Determination of Optimum X-Ray Tube Output Parameters kV and mA for Digital Radiography Testing of Welded Tubes

AyazJhanorwala, SatishTilva,
L & T MHPS Boilers Pvt Ltd., Hazira, Surat-394 510, India
0261-280-8837, Mo: +91 9558490033, ayaz.jhanorwala@lntmhps.com

Abstract

Study of Image quality parameters like Contrast, SNR and MTF for Digital Radiography with FPD were carried out at different X-Ray tube variables like energy of X-Ray (kV) and tube current (mA) for different welded tube thicknesses. Experiments of Digital Radiography were carried out on butt welded tubes. Images of these welded tubes were taken with different kV and mA on actual working setup keeping other variables constant. Percentage contrast was calculated with ASTM hole type IQI, SNR values noted on welded area of interest and MTF curves were plotted by using Duplex IQI EN 462-5. This study has been done to determine optimum parameters (kV and mA) for Digital Radiography of different tube thicknesses which gives desired image quality with minimum exposure to FPD.

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1. Introduction

Digital Radiography (DR) technology havethe advantage of a wide dynamic range. Due to the wide exposure latitude and post processing capabilitiesassociated with DR, resultant images will have similarappearances in terms of contrast and density whencompared to film-screen technologies independent of theexposure. However, if images are underexposed increasedquantum mottle will be evident in the image. Due to their large dynamic range inadvertent overexposure is possible since underexposure rather than overexposure is more likely to affect image quality. However, there is often less focus on overexposed images, unless saturation occurs [1]. Many parameters influence the sensitivity of digital radiographs, but only three are essential for the achievable contrast sensitivity. These essential parameters are the specific contrast, the Signal-to-Noise Ratio (SNR) and the basic spatial resolution in terms of MTF [2].

2. Equipment Details

The experiments for this study were done on FPD based Digital Radiography system. This system is capable to perform DR on wide range of thicknesses and materials. System consist of FPD, X-ray machine and software in which kV, mA, exposure time and processing parameters can be adjusted as per requirement.The X-ray machine has two focal sizes for adjusting geometrical unsharpness as per requirement. System is capable of acquiring, processing and analyzing digital images.

3. Experiment Details:

Welded tubes were used for experiments and placed between FPD and X-Ray tube for exposure. "Double wall Double Image technique" (Elliptical technique) was used for DR. Various images were captured using Duplex IQI EN462-5 and ASTM hole type IQI with shim placing towards source side of the tube. Several exposures of two different tube thicknesses were done with different kV and mA.

Three types of variations wereusedfor exposure at different kV and mA.

1) kV was varied over a range and mA was kept constant
2) kV and mA was varied,keeping multiplication of kV and mA constant
3) kV was kept constant and mA was varied over a range.

4. Analysis of Digital Images

Three image quality parameters Contrast, SNR and MTF were determined by analysis of captured digital images.

4.1 Contrast on ASTM Hole Type IQI

Contrast can be changed by kV by keeping other parameters constant. For bothwelded tube thicknesses at different kV, line profile was generated on required 2T hole of ASTM IQI and maximum& minimum grey values were recorded. The percentage contrast from the recorded grey values was calculated. Graph was plotted for contrastVs kV. It was noted from the graph that, over the selected range of kV,value of contrast increased first in small amount and reached maximum at intermediate kV and then it reduced with increase in kV. So the maximum kV, which should be used for a particular thickness was determinedto achieve maximum contrast. Above that value of kV, considerable amount of contrast was reduced. (Refer Figure 1)

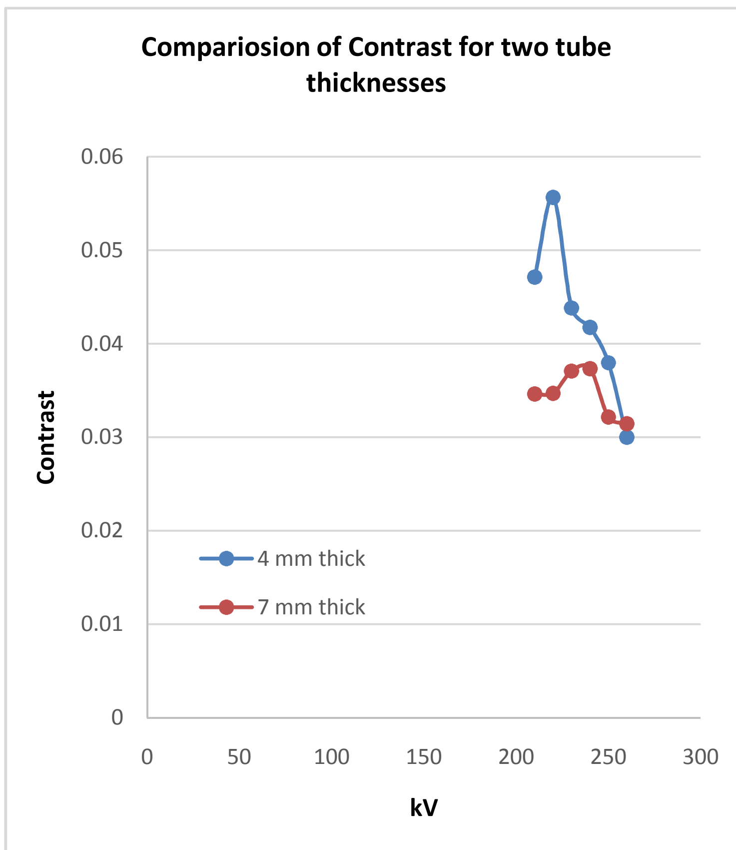


Figure 1: Contrast Vs kV

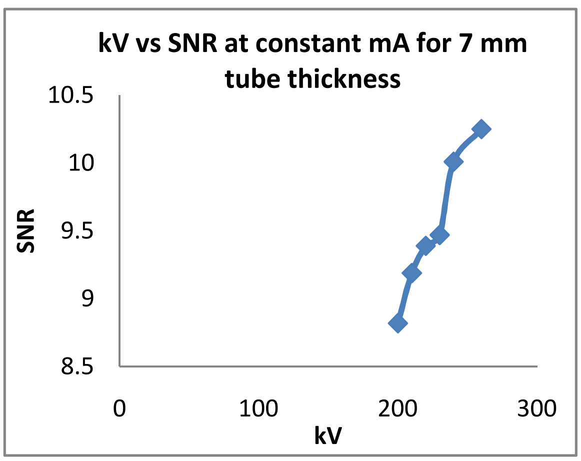
It was also noted that maximum contrast and overall contrast was observed to be lowerfor higher thickness tube for selected range of kVas shown in figure 1.This is due to more attenuation of low energy X-Ray in higher thickness.

4.2SNR

Due to low attenuation of high energy X-ray, more number of X-ray photons reaches to detector, thus single to noise ratio increases with energy of X-Ray. SNR values were noted on area of interest for each exposure and plotted against kV. It was found that with increment of kV, SNR increases continuously as shown in Figure 2.

SNR is proportional to square root of the no of X-Ray photons interacting with the FPD [7]. No of photons interacting with FPD can be increased by mA. Graph was plotted for SNR Vs mA at particular kV. It is observed that after certain tube current, rate of increase in SNR with respect to mA becomes saturated. So, SNR remains same after this value of tube current as evident from figure 3.

Hence, maximum mA was selected for maximum SNR value at particular thickness and kV. Beyond that mA, only the exposure to detector increases without significant increase in image quality.



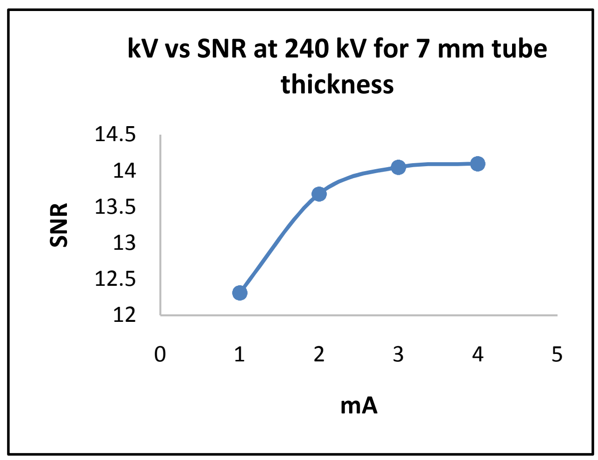


Figure 2: SNR Vs kV Figure 3: SNR Vs

4.3MTF

Duplex IQI was used to determine the unsharpness and basic spatial resolution [6]. If the relative contrast is measured on each line pair and plotted against the spatial resolution then MTF curve can be generated. During study multiplication of kV and mA was kept constant. For Plotting the MTF curve, the maximum and minimum grey values were recorded on each line pair of Duplex IQI. Relative contrast was calculated from recorded gray values. [3,4,5]. These contrast values were plotted against each line pair values (lp/mm). It was seen from the MTF graph that the spatial resolution was not affected by kV and mA (Figure 4).The same results were obtained for 7 mm thickness also.

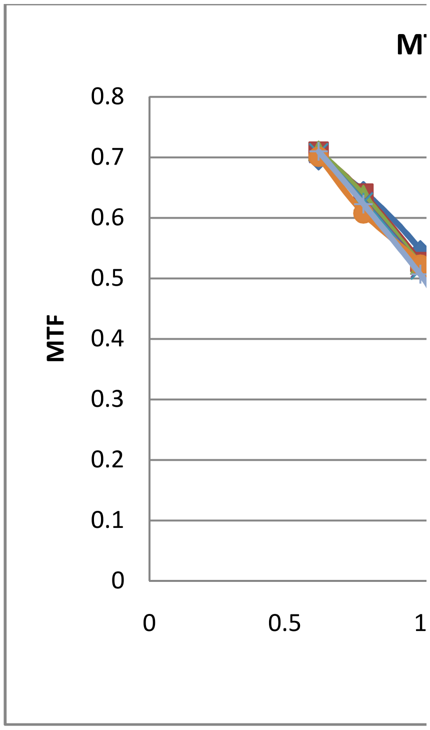


Figure 4: MTF

5. Conclusion

For required image quality, optimum kV and mA were decided from above experiments. The kV value was decided from Contrast Vs kV graph and the value of maximum mA was decided by the saturation of SNR curve from SNR Vs mA graph. Table – 1 shows imaging parameters before this study and optimized parameters after the study. It can be seen from the table that the optimum parameters requires less X-Ray tube output compared to earlier parameters. Reduction in X-Ray tube output parameter will lead to the better life of FPD. The other benefits are the less stray radiation from the X-Ray vault and hence better radiation safety.

Table – 1 Result Table

JOB THICKNESS	**BEFORE**			**AFTER**			FPD exposure reduction in %	X-Ray Tube Power reduction in %
	KV - MA	**CONTRAST**	**SNR**	**KV - MA**	**CONTRAST**	**SNR**		
4 mm	230 kV – 3.5 mA	4.4	12.13	220 kV – 3.0 mA	5.6	11.84	25.3	18.0
7 mm	270 kV – 3.3 mA	2.9	14.84	240 kV – 3.0 mA	3.7	14.04	34.7	19.2

6. References

1] Ursula Mothiram, BSc Diagnostic Radiography, MHlthSc, Patrick C. Brennan, Sarah J. Lewis, BAppSc, DR, Bernadette Moran & John Robinson, BAppSc, Journal of Medical Radiation Sciences; Digital radiography exposure indices: A review

2] Uwe EWERT, Uwe ZSCHERPEL, Mirko JECHOW, 18th World Conference on Non-destructive Testing, 16-20 April 2012, Durban, South Africa; Essential Parameters and Conditions for Optimum Image Quality in DigitalRadiology

3] AyazJhanorwala, Rishikesh Kumar, SatishTilva, National Seminar & Exhibition on Non-Destructive Evaluation, NDE 2014, Pune, December 4-6, 2014 (NDE-India 2014)Vol.20 No.6 (June 2015) - The e-Journal of Nondestructive Testing - ISSN 1435-4934www.ndt.net/?id=17842, Study of Spatial Resolution in LP/cm for FPD Based Digital RadiographySystem by Imaging the Converging Line Pair at Different GeometricMagnifications

4] Information is on www.studiodentisticovenuti.it/wp-content/uploads/.../x-ray-detectors.pdf. Chapter 8 of handbook of X-Ray Detectors

5] Andreas Staude, Jurgen Goebbels, International Symposium on Digital Industrial Radiology andComputed Tomography - Tu.4.1; Determining the Spatial Resolution in Computed Tomography –Comparison of MTF and Line-Pair Structures

6] Steven A Mango, IV ConferenciaPanamericana de ENDBuenos Aires – Octubre 2007; How to evaluate the radiographic performance and long-term stability ofa computed radiography system

7] M J Yaffe and J A Rowlands, Phys. Med. Biol. 42 (1997) 1–39. Printed in the UK, X-raydetectors for digital radiography