Proceedings of the Ninth EGS4 Users' Meeting in Japan, KEK Proceedings 2001-22, p.115-118

EXAMINATION OF THE X-RAY PIPING DIAGNOSTIC SYSTEM USING EGS4 (MEASURING THE THICKNESS OF A STEEL PIPE WITH RUST)

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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. In the present paper, I describe, based on our earlier results, how the thickness of steel pipes with rust can be measured. I conducted EGS4 simulation to measure the thickness of a combination of steel and rust and made an energy absorption diagram for this combination. The equivalent thickness of steel was obtained through experiments and the system operation. The thickness of the steel determined by using the diagram agreed well with the actual steel thickness obtained by the experiments. In the future, we will focus on how to automate this measurement procedure and how to use the same procedure to measure the thickness of pipes filled with water.

1 Introduction

The X-ray piping diagnostic system we previously developed has been used to measure the thickness of old steel pipes in buildings in more than 500 cases in the past ten years. In the original system, the thickness of steel pipes was a major concern and rust was neglected because there was no way to measure it. However, the accuracy of a piping diagnostic system degrades if there is rust in the pipe. When I learned about the existence of the EGS4 code, I though that the thickness of pipes with rust could finally be measured. The work to improve the original system could thus be continued.

2 Outline of the System

Briefly, the system starts by taking an X-ray photograph of a pipe, calculates the thickness of the pipe from the change in the film density, and then calculates the residual life of the pipe depending on the obtained thickness. In this process, a standard pipe is used as a so-called ruler and the change in the film density of the old pipe obtained by x-rays is compared to that of the standard pipe. (See X-ray photograph frame in Fig. 1)

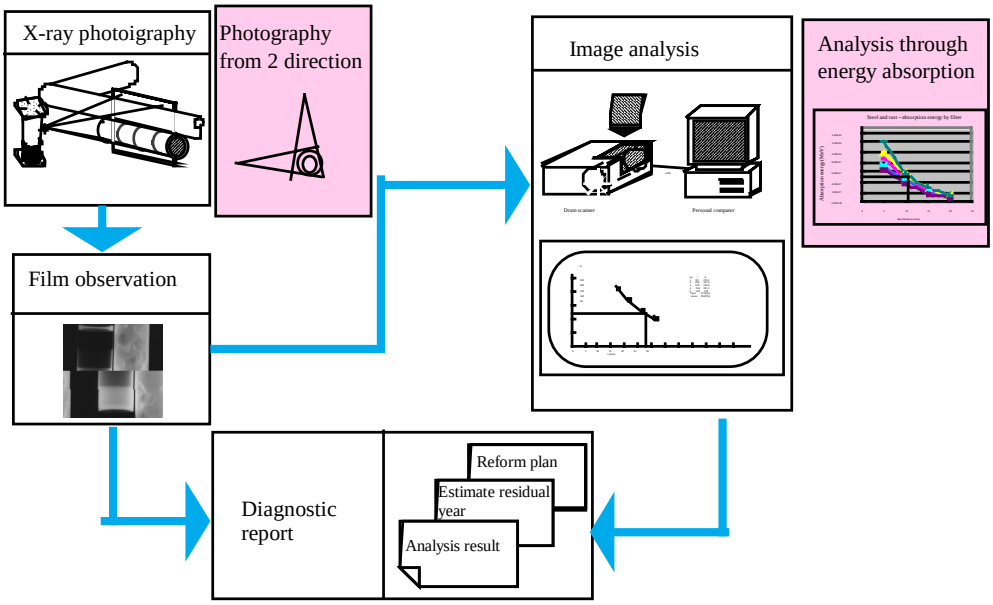

Fig.1 System outline
To treat the case when there is the rust, two frames:
Photography from 2 direction and Analysis through energy absorption, are added to the original system.

Figure 1: Model structure for simulation of steel and rust.

3 Determining the Thickness of a Steel Pipe with Rust

3.1 Preliminary work done prior to this work

The whole system was originally developed as an X-ray photography device using film as a detector. Computer simulation taking into account the X-ray spectrum has shown that the density of the film approximates well its energy absorption. This result shows that the thickness of a pipe can be simulated and measured by using film [1].

3.2 Measuring the thickness of steel including rust

When rust is present, the energy loss of the x-rays passing through the steel pipe increases. As a result, the energy of the X-rays that reach the film decreases, and so does the energy absorbed by the film.

The energy absorption for a combination of steel and rust can be obtained by analyzing the ingredients of the rust by EGS4 simulation. Following the simulation, an energy absorption diagram is made (See Fig. 6). Then we can calculate the combined thickness of the steel and rust from the equivalent thickness of the steel. The model for simulation is shown in Fig. 2. The total thickness and the equivalent thickness are used to obtain the thickness for the absorption diagram. This concept is shown in Fig. 3. The equivalent thickness is obtained by taking an X-ray photograph of the steel-pipe arrangement shown in Fig. 4 and by analyzing the film. X-ray photographs must

be taken from two directions to obtain the total thickness (See Fig. 5). Based on the above, the whole system is constructed (Fig. 1).

4 Verification of Results

In the energy absorption diagram, first, the equivalent thickness is set on the horizontal axis, and a cross point is obtained on the curve denoting a rust thickness of 0. Then, from that point, a straight line extended to the left shows the thickness of the steel with rust on the point where the line intersects the curve denoting the rust thickness.

We conducted three tests using X-ray photography for the arrangement in Fig. 4 and found that the results obtained by simulation and those obtained by measurement agreed well, as shown in Fig. 6.

5 Future Work

I plan to focus on automating currently manual operations and investigating how the same procedure can be used for pipes filled with water.

Acknowledgement

I am very grateful to prof. Hirayama of KEK (High Energy Research Organization) who assisted me in using EGS4.

References

1) G. Kajiwara,, "Examination of the X-ray piping diagnostic system using EGS4 (in case considering spectrum of X-ray)", Proceedings of the Eighth EGS4 users' meeting in Japan, 1999, p. 71 .

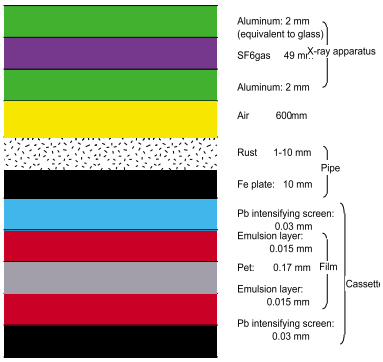

Figure 3: Model structure for simulation of steel and rust.

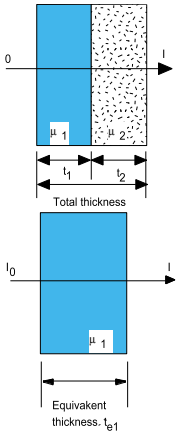

Figure 4: Total thickness and equivalent thickness.

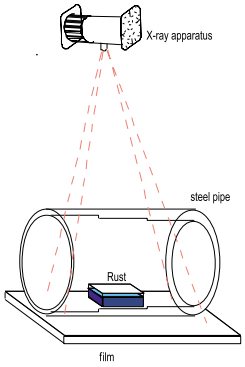

Figure 5: Arrangement of steel pipe and rust for X-ray photography.

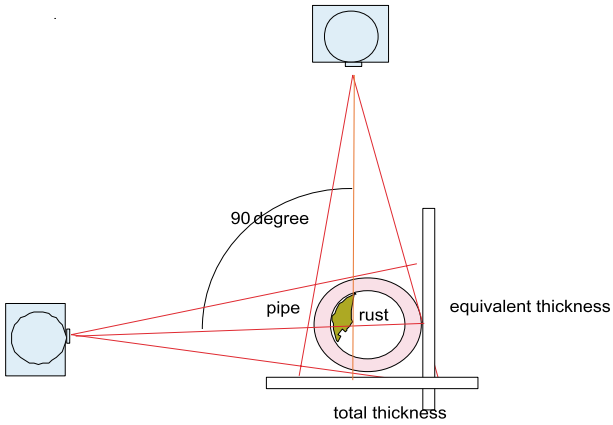

Figure 6: Taking X-ray photograph from two directions. By taking X-ray photographs changing the direction by 90 degrees, the total thickness of steel and rust can be obtained.

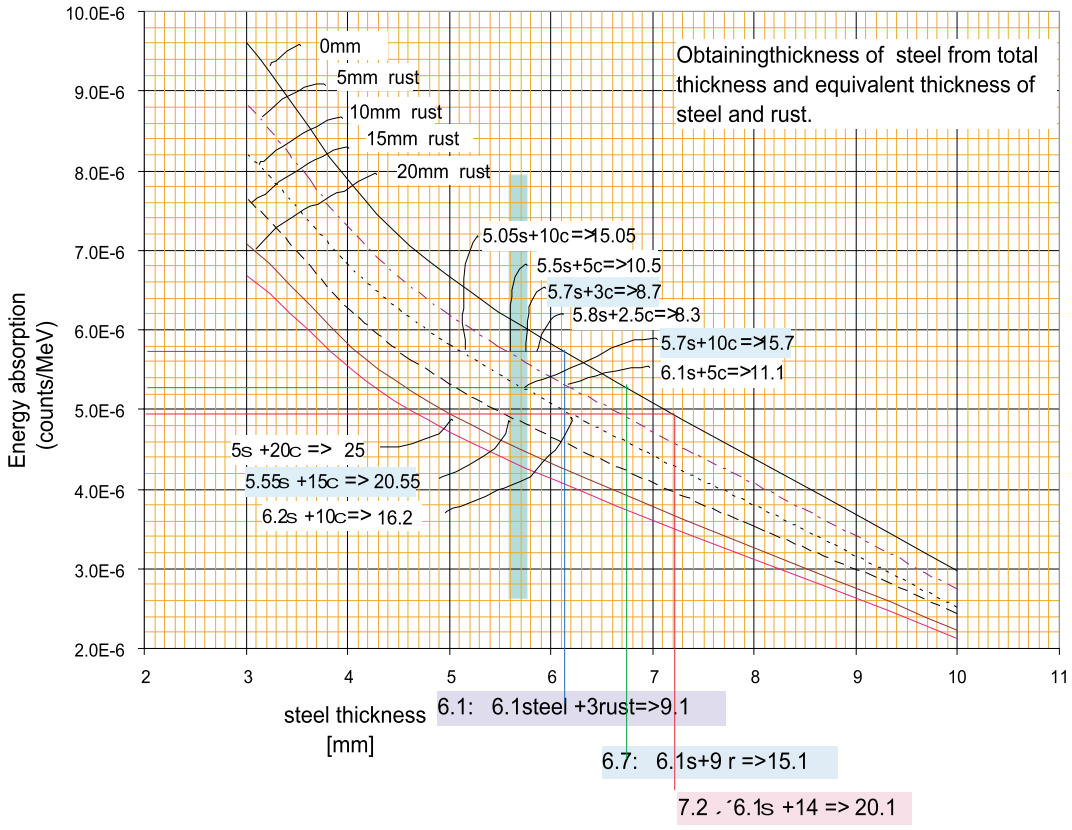

Figure 7: Steel thickness obtained by using energy absorption curve.