Spectrum Analysis with Monte Cralo Simulation, BEAMnrc, for Low Energy X-RAY

Z. Salehi Dehyagani, A. L. Yusoff

***Abstract*—**BEAMnrc was used to calculate the spectrum and HVL for X-ray Beam during low energy X-ray radiation using tube model: SRO 33/100 /ROT 350 Philips. The results of BEAMnrc simulation and measurements were compared to the IPEM report number 78 and SpekCalc software. Three energies 127, 103 and 84 Kv were used. In these simulation a tungsten anode with 1.2 mm for Be window were used as source. HVLs were calculated from BEAMnrc spectrum with air Kerma method for four different filters. For BEAMnrc one billion particles were used as original particles for all simulations. The results show that for 127 kV, there was maximum 5.2 % difference between BEAMnrc and Measurements and minimum was 0.7% .the maximum 9.1% difference between BEAMnrc and IPEM and minimum was 2.3% .The maximum difference was 3.2% between BEAMnrc and SpekCal and minimum was 2.8%. The result show BEAMnrc was able to satisfactory predict the quantities of Low energy Beam as well as high energy X-ray radiation.

***Keywords*—**BEAMnr , Monte Carlo , HVL

I. Introduction

RADIATION protection is always at the center of scientist's attention. In low energy radiations it is really important to know the information of beam exactly because mostly, especially radiographers think it's safe to work in this region because of the range of its energy but the recent researches have shown that low energy x-ray beam can increase the risk of cancers more than what we expected before [1]. Low energy x- ray beams have wide participation in medical and research fields especially in radiography. Nowadays, the role of radiography is going to be more and more highlight and the hazard of radiation most be more considered as well. So it's reasonable to use the new data using new more accurate methods instead of old data to find the radiation limits.Radiation exposure limits were introduced when the hazards of radiation were realized so it is really important to find the exact and complete information of radiation for human radiation protection.Nowadays, a very small amount of radiation dose can produce high quality X-ray images but the risk of cancer after properly supervised X-ray examinations must be considered although it is extremely small[2]. Staff in the X-raydepartments and clinics work with X-rays all the time and they would be exposed to quite a high dose of radiation especially if they stay beside every patient during radiography procedures. Researches demonstrate a higher incidence of cancer among exposed individuals and a greater probability of cancer as the level of exposure increases [2].

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To reach the better Perception of diagnostic x-ray energy we need to know the quality and spectra of beam which provides the complete description of beam.

For this case Monte Carlo is one of the best simulation's tools to find the spectrum and the other specifications of beam. BEAMnrc, which is one of the versions of Monte Carlo, is based on interactions between particles and matters that physically and scientifically has been approved [3]. Recently this method has been widely used due to its strong and powerful math base.

In 1996, Jan Persliden and Gudrun Alm Carlsson tried to find the Scatter rejection by air gaps in diagnostic radiology .Calculations using a Monte Carlo collision density method and consideration of molecular interference in coherent Scattering [4].In 1997, an accurate method for computer-generating tungsten anode x-ray spectra from 30 to 140 kV was introduced with John M. Boonea and J. Anthony Seibert. They used tungsten anode spectral model using interpolating polynomials to compute x-ray spectra at 1 keV intervals over that range [5].in 2002, J L Ioppolo1, R I Price1, T Tuchyna1 and C E Buckley used Monte Carlo (EGS4) to find effective dose in 100 kVp low energy x-ray and also they used TLD to

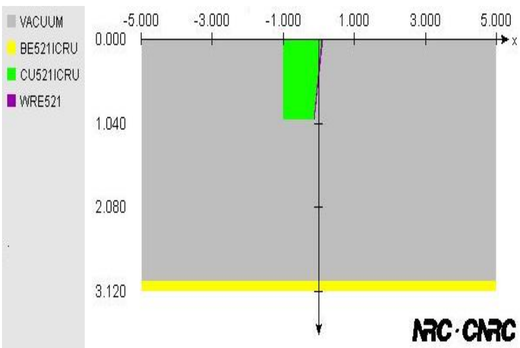

Fig. 1 BEAMnrc simulation for X-ray Tube using anode and Be window

find the accuracy of their simulation [6].In 2003, T. Akita, T. Tamiya, K. Tabushi and S. Koyama in Nagoya University School of Health sciences evaluated the radiation scattered from water phantom using EGS code [7].they calculated the average and the effective energy with their X-ray spectra. According to these papers the accuracy of Monte Carlo's calculation is comparable with practical measurements.

In this paper we have used BEAMnrc to find the spectrum and half value layer, HVL, of beam using different filters. The data have been compared with practical data and also with the data of Institute of Physics and Engineering in Medicine (IPEM) which provides the most accurate data in low energy radiations [8].

II. Material And Method

A. Measurement

PHILIPS X-RAY TUBE SRO 33 100/ROT 350 was used as X-ray machine. In this machine, 0.9 mm al filter was used as permanent filter and 1.6 mm al as additional filter and also there were three filters which were changeable filters include 2 mm al, 1 mm al + 0.1 mm cu and 1 mm al + 0.2 mm cu. The dosimeter was VICTOREEN 800 Nero mAx and all measurements were measured at 100 cm from source. The HVLs were found with this dosimeter and corrected for three energies. To find the angle of maximum energy, for using in IPEM and SpekCalc, the simple radiographic film (CR) has been used and the Images obtained have been analyzed by IMAGEJ [9]. In this Java based software the position of maximum intensity points have been found for different energies. It should be mentioned that the angle of anode was 13 degree but to compare with IPEM and SpekCalc it was needed to find the proper angles that based on the summation of the angle of maximum energy and target angle. They have been calculated using the IPEM catalogue [8].

B. BEAMnrc and BEAMDP

For simulation, BEAMnrc was used to find phase space file. For consideration of low energy characteristic radiations the options of Compton and photoelectric were turned on in the place of EGS parameters because of the characteristic edges in x-ray spectrum. Phase space file was used to find the spectral distribution with BEAMDP by 15*15 filed. Simulations were developed for X-ray tube with 0.3 mm WR,13 degree from z-axis and copper holder plus 1.2 mm Be Window as a slab .

One billion particles were used for this simulation. The pegs4 file which was used for this project was 521ICRU.The simulations were developed for three energies 127,103 and 84 kV plus three pure and combined filters. To calculate HVL, with using μ/ρ of NIST data [10], air kerma for each filter was found regarding to this fact that the thickness of aluminum could change air kerma to half amount of it. Also it was calculated at 100 cm from source in air because it was based on standard NERO dosimetry. Also with using BEAMdp, X-Y particles plot was obtained and angle of maximum energy was calculated. Figure 1 shows the main part of simulation includes target, with its holder, and also the Be window as a slab.

C. SpekCalc Software

SpekCalc is presented for the calculation of x-ray spectra from tungsten anode x-ray tubes. SpekCalc was designed primarily for use in a medical physics workers, for both research and education purposes, but May Also be of interest to those working with x-ray tubes in industry. Noteworthy Is the particularly wide range of tube potentials (40–300 kVp) and anode Angles (recommended: 6–30◦) that can be modelled the program is therefore Potentially of use to those working in superficial and orthovoltage radiotherapy, As well as low energy X-ray [11].

III. Result And Discussion

First of all the angle of maximum incident particles has been calculated for both IPEM 78 and SpekCalc and it was 22 degree for IPEM 78 and also 21 degree for SpekCalc. The Other angles were 22.5, 23.1 degrees respectively for 103 and 84 kV toward the center. With these angles the HVLs were calculated. For the filter of 2.5mmAl HVL calculated by BEAMnrc was 3.9 mmAl and SpekCalc found 3.88 also IPEM 78 reported 4.15 and with measurement it was calculated 3.98. But when the thickness of filter is increased the results changed significantly and they were becoming closely. For the filter of 4.5 mmAl BEAMnrc showed 5.42 mmAl as HVL and SpekCalc found 5.47 also with measurement it was found 5.63 and IPEM reported 5.5. In the next thickness of filter results developed for two combined filters. First the filter was adjusted to 3.5 mmAl + 0.1 mm Cu. For this filter BEAMnrc showd 6.7 mmAl for HVL and SpekCalc showd 6.8 also IPEM reported 6.8 and measurement showed 6.7.

For second combined filter which the accuracy was increased too results found for 3.5mmAl + 0.2 mmAl. For this filter IPEM showed 8.05 mmAl ,SpekCalc found 8.16 , BEAMnrc calculated 7.97 and measurement found 7.81 mm Al that it definitely shows with increasing the energy due to decreasing the scatter effect ,the agreement is increased rapidly.The data for HVLs show BEAMnrc has 4.7% difference with IPEM, 3.2 % with Spekcal and 3.6% with measurements. That is acceptable because as we know IPEM beam data is a bit harder than usual [8].

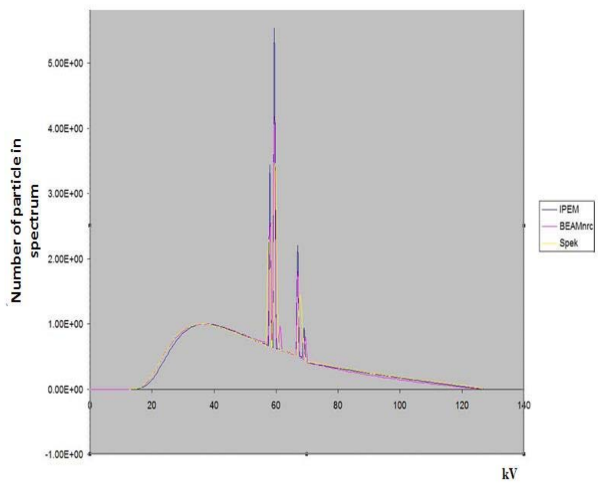

Fig. 2 Spectrum distribution for 127 kV X-ray using BEAMnrc for simulation of Sro 33 100 /ROT 350 compared with IPEM report and Spek after 2.5 mm AL and 1.2 mm Be

Results also show that with increasing the thickness and density of filter the agreement, due to harder beam, will be increased.In the next step the spectrums of beam were found in three energies and three filters. Figure 2 shows the spectrum of BEAM, IPEM and SpekCalc. It shows the characteristic lines in SpekCalc and IPEM are in about 57 kV and 67 kV. For BEAMnrc except of these lines there is one another line after 67 kV that the length of this line would be decreased with increasing the hardness of radiation and it's not a significant error. It seems that this line is because of the K-edge effect of one of the elements which have been introduced in PEGS4 file.The results show with increasing the thickness of filter or using the denser filter the agreement of spectrums would be increased rapidly.

IV. Conclusions

BEAMnrc Monte Carlo simulation code was used to find Spectrum and HVL of X-ray beam from tube x-ray SRO 33 1000/ROT 350 in low energy X-ray radiation for three energies 127,103 and 84 kV. Result showed BEAMnrc data can predict the spectrum as well as HVL. In these simulation a tungsten anode with 1.2 mm Be window were used as source. HVLs were calculated from BEAMnrc spectrum with air Kerma method for four different filters. For BEAMnrc one billion particles were used as original particles for all simulations. there was maximum 5.2 % difference between BEAMnrc and Measurements and minimum was 0.7% .the maximum 9.1% difference between BEAMnrc and IPEM and minimum was 2.3% .The maximum difference was 3.2% between BEAMnrc and Spekcal and minimum was 2.8%. The results show BEAMnrc was able to satisfactory predict the radiological quantities in low energy X-ray beam as well as high energy X-ray radiation.

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