COMPARATIVE ANALYSIS OF XYLON IMAGING SYSTEMS WITH DIFFERENT FOCAL TO FILM DISTANCE (FFD): 700 MM VS 1010 MM

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ABSTRACT

This study examines the effects of different Focal to Film Distances (FFD) on radiographic image quality in non-destructive testing of welded samples. Specifically, it compares FFDs of 700 mm and 1010 mm to determine which distance provides better image clarity and defect detection capability. Radiographs were taken at both distances and analysed for sharpness, contrast, density, and the ability to reveal defects such as porosity and cracks. Contrary to the conventional preference for longer FFDs, the results show that the 700 mm FFD yielded better overall image quality. Images taken at 700mm displayed higher contrast, clearer definition of defects, and achieved the optimal film density required for accurate defect detection. In contrast, the 1010 mm FFD did not meet the necessary film density standards, resulting in lower-quality images that may obscure defects. These findings suggest that optimal FFDs enhance the detection and analysis of imperfections in welded structures, supporting the use of appropriate FFD for more accurate and reliable radiographic inspections in industrial applications.

ABSTRAK

Kajian ini mengkaji kesan Jarak Fokus kepada Filem (FFD) yang berbeza terhadap kualiti imej radiografi dalam ujian tidak merosakkan sampel yang dikimpal. Secara khusus, ia membandingkan FFD 700 mm dan 1010 mm untuk menentukan jarak yang memberikan kejelasan imej yang lebih baik dan keupayaan pengesanan kecacatan. Radiografi diambil pada kedua-dua jarak dan dianalisis untuk ketajaman, kontras, ketumpatan, dan keupayaan untuk mendedahkan kecacatan seperti keliangan dan retak. Bertentangan dengan keutamaan konvensional untuk FFD yang lebih panjang, keputusan menunjukkan bahawa FFD 700 mm menghasilkan kualiti imej keseluruhan yang lebih baik. Imej yang diambil pada 700mm memaparkan kontras yang lebih tinggi, definisi kecacatan yang lebih jelas dan mencapai ketumpatan filem optimum yang diperlukan untuk pengesanan kecacatan yang tepat. Sebaliknya, FFD 1010 mm tidak memenuhi piawaian ketumpatan filem yang diperlukan, menyebabkan imej berkualiti rendah yang mungkin mengaburkan kecacatan. Penemuan ini mencadangkan bahawa FFD optimum meningkatkan pengesanan dan analisis ketidaksempurnaan dalam struktur yang dikimpal, menyokong penggunaan FFD yang sesuai untuk pemeriksaan radiografik yang lebih tepat dan boleh dipercayai dalam aplikasi industri.

Keywords: radiographic image quality, non-destructive testing, defect detection

INTRODUCTION

Radiographic testing (RT) is a vital non-destructive technique (NDT) employed to examine materials' internal structure and integrity, especially welded components [1]. The quality of the radiographic image is highly dependent on the Focal Film Distance (FFD), a key parameter that influences sharpness, contrast, and magnification. Traditionally, longer FFDs are believed to provide better image sharpness and less geometric distortion [2]. However, this experiment challenges that assumption by comparing radiographic image quality and defect detection efficiency at two FFDs: 700 mm and 1010 mm. This study aims to demonstrate that an optimal FFD of 700 mm can produce superior image quality, offering enhanced visibility of defects and improved diagnostic accuracy in welded samples. Additionally, it was found that the optimal film density required for accurate defect identification was only achieved at the 700 mm FFD and not at 1010 mm. This is caused by the voltage selection based on the exposure chart that refers to the 700 FFD. This observation highlights the importance of selecting the appropriate FFD to ensure high-quality radiographic images that meet the necessary standards for defect detection.

Focal To Film Distance (FFD)

The Focal to Film Distance (FFD), also known as Source to Image Distance (SID), is a critical parameter in radiographic testing. It refers to the distance between the X-ray source (focal spot) and the film or digital detector used to capture the radiographic image [3]. The FFD significantly affects the image quality, including sharpness, magnification, and contrast. A longer FFD generally results in better image sharpness and less geometric distortion, as the X-rays are more parallel when they reach the film, reducing the penumbra effect (blurring at the edges of structures) [4]. Conversely, an optimal FFD increases magnification and geometric distortion, which can obscure details and affect the accuracy of defect detection. However, a longer FFD requires a higher exposure time or increased radiation dose to achieve the same image density, which can be a consideration in practice.

The appropriate FFD is chosen based on the specific requirements of the inspection and the characteristics of the material being tested. Standards and guidelines, such as those from the American Society for Testing and Materials (ASTM) and the International Organization for Standardization (ISO), often provide recommended FFD values for different applications and materials to ensure optimal image quality and reliable defect detection [5]. Proper selection and maintenance of the FFD are essential for achieving high-quality radiographic images that accurately represent the internal structure of the tested material, allowing for reliable identification of defects and ensuring the integrity and safety of critical components and structures.

METHODOLOGY

Sample preparation

In the field of non-destructive testing, radiographic testing is a crucial technique used to examine the internal structure of welded samples without causing any damage. Proper preparation of these samples is essential to ensure accurate and reliable test results. The process begins by selecting welded samples that meet the specified thickness requirements, which in this case are 14 mm and 15 mm. It is vital to confirm that each sample conforms to these exact thickness specifications to maintain consistency and accuracy in testing. Once the correct thickness is verified, each sample must be identified using lead letters to mark it with a unique identifier as shown in Figure 1. This identification process, known as radiographic identification, is crucial for ensuring traceability and correct identification throughout the imaging and evaluation stages.

Following identification, an Image Quality Indicator (IQI) must be placed according to the standards specified for each thickness. The IQI, which varies based on the thickness of the sample, is strategically positioned on or above the welded structure to serve as a reference point for evaluating image quality. Made typically from the same material as the sample, the IQI helps in assessing the resolution and contrast of the radiographic images through its holes, thereby enabling a reliable evaluation of the internal features and potential defects in the welded samples. Then shim is kept below IQI to match the density of the IQI and the weld structure [6]. This meticulous preparation process ensures that the imaging system and parameters used are capable of detecting specific sizes and types of flaws, thus guaranteeing the integrity and reliability of the radiographic testing results.

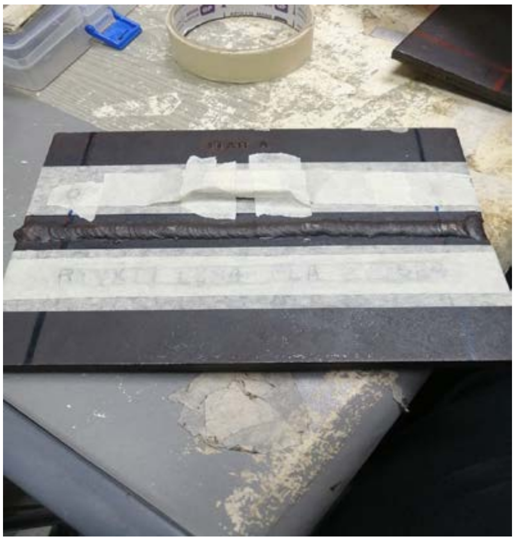


Figure 1 Welded sample with Radiographic identification and shim

Film preparation

In radiographic testing, proper film preparation is crucial for obtaining high-quality images and accurate results. The process begins in a dark room to protect the film from exposure to light, which can ruin its sensitivity. First, inspect the film cassette as shown in Figure 2 meticulously to ensure there are no holes or damages that could allow white light to enter, thereby compromising the film. Next, check the lead screen to confirm it is free from dust or any particles that might scratch or damage the film. After verifying these conditions, switch on the red safety light before turning off the white light to maintain visibility while protecting the film from exposure. During the film loading process, handle the film by its edges only to prevent introducing artifacts or fingerprints on its surface. Carefully place the film into the lead screen, followed by securing it in the cassette. Seal the film cassette with masking tape to ensure it is properly closed, and then label the film for identification purposes. This thorough preparation process ensures that the film remains in optimal condition, ready to capture clear and precise radiographic images.

Figure 2 Film cassette and radiographic film

Shooting preparation

Radiographic testing of welded samples involves precise setup and alignment to ensure accurate results. Begin by ensuring that the X-ray focal spot points downward to provide a direct path for the X-ray beam. Next, the minimum FFD is calculated to prevent distortion, geometrical unsharpness. that can decrease the film quality. The minimum FFD are calculated by using formula 2.1,

$$\boldsymbol{FFD_{min} = t(\frac{F}{\mu g_{max}} + 1)} \qquad \text{(eq 2.1)}$$

t = thickness

F = focal spot size

μg_{max} = maximum geometrical unsharpness

$$FFD_{min} = 14(\frac{0.4}{0.508} + 1)$$
$$= 25.02\ mm$$

From the calculation, we get the minimum FFD of 25.02 mm for this experiment. FFD minimum is the shortest allowable distance between the x-ray source and the film to achieve adequate image resolution and contrast. Using a measuring tape, measure the focal-to-film distance (FFD), set to 700 mm and 1010 mm respectively for this experiment, ensuring consistency and accuracy in image capture. Next, install a laser pointer at the focal spot to assist with alignment as shown in Figure 3. Move the laser pointer to the center, and place the sample beneath it, ensuring that the welded structure is positioned in the middle of the focal spot. This ensures that the area of interest receives the optimal exposure for clear imaging. Once the sample is correctly positioned, return the laser pointer to its original position before initiating the X-ray exposure. This meticulous setup process guarantees that the X-ray beam is accurately targeted and that the welded structure is properly aligned, resulting in high-quality radiographic images that can reliably reveal internal defects and characteristics.

FIGURE 3 Example of FFD 1010 mm and FFD 700 mm

Yxlon operating procedure

The YXLON Y.XMB 225 X-ray System is a sophisticated piece of equipment used for non-destructive testing in various industrial applications. Proper startup and operation of this system are crucial for ensuring accurate radiographic results and maintaining safety standards.

To begin, switch on the plug of the Y.XMB 225 X-ray System, then insert the key and turn the main switch to the right, positioning it to the "< ~ >" setting. Proceed by selecting "<1>" to continue with tube conditioning or "<0>" to skip this step, followed by entering the downtime days and pressing the "<F1>" key. Use the cursor keys "<2/4/6/8>" to choose the conditioning voltage for the tube, indicated by the highlighted figure. Turn the main switch to the right again to set it to the "<□>" position, which will automatically start the selected conditioning program once the high voltage is turned on.

After initiating the conditioning program, ensure no one is inside the bunker before closing the door, then turn the switch to the right and follow with the safety key. The red light will illuminate as shown in Figure 4, indicating that the X-ray system is active. It is crucial to wait until the red light on the control panel and the stairs turns off before entering the bunker. Use a survey meter to check for any radiation leakage. Once both red lights have turned off, turn the switch key back to the left, remove the key, and place it back in its box. Finally, open the door, remove the sample, and turn the main switch to the left to set it to the "< O >" position, then remove the key. This detailed procedure ensures the safe and effective operation of the YXLON Y.XMB 225 X-ray System, safeguarding both the quality of the radiographic testing and the safety of personnel.

Film processing

Film processing in radiographic testing is a critical step that involves developing the exposed film to produce a visible image that can be analyzed for defects and structural integrity. The process begins with the exposed film being transferred to a darkroom, where it is handled under safe light conditions to prevent further exposure. The film is then immersed in a series of chemical baths. The first bath is the developer, which reduces the exposed silver halide crystals in the film emulsion to metallic silver, creating a latent image. This is followed by a stop bath, which halts the development process by neutralizing the developer. Next, the film is placed in a fixer solution that dissolves the unexposed silver halide crystals, making the image permanent and light-resistant. After fixation, the film is thoroughly washed in water to remove any residual chemicals, which is crucial to prevent image degradation over time. Finally, the film is dried, ensuring that it is completely free of moisture before it is stored or analyzed. Proper film processing is essential for achieving high-quality radiographic images with the necessary contrast and resolution to accurately detect and evaluate internal features and potential defects in the tested material.

FIGURE 4 System parameters for the experiment and the control switch for YXLON Y.XMB 225 X – ray system

Film interpretation

After the film is processed to reveal the latent image, trained inspectors examine it to identify and evaluate indications such as cracks, voids, or inclusions in the tested object by using film viewer and densitometer as shown in Figure 5. This process requires interpreting variations in film density to detect defects or discontinuities that could affect the structural integrity or functionality of the material. First, switch on the film viewer, adjust the light's volume, and position the light to a suitable condition for interpretation. Then turn on the densitometer. Next densitometer is calibrated to zero density before placing the film on the film viewer. Then meticulously check the density at three points across the film without adjusting the densitometer, ensuring all measurements fall within the required density range of 1.8 to 4.0. Next, compare findings against established acceptance criteria, defined by industry standards or project requirements, to determine if the object meets specified quality and safety standards. Detailed documentation of interpretation findings is crucial for making informed decisions about the suitability of the tested object for its intended use.

Figure 5 Film viewer and densitometer

RESULT AND DISCUSSION

Density

Table 1 presents data on radiographic density measurements for welded sample Plate – A with thickness of 14 mm using a focal to film distance (FFD) of 1010 mm. This FFD was evaluated to determine if it could achieve adequate film density for clear and accurate radiographic images. The samples, identified as Plate A-3 and Plate A-4, were subjected to exposure conditions with a voltage of 180 kV and a current of 4.4 mA for 27 seconds.

Table 1 Density for FFD 1010 mm

Sample	Voltage (kV)	Current (mA)	Time (sec)	density			Thickness (mm)	conclusion
Plate A - 3	180	4.4	27	1.21	1.41	1.41	14	Film rejected
Plate A - 4				1.31	1.38	1.41		Film rejected

The density values for the samples were measured at three points each as shown in Table 1. Plate A-3 showed densities of 1.21, 1.41, and 1.41, while Plate A-4 had densities of 1.31, 1.38, and 1.41. These values are significantly below the acceptable range of 1.8 to 4.0 for radiographic evaluation, indicating that the film density achieved is insufficient. Low-density films result in poor image quality, making it challenging to detect such defects accurately. The samples had a thickness of 14 mm, which affects X-ray absorption and the resulting film density. Despite the consistent exposure conditions, the films were rejected due to their low density.

Next the experiment for FFD 700 mm was initiated. Table 2 presents data on radiographic density measurements for welded samples using a focal to film distance (FFD) of 700 mm. This FFD was selected to achieve higher film density, which is crucial for clear and accurate radiographic images. The sample, identified as Plate A-7, Plate

A-8 was subjected to specific exposure conditions, all at a voltage of 180 kV. The current was kept constant at 4.4 mA, while the exposure times ranged from 27 seconds.

Table 2 Density for FFD 700mm

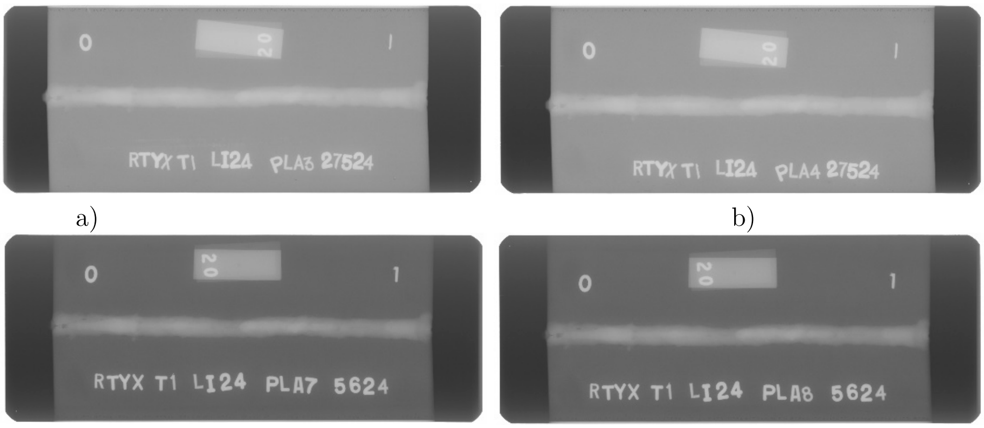
Sample	Voltage (kV)	Current (mA)	Time (sec)	density			Thickness (mm)	conclusion
Plate A - 7	180	4.4	27	2.10	2.21	2.28	14	Film accepted
Plate A - 8				2.05	2.14	2.14		Film accepted

According to Table 2, Plate A-7 showed densities of 2.10, 2.21, and 2.28, while Plate A-8 had densities of 2.05, 2.14, and 2.14. These density values indicate that the film density achieved falls within the acceptable range for radiographic evaluation for x-ray, which is typically between 1.8 and 4.0. This range ensures that any potential defects such as porosity or cracks can be accurately identified. All films were accepted, suggesting that the 700 mm FFD reliably produces quality radiographic images. The results support the hypothesis that an optimal FFD can achieve higher film density, which is essential for better image clarity and defect visibility.

This outcome suggests that an FFD of 1010 mm is less effective in achieving the necessary film density compared to 700 mm, which has been shown to produce higher density and better image clarity. The results highlight the importance of selecting an appropriate FFD to ensure high-quality radiographic images that meet the required standards for defect detection.

Film Quality

The film in Figure 6 shows the different image quality for the sample with the same thickness but with different FFD of 700 mm and 1010 mm respectively. Here we can see the contrast of the image of the film that is in the acceptable and unacceptable range density. Upon examining the film, PLA - 7 and PLA - 8 exhibit notably higher resolution compared to PLA - 3 and PLA - 4. This is evident in the clarity with which identification markers such as location markers, introduction number, date, and Image Quality Indicators (IQI) are displayed. Specifically, films taken at a Focal-Film Distance (FFD) of 700 mm appear darker and clearer, allowing for easier identification of details and defects. In contrast, films taken at FFD 1010 mm appear more plain and less distinct, making it more challenging to discern finer details and defects. These observations emphasize the critical role of FFD in radiographic testing, as it directly influences the visibility and resolution of inspection results. Adjusting FFD appropriately is essential for achieving optimal inspection outcomes and ensuring accurate defect detection.



a) b) c) d)

Figure 6 Film quality for, a) PLA - 3 and b) PLA - 4 for FFD 1010 mm and c) PLA - 7 and d) PLA - 8 for FFD 700 mm

CONCLUSION

In conclusion, optimizing the Focal-Film Distance (FFD) significantly impacts the clarity and resolution of Non-Destructive Testing (NDT) film results. Films captured at an FFD of 700 mm, specifically PLA - 7 and PLA - 8, demonstrated superior resolution with clearer visualization of the identification facilitating easier defect detection. Adherence to film density requirements further enhances reliability, ensuring consistent and precise radiographic testing evaluations. Conversely, films at FFD 1010 mm, like PLA - 3 and PLA - 4, which did not meet density standards, appeared less distinct and posed challenges in defect recognition. These findings underscore the critical role of both optimizing FFD and maintaining proper film density to achieve reliable defect detection and interpretation in radiographic industrial applications.

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