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Effect of Energy, Type and Thickness of Insulator on Flaw Detectability

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Abstract – *The aim of this research is to demonstrate the effect of X-ray flaw detectability on type of insulator at different thickness and level of x-ray energy. A steel tube was insulated with three types of insulator, which are Rock wool, Glass wool, Polyethylene Foam respectively. An X-ray machine using Digital Detector Array (DDA) as an image plate was used to capture artificial flaw picture. Three levels of X-ray energy were adjusted from 140 to 160 KV in the increment of 10 KV. An ASTM IQI (Image Quality Indicator) was attached on the tube surface and used to identify the detection ability. The size of tube is 60 mm.in diameter and its thickness is 5.5 mm. Different size of drill hole varied from 0.9 to 1.5 mm were drilled through the tube wall using as artificial flaw to identify detectable and to compare between its real size and the detectable size. The results show that the KV level, types of insulator and its thickness are affected on detection ability. The benefit of the paper is to reveal the capability and the limitation of using x-ray to inspect damage under insulator.*

Key Words: X-ray, Digital Detector Array, Insulator, Detectability, Image Quality Indicator, Non-destructive testing (NDT)

1. INTRODUCTION

In Petrochemical industry, inspection of components under insulator is one of a routine work. To take of the insulator is time consume and huge expense. It is also take longer shutdown time. Various types of advanced Non-Destructive Testing (NDT), for instance Long length Ultrasonic and Digital Radiographic (DIR) Testing, were implemented. Two types of DIR, computed Radiography (CR) and DDA, were typical used. CR is less expensive technique, however it is not a real time process. DIR is often used to detect corrosion or wall loss of the pipe line under insulator. The tangential technique was used and enhanced the accuracy of measurement by selection of a proper filter in a software (1)To make sure that DIR can be performed to detect flaw without baring of insulator.

In this paper, the effect of defect detectability on types of insulator and its thickness will be presented. A steel tube was insulated with three types of insulator. Insulator thickness and x-ray energy are also varied. An ASTM IQI attached on the top surface of the tube located under insulator to indicate the smallest flaw can be found. Drill hole will be used to indicate detectability and the variation of size.

2. THEORIES

In this paper a Digital Radiographic Testing using DDA is used to capture the digital picture to compare its detectability. The image sensitivity will be shown by the detection of the smallest diameter of the IQI wire type and drill hole.

2.1 Digital Radiographic Testing (2)

Digital radiography is a technique of radiography that uses x-ray image plates to capture and transfer the figure to a computer. Their advantages are immediate image preview and elimination of costly film processing steps. Two types of DIR are commonly used in Petrochemical plant are as follow;

a) Computed Radiography (CR) is a two-step radiographic image process first, a storage phosphor imaging plate (IP) is exposed by penetrating radiation; second, the luminescence from the IP's photo stimulable luminescent phosphor is stimulated, detected, digitized, and displayed on an image

b) Digital Detector Array (DDA) is an electronic device that converts ionizing or penetrating radiation into a discrete array of analog signals which are subsequently digitized and transferred to a computer for display as a digital image corresponding to the radiologic energy pattern imparted

2.2 Image sensitivity

The image sensitivity is the smallest size of the flaw can be detected. For DIR, various parameters are effected on its sensitivity. The crucial parameters are the X-ray unit (energy and current), the image plate (type, number of pixel and bit), the X-ray technique (Source to object distance: image plate to object distance). The proper technique will provide good sensitivity image. In general, Signal to noise ratio (S/N), basic spatial resolution and detectable wire IQI are normally used to ensure the detection sensitivity.

2.3 IQI (Image Quality Indicator)

The IQI consists of sets of wires arranged in order of increasing diameter. The IQI was shown in figure 1. There are four sets of IQI, set A,B,C and D respectively.

Fig-1 Image Quality Indicator (IQI)

This paper the IQI set A was selected to attach on the tube surface. There are six wires (identity number 1 to 6) in set A. The size of wire is shown in Table-1

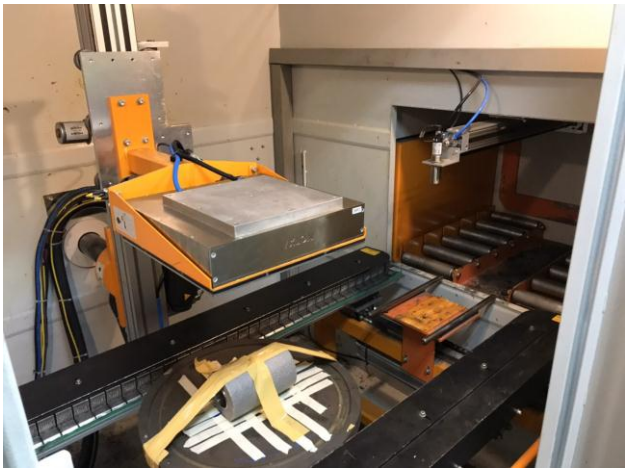
Table -1: Wire diameter of set A (3)

SET A		
Wire diameter		Wire identity
(inches)	(millimeter)	
0.0032	0.08	1
0.004	0.10	2
0.005	0.13	3
0.0063	0.16	4
0.008	0.20	5
0.010	0.25	6

It should be noted that, IQI of ISO standard comprises of seven wires, where there is only six wires in ASTM standard.

3. EXPEROMENTAL SETUP

X-ray machine model YXLON MU231XL was used. The maximum energy and current are 160KV and 6.25 mA respectively. The diameter of the carbon steel tube is 60 mm. its thickness is 5.5mm. Drill hole diameter of 0.9, 1.2, 1.3, 1.4 and 1.5 mm were drilled thorough the tube wall. Three types of the insulator are rock wool, glass wool and Poly ethylene (PE) foam were used to cover the tube. The thickness of insulator was also varied; 50 and 100 mm for rock wood, 25 and 80 mm for glass wood and only one size of PE at 50 mm. respectively. The thickness of insulator is not equivalent in each case because it was selected from the size which used in general used in the field. The ASTM- IQI set A were attached on the tube located between the tube surface and the insulator. The energy level were adjusted at 3 levels; 140, 150 and 160 KV respectively. The tube current is fixed at 6.25 mA. Source to the object and the object to DDA distance were set at fix equal distances. The experiment set up was shown in Fig-2



Fix-2 Experimental set up

The x-ray source was placed at the bottom and the DDA was located on the top. The steel tube was exposure with no insulator at 140 KV. After capturing the digital picture in to a computer, the wire identity number was carefully considered. The hole dimeter was measured and record see ability and size. Repeat the experiment by changing X-ray energy to 150 and 160 KV respectively. After that each insulator was wrapped on the tube and then repeated the experiment.

4. RESULTS

Figure 3 shows the example of the detection of IQI wire at 160 KV, 6.25 mA with no insulator. The IQI identity number 5 and 6 can be detected. The diameter of IQI identity number 5 is 0.20 millimeter.

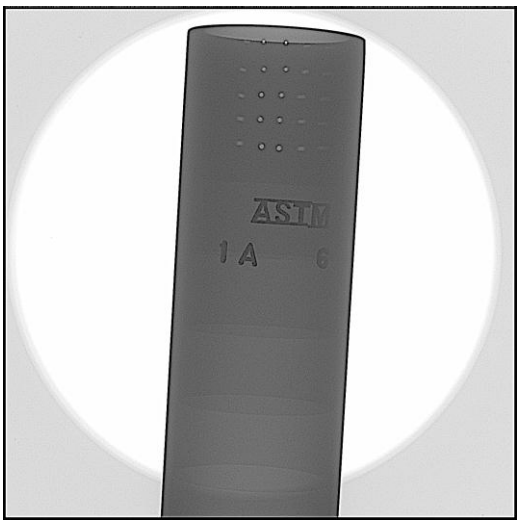


Fig-3 IQI wire at 160 KV, 6.25 mA with no insulator

Effect of X-ray energy and type and thickness of insulator and three levels of X-ray energy are illustrated in table-2.

Table -2: Effect of various parameters

Insulator type	Thickness (mm.)	X-ray energy (KV)	IQI detectable
No insulator		140	-
		150	No 5
		160	No 5
Rock Wool	50	140	-
		150	
		160	No 6
	100	140	-
		150	-
		160	No 6
Glass Wool	25	140	-
		150	-
		160	No 6
	80	140	-
		150	-
		160	-
Polyethylene	50	140	-
		150	-
		160	No 6

The results show that the maximum KV at 160 KV provides the best detectability. IQI number 6 can be seen for all type of insulator and all thickness except at 80mm of Glass Wool.

Without insulator, IQI identity number 5, which smaller size than number 6, can be seen at both 150 and 160 KV

The IQI wire cannot be seen at 80 mm thickness of Glass Wool insulator. at all level X-ray energy.

Figure 4 demonstrates the diameter measurement of hole.

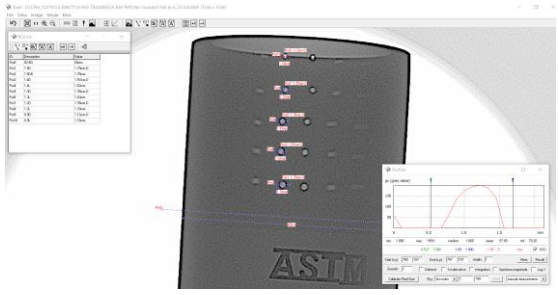


Fig-4 measurement of the size of hole

The size of hole measured from the digital images is as shown in table 3

Table -3: The size of hole measured from the digital images

Insulator type	Thickness (mm.)	X-ray energy (kV)	Measurement hole size				
			0.9	1.2	1.3	1.4	1.5
No insulator		140	1.11	1.32	1.38	1.56	1.78
		150	1.12	1.34	1.55	1.57	1.79
		160	1.05	1.33	1.35	1.57	1.79
Rock Wool	50	140	1.23	1.37	1.45	1.45	1.69
		150	1.00	1.36	1.39	1.48	1.72
		160	1.05	1.23	1.43	1.47	1.72
	100	140	1.05	1.32	1.34	1.58	1.58
		150	1.05	1.31	1.31	1.53	1.58
		160	1.14	1.32	1.39	1.57	1.73
Glass Wool	25	140	1.16	1.38	1.40	1.58	1.64
		150	1.17	1.31	1.40	1.64	1.78
		160	1.17	1.34	1.41	1.63	1.85
	80	140	*	*	*	*	*
		150	1.15	1.29	1.48	1.55	1.81
		160	1.28	1.40	1.37	1.57	1.81
Polyethylene	50	140	*	*	*	*	*
		150	1.15	1.29	1.47	1.58	180
		160	1.14	1.36	1.39	1.57	1.85

The measurement size of the hole is bigger than the real size because the image plate (DDA) is do not attach directly to the tube. All of drill holes can be detected except at 140 KV of both Glass Wood thickness of 80mm and Polyethylene at 50 mm. The images were not clear enough to measure their size. Glass wool and Polyethylene absorb more x-ray energy and exhibits more unsharpness than Rock wool. It can be concluded that type of insulator and energy level effect on the detectability.

5. CONCLUSIONS

Digital radiograph using DDA can be detected flaw on tube under insulator. Effect of each parameter can be concluded as follows;

1) The X-ray energy is the most important factor. The energy must high enough to penetrate through insulator and thickness of the tube. Comparing o three energy levels, the maximum at 160 KV provide the maximum sensitivity

2) Type of insulator shows different absorption. Glass Wool at 80 mm thickness cannot be detect IQI, whereas Rock Wool 100 mm can be detect IQI no 6

3) Thickness of Insulator exhibits influence on sensitivity. Glass wool at 25 mm can be detected IQI

identity number 6, but no IQI detectable for Glass wool at 80 mm

4) X-ray Glass wool and Polyethylene absorb x-ray energy than Rock wool. The edge of drill hold is not clear enough to measure the size.

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