TOMSK POLYTECHNIC UNIVERSITY

The XXVI International Scientific Conference of Young Scientists and Specialists

The possibility investigation of electron beam deep dose distribution formation by 3D-printed plastic bolus

Student and Engineer
of Tomsk Polytechnic University

Elizaveta Bushmina,

A. Bulavskaya, A. Grigorieva,
I. Miloichikova, S. Stuchebrov

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Relevance

Methods of treatment of oncological diseases:
- chemotherapy,
- surgery,
- **radiation therapy**.

2020*

10 millions deaths from cancer diseases in world

Radiation therapy is a method of treatment based on the destructive effect of **ionizing radiation** on a biological object.

* World Health Organization

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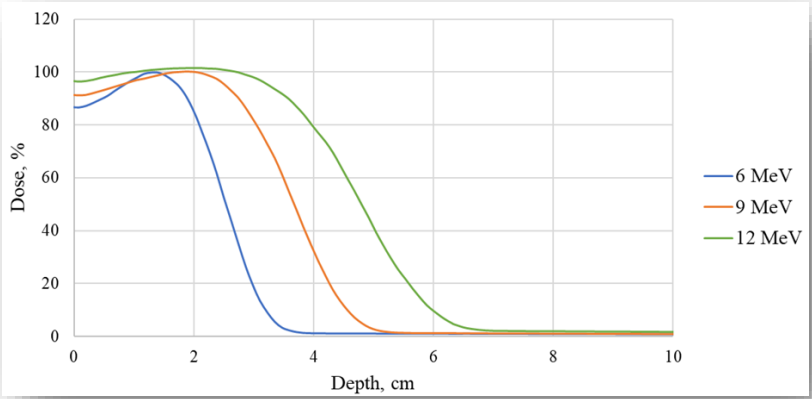
Electron beam therapy

Electron beam therapy – radiation therapy with electron beam energies from keV to MeV.



Example of percentage deep dose distributions in water phantom with different energies

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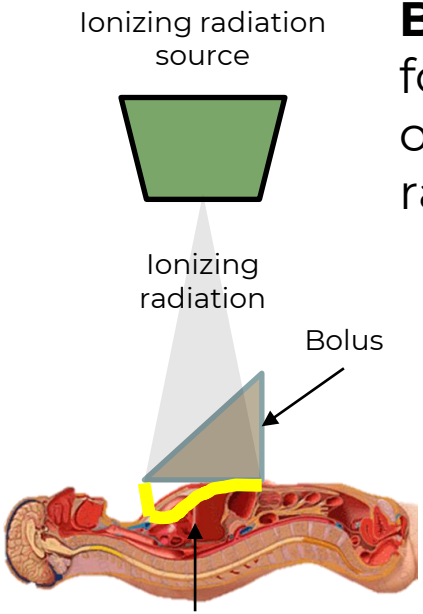
Introduction



Boluses are devices for forming the depth distribution of the dose received during radiotherapy procedures.

Examples of bolus application

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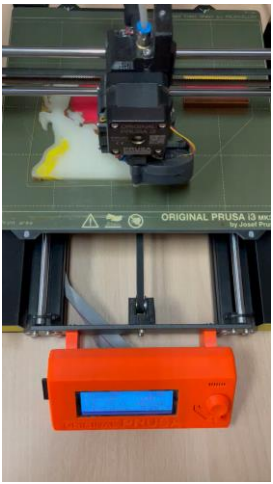
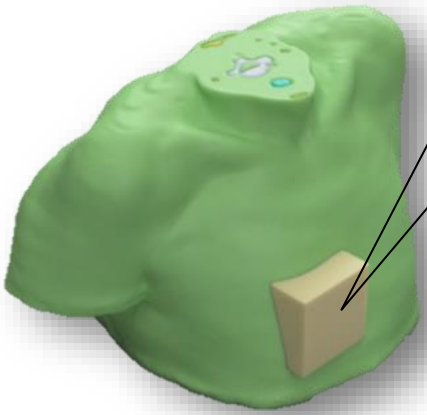
Introduction

It is proposed to make a plastic bolus for electron beam deep dose distribution formation by 3D-printing methods.



Example of 3D-printer's work



design of the bolus

3D bolus model

Design of a three-dimensional bolus model of a complex shape for the case of irradiation of the anterior chest wall

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Purpose and tasks

The main purpose of this work was to conduct a study on the formation of a deep dose distribution with plastic bolus and boluses made of standard materials when irradiated with medical electron beams.

Thereby some tasks were made:

1. Determine the chemical composition and mass density of standard materials for the manufacture of boluses used for electron beam therapy;
2. Simulate the depth distribution of the dose in standard materials;
3. Simulate the depth dose distribution in various plastics with different fill factors in order to select a plastic material suitable for making boluses;
4. Simulate the depth dose distribution behind standard materials and plastic suitable for the manufacture of products using 3D printing methods for different electron energies;
5. Make experimental paraffin and plastic bolus samples, investigate their characteristics;
6. Conduct experimental studies on medical electron beams in order to obtain a deep dose distribution in the materials under study;
7. Evaluate the effectiveness of the proposed method of creating boluses in comparison with boluses made from standard materials.

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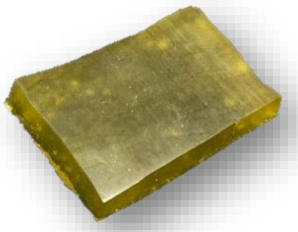
Forming devices

Composition of the standard bolus*



Action Bolx

Element	Fraction
Carbon	0,63900
Oxygen	0,25200
Hydrogen	0,09920
Nitrogen	0,00922
Tin	0,00026
Silicone	0,00053

The measured density of the **Action Bolx** bolus was **1,01 g/cm³.**

Disadvantages:

- the simplicity of their shapes;
- the import material.

Paraffin

Composition of the paraffin bolus

Element	Fraction
Carbon	0,32666
Hydrogen	0,67333

The measured density of the **paraffin** bolus was **1,009 g/cm³.**

Disadvantages:

- fragility;
- heterogeneity.

*Moyer R. F. et al. A surface bolus material for high-energy photon and electron therapy //Radiology. 1983. V. 146. №. 2. P. 531-532.

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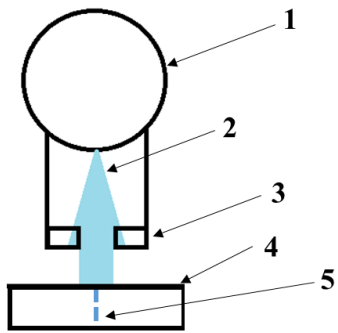
Numerical simulation of PDD

Numerical simulation of electron beams percentage deep dose distributions was carried out using the Geant4 toolkit.

1



The geometry of the calculation in the Geant4:
1 - electron source;
2 – electron beam;
3 - applicator;
4 – bolus;
5 – beam axis

2

Electron beam simulated percentage deep dose distributions in plastic samples 6 MeV: (a) ABS, (b) PLA and (c) HIPS plastics

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Numerical simulation of PDD

3 Electron beam simulated percentage deep dose distributions in bolus materials

Based on the data obtained, it was found that **PLA-plastic with fill factor = 84%** is suitable for the manufacture of boluses.

4

Electron beam simulated percentage deep dose distributions in water phantom formed by 1 cm bolus materials

Electron energy:
(a) 6 MeV,
(b) 12 MeV,
(c) 15 MeV

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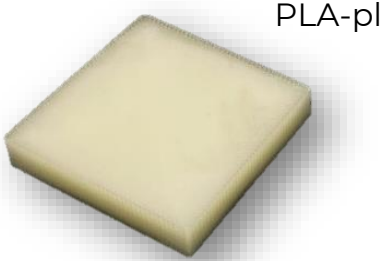
Fabrication of plastic bolus from PLA-plastic

The plastic sample was made using a Flashforge Creator 3 3D printer, based on the use of layer-by-layer deposition technology. The product was printed with **84%** coverage of the material by volume of the product.

PLA-plastic bolus



For the manufacture of the bolus **PLA-plastic** was used, which has the highest physical and X-ray density, that is, a smaller thickness is required for the necessary absorption of the beam, unlike other types of plastics.
The measured density of the plastic bolus was **1,01 g/cm^3**.

Printing parameters:
filament thread diameter - 1.75 mm,
layer thickness - 0.3 mm,
nozzle diameter - 0.4 mm,
print speed - 40 mm / min,
nozzle temperature - 215 °C,
table temperature - 90°C.

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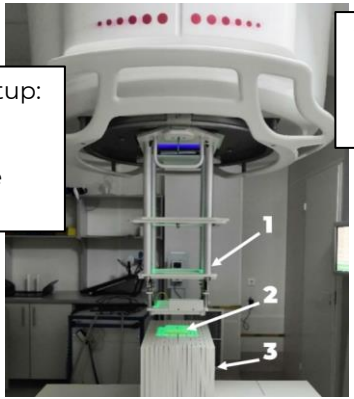
Experimental part

Experimental setup:
1 – applicator;
2 - bolus;
3 – solid-state phantom



The data obtained confirm that the experimental studies coincided with the numerical simulations.

Electron energy:
(a) 6 MeV, (b) 12 MeV, (c) 15 MeV

Electron beam experimental percentage deep dose distributions in solid-state phantom formed by 1 cm bolus

12 MeV:
(a) Action Bolx, (b) PLA plastic, (c) paraffin

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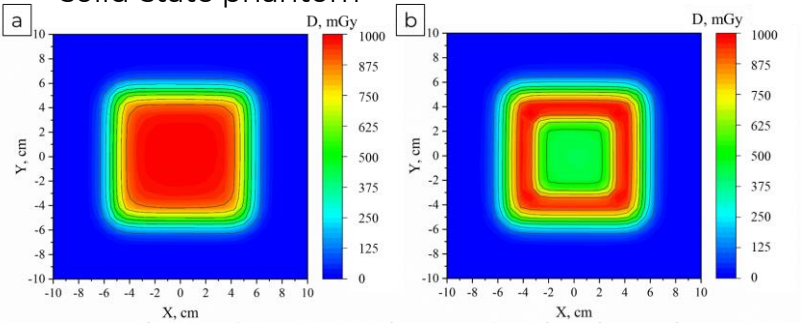
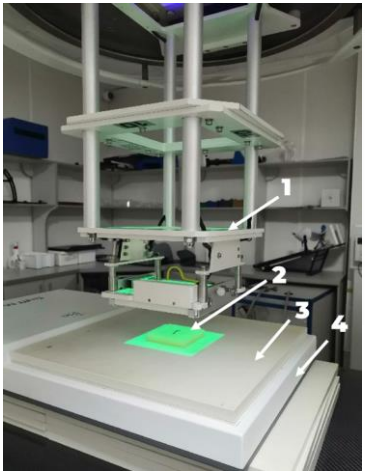
Experimental part

* 6 MeV electron beam experimental profiles in solid-state phantom





Experimental setup:
1 - applicator; 2 - bolus;
3 – solid-state phantom;
4 - detector MatriXX Evolution

Values of percent change in absolute dose

Electron energy, MeV / Bolus material	6	12	15
Action Bolx	37%	80%	87%
PLA-plastic	44%	85%	91%
Paraffin	41%	84%	91%

*(a) without a bolus; (b) with a bolus made of PLA-plastic

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Conclusion

- ✓ A study was conducted on the formation of a deep dose distribution with plastic bolus and boluses made of standard materials when irradiated with medical electron beams.
- ✓ According to the obtained results of measuring the absolute dose, it can be said that boluses made of PLA-plastic and standard materials are shielded equally within the error.
- ✓ The production of boluses from PLA-plastic by 3D printing has shown its effectiveness at the stages of numerical modeling and experimental studies.

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Thank you for your attention!

Contacts:
eab60@tpu.ru

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