X-ray Imaging of External Corrosion on Insulated Steel Pipes

AIM OF THIS DOCUMENT
To present the technical solution regarding tangential imaging of insulated pipes using low energy X-ray real-time imaging.

INTRODUCTION
The basis of this work is the need for assessment of pipe structural integrity under cladding (insulation). The aim is to detect and quantify corrosion underneath the insulation.

With X-ray technology, the traditional method is tangential imaging using film as the detector. This is a slow, expensive, and difficult to automate technique. With the tangential imaging technique, X-rays are emitted towards the detector, and a detector is placed on the other side of the pipe.
As the detector enables real-time imaging, a dynamic inspection can be accomplished so that the structure of the pipe outer surface is portrayed at a scanning speed up to several tens of centimetres per second. The X- radiation source and the detector can be moved (translated) and rotated around the pipe, so a full picture of the pipe corrosion condition can be obtained in a very short time.

With the traditional film-based technology, such assessment can take hours or even days.

Hence, the advantages of accomplishing a real-time imaging of these structure is very substantial from an economic as well as from a safety and environmental perspective.

FUNDAMENTAL IMAGING PRINCIPLE

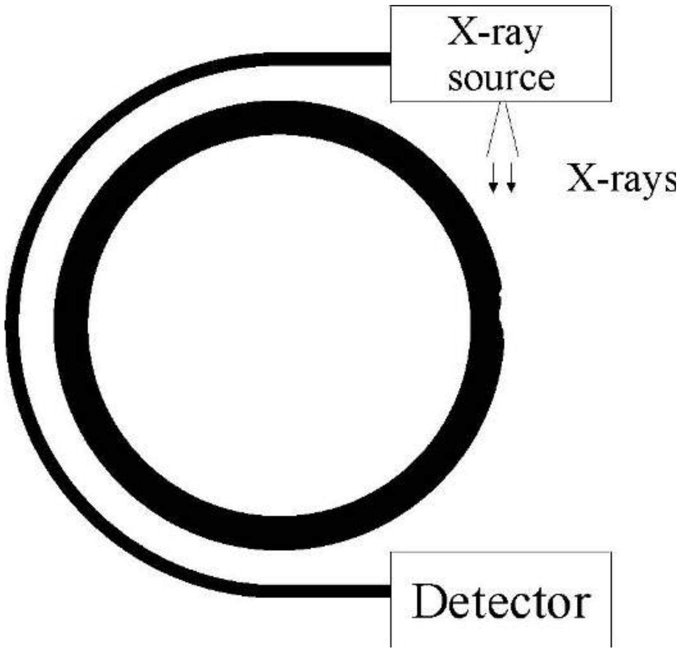

Fig. 1. The tangential imaging technique applied on an insulated pipe to detect corrosion under the insulation. The outer cover (atop the insulation) is usually aluminium or galvanised steel, 1 mm thick.

In Fig. 1 is shown a section of an insulated pipe with the position of the X-ray source and the detector, to provide a tangential section imaging of corrosion on the pipe external surface. The X-rays are blocked by the thick steel pipe, which appear as a black object. Surface roughness variations caused by external corrosion can be readily discerned by deviations in the otherwise straight line that the pipe outer surface represent.

Fig. 2. Corroded 6” test pipe. Corrosion pitting is up to 5-6 mm. Insulation removed to portray the corrosion pitting. Pitting is left to the “P” mark (upside down) in the middle.

HARDWARE CONSIDERED

The equipment necessary for the real-time tangential imaging is a compact mini focus X-ray source. The X-ray source is mounted on a pipe crawler which on its opposite side holds a scanning detector. This detector is of high resolution, high contrast, fast, compact, and light weight.

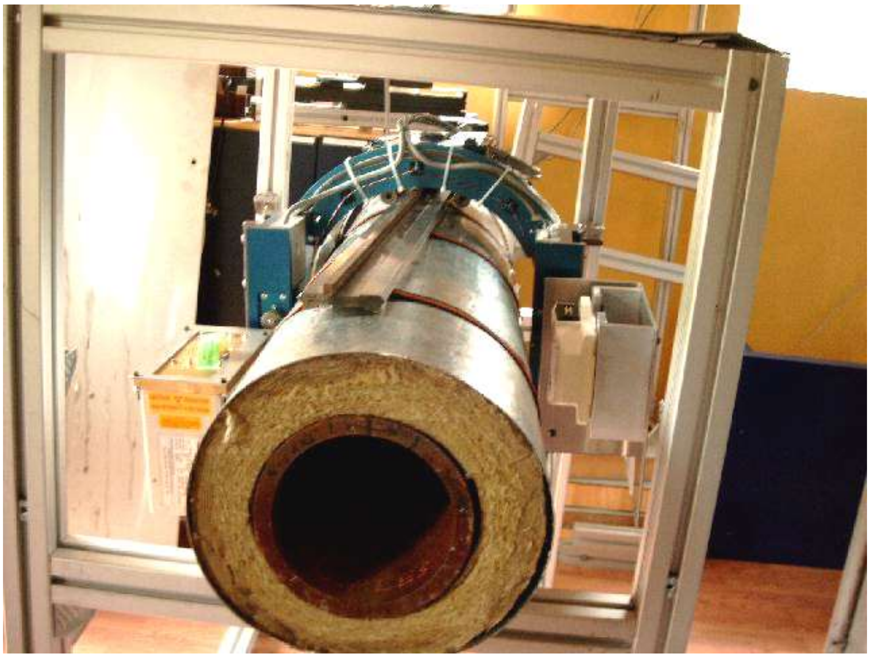

Fig. 3. Test set-up showing C-arm based crawler, mounbted with X-ray source and detector on an insulated pipe section.

IMAGING METHODOLOGY

The set-up is used to scan the test pipe for corrosion under the insulation. This is accomplished simply by moving the pipe crawler relative to the pipe. This movement can be rotational or linear (translation). During the movement, X-rays are emitted and the detector acquires the images continuously. Movement may be continuous, or discontinuous as required. Due to the set-up configuration where the pipe is positioned between the source and the detector, a magnification of about 1.6 is achieved.
The advantage of the scanning methodology is that at the low energy, the pipe is not at all penetrated. It remains black, whereas surface variations owing to corrosion immediately are seen as valleys or dips. The figures below clearly unveil that this technology enables a clear and distinct profiling of the surface corrosion of the pipe, facilitating a realtively simple task of automatic image analysis to detect corroded areas.

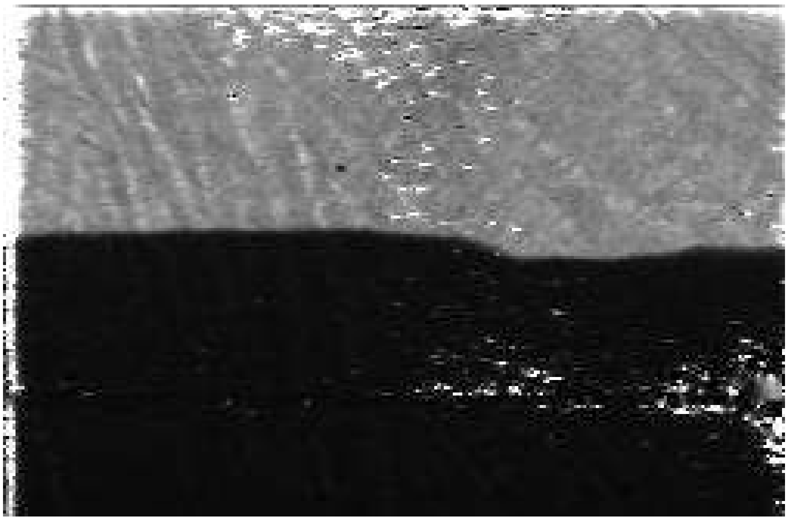

Fig. 4. Example of a single image acquired of the pipe tangential section, showing a clear surface roughness variation owing to corrosion of the pipe external surface. The image represents a 16 by 16 mm part of the images collated to form Fig. 7, below. Integration time 1 s. Note that even small surface roughness variations (in this case below 1 mm) can be detected.

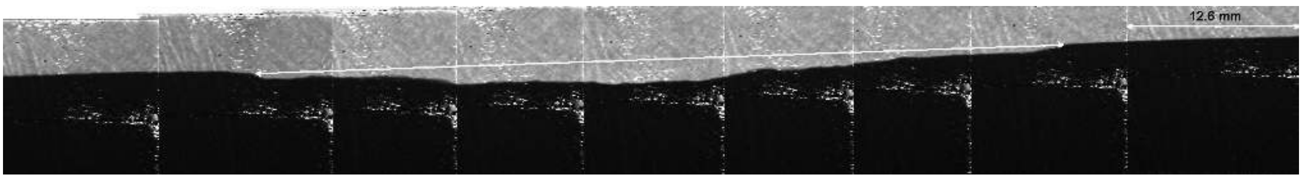

Fig. 5. Series of images acquired from a translation across a major corrosion pit on the test pipe, as seen in above. Maximum corrosion depth (measured on the pipe) is on the order of 4-5 mm (isolated deep pits), however the profile above intersects the pipe in a position where the maximum corrosion depth measured from the surface is about 3 mm. Integration time for each image 1 s.

PERFORMANCE CONSIDERATIONS

The technology relies on a stable movement of the scanner relative to the pipe due to the real-time imaging. The speed of inspection can be quite fast, as exhibited by the ability to perform real-time imaging at up to 300 images per second. The limitation is probably introduced more by the scanner mechanics rather than by the X-ray imaging.

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