

PEDS: SOFTWARE TO ASSESS WALL THICKNESS LOSS AND WELD THICKNESS LOSS IN OFFSHORE PIPELINES THROUGH DIGITAL RADIOGRAPHY

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RESUMO:

Um software de computador para avaliar a perda de espessura da parede e da solda dos canos das tubulações marítimas é apresentado. This software calculates the thickness loss through a data bank obtained using computational modeling based on Monte Carlo MCNPX code, and digital radiography images obtained using image plate (BaFBr) detector. In order to give users more flexibility, the computer software was written in Java, which allows it to run on Linux, Mac OS X and Windows. Tools are provided to image display, select and analyze specific areas of the image (measure average, area of selection) and generate profile plots. Applications of this software in onshore and offshore inspections are presented. Preliminary results shown good agreement between real and calculated value of thickness loss.

Palavras-chave: Software de Computador; Perda de espessura; Radiografia, MCNPX.

ABSTRACT:

A computer software to assess wall thickness loss and weld thickness loss in offshore pipelines is presented. This software calculates the thickness loss through a data bank obtained using computational modeling based on Monte Carlo MCNPX code, and digital radiography images obtained using image plate (BaFBr) detector. In order to give users more flexibility, the computer software was written in Java, which allows it to run on Linux, Mac OS X and Windows. Tools are provided to image display, select and analyze specific areas of the image (measure average, area of selection) and generate profile plots. Applications of this software in onshore and offshore inspections are presented. Preliminary results shown good agreement between real and calculated value of thickness loss.

Palavras-chave: Software de Computador; Perda de espessura; Radiografia, MCNPX.

1.INTRODUCTION

Degradation processes such as corrosion have a substantial bearing on the security and reliability, mainly in petroleum plants, causing leakages, fires, expensive non-programmed stops and even environmental disasters of great proportions (Cardoso, 2005; IAEA, 2005; DD, 1978). In order to guarantee the structural integrity of petroleum plants it is crucial to monitor the amount of wall or weld thickness loss in onshore and offshore pipelines. Computed radiography with imaging plate detectors is one of the most helpful techniques for the inspection of the most

helpful techniques for the inspection of onshore and offshore ducts (IAEA, 2005; Veith et al., 2001; HSE, 2005; Patel, 2005; Shinohara et al., 2002; Davis et al., 2000; Marinho et al., 2005). It has the potential to be used to perform inspection without costly removal of insulation material during operation of the plant, and it is also preferred because of lesser exposure time, no chemical processing, lesser cost of consumables and advantage of a digital image output (IAEA, 2005; Veith et al., 2001; HSE, 2005; Patel, 2005; Shinohara et al., 2002; Davis et al., 2000; Zscherel et al., 2000; Marinho et al., 2005). However, in spite of its relevance, the thickness loss is very difficult to

determine, due to both the large diameter of most pipes and the complexity of the multi-variable system involved (IAEA, 2005). Over the years, modeling became more important in modern non-destructive test (NDT) techniques. It is used to optimize techniques for complex applications and to support the preparation of written procedures. Depending on the formulated inspection problem or the influencing factors that should be accessed by modeling, an appropriate physical model can allow the implementation of NDT measurement models that are capable to predict the signals seen in NDT inspections and that can be used to quantitatively study the effects of various parameters on those signals. A methodology for calculation of wall and weld thickness loss using Monte Carlo code MCNPX and digital radiography was developed by our group (Correa et. al, 2009). This methodology takes into account the energy-dependent response of a BaFBr imaging plate detector. It has been used to obtain a data bank in order to calculate the thickness loss. With this in mind, the objective of this paper is to present an evolution of a computer software named PEDS (Souza et. al, 2010), to assess weld thickness loss in offshore pipelines, where the data bank previously mentioned was implemented. Moreover, PEDS also provides the main tools for image manipulation in non-destructive test (NDT) applications.

2. MATERIALS AND METHODS

2.1 THE PEDS SOFTWARE

The PEDS is a program originally developed to estimate weld thickness loss in offshore pipelines through a data bank obtained with computational modeling based on Monte Carlo code MCNPX (Correa et. al, 2009). The program correlates the ratio between the pixels's average intensity in the region of the discontinuity and the pixels's average intensity

in the neighborhood of the discontinuity in images obtained experimentally, with the ratio previously simulated in the data bank to estimate de thickness loss. This program, up to the present moment, allows not only the estimate of weld thickness loss, but also the estimate of wall thickness loss through digital radiography images obtained using image plate (BaFBr) detector, radiography technique of double wall single image (DWSI), and Iridium 192 (192Ir) source. Figure 1 shows the PEDS interface.

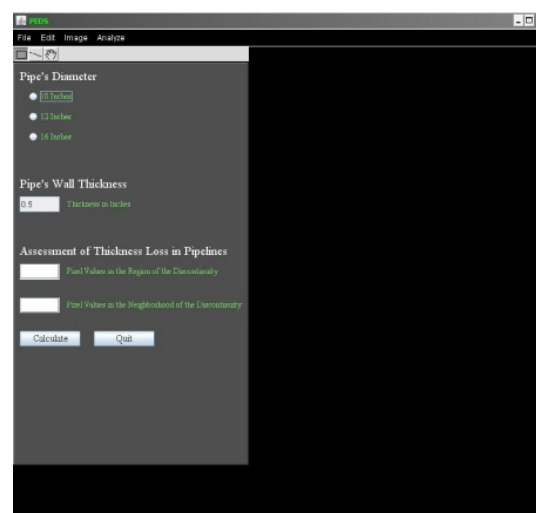


Figure 1. PEDS interface.

The PEDS is written in Java language. The development environment used is the NetBeans IDE version 6.9. NetBeans is a modular and extensible application framework for the development of Java desktop applications. It contains several application programming interfaces (API), thus providing the functionality that every programmer would have to write themselves, including: window management, saving state, connecting actions to menu items, toolbar items and keyboard shortcuts.

In order to give users more flexibility, the PEDS also provides the main tools for image manipulation in nondestructive test (NDT) applications. This program can read many image formats such as TIFF, GIF, JPEG, BMP and DICOM, besides display, edit and analyze 8-bit, 16-bit and 32-bit images. Moreover,

PEDS can calculate area and pixel value statistics of user-defined selections, and create density histograms and profile plots. It also supports standard image processing functions such as contrast and brightness manipulations. Additionally, in the PEDS the image can be zoomed up to 32:1 and down to 1:32, and all analysis and processing functions are available at any magnification factor. The program also supports any number of windows (images) simultaneously, limited only by available memory. In order to implement the tools for image manipulation in the PEDS, was considered the class structures of the ImageJ (public domain Java image processing program) available through tutorial (Bailer, 2006).

2.2 THE DATA BANK.

The data bank implemented in PEDS software consist of an set of equations obtained by simulations of several radiographic systems where the ratio between a value obtained by the detector aligned with the discontinuity and another obtained by the detector aligned with a region in the neighborhood of the discontinuity is correlated with the percentage of wall thickness loss or weld thickness loss in pipes. The calculations were made using the Monte Carlo code MCNPX version 2.5.0. (Pelowitz, 2005). The photons were transported taking into account photoelectric absorption, coherent and incoherent scattering, in order to reproduce the main phenomena involved in radiation interaction with the matter.

Offshore and onshore pipes are usually large-diameter steel tubes that are welded to one another to form a long pipeline. Due to the typically large diameters of this kind of pipes, radiographic inspections are only viable if the double wall single image (DWSI) technique is used (IAEA, 2005). Considering this, the simulation procedures in order to obtain the data bank involved DWSI radiographic system for inspection of steel pipes with 8, 10, 12,

16 and 20-in external diameter.

The iron pipe size-IPS (external diameter) and the wall thickness were defined according to the SCH 10-S schedule (ANSI B36.10, 1979). Defect percentages inserted in the pipes were larger than 20% in order to consider the thickness reductions where repairs of the pipes in terms of maximum allowable operating pressure are recommended (ASME B31G, 1991). The simulation procedures in order to obtain the data bank take in to account the presence of liquid (water) inside and outside the pipes, and pipe without water (air).

The DWSI radiography simulations reproduce a 0.3cm diameter Iridium 192 (^{192}Ir) source collimated into a cone by applying MCNPX's source biasing variance reduction technique (Pelowitz, 2005; LANL, 2003). This technique allows a radiation source to be modeled as if it were collimated, without compromising the final result of the simulation (Pelowitz, 2005). The radiation beam was directed through the center of the pipe's cross section. In DWSI radiographic technique, the thickness loss caused is determined by associating it with intensity differences between regions in the computed radiographic image after proper calibration. Considering this, point detectors (tally F5), placed at 0.1cm from the simulated object, have been used to detect photons emerging from the test specimen. The number of histories simulated in all cases assures the estimated statistical error is less than 5%. The layout of the radiography system developed for experimental weld thickness loss evaluation in offshore pipelines, and modeled in this work, and the locations of the point detectors (F5) and the ^{192}Ir source can be seen in Figure 2.

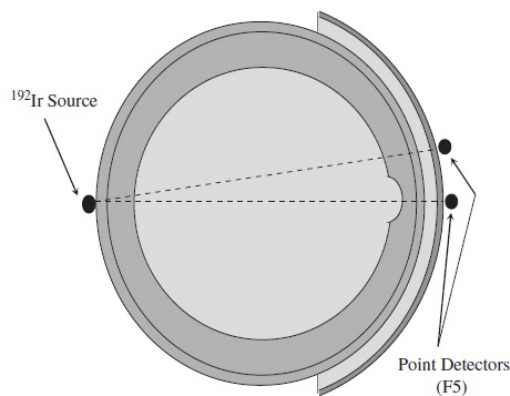


Figure 2. System designed for radiography of offshore pipes and locations of the point detectors, F5, and of ^{192}Ir source.

In order to take into account the energy response of the BaFBr image plate detector, the methodology for digital radiography simulation developed by our group was utilized (Souza et al., 2008; Correa et al., 2008). The curve which represents the wall thickness loss in 8-in pipe obtained by MCNPX simulations is shown in Equation 1, where R is the ratio between a value obtained by the detector aligned with the discontinuity and another obtained by the detector aligned with a region in the neighborhood of the discontinuity, and TL is the thickness loss.

$$TL = -1088.34368 + 1602.7375 \cdot (R) - 513.35807 \cdot (R)^2$$

2.3 VALIDATION OF THE METHODOLOGY

The software PEDS was tested with experimental digital radiography images. A gamma irradiator with a ^{36}Ci ^{192}Ir source of approximately 0.3cm diameter was used in the experiments. Every testing was performed through GEIT's computed radiography system CR50P. In order to analyze the wall thickness loss in onshore pipelines, the PEDS was tested with digital images of 8 and 12-in nominal external diameter pipe. In order to analyze the weld thickness loss, a digital image of a 10-in pipe with water inside and outside was utilized.

Table 1 show the specifications of the pipelines used in experimental procedures.

Pipe without water					
Pipe's external diameter (inch)	Pipe's external diameter (cm)	Pipe's wall thickness (cm)		Defect (%)	Defect depth (cm)
8	21.29	0.376		13.30	0.05
				15.96	0.06
				21.28	0.08
				29.25	0.11
12	32.39	0.457		50.53	0.19
				30.63	0.14
				50.33	0.23
Pipe with water inside and outside					
Pipe's external diameter (inch)	Pipe's external diameter (cm)	Pipe's wall thickness (cm)	Weld Thickness (cm)	Defect (%)	Defect depth (cm)
10	25.40	1.27	0.17	30%	0.38

Table 1. Specifications of the pipelines used in experimental and simulated procedures.

The thickness loss was correlated with the ratio between the pixels's average intensity in the region of the discontinuity and the pixels's average intensity in the neighborhood of the discontinuity. Images obtained experimentally helped make this correlation. This can be seen in Figure 3.

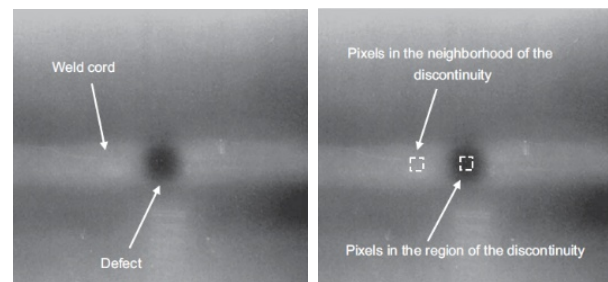


Table 1. Specifications of the pipelines used in experimental and simulated procedures.

3. APPLICATION OF THE PEDS

A script for the PEDS utilization is shown in the next sections.

3.1 READING IMAGE FILE

In order to open an image file in the PEDS, the menu command "File/Open" should be selected. Afterwards, the user should select the image file and click the open button ("Abrir"), as shown in Figures 4 and 5. TIFF, GIF, JPEG, BMP and DICOM formats can be supported by the PEDS by default. The image file is opened automatically.

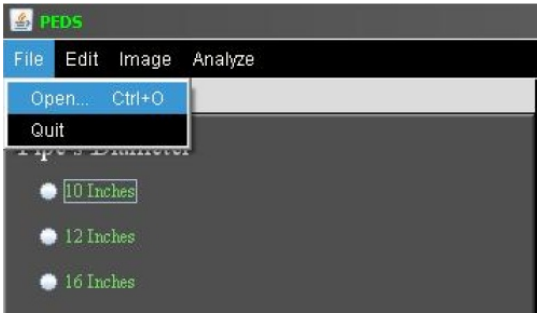


Figure 4. Opening a image file in the PEDS.....

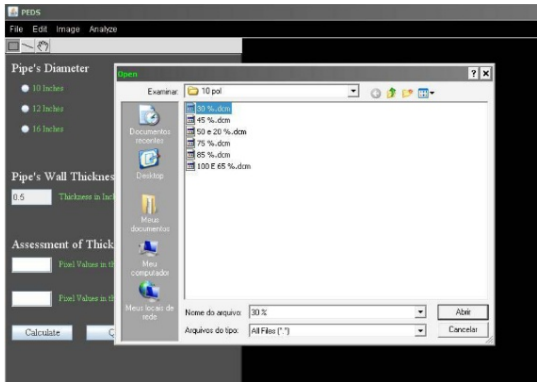


Figure 5. Selecting an image file to open in the PEDS.

3.2 BRIGHTNESS AND CONTRAST

To improve the visualization of the image, the displayed brightness and contrast can be adjusted with “Image/Adjust/Brightness-Contrast”. Figure 6 shows the brightness and contrast window.

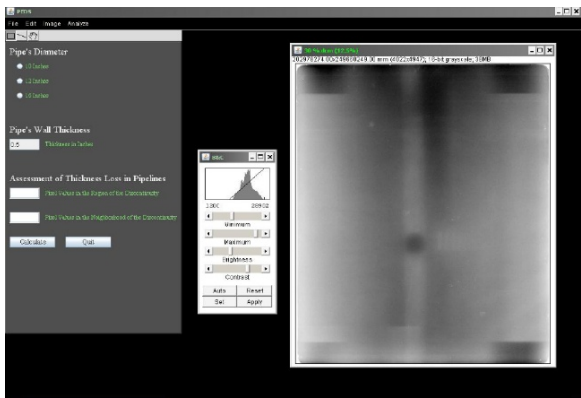


Figure 6. Brightness and contrast window.

In the Figure 6, “Minimum and Maximum” sliders control the lower and upper limits of the display range, and “Brightness and Contrast” sliders increase or decrease the brightness and contrast, respectively, by moving the display

range. The “Auto” applies an intelligent contrast stretch to the way in which the image is displayed. The brightness and contrast are adjusted based on an analysis of the image's histogram. “Reset” restores the original brightness and contrast settings, the “Set” allows to enter the minimum and maximum display range values in a dialog box, and the “Apply” applies the current display range mapping function to the pixel data. PEDS also allows the user obtain histogram plot, profile plot, and ordinary measurements such as average gray value within the selection, area of selection in square pixels, and maximum and minimum pixel values within the selection.

3.3 MEASUREMENTS

To access measurement function, “Analyze/Measure” should be selected and a rectangular selection must be created. Figure 7 shows the measurement window.

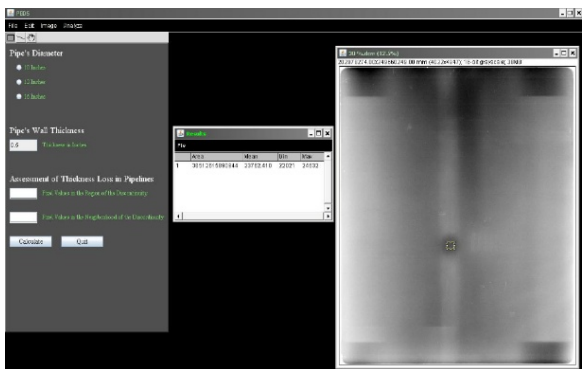


Figure 7. Measurement window.

3.4 ASSESSMENT OF THICKNESS LOSS IN PIPELINES

In order to assess the weld thickness loss, the first step is to choose the diameter of the pipelines. Afterwards, it is necessary to inform the pixels's average intensity in the region of the discontinuity and the pixels's average intensity in the neighborhood of the discontinuity. Those values can be obtained using the measurement function. The last step is the selection of the calculate button.

Figure 8 shows the weld thickness loss value.

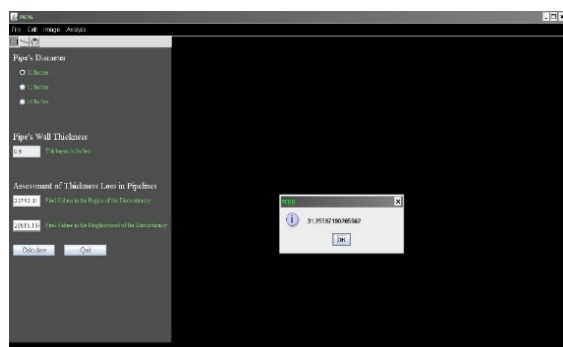


Figure 8. Weld thickness loss value.

In this specific case, PEDS presents 31.26% of thickness loss to a 8-in external diameter pipe.

4. RESULTS

In Tables 2, 3 and 4, the results obtained through computational modeling are compared with the experimental results for different values of thickness loss in 8, 10 and 12-in diameter pipes, whose specifications were showed in Table 1. There is good agreement between the simulated and the experimental results, as shown in Tables 2–4. The maximum percent difference found is 11.11 for a thickness loss equal to 29.25%, in 8-in diameter pipes, and 12.13 for a thickness loss equal to 50.33%, in 12-in diameter pipes. It shows that the methodology developed to estimate wall and weld thickness loss in pipes and implemented in PEDS software is useful to reproduce the NDA system and predict the detectability of imaging indicative details such as a reduction in welding thickness due to corrosion. The largest percentile differences observed between experimental and simulated results are due to variations in density, thickness or absorption characteristics of the material analyzed due to alterations in its composition, that have not been reproduced by MCNPX. It can influence the scattered radiation distribution in the detector, and consequently the quantitative measure of thickness loss.

Real Defect (%)	Ratio between the value at the discontinuity And the value in its neighborhood		PEDS Defect (%)	Relative percent difference (%)
	Experimental	Simulated with MCNPX		
13.30	1.024	1.027	14.56	9.40
21.28	1.040	1.040	23.25	9.25
29.25	1.045	1.059	26.00	11.11
50.53	1.099	1.100	53.03	4.90

Table 2. Wall thickness loss: comparison between the results obtained through PEDS and the experimental data for several values of thickness loss in 8-in diameter pipes.

Real Defect (%)	Ratio between the value at the discontinuity And the value in its neighborhood		PEDS Defect (%)	Relative percent difference (%)
	Experimental	Simulated with MCNPX		
30.63	1.049	1.03	29.40	4.00
50.33	1.11	1.10	56.44	12.13

Table 3. Wall thickness loss: comparison between the results obtained through PEDS and the experimental data for several values of thickness loss in 12-in diameter pipes.

Real Defect (%)	Ratio between the value at the discontinuity And the value in its neighborhood		PEDS Defect (%)	Relative percent difference (%)
	Experimental	Simulated with MCNPX		
30	1.16	1.15	31.26	4.2

Table 4. Weld thickness loss: comparison between the results obtained through PEDS and the experimental data for several values of thickness loss in 8-in diameter pipes.

5. CONCLUSIONS

The software PEDS has proven useful, being capable of successfully reproduce the processes of radiation interaction with matter, in good agreement with the experimental data.

6. PERSPECTIVES

As mentioned previously, the aim of this work is to present a first evolution about PEDS. As future perspectives, the aim is to increase the data bank for calculation of thickness loss including Selenium and Cobalt gamma radiation source and more radiography configurations.

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