WALL THICKNESS MEASUREMENT OF LARGE DIAMETER PIPES BY RADIOGRAPHY: 8 AND 12 INCHES

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Abstract

Radiography method is already used engineering practice for determining the quality of weld joint however this technique still not widely accepted by industry for wall thickness measurement of pipes. Furthermore, radiography has the advantages of penetrating an insulated and a large diameter of pipe. In this experiment, the tangential radiography technique is used to measure 8 and 12 inches diameter of pipes by using X-ray source. Based from our experiment it is shown that the penetrating length, Lmax for 8 inches pipe is 83 mm and for 12 inches is 103 mm. It was found that measuring outside thickness can be made for optical density less than 4 and in order to see the inside thickness in the pipe the optical density should more than 4. For double wall technique, we found that not significant change in value μ effective for both diameters pipes. However, there is slightly changing of this value when using x-ray for insulated pipes. Therefore, the correct μ effective in wall thickness measurement for insulated pipes.

1. Introduction

A major inspection challenge facing the oil and gas process industries is how to examine insulated piping for corrosion under insulation and internal erosion. Normally, the pipe is degradation because of the variety of mechanisms, or internal erosion from the flowing product. In Malaysia, most chemical plant and refineries have pipes with diameter between 75 – 250 mm and the thickness range up to 50 mm. The cold temperature pipe is insulation with calcium silicate material whereby the hot temperature pipes cover by polystyrene [1]. One of the most important parameters in a pipeline to be monitoring and measured is the wall thickness especially corrosive liquid flows through the pipe. Only radiographic technique assures inspection without costly removal of insulation material during operation of the plant. Development and propagation of tangential radiography and double wall techniques are very useful to assess corrosion, erosion, deposits and blockage of pipes which might cause fire, leaks, reduced production or unpredictable and costly shutdowns due to repair and replacement in the industries such as petroleum, power stations, refineries, petrochemical and chemical plants etc.

In this study, a simulation and validate the radiography measurement of defects that exist in large diameter pipes with or without insulation by using radiation sources (Iridium-192 and x-ray). This include a study the limits of detection for each radiation sources using tangential method. The double wall technique is also taken into consideration in this experiment.

2. Theoretical Background

2.1 Wall thickness determination [2]

A typical arrangement of tangential radiography method for wall thickness measurement is illustrated in Fig 1. The radioactive source is place a distance from the pipe at the centre position. To record the image of wall thickness the radiographic film is place between the radioactive source and the pipe. The schematic arrangement of the set-up is shown in Fig. 1.

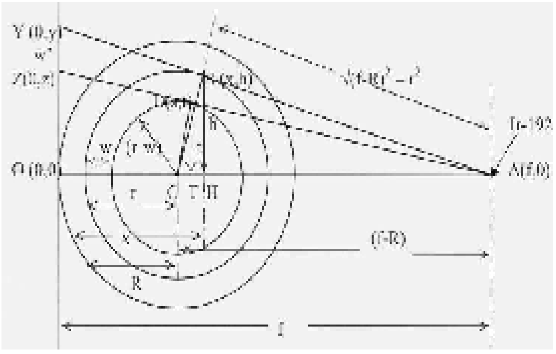

Fig. 2: The schematic diagram of determination wall thickness.

Let AY be the tangent to the circle of radius r at point B (x,h). Let h be the length of the perpendicular dropped from B to H on OA. By Pythagoras theorem,

$$AB = \sqrt{AC^2 - CB^2} = \sqrt{(f-R)^2 - r^2}$$

and therefore by Pythagoras theorem again,

$$h^2 = AB^2 - AH^2 = (f-R)^2 - r^2 - (f-x)^2 \quad (1)$$

However, the solution of the wall thickness measurement can be made by the derivation by using trigonometry and similar triangles.

By similar triangles, $\frac{AC}{CK} = \frac{OA}{OZ}$ that is $\frac{f-R}{(r-w)} = \frac{f}{t}$ and this implies

$$t = \frac{f(r-w)}{f-R}. \quad (2)$$

Therefore , $\frac{f(r-w)}{f-R} = \frac{rf}{f-R} - w'$

so that

Wall thickness ,

$$w = \left(1 - \frac{R}{f}\right)w' \quad (3)$$

Where w is measured wall thickness, R is radius of the pipe and f is source to film distance.

2.2 Determination of maximum penetration wall thickness[3]

The limitation of tangential radiography method is depending radiation source used. However, the suitable energy of the radiation used will depend very much on its calculation of thickness distribution at the inspected wall area and it is based on the maximum wall thickness, L_{max} at a given pipe diameter, D_a. The determination on the thickness penetration is illustrated in Fig. 2.

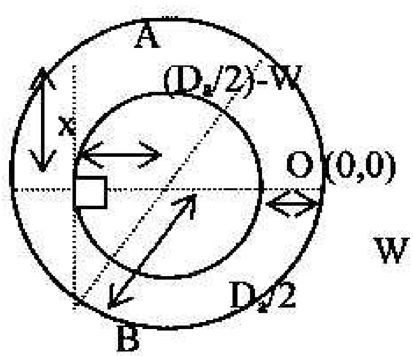

Fig. 2: Diagram used to derive maximum penetration thickness wall thickness, L_{max}.

Let AB be the maximum penetrated wall thickness L_{max}, W is the true wall thickness and D_a is the outer diameter of the pipe. By Pythagoras theorem,

$$\left[\frac{D_a}{2}\right]^2 = x^2 + \left[\frac{D_a}{2} - W\right]^2$$

$$\left[\frac{D_a{}^2}{4}\right] - \left[\frac{D_a{}^2}{4}\right] + D_a W - W^2 - x^2 = 0 \quad (4)$$

Solve (13) and yield

$$\frac{x^2}{W^2} = \frac{D_a}{W} - 1 \quad (5)$$

Next, square root (4) on both sides of the equation $\left(\frac{x^2}{W^2}\right)^{\frac{1}{2}} = \left(\frac{D_a}{W} - 1\right)^{\frac{1}{2}}$. This implies,

$$\frac{x}{W} = \sqrt{\frac{D_a}{W} - 1}$$

$$x = W\sqrt{\frac{D_a}{W} - 1} \qquad (6)$$

Since AB=L_{max} and AB=2x, hence,

$$2x = L_{\max}$$

$$x = \frac{L_{\max}}{2} \qquad (7)$$

By substitution the maximum penetration wall thickness is

$$L_{\max} = W\sqrt{\frac{D_a}{W} - 1} \qquad (8)$$

3. Material and Defects

The samples pipes are used in the study is carbon steel material and detail specifications are shown in Table 1.

Table 1: Pipes specification according to ANSI

Nominal Diameter (inches)	ANSI O.D. (mm)	ANSI O.D. (inches)	THICKNESS Required by ABA (mm)	ANSI SCH 30 Thk. (mm)	ANSI SCH 40 Thk. (mm)	ANSI SCH 40 S Thk. (mm)	ANSI SCH 80 Thk. (mm)	ANSI SCH 100 Thk. (mm)
8"	219.08	8.625	13.0		8.18		12.70	15.0
12"	323.80	12.750	8.0	6.38	10.31	9.52		

The artificial defects such as different thickness steps, holes of various sizes, ground patch are simulating as real defect of wall thickness due to corrosion, pitting and localised corrosion. All the artificial defects are shown in the engineering design of artificial defects on pipe reference block as Figure 3. In Table 2 is the thickness steps measurement of pipe 8 inches diameter and 12 inches are shown in Table 4.

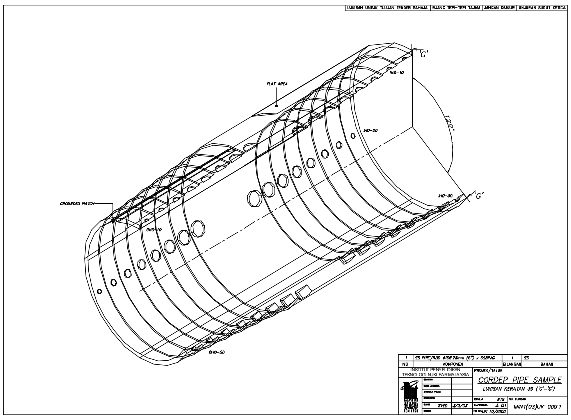

Fig.3 : The engineering design of artificial defects on pipe reference block.

Table 2: The Thickness steps measurement of pipe 8 inches

Step	Name	s	w	t	p(10%)	p(20%)	p(50%)	0.15w
0	IS0 – OS0	1.5	13	13.0	1.3	2.6	6.5	2.0
1	IS1 – OS1		13	11.5	1.2	[illegible]	5.8	
2	IS2 – OS2		13	10.0	1.0	2.0	5.0	
3	IS3 – OS3		13	8.5	0.9	1.7	4.3	
4	IS4 – OS4		13	7.0	0.7	1.4	3.5	
5	IS5 – OS5		13	5.5	0.6	1.1	2.8	
6	IS6 – OS6		13	4.0	0.4	0.8	2.0	
7	IS7 – OS7		13	2.5	0.3	0.5	1.3	

Note:

Carbon Steel Pipe 8"(219.08mm) – Outside diameter(OD)

w = wall thickness = 13 mm

t = Wall step thickness

IS = Inside step

OS = Outside step

p = hole depth

0.15w = Flat area depth and Grounded patch depth

s = step reduce = 0.1 * w, rounded to nearest half mm

OH = Outside hole diameter (Hole diameter will be equal to remaining wall thickness, minimum of 2 mm.)

ID = Inside hole diameter (Hole diameter will be equal to remaining wall thickness, minimum of 2 mm.)

4. 0 Experimental Procedure

The detail of experimental procedures of tangential radiography and double wall technique are described in other papers by the authors[4,5]. However in this study, several experiments were carried out as below:

(a) The tangential and double wall techniques of pipe blocks of 8 and 12 inches diameters with and without insulation for optical density more than 4 at step 4. Glass wool of 50 mm thickness was used for the insulation.

(b) Double wall technique to determinate of limit Lmax and μeff for 100, 200 and 300 kV using x-ray.

However the data on exposure conditions of each experiment, references pipes measurement and other experimental data are tabulated in excel spreadsheet developed by BAM procedures of defect dimensioning.[6].

5. 0 Results

From the data tabulated in the BAM procedures[6] and the observation of the radiographs of the both pipes using tangetial method, the information obtained are shown in Table 3, 4, 5 and 6 according to pipe diameter and optical density.

Table 3: Pipe diameter 8 inches of Outsides Vs Insides Steps with Insulation with optical density, D≤4

		STEP	10% HOLE	20% HOLE	30% HOLE	GP	FA
STD DEVIATI ON	I	0.0 – 0.2	–	-	-	0.0 – 2.4	-
	O	0.0 – 0.4	0.0 – 0.4	0.0 – 0.4	0.0 – 0.2		
ACCURA CY	I	0.0 to 2.2	-	-	-	-0.7 to 1.7	-
	O	-0.4 to 0.5	-0.2 to 2.2	-0.2 to 2.0	-0.7 to 0.5		
TRENDS		NO TREND	OVER ESTIMATED	NO TREND	NO TREND		OVER ESTIMATED

Table 4 : Pipe diameter 8 inches of Outsides Vs Insides Steps without Insulation with optical density , D>4.5

		STEP	10% HOLE	20% HOLE	30% HOLE	GP	FA
STD DEVIATION	I	0.0 – 0.2	0.0 – 0.2	0.0 – 0.2	0.1 – 0.2	0.2 – 2.5	0.2 – 0.4
	O	0.1 – 0.2	0.1 – 0.5	0.0 – 0.3	0.0 – 0.2		
ACCURACY	I	2.5 to 3.5	0.4 to 0.2	-0.3 to 2.1	-1.2 to 0.7	-0.2 to 0.1	-1.2 to -0.1
	O	2.0 to 3.4	-0.6 to 0.3	0.5 to 2.1	-0.5 to 0.2		
TRENDS		NO TREND	NO TREND	NO TREND	OVER ESTIMATED	OVER ESTIMATED	OVER ESTIMATED

Table 5: Pipe diameter 12 inches of Outsides Vs Insides Steps with Insulation with optical density, D≤4

		STEP	10% HOLE	20% HOLE	30% HOLE	GP	FA
STD DEVIATION	I	0.0 – 0.1	-	-	-	0.0 – 0.1	-
	O	0.1 – 0.5	0.1 – 0.5	0.1 – 0.3	0.1 – 0.2		
ACCURACY	I	0.1 to 0.4	–	–	-	1.8 to 0.0	-
	O	0.1 to 0.2	-0.5 to 0.3	-1.1 to 0.4	0.1 to 0.9		
TRENDS		NO TREND			NO TREND	NO TREND	NO TREND

Table 6: Pipe diameter 12 inches of Outsides Vs Insides Steps with Insulation with optical density, D>4.5

		STEP	10% HOLE	20% HOLE	30% HOLE	GP	FA
STD DEVIATION	I	0.1 – 0.3	0.0 – 0.2	0.0 – 0.2	0.0 – 0.1	0.0 – 0.2	0.0 – 0.8
	O	0.1 – 0.2	0.0 – 0.2	0.0 – 0.2	0.0 – 0.1		
ACCURACY	I	0.2 to 0.6	0.1 – 0.4	-0.5 to 1.5	0.7 to 0.0	-1.1 to 2.7	-1.1 to -0.8
	O	-0.4 to 0.1	0.3 to 0.5	-1.9 to 1.3	-1.4 to 0.0		
TRENDS		NO TREND		OVER ESTIMATED		NO TREND	

For the determination of *Lmax* and μ effective for pipes 8 and 12 inches diameter are obtained from calculation from experimental data of BAM excel sheets[6] and tabulated the result in Table 7.

Table 7: The Lmax and μ effective for pipes 8 and 12 inches diameter.

Reference Pipe	Radioactive source	Optical density	Lmax	μ effective
8 inch with insulator	Iridium - 192	D < 4	103	0.048
8 inch insulator	Iridium-192	D > 4	103	0.048
12 inch with insulator	Iridium - 192	D < 4	83	0.046
12 inch with insulator	Iridium - 192	D > 4	83	0.046

5. Discussion & concluding remarks

It was observed that from the experimental data oand Table 3 for pipe diameter 8 inches is possible to measure the outside step and see the outside holes up to 50% however is very difficult to measure inside wall thickness. Increasing the density outside the pipe greater than 4 as shown in table 4 will increase the contrast and the measurement the step can be made however there is possibility the burn out will be occur. Similarly this phenomenon will be happened for pipe diameter of 12 inches as shown in Table 5 and 6 for density < 4 and > 4 respectively. Therefore, the tangential radiography technique is suitable to be used for measuring pipe wall thickness of 8 and 12 inches diameter by using Iridium-192 radioactive source. Again, the double wall techniques can be used for wall thickness based from the experimental data of BAM excel sheets[6]. There is no significant affect on this thickness measurement between with and without insulation on the pipe when using Iridium-192 source. Based from our experiment we found that the Lmax for 8 inches pipe is 83 mm and for 12 inches is 103 mm is shown in Table 7. For double wall technique, we found that not significant change in value μ effective for both diameters pipes. However there is slightly changing of this value when using x-ray for insulated pipes.

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REFERENCES

[1]. A.R. Hamzah, et. al, Corrosion Evaluation in insulated pipes by Non Destructive Testing Method, Proc. Inter Nuclear Conference 2002, Seminar 5: Industry & Energy, (2002) 57–65.

[2]. S.M.M. Amir, et. al, Analytical Studies of Tangential Radiography Method – revisited, Proceeding on Conference on Advance in Theoretical Sciences(CATS 2003), Putrajaya, 2003.

[3]. S.M.M. Madiha et al., Tangential Radiography Technique for pipe wall thickness measurement using radiation-mathematical approach, Proceeding MINT R&D Seminar 2004, Bangi, Selangor

[4]. The First CRP meeting on validation of protocols for corrosion and deposit Evaluation in large Diameter Pipe by radiography, IAEA Vienna, 4-8 Nov 2002 (Internal report).

[5]. The Second CRP Co-ordination meeting on validation of protocols for corrosion and deposit Evaluation in large Diameter Pipe by radiography, IAEA Vienna, 5-9 March 2004 (Internal report).

[6] The Final CRP Co-ordination meeting on validation of protocols for corrosion and deposit Evaluation in large Diameter Pipe by radiography, IAEA Vienna, 8-11September 2005 (Draft)