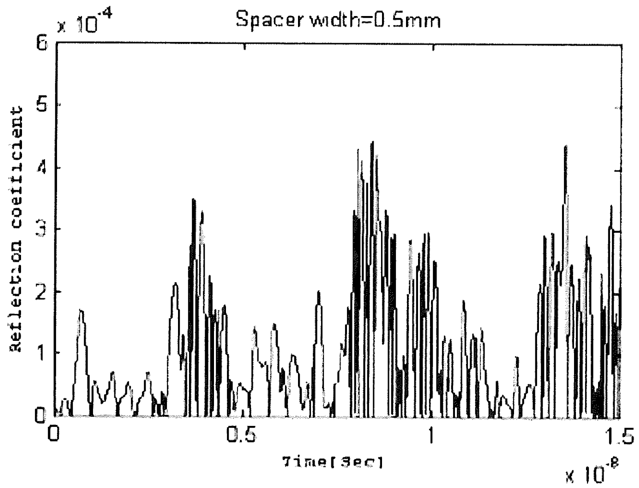

Fig.6 Variation of reflection coefficient versus time for spacer of 0.5mm width located at 600mm and plunger position of 133mm

Comparing Fig.5 and Fig.6 with Fig.3 and Fig.4 show that reflection in the case with the spacer is 10^{-2} times of order less than the case with the aluminum foil. In addition, small noise is appeared in the area between maximum points. As mentioned above in the case of the aluminum foil these noises are ignorable in comparing with reflections due to the foil.

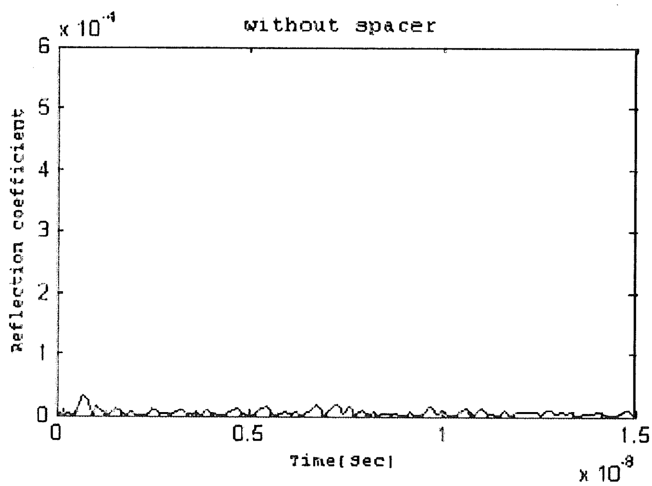

Fig.7 Variation of reflection coefficient versus time for the case without spacer

In the next step, an experiment is performed in the case of real crack. In this experiment, difference of reflection coefficient between with crack and without crack is evaluated. Fig.8 and Fig.9 show the results for crack located at 300mm and 700mm. Although these results show that difference of reflection coefficient in this case is 10^3 times smaller than that in case of aluminum foil, it is also possible to get information about TOF. Fig.9 shows that the TOF is a little longer than calculated one. In this case, the calculated time for 300mm and 700mm regarding to plunger position, are 7.97ns and 11.2ns, respectively. This fact shows plunger position, which controls mode of microwaves, is important for this NDT method.

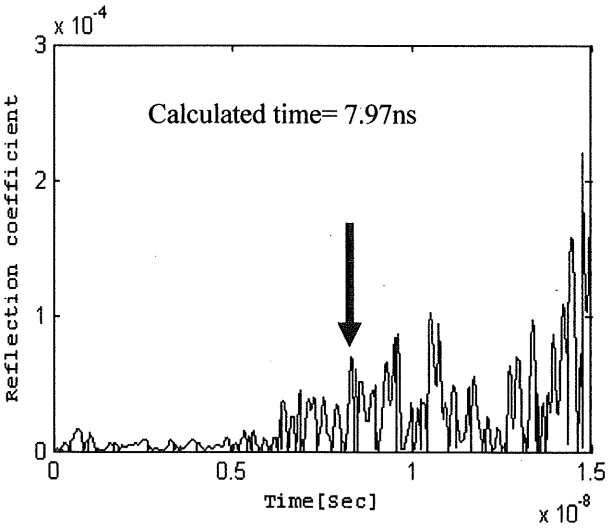

Fig.8 Difference of reflection coefficient for crack location=300mm and *l*=112mm

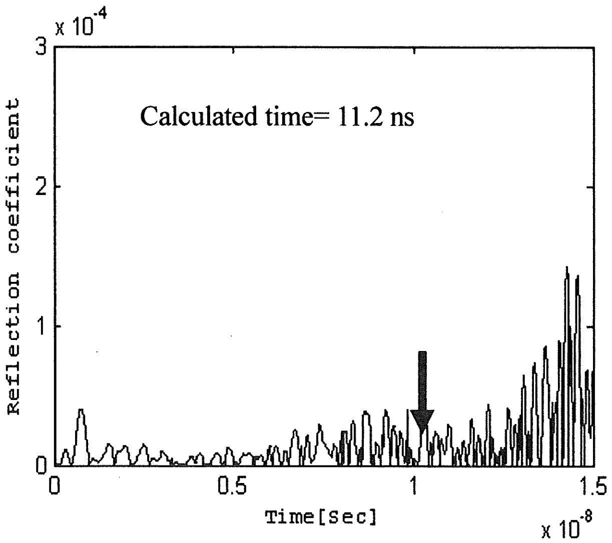

Fig.9 Difference of reflection coefficient for crack location=700mm and *l*=133mm

4. Conclusion

As the result shows the electromagnetic wave has capability to detect circumferential cracks in the pipes. ecause of sensitivity of electromagnetic wave to defect ,all defects such as jointing point of two pipes whose size is comparable to size of crack has affects on electromagnetic wave and reflects some part of these waves. It is needed to separate information of electromagnetic wave into the real crack and the connection point. From the results, difference of reflection coefficient is very small (in order of 10^{-4}). Other signals from other defects can affect to the reflected signal from the crack and consequently it causes change in TOF. As a future work it is necessary to consider how to treat this complex signal to get information of crack accurately.

References

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