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COMPARATIVE ANALYSIS OF DIRECT AND COMPUTED RADIOGRAPHY FOR BRASS STEP WEDGES

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Abstrak

This study investigates the differences in image quality between Direct Radiography (DR) and Computed Radiography (CR) when applied to brass step wedges. Radiography was performed using plate (CR) and digital panel (DR) detectors to establish radiographic procedures for brass materials. The study involved radiographing a brass step wedge specimen with X-ray machine at 5 mA current and an SFD of 930 mm. The voltage (kV) was selected within the range of 100-140 kV, with exposure time adjusted based on the material thickness, which ranged from 2 mm to 9 mm. Digital radiographic images were analyzed using Rhythm Review software to compare the grey value and sensitivity. The results showed the smallest grey value deviation of 0.043% at 3 mm, 5 mm, and 7 mm thickness using DR, while the largest grey value deviation of 0.102% occurred at 4 mm thickness using CR. The best sensitivity was achieved with DR (1.59%) compared to CR (4.64%). Based on these results, it is recommended to use DR for radiographic procedures on brass due to its superior image quality compared to CR. These findings contribute to better selection of radiographic techniques for brass material inspections in industrial applications

INTRODUCTION

The industrial era 4.0 is rapidly advancing, driving innovation through the integration of technology in the industrial sector. The adoption of technology enhances industries by implementing digital intelligence systems, which, in turn, improve quality assurance. One of the methods to ensure quality is through nondestructive testing. (Li et al., 2020)

In Indonesia, the use of radiography in the industrial field has been on the rise. Industrial radiography involves the examination of material structures and/or quality using radiation as a nondestructive testing method (Jumpeno, 2000; Saeed et al., 2022).

The development of the digital industrial revolution has shifted industrial radiography from conventional film-based methods to digital techniques, eliminating chemical processing and offering faster image acquisition. The advancement of digital radiography provides several benefits, including faster image processing and analysis times(Abidin et al., 2019; Suryaningsih et al., 2015).

Brass is an alloy of copper and zinc (Jasper et al., 2025; Rahayu, 2018; Samlawi & Siswanto, 2016). It is highly malleable, a good conductor of heat, and generally resistant to water and salt corrosion. These properties make brass an ideal material for manufacturing ship components, engine parts, art objects, and household appliances (Rizal & Setiawan, 2017; Zhang et al., 2020). Brass is also widely used in industrial components such as condenser pipes, radiator cores, pump impellers, ship propellers, faucets, valves, gears, and more. In the shipping industry, brass is commonly used in propellers, fittings, valves, flanges, and seamless brown pipes (Rizal & Setiawan, 2017; Zhang et al., 2020).

Currently, there is a lack of data regarding the comparison of radiographic image quality between Direct Radiography (DR) and Computed Radiography (CR) using brass specimens. This study aims to analyze the image quality of these two digital radiography devices by measuring grey values and calculating their sensitivity. The findings from this study can serve as a reference and guide for selecting the appropriate radiographic method—either DR or CR—when working with brass materials in industries such as shipping, metalworking, and other applications.

METHODOLOGY

This research was conducted by analyzing the images obtained from irradiation using the Eresco-MF4 X-ray machine, Direct Radiography (DR), and Computed Radiography (CR) on brass step wedges with thickness variations ranging from 2 mm to 9 mm. The analysis was performed using the Rhythm Review application.

The irradiation process was conducted using a tube current of 5 mA and a Source-to-Detector Distance (SDD) of 930 mm. The voltage applied ranged from 100 to 140 kV, and exposure time was adjusted according to the thickness of each step. The data analyzed included grey values and sensitivity.

Thickness Variation Determination

Exposure charts and equations for calculating irradiation factors are typically designed for iron materials (Bazalova-Carter et al., 2020; Kumar & Kumar, 2019). Therefore, in this study, the thickness of the brass specimens was converted to the equivalent thickness of standard materials (iron) for accurate comparison.

Grey Value Deviation

Grey value data were collected at three points near the required IQI (Image Quality Indicator) wire. The grey value data were then processed mathematically to calculate the grey value deviation using the following equation:

$$\text{Deviation (\%)} = [(Mgv - Ged\_ref) / Ged\_ref] \times 100\%$$

Where :

Mgv = grey value measurement

Ged_ref=grey value at density 2

In this study, the grey value deviation threshold was set that the grey value deviation should not exceed 1% to ensure that the sensitivity comparison is accurate and reliable.

Sensitivity Analysis

Sensitivity was analyzed by observing the smallest Image Quality Indicator (IQI) wire number that appeared in the three radiographic images for each thickness. The diameter of the smallest visible IQI wire was then used to calculate the sensitivity value of the image (Bazalova-Carter et al., 2020)

$$Sensitivity\ (\%) = (\frac{d_{wire}}{t_{material}}) \times 100\%$$

RESULT AND DISCUSSION

Determination of Thickness Variation

In this study, the brass thickness variations were standardized to the equivalent iron thickness using the radiographic equivalence factors for different metals from the ASME V SE-94 table and equation.

Grey Value Deviation

Table 1 presents the results of the grey value deviation calculations for each brass thickness variation, expressed as a percentage. The grey value deviation in Direct Radiography (DR) was found to be smaller than that in Computed Radiography (CR).

Table 1. Grey Value Data

Brass Thickness (mm)	Direct Radiography Grey Value	DR Grey Value Deviation (%)	Computed Radiography Grey Value	CR Grey Value Deviation (%)
2	7003.67	0.052%	32029	0.091%
3	7003.00	0.043%	32031.33	0.098%
4	7003.33	0.048%	32032.67	0.102%
5	7003.00	0.043%	32029.67	0.093%
6	7003.67	0.052%	32031	0.097%
7	7003.00	0.043%	32030.67	0.096%
8	7003.33	0.048%	32030.33	0.095%
9	7003.33	0.048%	32029	0.091%

The grey value deviation calculation results are more clearly visualized in the histogram shown in **Figure 1**. As observed, the smallest grey value deviation, 0.043%, occurred at brass thickness variations of 3 mm, 5 mm, and 7 mm using Direct Radiography. Conversely, the largest grey value deviation, 0.102%, was observed at a 4 mm brass thickness variation when using Computed Radiography.

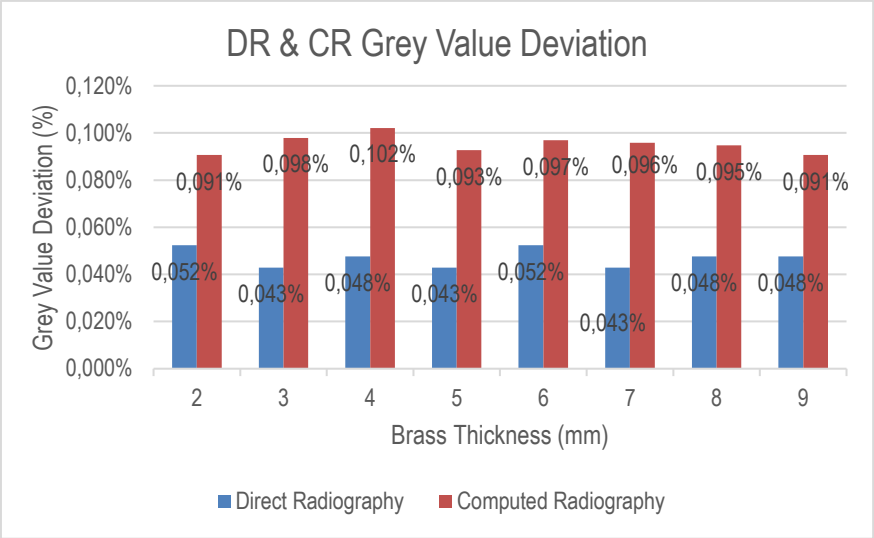

Figure 1. Grey Value Deviation Histogram for DR and CR

This indicates that the CR images generally exhibit higher contrast than DR images, as reflected by the larger grey value deviation. This is evident from the grey value deviation being higher in CR compared to DR (Kandemir et al., 2021). The higher grey value deviation in CR, associated with a positive density deviation, results in a darker image compared to DR. This suggests that radiographic contrast affects image quality between the two digital radiography methods.

Sensitivity Observation

Sensitivity was assessed by observing the smallest Image Quality Indicator (IQI) wire number that appeared in the radiographic images (Kandemir et al., 2021; Kumar & Kumar, 2019). This observation was based on one image meeting the grey value deviation requirement of less than 1%, along with two additional images as evidence to support the sensitivity analysis according to ASME V Article 2. Below are the images of DR and CR irradiation results:

Figure 2. Direct Radiography Image of 2 mm Brass step

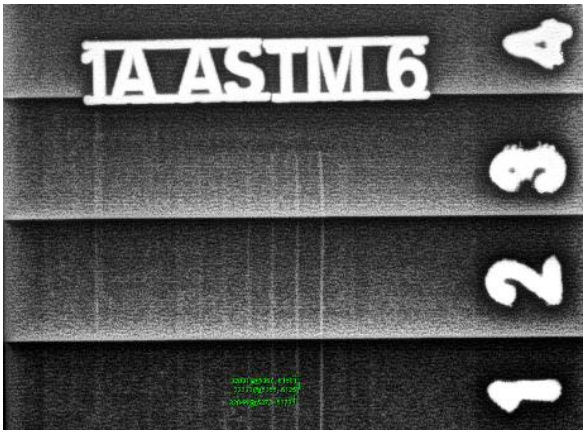

Figure 3. Computer Radiography Image of 2 mm Brass step

Image Quality Comparison

The images from both Direct Radiography and Computed Radiography meet the density or grey value requirements according to ASME V Article 2 for each brass thickness variation. The grey value deviation in both methods was below 1%, allowing for a more accurate sensitivity analysis of the radiographic images. As a result, the contrast in CR is higher than in DR, which is reflected in the greater grey value deviation observed in CR. Consequently, the image produced in CR appears darker than in DR, which impacts the overall sensitivity.

Sensitivity Comparison

Direct Radiography and Computed Radiography both meet the wire number requirements specified in ASME V Article 2. Sensitivity is considered better when the percentage value of the smallest visible wire number is smaller. This is directly related to the system's spatial resolution and contrast capabilities. Kandemir et al. (2021) demonstrated that DR systems deliver higher spatial resolution and a better contrast-to-noise ratio than CR systems under identical conditions, which enables clearer detection *of smaller IQI wires.* Therefore, this study compares the sensitivity percentages of DR and CR at each brass thickness. The sensitivity of DR is better, as it shows smaller percentage values compared to CR.

The sensitivity results are summarized in the following table and visualized in **Figure 4** as a histogram:

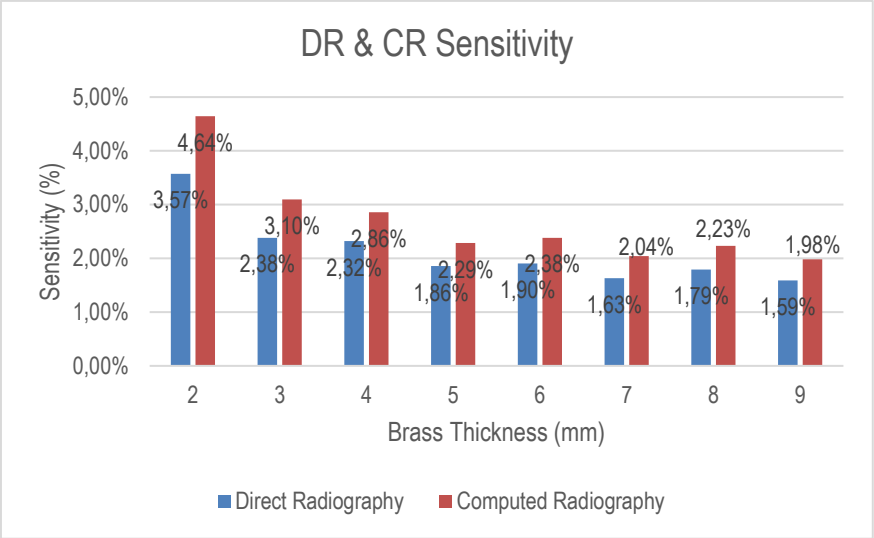

Figure 4. DR and CR Image Sensitivity Histogram

The study findings show that Direct Radiography demonstrates better sensitivity in capturing the smallest image details compared to Computed Radiography.

Radiographic Image Quality

The quality of radiographic images is influenced by contrast and definition. In this study, DR exhibited lower contrast than CR, which impacted the latitude and definition of the images. The smaller IQI wire details were more clearly visible in DR, which resulted in better sensitivity. The smaller sensitivity value in DR suggests that irradiation using DR has higher sensitivity compared to CR. This can be attributed to the real-time image processing in DR, which avoids any lag time that may occur in CR due to the imaging plate. As a result, the study concluded that the digital image quality in DR is superior to that of CR.

CONCLUSION

1. The thickness of brass was standardized using an equivalence factor to the standard thickness of iron to determine the irradiation parameters.
2. The grey value deviation for both Direct Radiography and Computed Radiography was found to be below 1%, with DR having a lower contrast compared to CR.
3. Direct Radiography exhibited better radiographic digital image quality than Computed Radiography, as evidenced by the smaller sensitivity value of DR (1.59%) compared to CR (4.64%).

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