VALIDATION AND APPLICATION OF COMPUTED RADIOGRAPHY (CR) TANGENTIAL TECHNIQUE FOR WALL THICKNESS MEASUREMENT OF 10 INCH CARBON STEEL PIPE

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Abstract

Oil and gas industry requires Non Destructive Testing (NDT) to ensure each components, in-service and critical, are fit-for-purpose. Pipes that are used to transfer oil or gas are amongst the critical component that needs to be well maintained and inspected. Typical pipe discontinuities that may lead to unintended incidents are erosion, corrosion, dent, welding defects, etc. Wall thickness assessment, with Radiography Testing (RT) is normally used to inspect such discontinuities and can be performed with two approaches; (a) center line beam tangential technique (b) offset from the centre pipe tangential technique. The latter is a method of choice for this work because of the pipe dimension and limited radiation safe distance at site. Two successful validation approaches (simulation and experimental) were performed to determine the probability of successfulness before the actual RT work with tangential technique is carried out. The pipe was a 10 inch diameter in-service wrapped carbon steel. A 9 Ci Ir-192 and white Imaging Plate (IP) were used as a gamma radiation source and to record the radiographic image. Result of this work suggest that RT with tangential technique for 10 inch wrapped in-service carbon steel pipe can be successfully performed.

Keyword: Nondestructive Testing (NDT), radiography testing (RT), computed radiography (CR), tangential radiography technique

Abstrak

Industri minyak dan gas memerlukan teknik-teknik Ujian Tanpa Musnah (NDT) untuk memastikan setiap komponen, dalam perkhidmatan dan yang dianggap kritikal, adalah sesuai dan selamat untuk digunakan. Paip yang digunakan untuk memindahkan minyak atau gas adalah antara komponen kritikal yang perlu dijaga dengan baik dan diperiksa. Ketidakselanjaran yang wujud pada paip tersebut boleh membawa kepada kejadian yang tidak diingini. Antara ketidakselanjaran yang dimaksudkan ialah hakisan, kakisan, lekuk, kecacatan kimpalan, dan lain-lain. Pengukuran ketebalan dinding paip dengan menggunakan Teknik Radiografi (RT), (a) samada teknik tangen garis tengah paip atau (b) teknik tangen menjauhi dari garis tengah paip, biasanya digunakan untuk menilai ketidakselanjaran yang dinyatakan. Teknik tangen merupakan kaedah pilihan untuk kerja-kerja ini kerana dimensi paip dan jarak perlindungan radiasi selamat yang terhad di tapak. Dua pendekatan pengesahan (simulasi dan eksperimen) telah dijalankan untuk menentukan kebarangkalian kejayaan sebelum kerja RT dengan teknik tangen dijalankan. Paip yang diuji diperbuat dari keluli berkarbon berdiameter 10 inci dan berbalut. Sumber sinaran gamma, Ir-192 dengan kekuatan 9 Ci dan plat pengimejan putih (IP) telah digunakan didalam kerja ini. Hasil kerja ini mencadangkan bahawa RT dengan teknik tangen untuk 10 inci yang dibalut dalam perkhidmatan paip keluli karbon boleh berjaya dilakukan.

Kata kunci: Ujian tanpa musnah (NDT), ujian radiografi (RT), radiografi berkomputer (CR), teknik radiografi tangen.

INTRODUCTION

The introduction of powerful computers and reliable imaging technologies has significant impact on the currently used NDT methods. New radiologic imaging technique in Digital Radiography; Computed Radiography (CR) with phosphor imaging plates have increased the capacity and accuracy for visualization and measurement of defects.

Phosphor Imaging Plate (IP) is media for film-free radiography. This technology is commonly called Computed Radiography or CR. This technology has been introduced and applied in the fields of NDT. CR could have the way to new areas of applications since higher sensitivities allow shorter exposure times and the results can be directly evaluated digitally.

Imaging plates are exposed analogously to films. The image information is readout from the plates with a laser scanner and the plates are erased at the same time or in a follow up erasure unit. This makes any chemical developing process as for films obsolete, the results are available on the computer for evaluation immediately after the readout. The plates can be reused up to thousand times without any significant loss in quality if no mechanical damages appear.

A typical application for Computed Radiography (CR) is the quantification of corrosion effects in pipe walls (shadow technique or projection radiography). The inspection for corrosion in pipes is one of the most important NDT precautions measures in the chemical industry. The pipes are thermally insulated and the insulation material is held together with an aluminium collar. The radiographic inspection is accomplished without removing the insulation. This is an advantage over the ultrasonic method that needs a direct contact with the pipe.

The classification of tangential radiographic technique are divided into two classes. There are basic technique TA and improved technique TB. The basic technique, TA are intended for tangential radiography of generalized wall loss, such as that due to erosion or large scale corrosion. The improved technique, TB should be used for the more demanding tangential radiography of localized corrosion pitting flaws, which require higher sensitivity for detection and sizing.

TANGENTIAL RADIOGRAPHY TECHNIQUE

Two techniques recommended for making tangential radiograph. There are radiation source located on the pipe centre line as figure 1 and radiation source located offset from the pipe centre line as figure 2. The suitable technique used in this validation, application and inspection is the technique TA where there are intended for tangential radiography of generalized wall loss and the radiation source is located offset from the pipe centre line.

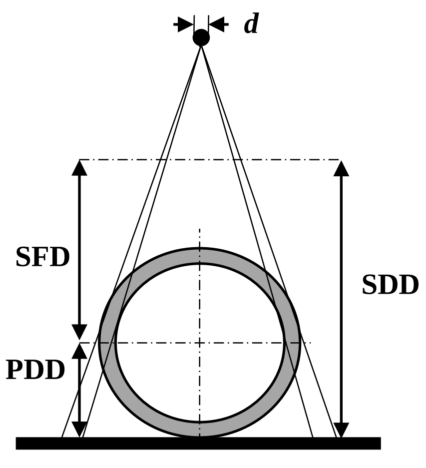


Figure 1: Test arrangement and distances for tangential radiography with the source located on the pipe centre line

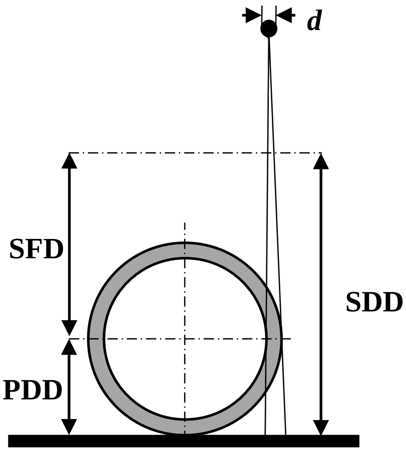


Figure 2: Test arrangement and distances for tangential radiography with the source offset from the pipe centre line

For tangential radiography, the choice of radiation source should be determined by the maximum penetrated thickness of the pipe, W_{max} which occurs for the path forming a tangent to the pipe inner diameter, as shown in figure 3.

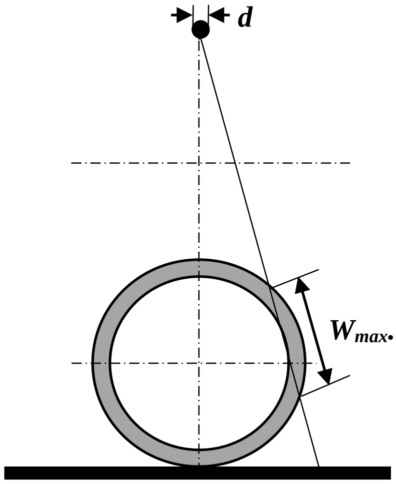


Figure 3: Maximum penetrated thickness, W_{max}, for the tangential radiography technique

Below (equation 1) is the mathematical equation to calculate the penetrated thickness, W_{max}. Where t is the nominal thickness of the pipe and D_e is the outside diameter of the pipe.

$$W_{max} = 2\sqrt{t\,(D_e - t)} \qquad (1)$$

Table 1 gives recommended limits on the maximum penetrated thickness for different radiation sources.

Table 1 – Maximum penetrated thickness range for different radiation sources for steel

Radiation Source	Limits on maximum penetrated thickness W_{max} mm	
	Basic (for generalized wall loss)	**Improved (for pitting flaws)**
X-ray (100 kV)	≤ 10	≤ 7
X-ray (200 kV)	≤ 30	≤ 20
X-ray (300 kV)	≤ 40	≤ 30
X-ray (400 kV)	≤ 50	≤ 35
Se 75	≤ 55	≤ 40
Ir 192	≤ 80	≤ 60
Co 60	≤ 120	≤ 85

For digital radiographs, somewhat higher values for the limits on maximum penetrated thickness than those given in Table 1 may be used.

To identify and determine the appropriate radiation source for a particular pipe, the maximum penetrated thickness, W_{max} should be determine using mathematical formula (1) and compared with the values given in table 1.

In this case, where radiographs are produced using gamma rays, the total travel–time to position and rewind the source shall not exceed 10% of the total exposure time.

For offset tangential radiography, the true wall thickness t_{act} at the tangential pipe position can be calculated from the measured wall thickness t_{meas} using the approximate formula as below:

$$t_{act} = \frac{SPD}{SDD} \times t_{meas} \qquad (2)$$

TANGENTIAL RADIOGRAPHY USING SIMULATION

Before carrying out the actual radiographic exposure, a simulation using the software aRTist has been done. One object is created in this simulation where the pipe schematic diagram and the details for the dimension of the pipe is as figure 4.

Figure 5 is a preparation for the radiography simulation set-up. It consists of a radiation source Ir-192 (source strength activity 9 Ci), carbon steel object with nominal thickness 9mm and inside there is a groove at the centre of the part measured 45% wall loss (4.95mm), the detector is white Imaging Plate (IP) and also used the duplex wire EN 462-5 as a determinant for the calibration of the measurement. In this simulation, the tangential radiography technique is selected to identify and determine the thickness of the pipe wall.

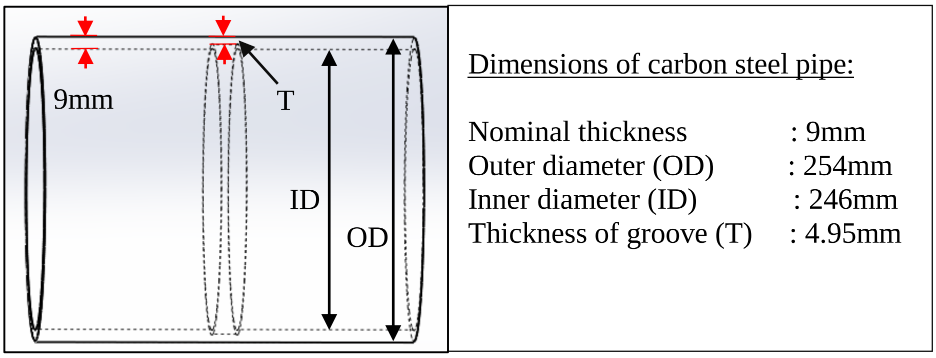


Figure 4: Schematic diagram of the pipe

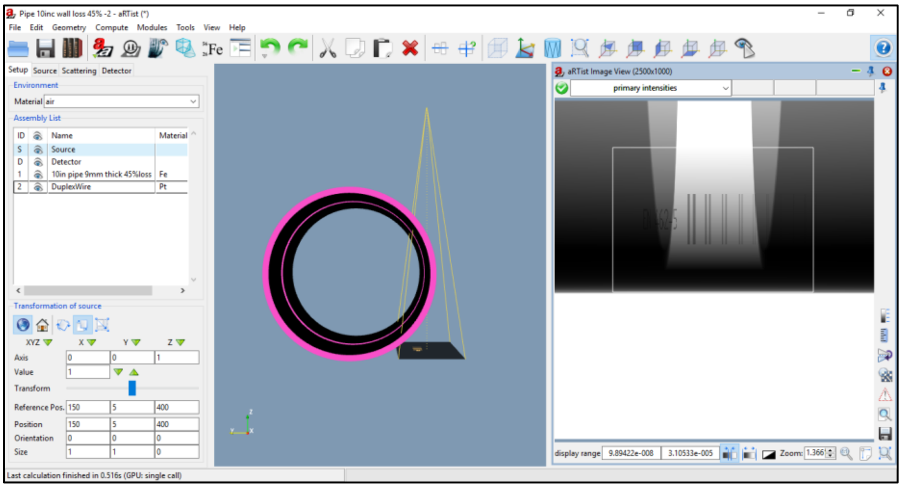


Figure 5: Simulation using aRTist software

Image from the figure 6 below shows the result from the simulation. At the area where the 45% groove is created, the thickness calculated is 4.95mm. It is mean the value for measured and calculated is equal. Here, the simulation of Computed Radiography (CR) tangential technique for wall thickness measurement of 10 inch carbon steel pipe was identified and determined.

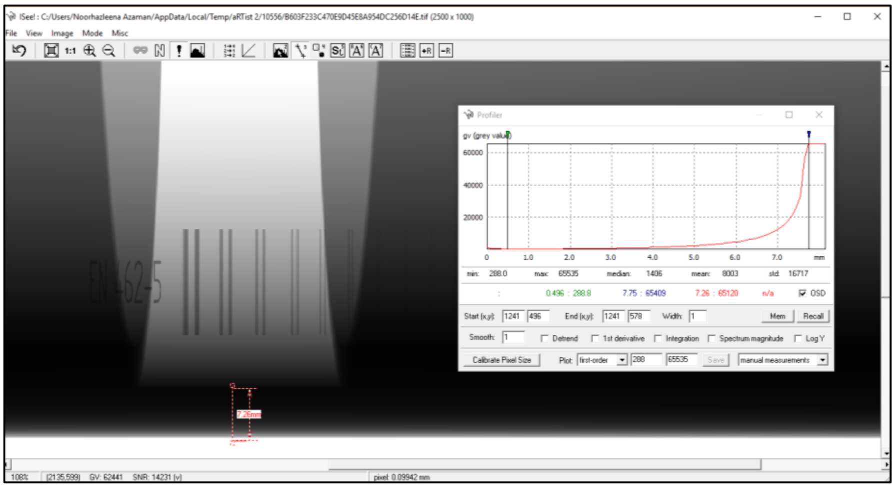


Figure 6: Result radiography image from simulation

TANGENTIAL RADIOGAPHY INSPECTION AT FSO PUTERI DULANG

FSO Puteri Dulang is a facilities floating storage and transfer vessel of crude oil. It is located approximately 175Km from the east coast of Peninsular Malaysia at Dulang field. Radiography work is carried out here in order to identify and determine the thickness of the carbon steel pipe wall of 10 inch outer diameter with wrapping as shown in figure 7. The most suitable technique used for this test is tangential radiograph technique.

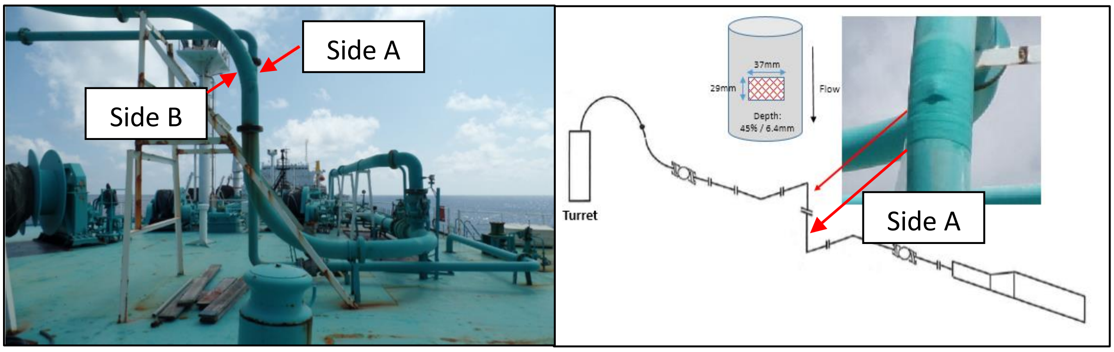


Figure 7: Location of radiographed 10 inch pipe with wrapping

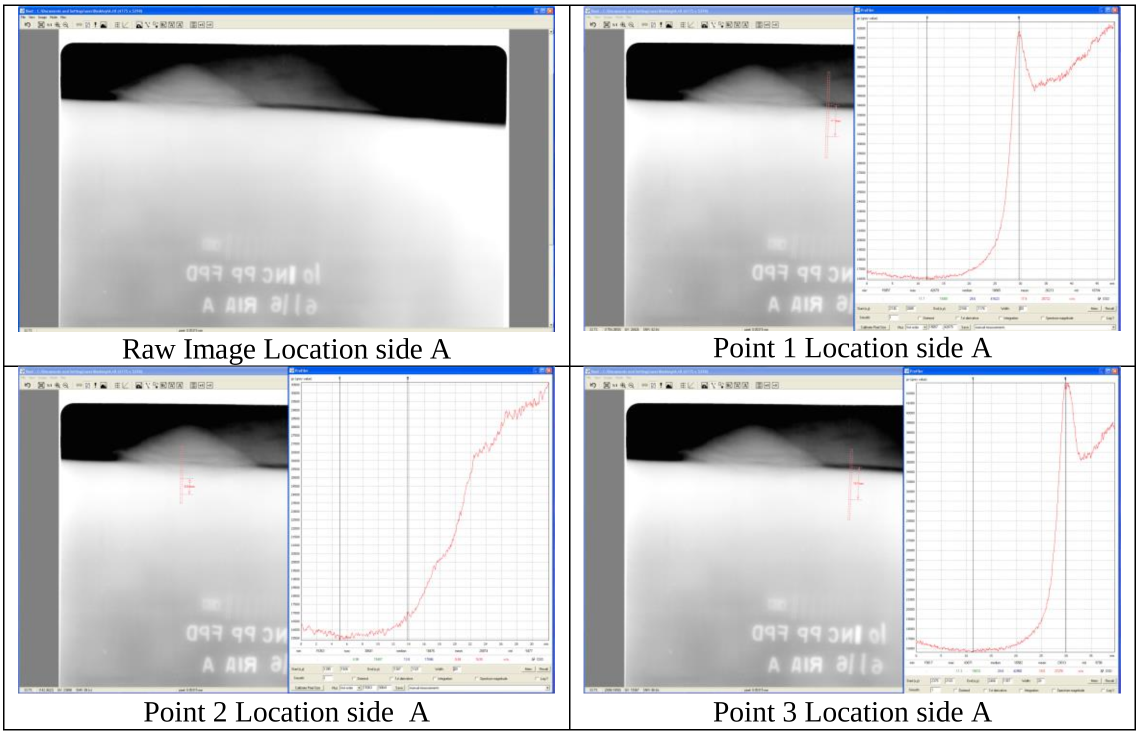
In this inspection, CR and white IP were used as an equipment and tools in order to get the image as figure 8 below. For the figure 9, it is the set-up for the real radiography exposure.

Figure 8: Computed Radiography (CR)

Figure 9: Experimental tangential radiography set-up in real inspection

RESULT AND DISCUSSION

Figure 10 and 11 shows that the image from the result of inspection through a real exposure experimental using computed radiography and the imaging plate as a detector. The reading are collected from the three points at location side A and B. From table 2 was tabulated the result for wall thickness of 10 inch carbon steel pipe.



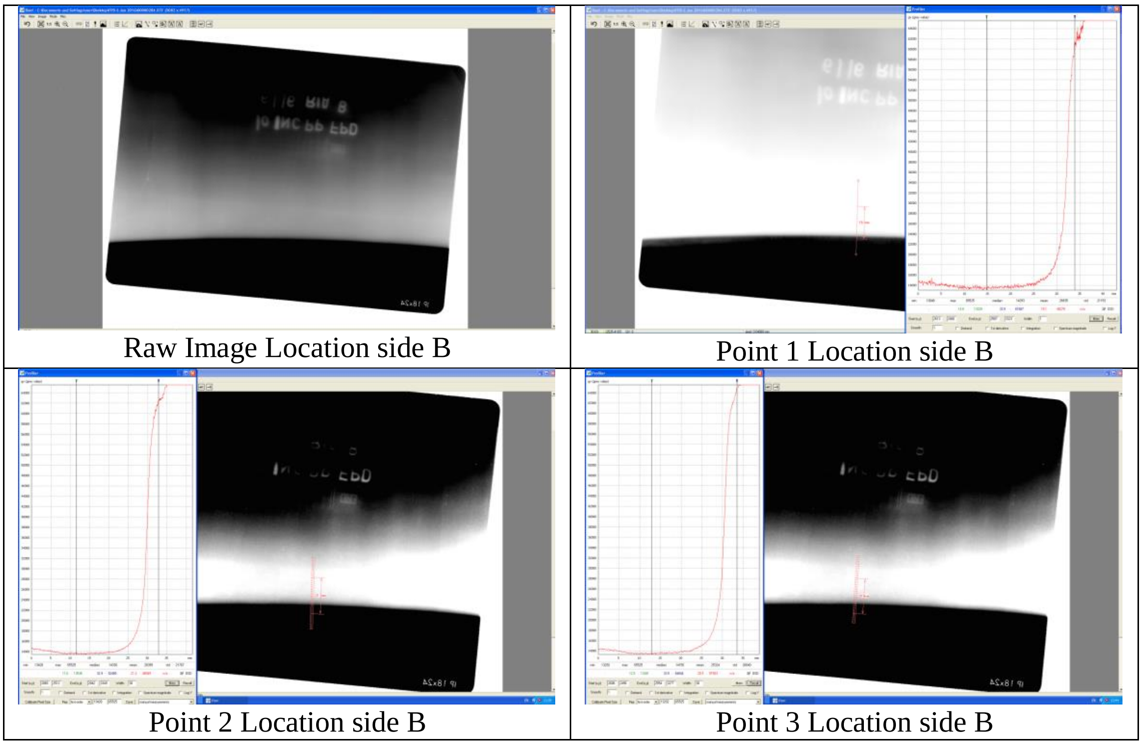
Raw Image Location side A

Point 1 Location side A

Point 2 Location side A

Point 3 Location side A

Figure 10: Image at location side A of the pipe



Raw Image Location side B

Point 1 Location side B

Point 2 Location side B

Point 3 Location side B

Figure 11: Image at location side B of the pipe

Table 2: Result of thickness at location side A and B

Location side	Source to Detector Distance, SDD (mm)	Measured thickness, t_{meas} (mm)	Pipe Centre to Detector Distance, PDD (mm)	Corrected thickness, t_{act} (mm)
A - Point 1	400	17.9	136.5	6.11
A - Point 2	400	8.84	136.5	3.02
A - Point 3	400	18.5	136.5	6.31
B - Point 1	430	19.1	136.5	6.06
B - Point 2	430	21.2	136.5	6.73
B - Point 3	430	20.5	136.5	6.51

The high priority or the critical interest area for this inspection is at the side A and the inspection at the side B is for the confirmation average of the thickness remaining for that pipe. From the results, it shows the remaining wall thickness of outer diameter 10 inch carbon steel pipe is around 6mm. While result on the area at side A point 2 shows the remaining thickness is 3mm. On the thinnest area of 3mm it is because of the high critical area of the corrosion to happen. From the results, it gives the reliable data for the wall thickness measurement.

CONCLUSION

The tangential radiography is useful tool that allow to inspect the wall thickness with the wrapped pipe. The image of radiography for simulation and real exposure (experiment) were analysed. The result image from simulation shows that the calculated and measured pipe with groove 4.95mm thickness results are equal. The result calculated is according to the standard of EN 16407-1 for tangential radiography. The real radiography exposure (experiment) at the field were analysed and the true wall thickness t_{act} was calculated from the measured wall thickness t_{meas} based on the equation for the offset tangential radiography. According to the standard, for digital radiographs, somewhat higher values for the limits on maximum penetrated thickness than those given in Table 1 may be used.

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