

# Change of notch impact strength depending on radiation dose and test temperature

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**Abstract.** The main purpose of this paper has been determine the effect of radiation crosslinking on the notch impact strength of polyamides filled with fiberglass. These properties were examined in dependence on the dosage of the ionizing beta radiation (non-irradiated samples and those irradiated by dosage 66 and 132 kGy were compared) and on the test temperature (23 – 150 °C).

## 1 Introduction

The modification of polymer properties by irradiation is constantly evolving area. Ionic and ionizing radiation are the main types of radiation which are used for the polymer modification. Gamma radiation created from radioactive isotope Co-60 (<sup>60</sup>Co) belongs to ionizing radiation as well as beta radiation (electron beam) and X-ray radiation. All of these types significantly differ, however during these all process the energy transfer to atoms of irradiated material occurs [1-6].

As stated in previous investigations [6-16], it is possible to effectively change physical, mechanical and biological properties of irradiated material by ionizing radiation. These changes are probably caused by primary and secondary processes which are created due to interaction of ionizing radiation with polymer [1,2].

The crosslinking level can be adjusted by irradiation dosage and often by means of a crosslinking booster. The main difference between electron beta and photon gamma is in their different abilities of penetrating the irradiated material. Gamma rays have a high penetration capacity. The penetration capacity of electron rays depends on the energy of the accelerated electrons. Due to accelerated electron the required dose may be applied for seconds, whereas several hours are required on the gamma radiation plant. The electron accelerators operate on the principle of the Braun tube, whereby a hot cathode is heated in vacuum to such a degree that electrons are released [17-21].

This study deals with the influence of different doses of ionizing beta radiation (66 and 132 kGy) on notch impact strength of polyamides under thermal loading and follows previous studies [3, 5, 7, 9, 10], which described the change of mechanical properties of selected types thermoplastics.

The previous study [3, 5, 7, 9, 10] proved the positive irradiation effect on mechanical of selected types polymers. Nevertheless, some findings are not explained yet, namely the change of dynamic properties during the

application of beta radiation on material under thermal loading. Each new finding on the effect of radiation crosslinking on the properties of polymer materials may thus contribute to a better understanding of the issue and can extend the field of new applications.

## 2 Experimental

### 2.1 Materials

For this experiment two types polyamides were used. Both materials are filled with glass fibers and their commercial names are:

- Polyamide 66 GF 30 – V – PTS – CREAMID A3H7.2G 6\*M0129A Schwarz
- Polyamide 7T GF 56 – V – DURAMID TH7 G12.0SZB\*9207

The basic properties of used materials are shown in Table 1 and 2.

**Table 1.** Properties of PA 66 GF 30.

PA 66 GF 30	
Density [g/cm <sup>3</sup> ]	1.37
Impact toughness [kJ/m <sup>2</sup> ]	8
Tensile modulus [MPa]	10000
Bending strength [MPa]	260
Softening temperature [°C]	255

The samples were made using the injection molding technology on the injection molding machine Arburg Allrounder 470H 1000-400. The samples had the shape and dimensions according to the CSN EN ISO 179. Processing conditions during the injection moulding

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were according to the recommendation of the procedures.

Test specimens were equipped with a notch type V (size 2 mm).

**Table 2.** Properties of PA 7T GF 56.

PA 7T GF 56	
Density [g/cm <sup>3</sup> ]	1.63
Impact toughness [kJ/m <sup>2</sup> ]	25
Tensile modulus [MPa]	19000
Bending strength [MPa]	290
Softening temperature [°C]	229

All samples were irradiated with electron (beta) rays (electron energy 10 MeV, radiation doses: 66 and 132 kGy) in the firm BGS Beta Gamma Service GmbH & Co, Saal am Danau – Germany [7, 14, 15].

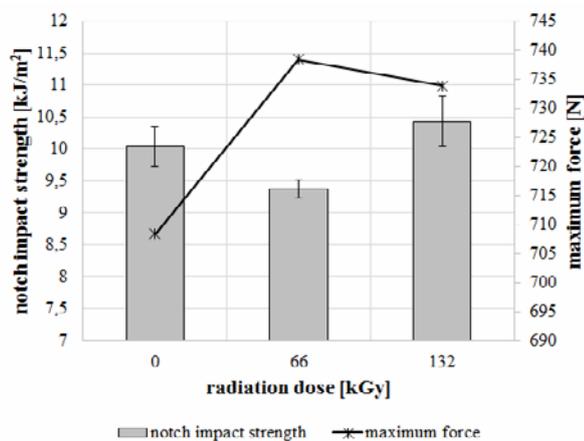
### 2.2 Determination of mechanical characteristic

For testing the mechanical properties there was used a dynamic test on the test machine Zwick HIT50P. Test conditions were according to the CSN EN ISO 179. The energy of the hammer was 50 J and test data was processed by Test Xpert II software.

## 3 Results and discussion

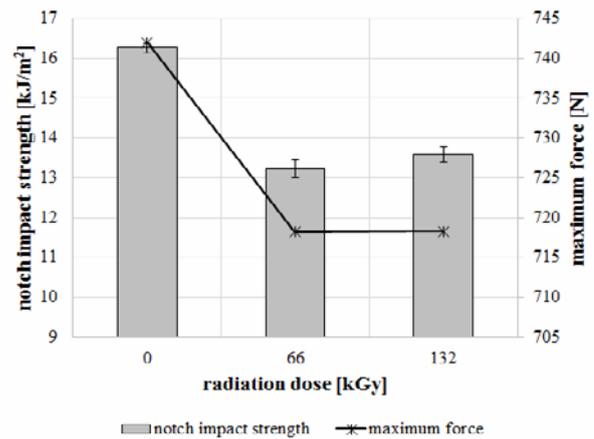
### 3.1 Notch impact strength – PA 66 GF 30

Comparison of notch impact strength and maximum force (at 23, 50, 75, 100, 125, and 150 °C) of PA 66 GF 30 before and after irradiation is given in the Figures 1 to 6.



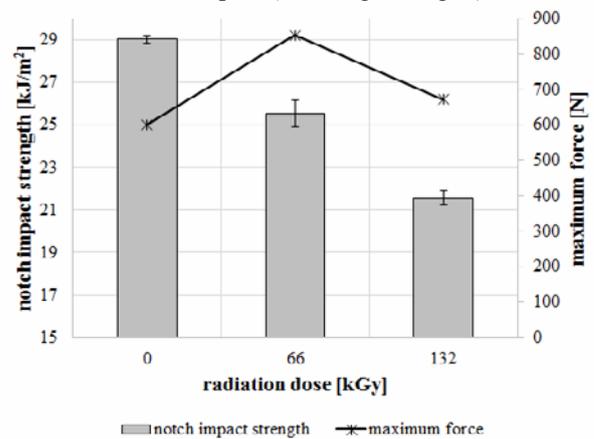
**Fig. 1.** Notch impact strength and maximum force (PA 66 GF 30, test temperature – 23 °C).

In the case of test temperature 23 °C the highest value of notch impact strength was achieved by the irradiation with dose of 132 kGy and the highest value of maximum force was achieved by the irradiation with dose 66 kGy (referring to: Fig. 1).



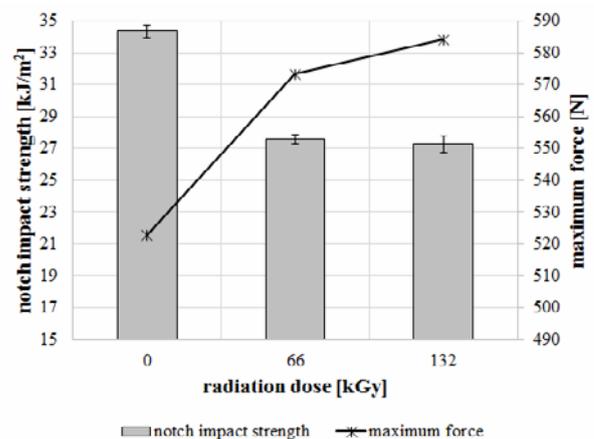
**Fig. 2.** Notch impact strength and maximum force (PA 66 GF 30, test temperature – 50 °C).

In the case of test temperature 50 °C the highest value of notch impact strength and maximum force was achieved at non-irradiated samples (referring to: Fig. 2).



**Fig. 3.** Notch impact strength and maximum force (PA 66 GF 30, test temperature – 75 °C).

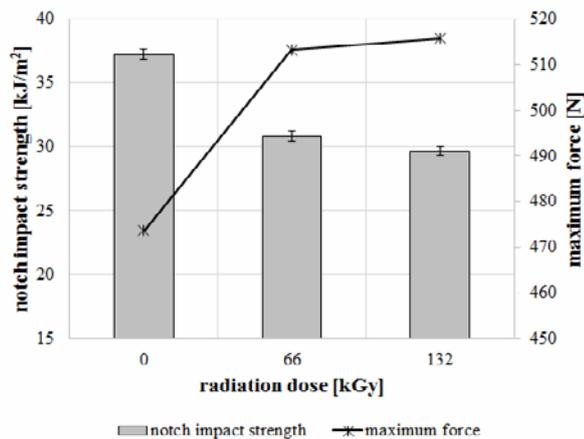
In the case of test temperature 75 °C the highest value of notch impact strength was achieved at non-irradiated samples and the highest value of maximum force was achieved by the irradiation with dose 66 kGy (referring to: Fig. 3).



**Fig. 4.** Notch impact strength and maximum force (PA 66 GF 30, test temperature – 100 °C).

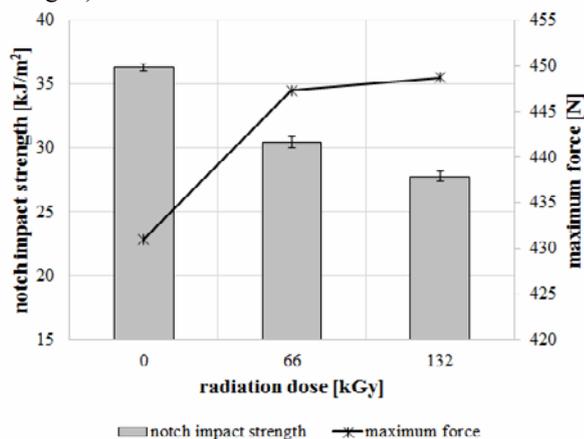
In the case of test temperature 100 °C the highest value of notch impact strength was achieved at non-irradiated

samples and the highest value of maximum force was achieved by the irradiation with dose 132 kGy (referring to: Fig. 4).



**Fig. 5.** Notch impact strength and maximum force (PA 66 GF 30, test temperature – 125 °C).

In the case of test temperature 125 °C the highest value of notch impact strength was achieved at non-irradiated samples and the highest value of maximum force was achieved by the irradiation with dose 132 kGy (referring to: Fig. 5).

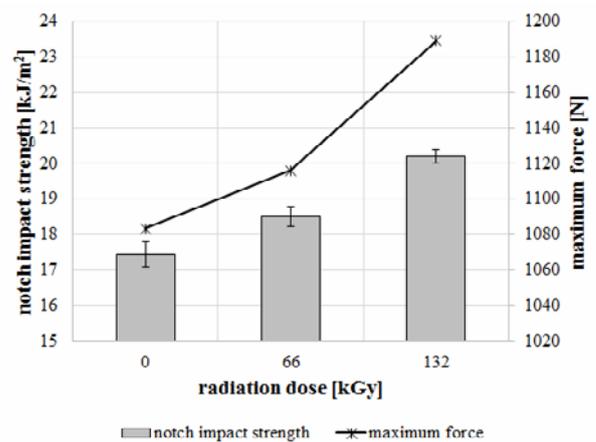


**Fig. 6.** Notch impact strength and maximum force (PA 66 GF 30, test temperature – 150 °C).

In the case of test temperature 150 °C the highest value of notch impact strength was achieved at non-irradiated samples and the highest value of maximum force was achieved by the irradiation with dose 132 kGy (referring to: Fig. 6).

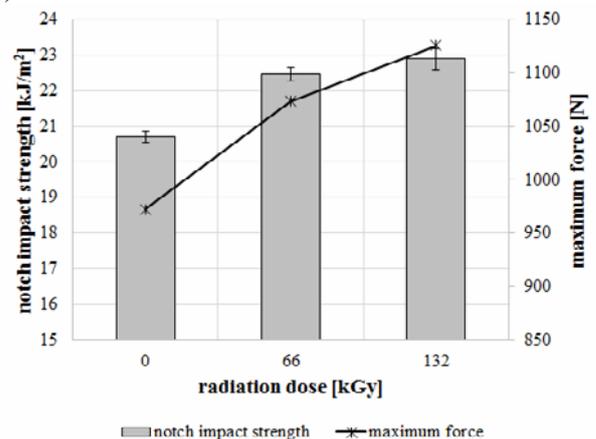
### 3.2 Notch impact strength – PA 7T GF 56

Comparison of notch impact strength and maximum force (at 23, 50, 75, 100, 125, and 150 °C) of PA 7T GF 56 before and after irradiation is given in the Figures 7 to 12.



**Fig. 7.** Notch impact strength and maximum force (PA 7T GF 56, test temperature – 23 °C).

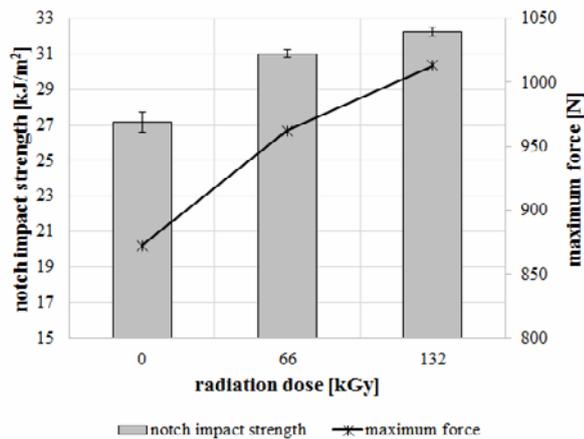
In the case of test temperature 23 °C the highest value of notch impact strength and maximum force was achieved by the irradiation with dose of 132 kGy. The value of notch impact strength increased from 17.5 kJ/m<sup>2</sup> (non-irradiated samples) to 20.2 kJ/m<sup>2</sup> (dose of 132 kGy), which is a hike of approximately 15 % (referring to: Fig. 7).



**Fig. 8.** Notch impact strength and maximum force (PA 7T GF 56, test temperature – 50 °C).

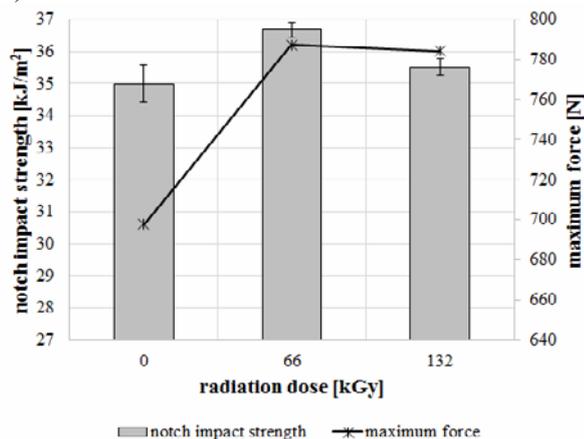
In the case of test temperature 50 °C the highest value of notch impact strength and maximum force was achieved by the irradiation with dose of 132 kGy. The value of notch impact strength increased from 20.7 kJ/m<sup>2</sup> (non-irradiated samples) to 22.9 kJ/m<sup>2</sup> (dose of 132 kGy), which is a hike of approximately 10 % (referring to: Fig. 8).

In the case of test temperature 75 °C the highest value of notch impact strength and maximum force was achieved by the irradiation with dose of 132 kGy. The value of notch impact strength increased from 27.2 kJ/m<sup>2</sup> (non-irradiated samples) to 32.2 kJ/m<sup>2</sup> (dose of 132 kGy), which is a hike of approximately 18 % (referring to: Fig. 9).



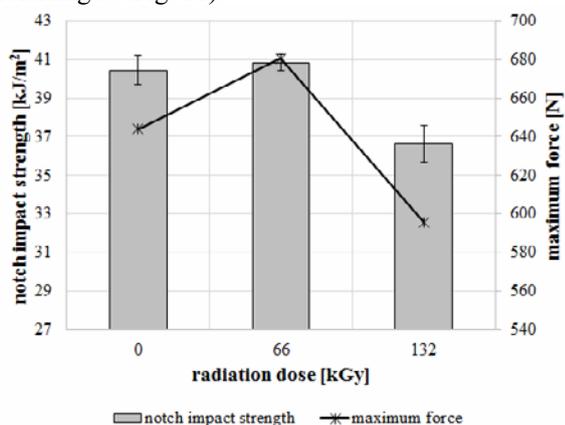
**Fig. 9.** Notch impact strength and maximum force (PA 7T GF 56, test temperature – 75 °C).

In the case of test temperature 100 °C the highest value of notch impact strength and maximum force was achieved by the irradiation with dose of 66 kGy. The value of notch impact strength increased from 34.9 kJ/m<sup>2</sup> (non-irradiated samples) to 36.7 kJ/m<sup>2</sup> (dose of 66 kGy), which is a hike of approximately 5 % (referring to: Fig. 10).



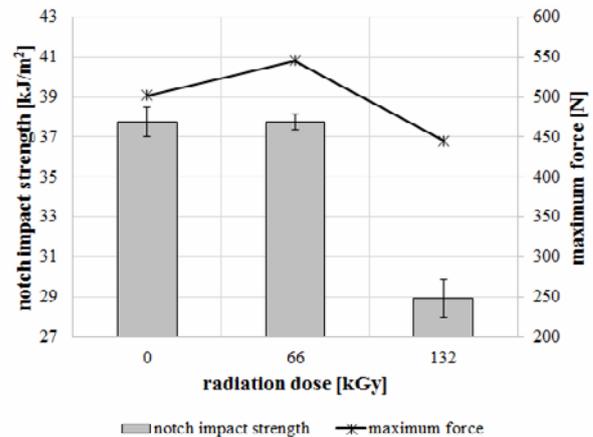
**Fig. 10.** Notch impact strength and maximum force (PA 7T GF 56, test temperature – 100 °C).

In the case of test temperature 125 °C the highest value of notch impact strength and maximum force was achieved by the irradiation with dose of 66 kGy. (referring to: Fig. 11).



**Fig. 11.** Notch impact strength and maximum force (PA 7T GF 56, test temperature – 125 °C).

In the case of test temperature 150 °C the highest value of notch impact strength and maximum force was achieved by the irradiation with dose of 66 kGy. (referring to: Fig. 11).



**Fig. 12.** Notch impact strength and maximum force (PA 7T GF 56, test temperature – 150 °C).

## 4 Conclusion

This article describes the effect of radiation crosslinking on the notch impact strength of polyamides (with glass fiber filler) under thermal stress. Changes due to irradiation were seen primarily in material with higher content of filler (PA 7T GF 56).

## Acknowledgments

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