Parameters of ISO 4037 wide spectrum X-ray reference field

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ABSTRACT

The parameters of the ISO-4037 wide spectrum (W-series) X-ray reference fields were simulated using the SpekPy web-based simulation software. One of the most important physical quantities (air Kerma rate) and other radiation quantities (X-ray fluence spectrum and its averaged energy, the first and the second half value layers, as well as the beam homogeneity coefficient) were also deduced. The comparison in radiation quantities between the simulated (obtained from this work) and the ISO-published data was performed to confirm the reliability of SpekPy simulations (the maximum discrepancy between them was less than 4.0%). The air Kerma rate trend as a function of the W-series X-ray reference field was investigated and presented in this work. The values of air Kerma rates can be applied in calibrations of wide-spectrum X-ray measuring devices.

Keywords: Air Kerma rate; SpekPy; Fluence spectrum; Physical quantity.

1. INTRODUCTION

The International Organization for Standardization (ISO) has released the ISO-4037 series [1-3] concerning on the establishment of photon (X-ray and gamma) reference fields for purposes of calibration of radiation measuring devices. The ISO-4037 includes the guidance for establishing the wide spectrum X-ray reference fields (denoted as "W-series"; "series" is the nominal maximum X-ray energy).

Parameters of the ISO-4037 W-series X-ray reference fields are considered as consisting of radiation and physical quantities. While the radiation quantities provide readers with a quick understanding of the qualitative radiation reference fields, the physical quantities are the most important ones applied in calibrations of radiation measuring devices as well as in dosimetric radiation metrology.

In this work, the following W-series (i.e., W-30, 40, 60, 80, 110, 150) X-ray reference fields were characterized using the SpekPy web-based simulation software. The ISO-4037 W-series X-ray reference fields were characterized in terms of radiation quantities (X-ray fluence-spectrum - Φ and its averaged energy - $\bar{E}$; the first half value layers - HVL_1; the second half value layers - HVL_2, the beam homogeneity coefficient - $h = HVL_1/HVL_2$) as well as dosimetric physical quantity (air Kerma rate -$\dot{K}$). Moreover, the radiation quantities were compared with those from the ISO publication [1] and the values of $\dot{K}$ were drawn as a function of W-series X-ray energies.

2. X-RAY SYSTEM AND SPEKPY SIMULATION SOFTWARE

The MXR-160/22 model Hopewell Design Inc. (USA) X-ray system was installed at the Institute for Nuclear Science and Technology (Hanoi – Viet Nam) as a reference X-ray machine applying for establishing X-ray reference fields for calibrations of radiation measuring devices. The X-ray machine was designed with a back tilt anode-cathode axis of 5.2^o to the emitted X-ray direction (in comparison with the vertical axis). The target of the

X-ray system is tungsten with a tilt angle of 20^o (in comparison with the electron incident angle). The configuration of the X-ray machine was considered in SpekPy simulations.

In this work, the SpekPy (version 2.0.8) web-based simulation software [4] was used to simulate W-series X-ray fluence spectra at 250 cm from the X-ray focal spot. An X-ray spectrum, ϕ_i is considered as the distribution of individual X-ray fluence in a specific energy bin width [$\varphi_b(E_b)$] as a function of central bin energy [E_b]. Since the value of ϕ_i is available, the spectrum-averaged energy ($\bar{E}$) as well as the dosimetric physical quantity ($\dot{K}$) are respectively deduced as Eq.(1) and Eq. (2). Where, $k_{\varphi \to K}$ is the conversion factor from X-ray fluence to air Kerma rate (these are available in Ref. [5]). The other radiation quantities (HVL_1; HVL_2, $h = HVL_1/HVL_2$) are also automatically calculated using the SpekPy software.

$$\bar{E} = \frac{\sum_{b=1}^{n} \varphi_b(E_b) \, . \, E_b}{\sum_{b=1}^{n} \varphi_b(E_b)} \quad (1)$$

$$\dot{K} = \sum_{b=1}^{n} \varphi_b(E_b) \, . \, k_{\varphi \to K} \quad (2)$$

In SpekPy simulations, the following parameters were set: physics model (kqp); attenuation data (Penelope); energy bin (0.5 keV); output X-ray spectrum with Bremsstrahlung and characteristic peaks included. As results, follows parameters were obtained: (1) the W-series (W-30, W-40, W-60, W-80, W-110, W-150) X-ray fluence spectra; (2) HVL_1, HVL_2 values; (3) beam homogeneity coefficient, h; (4) the spectrum-averaged energy; and (5) $\dot{K}$ value.

3. RESULTS AND DISCUSSION

3.1. W-series X-ray fluence spectrum

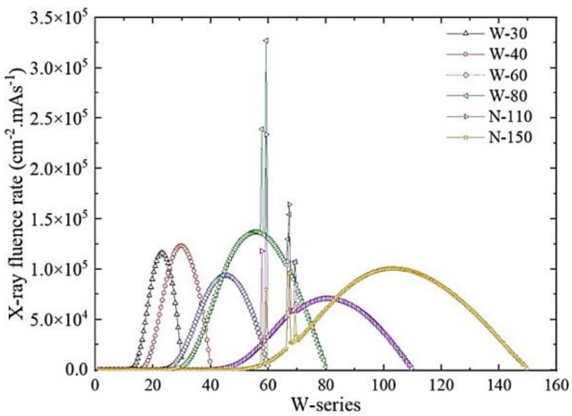

Figure 1. *ISO 4037 W-series X-ray fluence spectra at 250 cm from the X-ray focal spot. Data were simulated using SpekPy web-based software.*

W-series X-ray fluence spectra are shown in Fig. 1, ones can figure out that there are high magnitude characteristic X-ray peaks (of tungsten) appeared in W-80, W-110, and W-150 spectra (while they do not appear in spectra of lower nominal maximum X-ray energies (i.e., for beam qualities of W-30, W-40, and W-60).

3.2. Radiation quantity of W-series X-ray fluence spectrum

The values of HVL_1, HVL_2 were tabulated in table 1, in comparison with those from the ISO publication [1]. Ones can recognize that, there is a good agreement between them. That means the simulation data are believable. Then, the beam homogeneity coefficients of beam qualities were calculated, which ranged from 0.81 to 0.88 (satisfied the recommendation range stated in the ISO 4037-1:2019, from 0.81 to 0.97).

Table 1. *Physical and radiation quantities of the ISO 4037 W-series X-ray reference fields at 250 cm from the X-ray focal spot.*

W-series	HVL_1 (mmCu)		HVL_2 (mmCu)		HVL_1/HVL_2	$\bar{E}$ (keV)		$\dot{K}$ (μGy/mAs)
	*	[1]	*	[1]	*	*	[1]	
W-30	0.026	-	0.030	-	0.86	23	22.9	1.60
W-40	0.053	-	0.063	-	0.84	30	29.8	1.40
W-60	0.180	0.181	0.210	0.215	0.84	45	44.8	0.77
W-80	0.350	0.350	0.430	0.434	0.81	56	56.5	1.40
W-110	0.920	0.934	1.100	1.080	0.87	79	79.1	0.95
W-150	1.800	1.790	2.000	2.040	0.88	100	104	2.30

Notation:

**: Data from this work;*

HVL_1, HVL_2*: The first and the second half value layers, respectively;*

$h = HVL_1/HVL_2$*: The beam homogeneity coefficient;*

$\bar{E}$*: X-ray fluence-spectrum-averaged energy;*

$\dot{K}$*: Air Kerma rates obtained from the SpekPy simulations.*

The W-series X-ray fluence-spectrum-averaged energies were also calculated and presented in table 1 (together with those stated in the ISO publication [1]). Ones can also find a good agreement between them (the biggest difference is less than 4.0%). This difference can be acceptable since it does not make a remarkable change in the calculation of a dosimetric quantity (e.g., air Kerma rate). That, once again, implies the reliability of SpekPy simulation data.

3.3. Tendency of air Kerma rate of W-series X-ray fluence spectrum

Figure 2 shows the air Kerma rate tendency of the ISO 4037 W-series X-ray reference fields as a function of the nominal maximum X-ray energies.

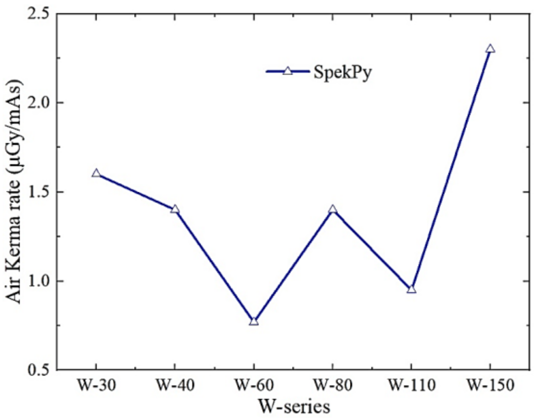

Figure 2. *Air Kerma rate tendency of the ISO 4037 W-series X-ray reference fields. Data were simulated using SpekPy web-based software.*

The standard uncertainties of simulated radiation, as well as physical quantities, were not mentioned in SpekPy. However, some of the simulated radiation quantities were compared with those from the ISO publication [1], the difference between them are acceptable. That means the simulated data of $\dot{K}$ can be believable. Thus, the values of $\dot{K}$ can be reasonably applied in calibrations of X-ray dosimetrically measuring devices.

4. CONCLUSIONS

The radiation and physical quantities of the ISO 4037 W-series X-ray reference fields were simulated using SpekPy web-based software. The comparison between the simulated and the ISO published data shows good agreement with a negligible difference. The values of air Kerma rate of W-series X-ray reference fields can be applied for calibrations of X-ray dosimetrically measuring devices.

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TÓM TẮT

Thông số của trường chuẩn bức xạ tia X phổ rộng theo tiêu chuẩn ISO 4037

Các thông số của trường chuẩn bức xạ tia X phổ rộng (chuỗi W) theo tiêu chuẩn ISO-4037 được mô phỏng sử dụng phần mềm trực tuyến SpekPy. Một trong các đại lượng vật lý đo liều quan trọng nhất (suất Kerma trong không khí) và các đại lượng bức xạ khác (phổ thông lượng tia X và năng lượng trung bình của chúng, bề dày làm yếu một nửa lần thứ nhất và lần thứ hai, cùng với hệ số đồng nhất chùm tia) cũng được xác định. So sánh về giá trị các đại lượng bức xạ giữa kết quả mô phỏng (từ nghiên cứu này) và kết quả đăng tải bởi tiêu chuẩn ISO được thực hiện nhằm khẳng định độ tin cậy của các kết quả mô phỏng sử dụng SpekPy (sự khác nhau lớn nhất giữa chúng nhỏ hơn 4.0%). Xu hướng của giá trị suất Kerma trong không khí phân bố theo hàm của sự biến thiên năng lượng với các phẩm chất chùm tia X phổ rộng cũng được nghiên cứu và trình bày trong bài báo này. Kết quả suất Kerma trong không khí có thể được sử dụng trong công tác hiệu chuẩn các thiết bị đo liều tia X phổ rộng.

Từ khóa: Suất Kerma trong không khí; SpekPy; Phổ thông lượng; Đại lượng vật lý.