Performance assessment of the X-rays imaging system fabricated in King Saud University[1]

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Abstract

All imaging system and especially X-rays should possess excellent image quality. Which is linked with accuracy and the superior performance of the X-ray tube itself to investigate the imaging performance and the commissioning tests. The accuracy requires the holder for the X-ray imaging system is good enough to withstand the weight of the imaging system and allows it to move and rotate in all directions. Therefore, an approach for design and analysis of mechanism frame using advanced computer aided engineering (CAE) tools will be applied for shielded fabricated holder as well as locally reassembled with a collimator. In addition, most standard, commissioning and acceptance tests (reproducibility, kVp accuracy, stability with change in tube voltage, half value layer and tube output) have been applied to the SB-80-250 X-ray imaging system to assess its performance. The stress values and reported results were within the international standards.

Keywords: *X-ray tube, performance, reproducibility*

1. Introduction

X-ray radiography imaging system offers the potential of providing opportunities for early detecting of diseases and thus considered the most important technique for diagnose. However, it is always a problem to carry the X-ray to scan a patient in which the stability and accuracy are the major role for fine scanning results. Therefore, it must possess both excellent spatial resolution and optimum contrast. The image quality from such system is intimately linked to the precise and accurate acquisition of information from the X-ray beam attenuated from the patient [1].

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The main aim of this study is to make the SB-80-250 X-ray tube geometrically suitable for use in imaging application, then performance assessment of the X-rays imaging system.

This is obtained throughout the initial implementation we were unable to move the X-ray system at any angle or at any direction, i.e. on six axes of movement, Consequently, the system motion will be in x, y, z directions. This is allowed movement in forward/backward, up/down and left/right directions. , the tube can be used in all geometrical set-ups. Then, we can determine how is a SB-80-250 X-ray tube easy achieve any experimental test, such use it for 3D-imaging of the uncompressed breast. The test methods and standards applied in performance test, are mainly derived from safety report series NO.39 [2] and radiation protection NO.91 [3] and the Canadian Guidelines [4].

2. Materials and Methods

Figure 1 shows the SB-80-250 X-ray tube possesses a 35-80 kVp, 10-250μA, stability 0.5% [5]. The system was fabricated and locally reassembled with a collimator. The collimator is a British made and its model is Picker international limited. It characterized by having a small light that can be used to determine the centre point of the area being imaged. Two dosimeters was used to commissioning and acceptance testing of the X-ray imaging system. Unfors RaySafe Xi whose possesses 0.05 – 9999 mAs, reproducibility < 0.5 %, dose range 10 μGy-9999 Gy and 35-160 kVp. In addition Fluke TNT 12000 with 0-999.9 mAs, with reproducibility of ±0.5 %, dose range from 5 mGy upto 999 Gy, and kVp from 22 up to 150 kVp [6]. For design [7] a good model. an arm with six full rotation holders for holding the X-ray detector. It has to operate safely. In addition, it needs to be made of material of high mechanical properties to resist fracture, deflection, buckling and corrosion. The holder should be able to sustain the weight of the X-ray and its accessories which is about 40kg. Also, it should be relatively light so that it can be moved easily. The material of the base metal used in this work is austenitic stainless steel (AISI 304) sheet with 1.00 mm thickness. The mechanical properties of this material are found to be: Modulus of Elasticity 193.7GPA; Poisson’s ratio 0.3; Yield Stress 277.3MPa and; Ultimate Stress 737MPa. These are the average values obtained from the standard tensile tests performed on three standard samples of this material according to ASTM standard E8-81 [8].

Figure 1 The SB-80-250 X-ray tube

3. Results and Discussions

3.1 SB-80-250 X-ray tube geometric development

For using SB-80-250 X-ray tube to imaging at different positions and angles. it needs to be held on a mechanism that provides six degrees of freedom motion. Therefore, a holder is designed locally on site so that it can give a full six degrees of freedom motions. Three translation in x, y, z directions, and three rotations about x, y, z axes.

This mechanism has the following four degrees of freedom: move up/down (z-axis), forward/backward (x-axis), left/right (y-axis), and rotate about z-axis (yaw axis). The other missing two degrees of freedom are: rotate about the x-axis (roll axis) and rotate about y-axis (pitch axis). To add these two missing degrees of freedom, an additional parts need to be manufactured. These parts are first designed using CAD software as shown in Figure 2. Part one is the base, part two is the connecting holder, part three is the bolt. As seen in Figure 3 the new model of x-rays device after add these parts were manufactured locally.

It is very important to isolate the sides of the X-ray machine from all sides except the focal point to insure that no X-ray radiation getting outside from all sided except the focal point. Therefore, a shielding material made of lead with a thickness of 2 mm is used. radiation leakages were counted by the survey device and the measured value found to be zero. To collimate the beam of the X-ray device a filter device to the x-ray beam such as collimator is added. Finally, the X-ray device on a long standing holder for the thyroid to make it negotiable to lift and reduction to use it at any source to image distance as shown in Figure 4.

Figure 2 The CAD models of the required parts (1-3)

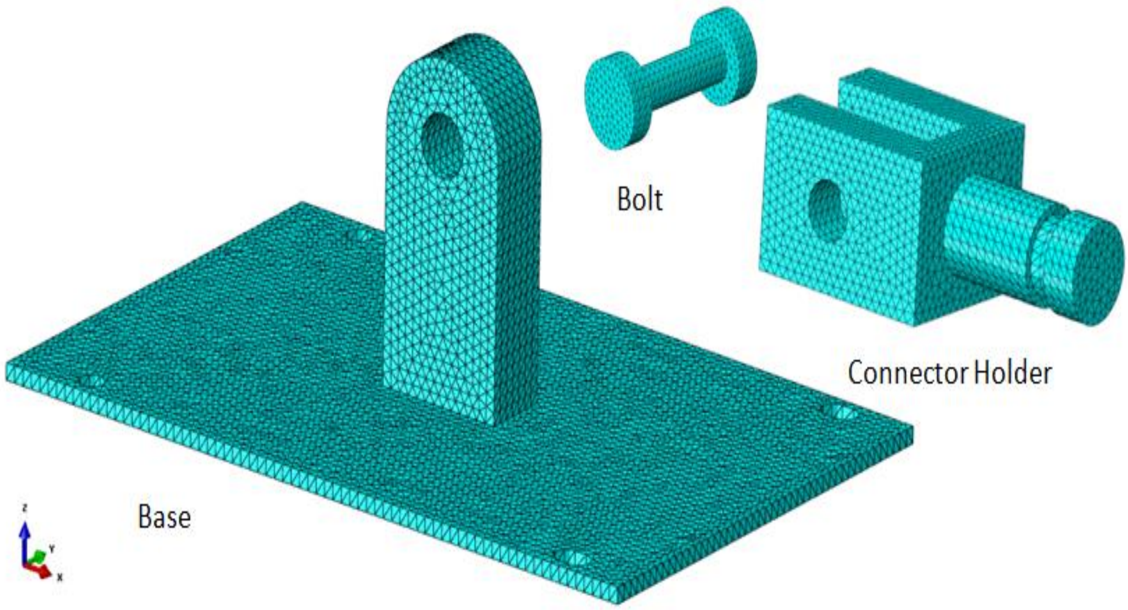


Figure 3 Assembling all the locally manufactured parts to the X-ray (SB-80-250) device

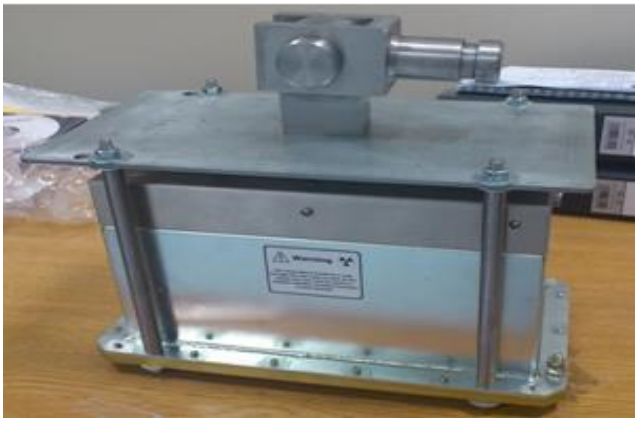


Figure 4 The imaging system showing the placement of lead shied on the SB-80-250 X-ray tube joined with the collimator and thyroid holder

3.2 Performance testing and commissioning of the SB-80-250 X-ray tube

Before using the X-ray tube for imaging it is necessary to test the performance of the tube to obtain accurate assessment with minimum dose to patients and staff. Therefore, Initially we confirmed the tube voltage is constant over time and the current. To start investigate the performance assessment and commissioning tests of a SB-80-250 X-ray tube. Most standard, commissioning and acceptance testing of the X-ray imaging system will be reported. This includes, tube output, reproducibility, kVp accuracy, stability with change in tube voltage and half value layer. The radiation scattered and leakage were measured using both Radcale and Fluke detectors. Then, we have performed the acceptance for the X-ray source used for our study as follows:

3.2.1 Radiation leakage

We found that the leakage radiation from the X-ray tube housing, with all the shutters closed, not exceed 2.5 mR/hr at 5 cm from the surface as recommended [3].

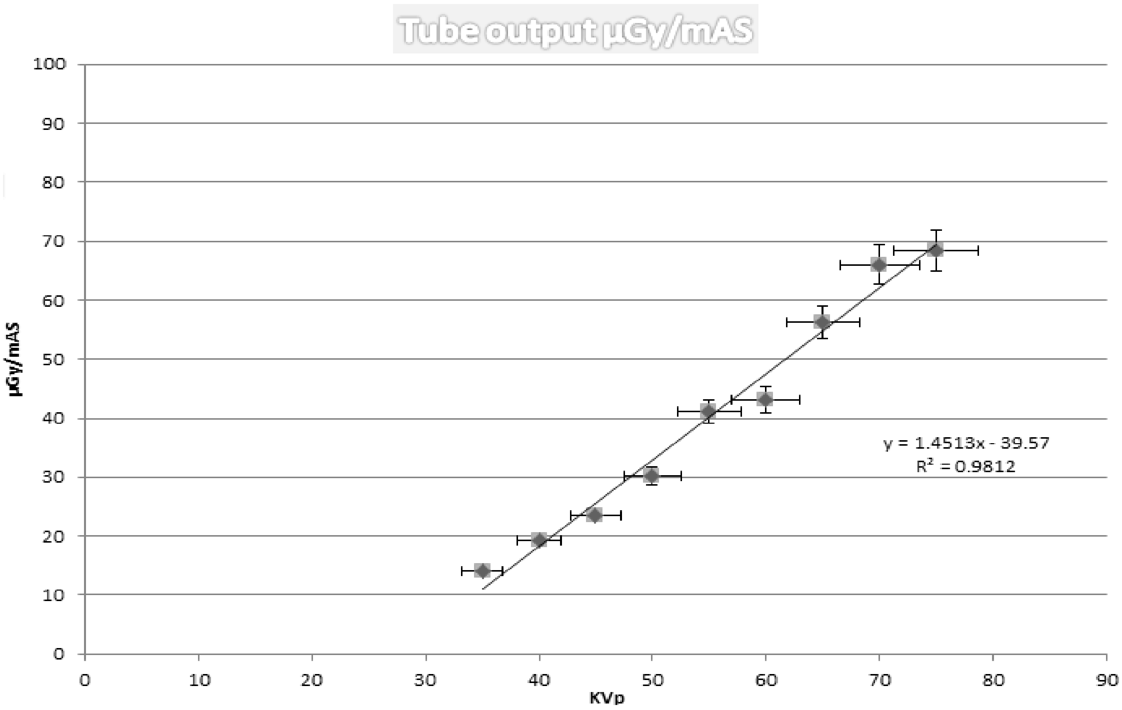
Then, we measured the radiation leakage to the SB-80-250 X-ray at 80 kVp and 250 µAs for 10 sec by applying a lead sheet stopper to discard the primary radiation beam using Radcal 2026C, was 0.1584 mGy/h at 0.3m, 0.014256 mGy/h at 1 meter, much less than 1mGy during 1 hour of exposure at 1 meter distance from the source according to international recommendations [2].

3.2.2 Tube output

Figure 5 give an overview of the tube output measurements for every voltage. Such output was within the desirable interval that reported [9].

The tube output of an X-ray system is the dose generated at 1 m distance of the focus, per unit of mAs. At focus to detector distance FDD=600 mm, the tube output was measured for different kVp settings from 35 to 80 kVp, ten dose measurements were taken by Fluke dosimeter detector TNT 12000 DoseMate at 250 µAs settings and 10 sec. The average exposure was found to be between 39.31-239.36 µGy/mAS as in the table 1, consequently the specific tube output at a distance of 1 meter was between 14.15-86.16 µGy/mAS .

Figure 5 Overview of the tube output to the SB-80-250 X-ray tube



Source: Author's calculation

Table 1 Tube output to the SB-80-250 X-ray tube

	Dose	***Dose***	***Tube output***	***Tube output at 1 m***
KVp	***mR***	***µGy***	***µGy /mAS***	***µGy/mAS at 1m***
35	*11.17*	*98.296*	*39.3184*	*14.15462*
40	*15.23*	*134.024*	*53.6096*	*19.29946*
45	*18.63*	*163.944*	*65.5776*	*23.60794*
50	*23.89*	*210.232*	*84.0928*	*30.27341*
55	*32.45*	*285.56*	*114.224*	*41.12064*
60	*34*	*299.2*	*119.68*	*43.0848*
65	*44.4*	*390.72*	*156.288*	*56.26368*
70	*52.1*	*458.48*	*183.392*	*66.02112*
75	*54*	*475.2*	*190.08*	*68.4288*
80	*68*	*598.4*	*239.36*	*86.1696*

Source: Author's calculation

3.2.3 Reproducibility

At fixed tube voltage of 35and 80 kVp, the reproducibility was evaluated by repeating the measurement 10 times for each KVp, using the kVp meter. The measured kVp was within the range of (35.1 – 35.3 kVp) and (80 – 80.2) respectively , fulfilling the recommendation to be within ± 0.5 kV [3].

3.2.4 Accuracy

The accuracy was assessed by applying a number of tube voltages, covering all the range of KVp used settings (35 - 80 kVp) and the results were all cases within a ± 1 kV error interval [3].

3.2.5 Half value layer

For many years medical physicists had been using half-value layer (HVL) in order to specify the quality of X-ray beams [10]. By used different KVp and 250 µA an accurate measurement of the half value layer (HVL) is required to many of the experiments. Such parameter were obtained by adding Aluminium filters of density 2.7 g/cm3 and purity of 99.59 % to the X-ray beam and measuring the attenuation effect according to the following equation (1) [4]:

$$HVL = \frac{X1 \times Ln\left(\frac{2Y2}{Y0}\right) - X2 \times Ln\left(\frac{2Y1}{Y0}\right)}{Ln\left(\frac{Y2}{Y1}\right)} \qquad (1)$$

Where Y1 and Y2 are the exposure readings, with added aluminium thickness of X1 and X2 respectively and Y0 correspond to the primary exposure. We found a HVL in the Table 2 as recommendation [4] to be as the following equation (2):

$$HVL \geq \frac{KVp}{100} + 0.03 \qquad (2)$$

Table 2 HVL amusement to the SB-80-250 X-ray tube

X-Ray tube voltage KVp	***HVL Al mm***	***Accepted HVL ≥***
35	*0.926*	*0.38*
40	*1.024*	*0.43*
45	*1.090*	*0.48*
50	*1.296*	*0.53*
55	*1.674*	*0.58*
60	*1.505*	*0.63*
65	*1.299*	*0.68*
70	*1.454*	*0.73*
75	*1.654*	*0.78*
80	*1.352*	*0.83*

Source: Author's calculation

4. Conclusion

An approach for design and analysis of mechanism frame using advanced computer aided engineering (CAE) tools was applied. All stress values were compared to the elastic limits of the materials used in the study. An arm with six full rotation holders for holding the X-ray detector was design. It operates safely. The configuration model is able to sustain the weight of the X-ray and its accessories which is about 40kg.

Then, most of the commissioning and performance tests were performed on such system. The obtained results of all tests were within the international standards. The commissioning and performance testing of SB-80-250 X-ray tube includes tube output, reproducibility, kVp accuracy, stability with change in tube voltage and half value layer.

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