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Notch and load direction influence on impact toughness of composites reinforced with long fibers produced by 3D printing

M. Vaško, J. Majko, M. Handrik, A. Vaško, M. Sága

Faculty of Mechanical Engineering, University of Žilina, Univerzitní 8215/1, 301 00 Žilina, Slovak Republic

1. Introduction

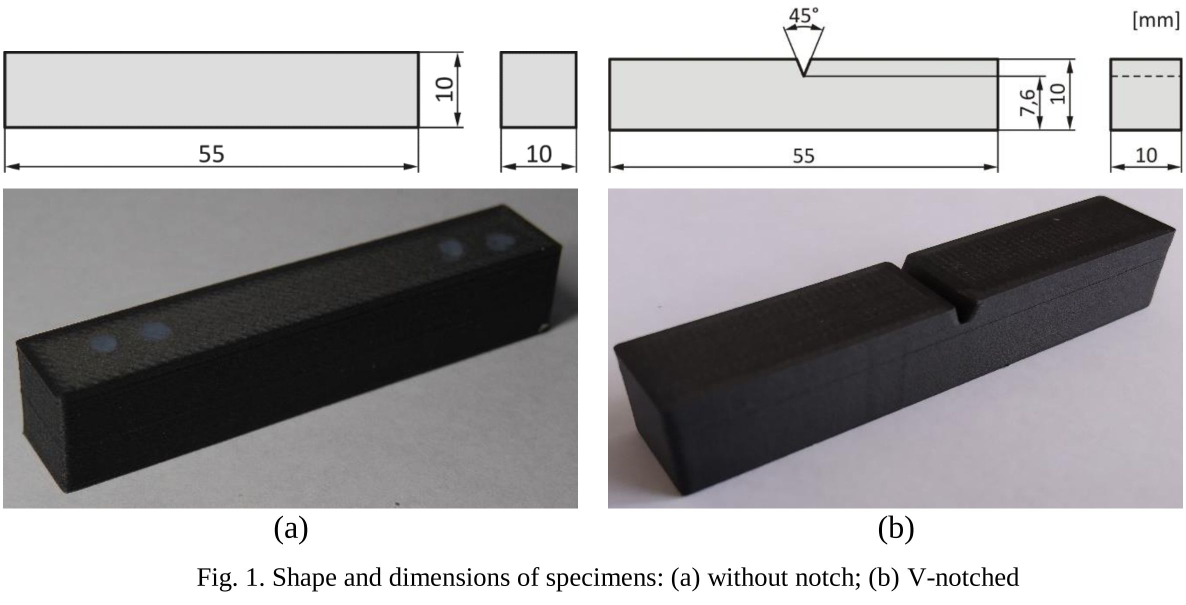
Composites are materials composed of two or more components. One of the components serves as a matrix, i.e. holds the object shape, transfers the load to the reinforcement and protects the reinforcement. The second component is the reinforcement, which has a strengthening function.

The progress FFF method by adding one additional nozzle opened the possibility to print continuous fibre-reinforced thermoplastic composites. Unlike conventional production methods, the user adjusts the location of the fibre in the structure of the composite and adapts the mechanical properties of the composite, see [1].

In the past, the authors published a scientific article [4] focused on the Charpy impact test and comparison of selected printing parameters (infill orientation, fibre type, fibre volume fraction) influence on impact toughness. All observed series of specimens were without a notch as allows the relevant standard. However, in similar studies [2, 3], the other authors selected notched specimens. Therefore the authors aimed to perform preliminary assessment of notch application possibility and identification of notch effect on the impact toughness.

2. Experiment preparations

The Charpy impact test was performed on a series of specimens with the shape and dimensions defined in Fig. 1. Each of series comprised five specimens.



(a) (b)

Fig. 1. Shape and dimensions of specimens: (a) without notch; (b) V-notched

The function of the matrix was fulfilled by nylon reinforced with chopped carbon fibre (trademark Onyx). The selected laminas contained reinforcement in the form of HSHT glass fibre. The data provided by the printer manufacturer reveals the following mechanical properties.

Table 1. Mechanical properties of composite components (data provided by manufacturer)

	Young Modulus [GPa]	**Tensile strength [MPa]**	**Flexural strength [%]**
Onyx	1.4	30	50
HSHT Glass fiber	21	600	420

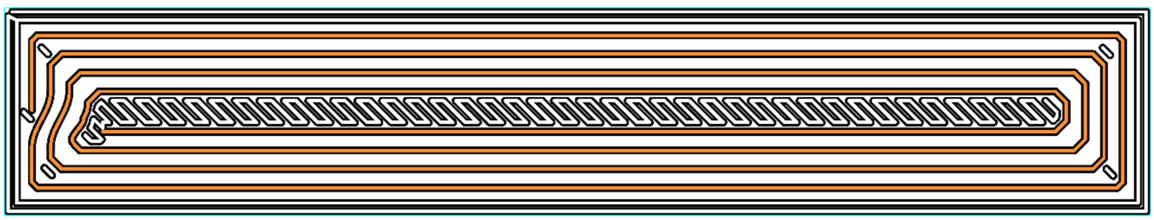
3. Nylon reinforced with chopped carbon fibre and continuous HSHT fibre

As part of the preparation process, the authors modified the printing parameters (Table 2). Each laminate comprised 100 layers, whereas the thickness of laminas was 0.1 mm. The infill type was a solid fill with an infill density of 100%.

Table 2. Printing parameters

Parameter	**Value**
Lamina thickness [mm]	0.1
Number of walls	2
Reinforcement	HSHT glass fibre
Reinforcement deposition strategy	Concentric rings (Fig. 2a and Fig. 2b)
Loading direction	Direct (Fig. 3a) or perpendicular (Fig. 3b)

The resulting laminate structure was a sandwich with a suitable fibre location concerning the presence of a notch and the need for comparability of results. The selected arrangement type of the reinforced fibres in the laminas was concentric rings.



(a)

(b)

Fig. 2. Concentric rings: (a) specimen without notch; (b) specimen with notch

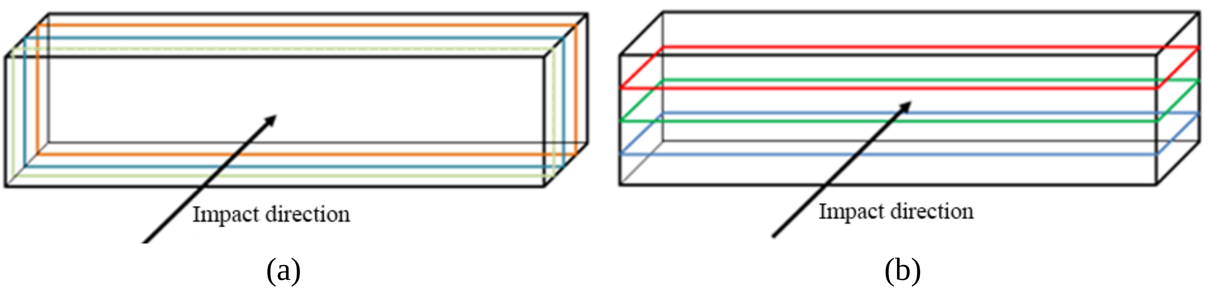


Fig. 3. Loading direction: (a) direct to stacking of laminas; (b) perpendicular to stacking of laminas

The resulting laminate structure was a sandwich with a suitable fibre location concerning the presence of a notch and the need for comparability of results (Fig. 4).

Fig. 4. Stacking of the reinforced laminas in the structure: matrix laminas (purple); reinforced laminas (orange)

4. Results

The average results of the conducted Charpy impact test are provided in Table 3.

Table 3. Charpy impact test results

Series	Notch presence	Direction of loading	Energy [kJ/m^2]
Alpha	No	Perpendicular	440
Beta	Yes	Perpendicular	220
Gamma	No	Direct	480
Delta	Yes	Direct	475

The results showed the effect of loading orientation on the impact toughness of the specimens. In both cases, the specimens loaded directly had higher impact toughness. In the case of direct loading, the differences between the notched and unnotched specimens were negligible. On the other hand, in the case of perpendicular loading, the application of a notch resulted in a 50% decrease in impact toughness. Part of the obtained data was also processed and analyzed using algorithms programmed in the MATLAB software package.

5. Conclusion

The primary aim was to identify the effect of a notch on the impact toughness. In the case of specimens with laminas oriented perpendicular to the direction of the loading, the notch influence was observed. The value of impact toughness of specimens with notch was significantly reduced. On the contrary, no decrease in absorbed energy was observed for specimens loaded directly.

Acknowledgements

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