The Radiation Dose Determination of the Pulsed X-ray Source

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Abstract. In this paper the radiation dose measurement technique of the pulsed X-ray source RAP-160-5 is described. The dose rate measurement results from the pulsed X-ray beams at the different distance between the pulsed X-ray source focus and the detector obtained with the help of the thermoluminescent detectors DTL-02, the universal dosimeter UNIDOS E equipped with the plane-parallel ionization chamber type 23342, the dosimeter-radiometer DKS-96 and the radiation dosimeter AT 1123 are demonstrated. The recommendations for the dosimetry measurements of the pulsed X-ray generator RAP-160-5 under different radiation conditions are proposed.

1. Introduction

At present time there is a wide range of various X-ray sources for the radiographic analysis in the nondestructive and medical examinations [1]. However, all these techniques have limitations related to the radiation dose for the biological objects. Nowadays the issue of the radiation doses estimation of the biological objects in the radiographic examination is relevant for different types of the X-ray diagnostics. One of the dose reduction techniques is use of the pulsed X-ray source synchronized with the detecting device.

Such X-ray visualization devices based on the different linear detectors were developed in the Applied Physics Department at Tomsk Polytechnic University. The emitting source in both devices is a pulsed X-ray generator RAP-160-5. These setups can be used for receiving shadow projection images and tomograms. The purpose of developing experimental setups is using obtained results in medicine [2].

One of the main aims of the development is to find out the radiation burden estimation methods of the pulsed X-ray sources.

The dose measurement from a pulsed source has a number of difficulties. Due to the fact that the X-ray tube RAP-160-5 emits only 2% of the time the current pulse is relatively high – about 50 times more integral values. Consequently, the dosimetric equipment should be capable of working with a sufficiently high dose rates. In addition, the pulse-repetition rate is high enough and the profile of the beam intensity is fast-changing. Thus, specific requirement for response rate of the recording equipments are arisen in these conditions [3].

The research objectives are:

- to measure the radiation doses of the pulsed X-ray source using the thermoluminescent detectors, the plane-parallel ionization chamber, the dosimeter-radiometer DKS-96 and the radiation dosimeter AT 1123;
- to compare obtained results;

- to elaborate recommendations for future dosimetry measurements of the pulsed X-ray generator RAP-160-5.

2. Materials and methods

2.1. Emitting source
The irradiation was performed using the pulsed X-ray generator RAP-160-5. The main parameters of the X-ray generator are: the anode voltage varies from 40 to 160 kV; the anode current varies from 0.4 to 5 mA; the peak X-pay tube power is 0.6 kW; the impulse frequency radiation varies from 60 to 700 Hz; the duration of one pulse is about 140 μs; the pulse form is nearly rectangular; the focal spot size is 1.2 ×1.2 mm. The X-ray generator RAP-160-5 can be synchronized with the other devices [4].

2.2. Dosimetry equipment
The main problem associated with the dosimetry of the pulsed X-ray radiation is the response rate of the dosimeters. This problem can be solved by using storage detectors. One of this can be the thermoluminescent detectors, which can be used for accurate measurements of dose distribution and estimate the integrate dose in the medical examination.

In the experiment the solid thermoluminescent detectors DTL-02 (thermoluminescent material – LiF: Mg, Ti) designed for personal dosimetry of staff were used. These dosimeters comply with requirements of the task. Operating limits of the dose rates and absorbed doses correspond to the operation conditions. These detectors DTL-02 can work in the energy range 15 keV – 10 MeV of gamma-radiation, the dose range is 20 μSv – 10 Sv [5].

For diagnostic radiological measurement of air kerma the most common type is a plane parallel chamber. Plane-parallel ionization chambers are acceptable for absolute dosimetry of soft X-ray beams. In the experiment the universal dosimeter for radiation therapy and diagnostic radiology UNIDOS E equipped with a PTW soft X-ray plane-parallel ionization chamber type 23342 (the energy range is 7.5 – 70 keV; the dose range is 3 mGy – 30 Gy; the measuring volume – 0.02 cm^3) was used [6, 7].

In the experiment the dosimeter-radiometer DKS-96 was used as a dosimetry equipment. This dosimeter is used in medical institutions for task-related and routine monitoring of radiation environment. The dosimeter-radiometer provides the measurement of exposure dose rate of continuous and pulsed X-ray and gamma-radiation. The dosimeter-radiometer DKS-96 can work in the energy range 15 keV – 10 MeV of X-ray and gamma-radiation, the dose range is 0,1 μSv – 10 Sv [8].

In the experiment the radiation dosimeter AT 1123 was used as a dosimetry equipment. This dosimeter is tissue-equivalent detector. The dosimeter can be used for measuring continuous, short-term and pulsed X-ray and gamma radiation. The radiation dosimeter AT 1123 can work in the energy range 15 keV – 10 MeV of X-ray and gamma-radiation, the dose range is 10 nSv – 10 Sv [9].

2.3. Experimental setup
The irradiation was produced by the X-ray generator RAP-160-5 according to the scheme shown in figure 1.

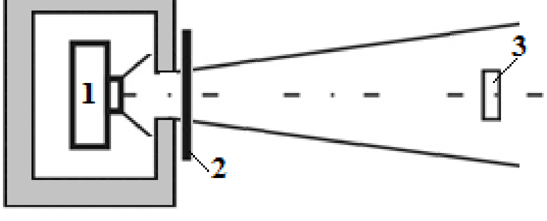

Figure 1. The scheme of irradiation of the dosimeters at the X-ray generator RAP-160-5.

Between the X-ray source (1) and the detecting device (3) an aluminum filter (2) was installed (3.0 mm thick) to reduce the contribution of soft X-rays of the spectrum, which did not correspond to the dosimeters operating modes (figure 1). The distance between the X-ray source focus and the detector varied from 40 cm to 60 cm.

The radiation was produced by the following parameters of the X-ray tube:

- the anode voltage was 70 kV;
- the anode current varied from 0.6 to 3.5 mA.

2.4. The radiation doses measurements of the pulsed X-ray source

According to the scheme on figure 1 the thermoluminescent detectors DTL-02 was used for the dose measurement of the pulsed X-ray source. The dose rate values were calculated. The measurements were carried out by three different DTL-02 dosimeters at the equal parameters of the X-ray tube, and then the average values were calculated.

In the second part of the experiment the dose and the dose rate measurements were produced by the dosimeter UNIDOS E (the measurement mode was "LOW") equipped with an ionization chamber type 23342.

According to the experimental set up in the figure 1 the dosimeter-radiometer DKS-96 was used for the dose and the dose rate measurement of the pulsed X-ray source. The regimes with the X-ray tube anode current equal to 3.0 and 3.5 mA at the distance between the X-ray source focus and the detector equal to 50 cm were out of operating mode of the dosimeter-radiometer DKS-96. The results received with these regimes have shown poor accuracy.

In the last part of the experiment the dose rate measurement was produced by the radiation dosimeter AT 1123. The dosimeter was used in the pulsed measurement mode. The sensitivity range switching occurs automatically. The resulting dose rate data from the dosimeter AT 1123 are over 3-fold more than the data from the other types of detectors.

3. Results and discussion

On figure 2 and figure 3 the dose rate dependences on the anode current of the pulsed X-ray tube are presented. The results were obtained with the help of the solid thermoluminescent detectors DTL-02, the plane-parallel ionization chamber type 23342, the dosimeter-radiometer DKS-96 and the radiation dosimeter AT 1123. The measurements were carried out in the air. The dose and the dose rate measurement results for the equal X-ray tube operating mode are average over three different DTL-02 dosimeters for accuracy increase. Results are presented for the distance between the X-ray source focus and the detector equal to 50 cm (figure 2) and 60 cm (figure 3).

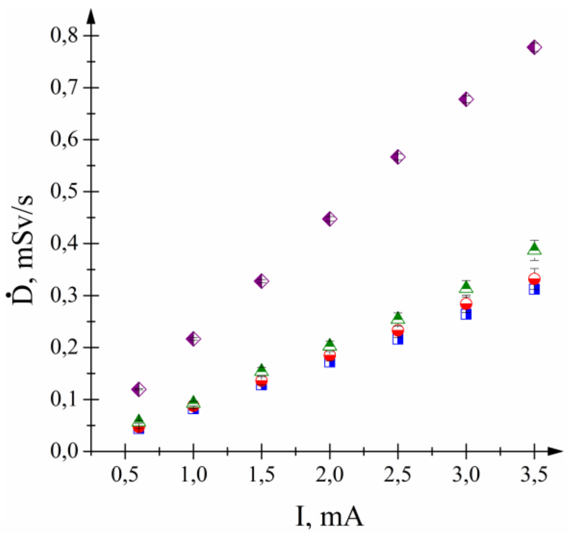

Figure 2. The dependence between the dose rate of the pulsed X-ray beam and the anode current at the distance between the X-ray source focus and the detector equal to 50 cm (the anode voltage equal to 70 kV): ▲ – the detector DTL-02 results; ◧ – the plane-parallel ionization chamber results; ◒ – the dosimeter-radiometer DKS-96 results; ◈ – the radiation dosimeter AT1123 results.

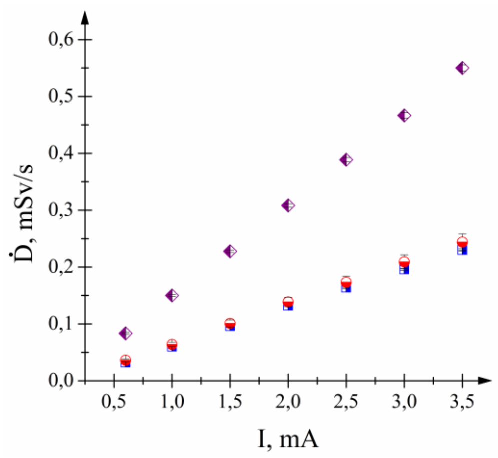

Figure 3. The dependence between the dose rate of the pulsed X-ray beam and the anode current at the distance between the X-ray source focus and the detector equal to 60 cm (the anode voltage equal to 70 kV): – the plane-parallel ionization chamber results; – the dosimeter-radiometer DKS-96 results; – the radiation dosimeter AT1123 results.

The results show that the dose rate measurements obtained with the help of the thermoluminescent detectors, the plane-parallel ionization chamber and the dosimeter-radiometer DKS-96 are in a good agreement. One can see that the plane-parallel ionization chamber can be used for dosimetry measurements of the pulsed X-ray generator RAP-160-5 under demonstrated radiation conditions.

However, for obtaining better results, the presented X-ray tube parameters of the pulsed X-ray generator RAP-160-5 using the dosimeter-radiometer DKS-96, the distance between the X-ray source focus and the detector should be more than 50 cm. The dose rate measurements obtained with the help of the radiation dosimeter AT 1123 show that other X-ray tube parameters should be used.

4. Summary

In this study, some methods of radiation dose measurement of the pulsed X-ray generator RAP-160-5 are presented. Experimental results show the advisability of using the solid thermoluminescent detectors DTL-02 and the plane-parallel ionization chamber for future dosimetric measurements of the pulsed X-ray generator RAP-160-5 under different radiation conditions. For example, the solid thermoluminescent detectors DTL-02 can be used for the measurement of the radiation burden of the X-ray source in the process of stabilization and the plane-parallel ionization chamber type 23342 can be used for the measurement of the dose rate spatial distribution produced by the pulsed X-ray source.

Acknowledgements

This work was partly supported by Competitiveness Enhancement Program of Tomsk Polytechnic University.

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