International Journal of Innovative Research in Advanced Engineering (IJIRAE) ISSN: 2349-2163
Issue 10, Volume 4 (October 2017) www.ijirae.com

DETERMINATION OF SPATIAL RESOLUTION IN COMPUTED RADIOGRAPHY (CR) BY COMPARING THE EDGE SPREAD FUNCTION-POINT SPREAD FUNCTION (ESF-PSF) AND IN-PLANE POINT SPREAD FUNCTION (IP-PSF) METHODS

Nadia Surahmi,
Magister of Physic, Diponegoro University,Indonesia
nadhya.dhira@st.fisika.undip.ac.id
Catur E. W. *
Department of Physics, Diponegoro University, Indonesia
catur.ediwidodo@undip.ac.id
Suryono
Department of Physics, Diponegoro University, Indonesia
suryono@undip.ac.id

Manuscript History
Number: **IJIRAE/RS/Vol.04/Issue10/OCAE10900**
DOI: 10.26562/IJIRAE.2017.OCAE10900
Received: 27, September 2017
Final Correction: 12, October 2017
Final Accepted: 20, October 2017
Published: **October 2017**
Citation: Surahmi, N.; *, C. E. W. & Suryono (2017), 'DETERMINATION OF SPATIAL RESOLUTION IN COMPUTED RADIOGRAPHY (CR) BY COMPARING THE EDGE SPREAD FUNCTION-POINT SPREAD FUNCTION (ESF-PSF) AND IN-PLANE POINT SPREAD FUNCTION (IP-PSF) METHODS', Master's thesis, Department of Physics
Editor: Dr.A.Arul L.S, Chief Editor, IJIRAE, AM Publications, India

Abstract— The QC (Quality Control) testing of spatial resolution in CR (Computed Radiography) using ESF-PSF and IP-PSF methods has been investigated. The object used in this study is a phantom made of copper with 15 cm both in lenght and widht, and 1 mm in thickness. The exposure to phantom was occured with some variation of voltage, i.e. 50 kV, 60 kV, 70 kV and 80 kV for CR system. Current variation wass performed by four times for each voltage, i.e. 1.6 mAs; 4 mAs; 16 mAs and 32 mAs. Digital image data used for the acquisition is in the DICOM format. Measurement of image's spatial resolution wass performed by calculate the value of FWHM as an indicator of good or poor spatial resolution of images. Measurement of FWHM value has performed by using MATLAB R2015b and Corel Draw X7 programs. The FWHM value was obtained from gaussian function which provides a complete information on opaqueness effects that occur in images. The results showed that the best value of spatial resolution for the ESF-PSF methode is 2.50 lp/mm and the worst value is 2.36 lp/mm, while for the best resolution using IP-PSF is 2.85 lp/mm and worst is 1.01 lp/mm. The value of spatial resolution is proportional to the voltage of the tube, where the higher voltage provides the higher value of spatial resolution. But the value of spatial resolution has decreased with the current variation due to the higher current of mobile X-ray's tube.

Keywords— Spatial resolution, ESF-PSF, IP-PSF, FWHM, Computed Radiography

I. INTRODUCTION

One of the QC parameters is the spatial resolution which is an important component and become the main force of a modality [1]. The spatial resolution can be obtained by means of visual and calculations. The spatial resolution is defined as the minimum distance between two objects were still distinguishable [2]. Measurement of spatial resolution of an image can be performed to obtain a digital image, then used an interpretation of Point Spread Function (PSF) as part of the Quality Control [3]. Interpretation of PSF is suitable for images generated by a very small target [2], which is in accordance with the manual book that explains the test targets is equal to 80 microns. PSF can explain the detailed information related to the spatial resolution of an image. The spatial resolution can be obtained by measuring the FWHM and FWTM using In Plane Point Spread Function (IP-PSF) method. From small-sized targets will obtain a PSF curve through curve fitting Gaussian which later was named the IP-PSF method [4]. Basically the method of MTF, ESF, LSF and PSF can be used in the spasial resolution measuring method. However, the method that considered as the most convenient and practical is a method by using the ESF [5], It is because the LSF and PSF methods are a derivative of the function of the ESF which are interconnected each other [6]. QC on CR is very important to obtained a good image quality. However, a study to compare the image quality by using IP-PSF and ESF-PSF in a similar case has never been done before. Both methods have advantages and disadvantages, respectively. IP-PSF is able to interprete the image of a point generated by a very small target directly, while ESF-PSF can be used on images that have poor resolution or low image quality without the use of small targets.

II. METHOD

The procedures performed in this study consists of the preparing some copper phantoms. The next stages were scanning phantom, making the FWHM counter program using ESF and IP-PSF methods, calculating the value of FWHM and Spatial Resolution, analysing the spatial resolution value and making the comparisons of Spatial Resolution value that obtained using the ESF and IP-PSF methods.

A. Phantom Scanning

The initial stage of this research is taking a digital image of a copper phantom with size of 15 cm x15 cm, with a thickness of 1 mm. X-ray source used is a mobile X-Ray. Eksposure factors used are some variations of the X-ray tube voltage and current X-ray tube. The variation of the X-ray tube voltage for CR systems in succession is 50 kV, 60 kV, 70 kV and 80 kV. The voltage variation range that was used is in the standard of voltage for QC activities of diagnostic devices according to KMK number 1250 2009. The variations in the X-ray tube current was conducted four times, on each voltage, ie 1.6 mAs; 4 mAs; 16 mAs and 32 mAs. Variations in the flow tube was used has been adapted to the type of material and thickness of the phantom object. Exposure phantom in CR systems was conducted by a FFD distance of 90 cm. The data obtained are then copied into a CD (Compact Disk) for further calculation of spatial resolution on a computer that has been equipped with software Matlab. The resulting digital image on the CR system is in DICOM format.

B. Calculation of FWHM and Spatial Resolution

Calculation of spatial resolution can be done by observing the impulse response of the impulse response of a point or a line on the image. This impulse response is described in the form of Point Spread Function (PSF) for a point and Line Spread Function (LSF) for the line. The resolution can be calculated by taking the value of FWHM (Full Width at Half Maximum) is done MATLAB R2015b program and Corel Draw X7 of PSF or ESF. To express the magnitude of spatial resolution (RS) with units lp / mm or lp / cm obtained from the value of FWHM can use the following equation [7].

$$\text{Resolusi Spasial} = \frac{1}{FWHM}$$

III. RESULT AND DISCUSSION

A. Scanning Phantom

Qualitatively, it can be seen that the change in the X-ray tube voltage affect the sharpness of a digital image. The higher the voltage that has been used, the greater the penetrating power of X-rays so that the resulting image has a lower gray level after reaching the optimal voltage level [8]. At the highest voltages used in this study of 80 kV was obtained the image with the sharpest gray level. This is because the penetrating power of X-rays at a voltage of 80 kV is highest power so that the phantom copper absorb more X-rays.

In the Figure 1 can be seen the changes in gray level for any change in the applied voltage.

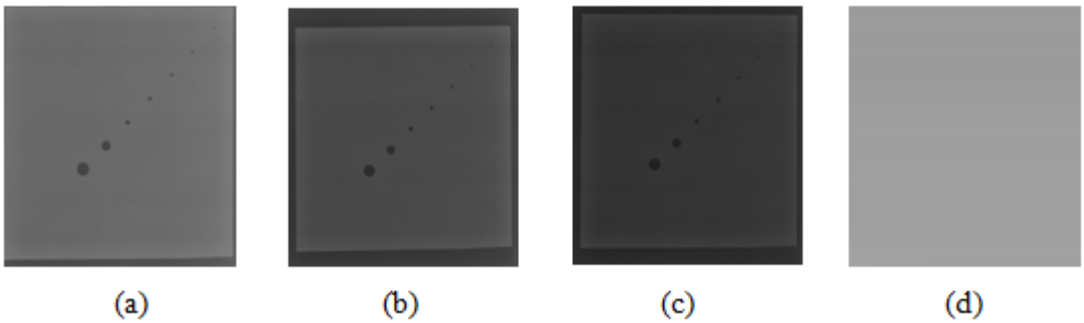

Fig. 1. CR digital image in the voltage of : (a) 50 kV; (b) 60 kV; (c) 70 kV; and (d) 80 kV.

B. Calculation of Image Element Resolution

The measurement of distribution pixel was perfomed to convert the data to the pixel spacing in mm or cm. The number of pixels at a distance of 150 mm was calculated using Matlab program. With the assistance of Matlab program it is easy to calculate the number of pixels in certain distance. The calculation result of pixel resolution of of the image can be shown in Table 1. Table 1 menunjukkan that 1 pixel = 12.09 pixel/mm.

TABLE I
CALCULATION OF PIXEL RESOLUTION

No	Vollage (kV)	Current (mAs)	Coordinate x1	x2	*Pixel*	Averange of *Pixel*	Standard Deviation
1	50	1,6	63	1640	1577	1572,25	1,60
		4	45	1571	1571		
		16	69	1640	1571		
		32	76	1646	1570		
2	60	1,6	63	1646	1583	1579,5	2,06
		4	93	1670	1577		
		16	105	1583	1583		
		32	87	1662	1575		
3	70	1,6	57	1640	1583	1550,5	26,61
		4	69	1640	1571		
		16	129	1706	1577		
		32	177	1748	1471		
4	80	1,6	159	1748	1589	1586,33	1,76
		4	63	1646	1583		
		16	121	1708	1587		

C. The Effect of Voltage to FWHM

In the Figures 2-5 is also displayed the image with the current of 1.6, 4, 16, and 32 mAs as a function of voltage. For example in Figure.3, resulting pattern showed that the FWHM value has tended to increase with the increasing of applied voltage. Wherein at a voltage of 50 kV to 60 kV, the FWHM values increases, then at a voltage of 70 kV decline but then increase at a voltage of 80 kV.

Not much different from the FWHM values in the image produced in 16 mAs, the resulting pattern showed FWHM values rise with increasing the applied voltage as shown in Figure 4. It also occurs in the image with others variation of voltage and current. But in the voltage of 80 kV, it occurs the significantly decline at any point due to the image generated by the current of 32 mAs and voltage of 32 kV has a very sharp gray level.

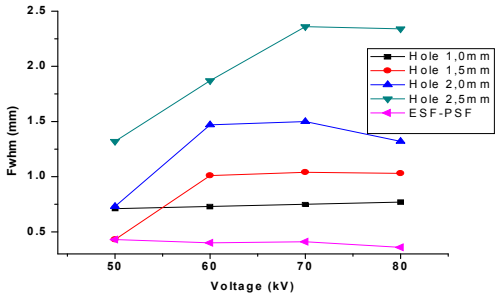

Fig.1 The curve of the effect of voltage (kV) to FWHM in the current of 1,6 mAs

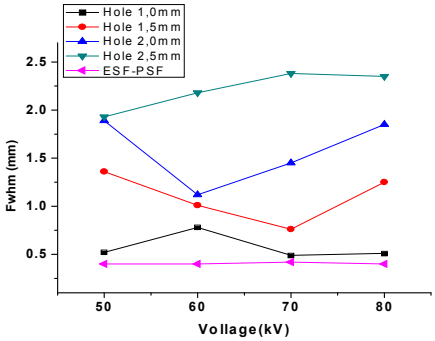

Fig.2 The curve of the effect of voltage (kV) to FWHM in the current of 4 mAs

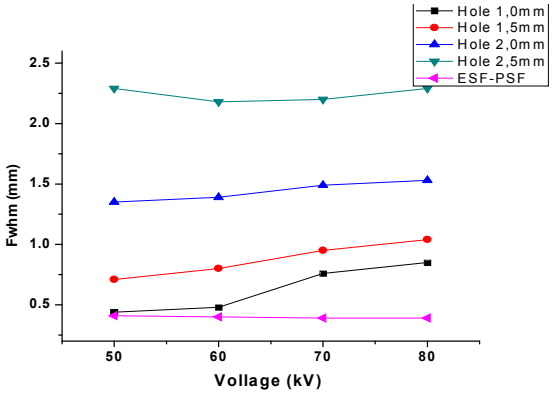

Fig.4 The curve of the effect of voltage (kV) to FWHM in the current of 16 mAs

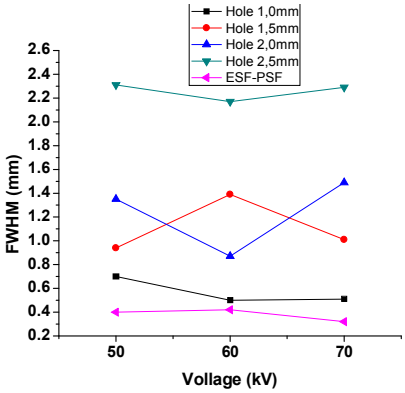

Fig.5 The curve of the effect of voltage (kV) to FWHM in the current of 32 mAs

D. Effect of current to FWHM

Effect of tube current to the FWHM values is shown in Figures 6-8. Figure 6 shows the curve of current versus with the variation of voltage of 50 kV, 60 kV, 70 kV and 80 kV for CR system. According to the regulations of KMK number 1250 in 2009, the voltage of 50 to 85 kV are the voltage range to be applied in QC procedures for diagnostic equipment. Based on the Figure 7 at voltage of 60 kV, an increase in the value of spatial resolution occurs at currents of 1.6 mAs to 4 mAs. The FWHM value decreases with the increase in tubes current that are used in mobile X-Ray. While in the current of 32 mAs, the FWHM value was decreasing.

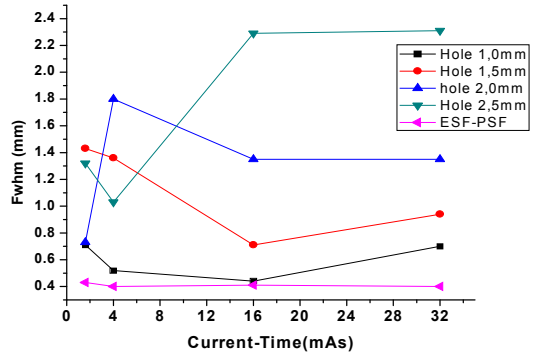

Fig.6 The curve of the effect of current (mAs) to FWHM at voltage of 50 kV

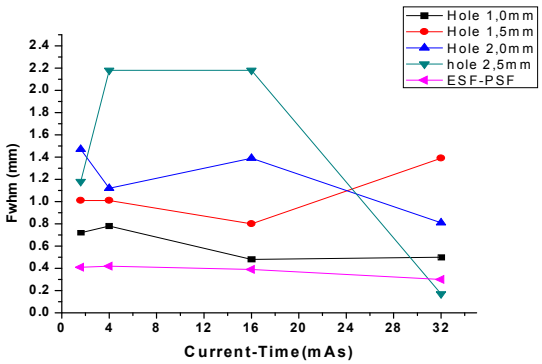

Fig.7 The curve of the effect of current (mAs) to FWHM at voltage of 60 kV

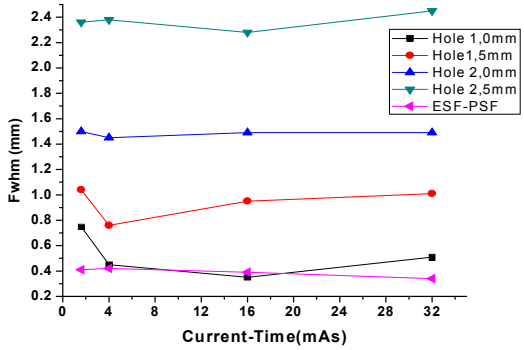

Fig.8 The curve of the effect of current (mAs) to FWHM at voltage of 70 kV

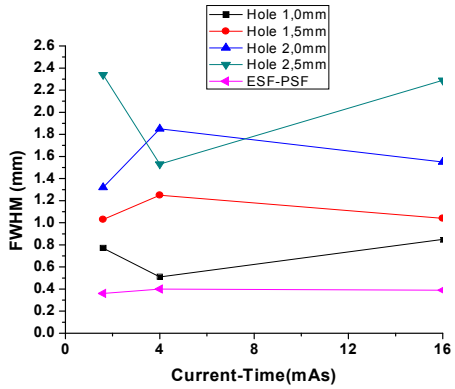

Fig.8 The curve of the effect of current (mAs) to FWHM at voltage of 80 kV

The decrease in value due to the high spatial resolution of current tube is used in mobile X-ray. It also occurs in the 70 kV voltage variation shown in Figure 4.12 with FWHM values were decreased in current 1.6 mAs to 4 mAs. While the increase in current value of FWHM at 16 mAs, After impaired FWHM namely the current 32 mAs. The higher the applied current, resulting in the number of electrons striking the anode so that the X-rays coming out of the tube are also getting bigger. Thus, the absorption of X-rays to the object phantom high copper. The high absorption of X-rays that has resulted in a digital image produced has a low gray level [9].

E. The effect of Voltage to Spatial Resolution Value

From the results, changes in the value of spatial resolution for voltage variations used in research with a steady current 4 mAs as shown in Figure 4.14. Based on the Graph 4.14, using a phantom copper thickness of 1 mm spatial resolution values continue to increase until the voltage of 80 kV. Value spatial resolution is directly proportional to the voltage of the tube is used, ie the higher the voltage used. Thus, it can be said that the entire voltage variation used in this study can be used as the basis for the implementation of QC spatial resolution of CR systems using phantom copper thickness of 1 mm.

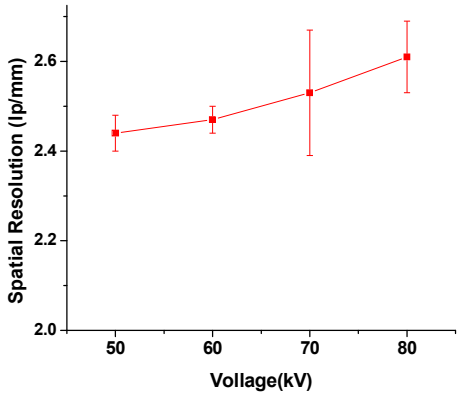

Figure 9. The curve of the effect of voltage (kV) to the spatial resolution at the current of 4 mAs

F. Pengaruh arus terhadap nilai resolusi spasial

Effect of tube current to the value obtained from the spatial resolution CR system is shown by Figure 4.15. Figure 4.15 is based on a fixed voltage of 50 kV, an increase in current value of the spatial resolution of up to 32 mAs 1.6 mAs. However, the increase in the value of spatial resolution are stable only happen from current 4 mAs and 16 mAs only. At a voltage of 50 kV, the flow optimally located at 4 mAs.

After experiencing the optimal point, the value of spatial resolution decreases with increasing current tubes used in mobile X-Ray. Values continue to increase the spatial resolution of current 4 mAs and 16 mAs. But after reaching the optimal current at a voltage of 60 kV which is 4 mAs, decreasing the value of spatial resolution.

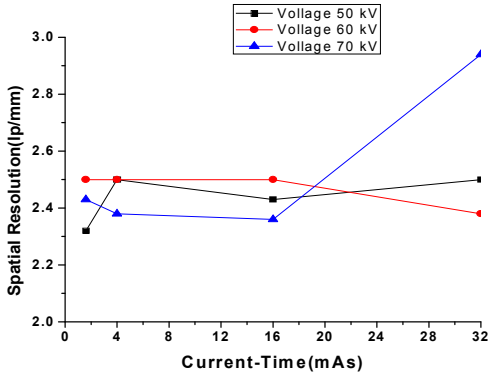

Figure 10. The curve of the effect of current-time (mAs) to the spatial resolution value

Impairment of spatial resolution occurs in current 32 mAs. The decrease in value due to the high spatial resolution of current tube is used in mobile X-ray.

G. Eligibility Test of CR Modalities

In Figure 4.16 spatial resolution imagery obtained smallest value is 1.28 lp / mm spatial resolution and the best image is 2.5 lp / mm. According to AAPM that the quality of digital images is in conformity with the standards of the best value for the spatial resolution X-ray, which is in the range of 1.90 lp / mm to 3.00 lp / mm. Based on a range of factors eksposi used in this study, it can be said CR system is still in good condition.

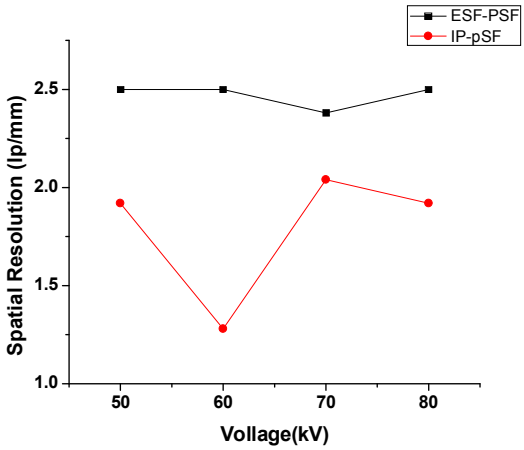

Figure 11. The curve of spatial resolution as a function of voltage (kV)

Based on data obtained just one image alone is not acceptable because it has a resolution of the image below 1.90 lp / cm. The image that does not pass the test that image with a voltage of 60 kV for current variation-time 4 mAs. So based on the spatial resolution test image through the analysis of the ESF-PSF and IP-PSF with a Gaussian distribution and validation approach using AAPM standard rules and evaluation that produced the best CR still fit for use.

IV. CONCLUSIONS

Based on the results obtained in this study, it was concluded that: QC CR spatial resolution imagery can quantitatively performed using ESF-and IP-PSF PSF. Best spatial resolution obtained the best CR method ESF is 2.50 lp / mm, while for the best resolution using the IP-PSF is 2.85 lp / mm. IP-PSF method with a hole 1 mm is suitable for measurements represent the value of spatial resolution ESF-PSF. Additionally obtained that the spatial resolution is proportional to the voltage of the tube is used, ie the higher the voltage used, the value is also higher spatial resolution. But the value of spatial resolution decreased as do current variation. The decrease in value due to the high spatial resolution of current tube is used in mobile X-ray.

ACKNOWLEDGMENT

Nadhya Surahmi would like to acknowledge to Dr. Catur E.Widodo and Dr. Suryono at Department of Physics, Diponegoro University Indonesia who have supported them all of the facilities for this Research. Conflict of Interest: The authors have no conflicts of interest to report in regard to this manuscript.

REFERENCES

1. E. Lin, and A. Alessio, "What Are The Basic Concepts of Temporal, Contrast, and Spasial Resolution in Cardiac CT," *Journal of Cardiovascular Computed Tomography*, vol. 3(6), pp. 403-408, 2009.
2. J.T. Bushberg, J.A. Seibert, J.M. Boone, and E.M. Leidholdt, E. M., *The Essential Physics of Medical Imaging*,Philadelphia, USA: Lippincott Williams & Wilkins, 2002, second edition.
3. R.W. Cole, T. Jinadasa, and C. M. Brown, "Measuring and interpreting point spread functions to determine confocal microscope resolution and ensure quality control," *Nature. Protocols*, vol. 6(12), pp. 1929–1941, 2011.
4. J.M. Thijssen, G. Weijers, and C.L. Korte, "Objective Performance Testing and Quality Assurance of Medical Ultrasound –Equipment," *Ultrasound Medical Biological*, vol. 33, pp. 460-471, 2007.
5. R.C.Staunton, "Detected Edge Position Evaluation Using Measured Acquisition System Parameters," *Pattern Recognition Letters*, vol. 26(11), pp. 1609-1619, 2005.
6. F.R. Verdun, D. Racine, J.G. Ott, M.J. Tapiovaara, P. Toroi, F.O. Bochud, W.J.H. Veldkamp, A. Schegerer, R.W. Bouwman, I.H. Giron, N.W. Marshall, and S. Edyvean, "Image Quality in CT: From Physical Measurements to Model Observers," *Physica Medica*, vol. 31(8), pp. 823-843, 2015.
7. J. Papp, *Quality Management in The Imaging Sciences*, USA: Saint Louis Mosb, 2006, 5th Edition.
8. D.S. Artz, "Computed Radiography for the Radiological Technologist," in *Seminars in Roentgenology XXXII,* 1997, paper (1), pp. 12-24.
9. G. Andria, F. Attivissmo, G. Guglielmi, A.M.L. Lanzolla, A. Maiorana, and M. Mangiantini, "Towards Patient Dose Optimization in Digital Radiography," *Measurement*, vol. 10(16), pp. 232-241, 2015.

