THE EFFECT OF ANODE SURFACE ROUGHNESS ON RADIATION OUTPUT FOR DIAGNOSTIC X-RAY SOURCES

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The calculation of entrance surface dose to patients in diagnostic radiology from tube output data is determined by often-unknown sources of inherent filtration. One of these sources is the roughness of the anode surface increasing with tube ageing. This effect increases the inherent filtration of the x-ray tube noticed by a reduced radiation output and increased half-value layers (HVL). To study this effect used rotating anodes were collected and the surface profile of 8 focal tracks was measured in radial direction using an instrument with a diamond tipped stylus (90° tip, 1 μm radius).

Surface roughness was determined as the arithmetic mean R_a of the deviation in the profile from the centre line for 200 μm reference lengths ranging from 1.32 μm (sandblasted finish without surface degradation) to 5.22 μm (a track for a small focus). The surface profiles were then used to calculate x-ray spectra using a computer code [1] similar to the method from [2]. For each surface about 40000 spectra were calculated with the electrons entering the anode at random position and spectral parameters were then determined.

The simulation showed that for rough surfaces the x-rays have to penetrate an additional absorbing layer of tungsten increasing in thickness with anode roughness. The anode with the roughest focal track (R_a=5.22 μm) yields a mean additional absorber thickness in direction of the x-ray beam of about 18 μm. The corresponding loss in air kerma for this anode was about 20% at 70 kVp.

The effect on mean photon energy is rather small but highest at 70 kVp (+1 keV at R_a=5.22 μm) and lowest at 140 kVp (~0 keV). This is due to the K-edge in the attenuation coefficients of tungsten at 69.5 keV. Beam hardening is thus reduced for higher voltages as absorption at lower photon energies is balanced by higher absorption above the K-edge while at lower voltages beam hardening is fully effective. The pattern of changes in HVL is more complex but in essence also reflects voltage, roughness and tungsten K-edge. Again, the variation of HVL due to roughness and beam hardening is highest at around 70 kVp and decreases for higher tube voltages.

Without an experimental x-ray tube with anodes of known surface roughness, it is difficult to verify the simulated results. Inherent filtration is commonly determined as given in [3]. To compare the simulated with measured data attenuation curves were made with a clinical x-ray unit using 99.99% Al-absorbers in a low radiation scatter setup and an ionisation chamber (DALI, PTW, Germany). Inherent filtration was then determined according to [3] as 3.12 mm Al (nominal inherent filtration was 2.5 mm Al). X-ray output was calculated with the same parameters and compared (Fig. 1a).

In another comparison the filtration was kept at the nominal value of 2.5 mm Al but an additional filter of 6.37 μm tungsten was used (Fig. 1b). This conforms to an anode of medium surface roughness. An improved agreement of measured and calculated attenuation curves is found indicating that tube aging could be better described by an additional filtration of tungsten than aluminium.

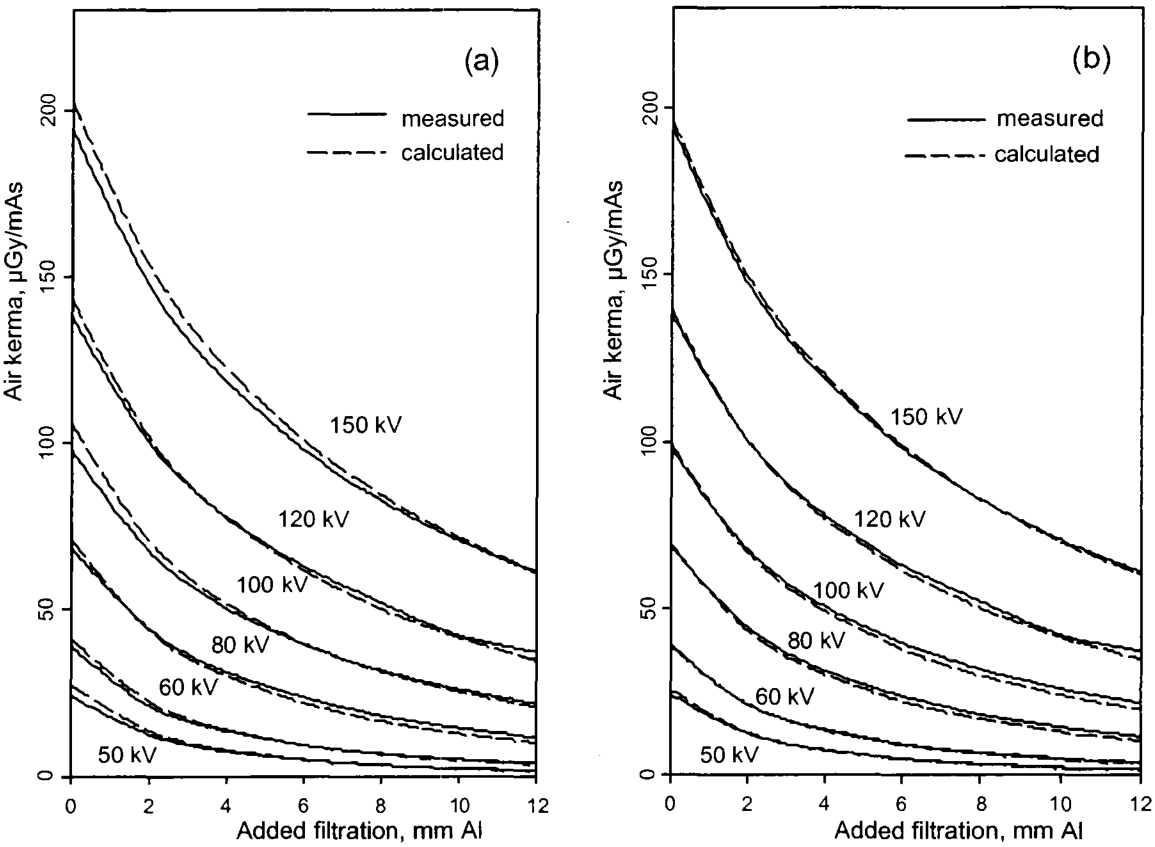

FIG. 1: Measured attenuation curves for various tube voltages obtained with an x-ray unit with 16° anode tube angle, 3.4% voltage ripple and 2.5 mm Al nominal inherent filtration in 100 cm distance: (a) data calculated with the same parameters but 3.12 mm Al inherent filtration, (b) data calculated with 2.5 mm Al inherent filtration plus an additional filter of 6.37 µm W.

REFERENCES

[1] Nowotny, R., Höfer, A., "Ein Programm für die Berechnung von diagnostischen Röntgenspektren", Fortschr. Röntgenstr. **142** (1985) 685-689.

[2] Birch, R., Marshall, M., "Computation of bremsstrahlung X-ray spectra and comparison with spectra measured with a Ge(Li)-detector," Phys. Med. Biol. **24** (1979) 505-517.

[3] ISO 4037-1:1996, "X and gamma reference radiation for calibrating doesmeters and doserate meters and for determining their response as a function of photon energy – Part 1: Radiation characteristics and production methods", Int. Organisation for Standardisation, Geneva, 1996.