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Optimization of exposure factors for X-ray radiography non-destructive testing of pearl oyster

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Optimization of exposure factors for X-ray radiography non-destructive testing of pearl oyster

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Abstract. One of the processes in pearl oyster cultivation is detecting the pearl nucleus to gain information whether the pearl nucleus is still attached in the shell or vomited. The common tool used to detect pearl nucleus is an X-ray machine. However, an X-ray machine has a drawback that is the energy used is higher than that used by digital radiography. The high energy make the resulted image is difficult to be analysed. One of the advantages of digital radiography is the energy used can be adjusted so that the resulted image can be analysed easily. To obtain a high quality of pearl image using digital radiography, the exposure factors should be optimized. In this work, optimization was done by varying the voltage, current, and exposure time. Then, the radiography images were analysed using *Contrast to Noise Ratio* (CNR). From the analysis, it can be determined that the optimum exposure factors are 60 kV of voltage, 16 mA of current, and 0.125 s of exposure time which result in CNR of 5.71.

1. Introduction

Due to its high value product, pearl farming has become an attractive business venture. Moreover, pearl farming is an environment-friendly process and is simple to learn. One of the important stages in pearl cultivation is detecting the pearl nucleus to determine whether it is still attached to the oyster shell. The common tool used to detect the pearl nucleus is an X-ray machine. However, X-ray machine has a drawback of high energy usage. The high energy make the resulted image has high brightness and low contrast. Moreover, the resulted image cannot be recorded. Therefore, an alternative method to detect pearl nucleus inside oyster is required to provide accurate results which will further improve pearl production. In contrast to research on pearl quality inspection [1-3] which gain much attention among researchers, research on pearl detection method has not been widely explored. In this work, we proposed to use digital X-ray radiography to detect pearl inside oyster.

Digital X-ray radiography has been used for non-destructive testing (NDT) in various applications such as evaluation of friction stir welded aluminium butt joints [4], monitoring of pipeline quality in oil and gas industry [5], analysis of aluminium alloy hemmed joints for automotive applications [6] and investigation of a tubular metal object [7]. Digital X-ray radiography system has advantages since the energy can be adjusted and the image can be recorded and stored in a computer. In digital radiography, the analogue radiography image is converted to a digital image and is then stored in a computer. However, to obtain high quality image of pearl, it is important to conduct research to determine optimum exposure factors. Therefore, this work presents an optimization of exposure factors of digital radiography to be used as NDT for pearl oyster. Optimization of the exposure factors were done by assessing the quality of the image resulted from various exposure factors values. To analyse the image quality, contrast to noise ratio method (CNR) was used since it is computationally simple and it measures the image quality rather than image noise [8, 9].

Exposure factors are factors that determine image quality of radiography, i.e. voltage, current and exposure time. In radiology, image quality determine effectiveness of diagnose that will be performed [10].

Voltage highly influences the quantity and quality of the X-ray resulted from the tube. As voltage increases, the energy of X-ray increases which further improve its penetrability. Moreover, high voltage will also results in more X-rays that is produced by the X-ray tube. In other words, high voltage results in high X-ray intensity. Therefore, high voltage will produce bright image. In contrast, low voltage value results in dark image.

Other exposure factors is current or widely known as Milliamperage (*ma*). Like kV, *ma* also determines the quantity of x-rays produced. Other term of exposure factors in terms of current is *m-A-s* factor which is defined as time × milliamperes, where time is the exposure time. The *m-A-s* factor determines the X-ray photons that reach the film, thus will affect the X-ray density. If the quantity of X-rays reaching the film is too low, the film will be pale. Therefore, there is high dependence between current and exposure time. If the current or *ma* is set to be high, then low exposure time is sufficient to produce good image.

CNR is a quantitative parameter that provides information of image performance (contrast) and data quality i.e. noise caused by radiography system [11]. It is defined as the difference between the mean of region of interest (ROI) of the object with the mean of the ROI of the background divide by the deviation standard of the background, σ_o [12] as shown in equation (1) below

$$CNR = \frac{S_A - S_B}{\sigma_o} \tag{1}$$

where S_A is the mean of ROI of the object and S_B is the mean of ROI of the background. High CNR indicates good image quality. Image with low contrast either too bright or too dark will result in low CNR. Due its simplicity in computational algorithm and good measurement of image quality, CNR has been widely used in image quality assessment, such as in mammography [13], magnetic resonance imaging [11] and computed tomography [14].

2. Methods

Digital radiography equipment used was digital radiography developed in Physics laboratory, Physics Department, UNNES. The equipment was a modification of conventional radiography Mednif/SF-100BY Mobile X-ray. The image capturing film was replaced by light tight tube. The light tight tube is used to change invisible X-ray to be visible X-ray. Then, the image in the intensifying screen is captured and recorded using Digital Single Lens Reflex (DSLR) camera which is connected to a computer so that the image can be observed at the computer monitor as shown in Figure 1.

The research was done in three stages which are voltage optimization, current optimization and exposure time optimization. The image was taken by capturing the image of the pearl oyster using Digital Radiography System using various exposure factors value. The pearl oyster used was *Pinctada maxima* species as shown in Figure 2. The voltage value was varied from 50 kV to 70 kV with increment of 5kV while current and exposure time were maintained at 16 mA and 0.125s, respectively. The images obtained were then analysed using CNR method. Voltage value which result the highest CNR was then used as a voltage for capturing other images by varying the current while the time was maintained at 0.125s. The current values used were 16 mA, 32 mA, and 63 mA. The optimum voltage and current value was then used to optimize the exposure time. The exposure time was varied for 0.1s, 0.125s and 0.16s.

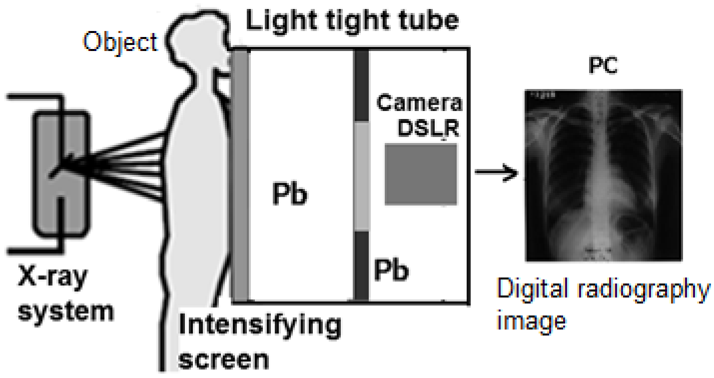


Figure 1. Diagram of digital radiography system modified from conventional radiography system

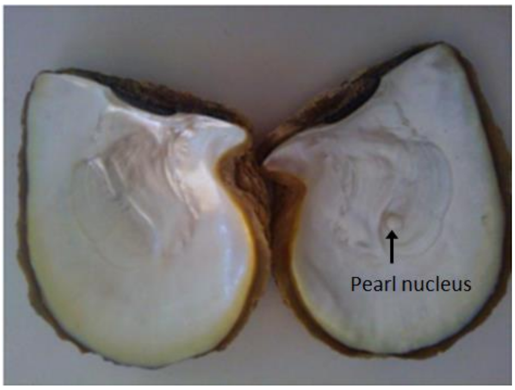


Figure 2. Pearl nucleus inside pearl oyster *Pinctada maxima.*

3. Result and Discussion

CNR analysis was done by selecting pearl nucleus indicated by black spot in the image as the object and an small area near the nucleus as background as shown in Figure 3. The background selection was mantained at the same location for all CNR analysis of all images to obtain fair comparison of the CNRs.

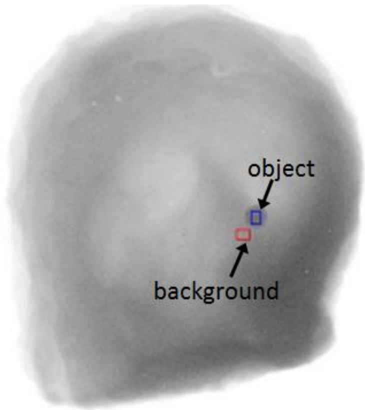


Figure 3. Object and background selection for the CNR analysis.

3.1. Voltage Optimization

CNR for various voltage values are plotted in Figure 4. It is shown that CNR increases as voltage increase. However, futher increase of voltage results in the decrease of CNR. Low CNR at low voltage occured since low voltage provides low X-ray energy, thus the X-ray has low penetrability. Therefore, the image resulted from low voltage is dark and has low contrast. As voltage increases, the X-ray energy increase and the image is brighter, thus the CNR value also increase. Further increase of voltage make the image brightness increases so that the image contrast decreases and thus CNR decreases. It is shown that the optimum volatge is 60 kV which produced CNR of 5.71.

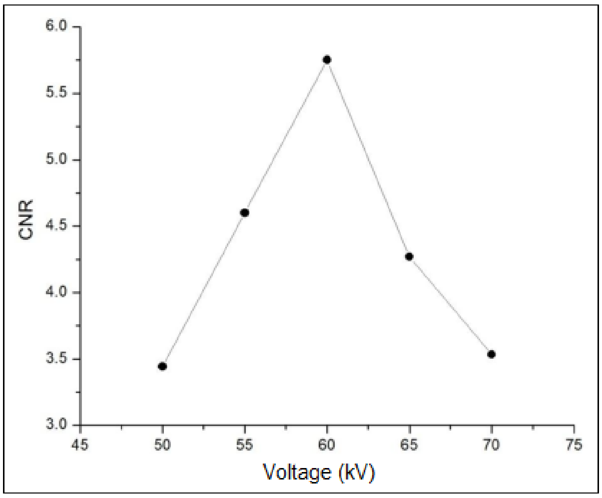


Figure 4. CNR vs. voltage for pearl oyster image.

3.2. Current Optimization

CNR for various current values are tabulated in Table 1. It is shown that the higher the current, the lower the CNR value. The results are acceptable since high current value results in high intensity of X-ray which further results in bright image. Due to the high brightness, the contrast of the image is low and thus the results in low CNR. It was found that the optimum current value is 16 mA with CNR of 5.751.

Table 1. CNR for various current values

Current (mA)	ROI mean of the object	ROI mean of the background	CNR
16	115.434	145.463	5.751
32	130.575	159.039	5.455
63	156.142	174.217	3.429

3.3. Exposure Time Optimization

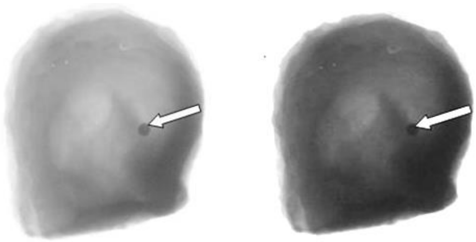
The exposure time affect the radiation intensity that reach the object. By adding the exposure time, the radiation amount will increase. As a concequence, the longer the object exposed to the radiation, the sharpness of the resulted image was decreasing and the noise is high. Therefore, the CNR value also decreases as shown in Table 2.

Table 2. CNR for various exposure time

Exposure time (S)	ROI mean of the object	ROI mean of th background	CNR
0.1	112.456	134.421	4.176
0.125	115.434	145.463	5.751
0.16	144.244	165.966	4.140

It is shown in Table 2 that the highest CNR value is 5.751 with expose time at 0.125s. Therefore, from the results above, it can be concluded that the optimum exposure factors are 60 kV of voltage, 16 mA of current and 0.125s of exposure time.

From CNR analysis above, it was found that the highest CNR is 5.751 and the lowest CNR is 3.443. The images resulting both CNR values are shown in Figure 5.



(a) (b)

Figure 5. The image with CNR of 5.751 (a) and the image with CNR of 3.443(b)

4. Conclusion

It can be concluded that the optimum exposure factors for digital radiography NDT for pearl nucleus detection are 60 kV of voltage, 16 mA of current and 0.125s of exposure time. The CNR value obtained from the image with those exposure factors is 5.751.

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References

[1] Revol V, Hanser C and Krzemnicki M 2016 *Case Studies in Nondestructive Testing and Evaluation* **6** 1
[2] Rosc J, Hammer V M F and Brunner R 2016 *Case Studies in Nondestructive Testing and Evaluation* **6** 32
[3] Krzemnicki M S, Friess S D, Chalus P, Hänni H A and Karampelas S 2010 *Gems & Gemology* **46** 128
[4] Saravanan T, Lahiri B B, Arunmuthu K, Bagavathiappan S, Sekhar A S and Pillai V P M 2014 *Procedia Engineering* **86** 469
[5] Klimenov V A, Buller A, Moskalev Y, Chakhlov S and Shteyn M 2012 *Proc. 18th World Conf. Nondestructive Testing* (Durban, South Africa)
[6] Zheng S, Vanderstelt J, McDermid J R and Kish J R 2017 *NDT & E International* **91** 32
[7] MacDonald B L , Vanderstelt J, O'Meara J and McNeill F E 2016 *Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms* **367** 46
[8] Yao S, Lin W, Oong E P and Lu Z 2005 Proc. *IEEE Int. Conf. on Image Processing (Italy/IEEE)* p I-397-400.
[9] Kalender W A, Deak P, Kellermeier M, van Straten M and Vollmar S V 2009 *Med Phys* **36** 993
[10] Strauss L J and Rae W I, *Image quality dependence on image processing software in computed radiography* **16**, 2012.
[11] Geissler A, Tahamtan A R, Gartus A, Beisteiner R, Foki T and Barth B2007 *Jurnal of Magentic Resonance Imaging* **25** 1263
[12] Song X, Pogue B W, Jiang S, Doyley M M, Dehghani H and Tosteson T D 2004 *Appl Opt* **43** 1053
[13] Metaxas V, Delis H, Kalogeropoulou C, Zampakis P and Panayiotakis P 2015 *Journal of Physics: Conference Series* **637** 012017
[14] Bechara B, McMahan C A, Moore W S, Noujeim M, Geha H and Teixeira F B 2012 *Journal of Oral Science* **54** 227