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EXAMINATION OF THE X-RAY PIPING DIAGNOSTIC SYSTEM USING EGS4

(MEASURING THE THICKNESS OF A PIPE WITH RUST WHEN THE PIPE IS FILLED WITH WATER)

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Abstract

In a series of papers entitled "Examination of the X-ray piping diagnostic system using EGS4" presented at the proceedings of the EGS4 users' meetings, I discussed the possibility of measuring the thickness of piping walls with rust. Last year, I described, based on our earlier results, how the thickness of steel pipes with rust can be measured in an empty pipe. The thickness of the steel determined by using the diagram that I made by using EGS4 simulation, agreed well with the actual steel thickness obtained by the experiments. In this paper, I describe how to use the same procedure to measure the thickness of pipes filled with water and the result which I obtained.

1. Introduction

The piping diagnostic system I described in my previous paper was developed to examine old pipes in buildings because such inspections require a system that is compact and easy to handle. This compact system also helps save times during inspections. In the past ten years, this system has been used to examine pipes in more than 500 buildings. Rust was not taken into account when the logic of the system was configured, so the accuracy of the system may change when there is rust in a pipe. This problem has been examined in the past using EGS4 as I have reported in my previous papers. Last year I measured the steel thickness of an empty pipe with rust using EGS4, and found a good agreement between the calculated thickness and the actual. In this study I measured the thickness of steel of a pipe filled with water.

2. Outline of the System

First an X-ray photograph of an old pipe is taken, and the image of the pipe is obtained on film. Then the thickness of the pipe is measured from the change in the density of the film image of the pipe, and the residual number of years of the pipe is calculated depending on its original thickness and the corrosion speed, which is also calculated from the image. The system outline is shown in Fig. 1. See also ref. [2].

3. Measuring the Thickness of Steel with Rust

3-1. Preliminary work done prior to this work

The whole system consists of an X-ray apparatus with an X-ray bulb, film, an intensifying screen and other components are shown in Fig. 1.

I did a series of computer simulations using an X-ray bulb, a steel block, an intensifying screen and an X-ray film, taking into account the X-ray spectrum. The simulations showed was done and showed that the density of the film correspond well to its energy absorption [2]. This result meant that it was possible to measure the thickness of steel with rust, and I thus decided to improve the system based on this simulation results for the measurement of steel thickness with rust. In a previous study, an X-ray photograph was taken of an empty pipe and the thickness of steel with rust was calculated. The calculated thickness agreed well with the measured one [3].

3-2. Measuring the thickness of steel with rust in a pipe filled with water

To measure the thickness of steel with rust in a pipe filled with water, I used the same method as the one used to measure the thickness of steel in an empty pipe. X-rays become weaker when they pass through a pipe filled with water, that is, they lose their intensity as they pass through layers of steel, water and rust. As a result, the energy that reaches the detector decreases, and the energy that is absorbed in the film becomes weaker. By analyzing the rust in the pipe, the components of the rust were obtained. A simulation model was configured as shown in Fig. 2, and an X-ray photograph was taken as shown in Fig. 3. Based on the results of the computer simulation using EGS4, an energy absorption diagram (Fig. 5) was drawn for the pipe filled with water.

By tracing the lines showing the relationship between steel thickness and energy absorption in the diagram sequentially, the thickness of the steel was obtained using the concept of total thickness and equivalent thickness for steel and rust (See Fig. 4). The detailed process is as follows. First, by using the existing piping diagnostic system, equivalent thickness is obtained for the components of steel and rust. The point for the obtained equivalent thickness of 19.8 mm is located on the x-axis of the diagram at 19.8 mm as shown in Fig. 5. Then a vertical line is drawn from this point to the uppermost oblique line that represents steel with no rust. From the point of intersection a line is drawn horizontally, and it meets with oblique lines at points that show the equivalent thickness of the components of the steel and rust in the pipe filled with water. Among these points there is one representing the total thickness of rust and steel that agrees with the true thickness. By finding the total thickness that is the closest to the true value, the steel thickness can be obtained. In the actual measurements, the total thickness was obtained through an X-ray photograph taken from the side direction. Numerical analysis was also used to find the closest value to enhance the accuracy of the measurements. The resultant error was reduced to about 10% (See Tab. 1).

4. Summary

The thickness of steel in a pipe filled with water was calculated using EGS4. The error was less than 10%. In the future I plan to computerize the process of measuring the thickness of steel with rust which is now being done manually.

Acknowledgement

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References

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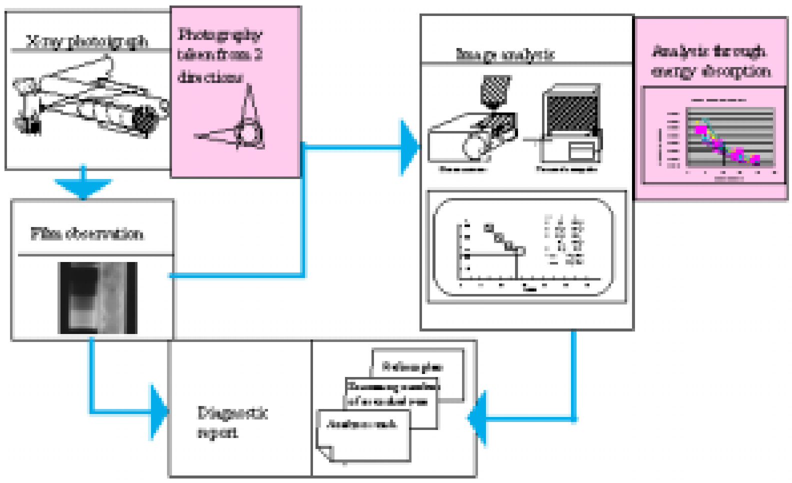

Fig.1 System outline. To treat the case when there is rust in pipes, two frames: Photography from 2 directions and analysis through energy absorption, are added to the original system.

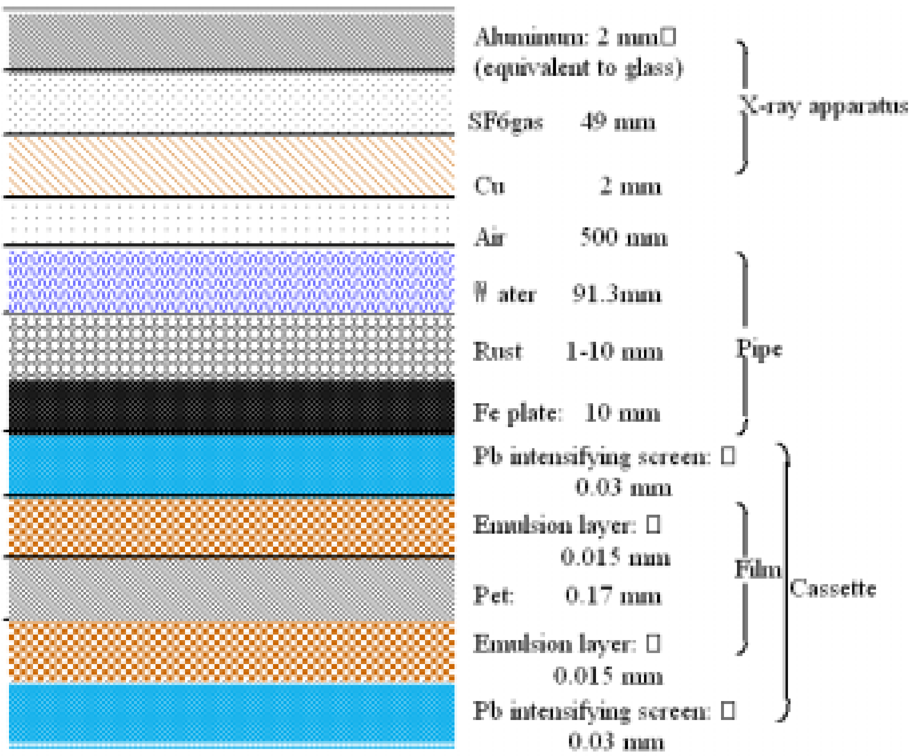

Fig.2 A model structure to simulate a steel, pipe with rust, filled with water.

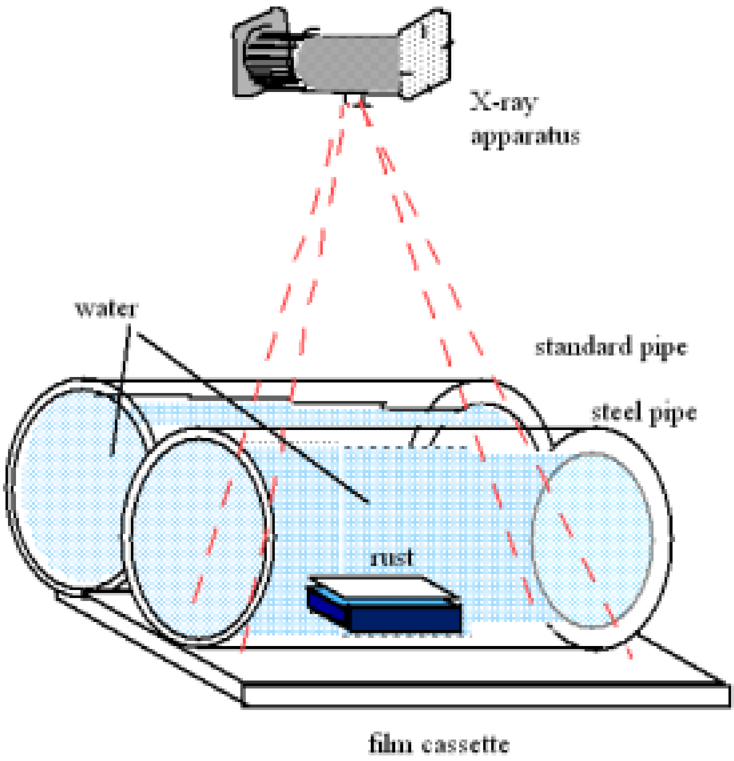

Fig.3 Taking an X-ray photograph of a steel pipe with rust, filled with water

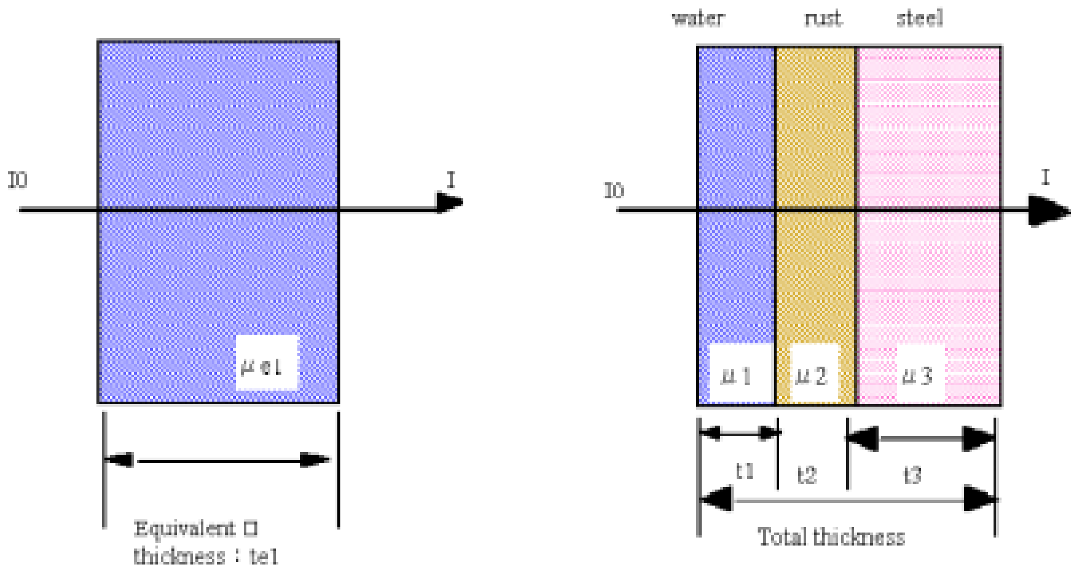

Fig.4 Total thickness and equivalent thickness

Table.1 Resultant thickness of calculation. Unit:mm

No	Rust Thickness	Calculated total Thickness	Calculated Steel Thickness	True Thickness	Exactness (%)
1	5	18.702	5.4952	6.1	0.901
2	10	18.142	5.5834	6.1	0.915
3	15	17.438	5.5052	6.1	0.903