Investigations on the applicability of the highly stressed material volume concept for components made of short fiber reinforced polymers

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Abstract

This paper gives attention to the fiber alignment of sharp notched flat specimen made of short glass fiber reinforced polyamide 66 in the critical notch area. For it images were taken by scanning electron microscopy.

1 Introduction

Materials such as short fiber reinforced polymers are being increasingly used in structural durability applications. Mostly these components are manufactured by injection molding, where the hot viscous melt is injected into a mold. Due to this process the short fibers of the material are orientated. The notches of injection molded components are produced by an insert in the mold, which causes reorientations of the fibers around the notch.

In general, for the dimensioning of components, local concepts such as the highly stressed material volume can be used. This concept determines the material volume that is stressed from the highest stress in the notch root to a defined percentage of stress, e.g. 80 percentages.[1]

Since notched components made of short fiber reinforced polymers (SFRP) have reorientations in the critical area of the notch, this paper gives attention to the applicability of this local concept for such materials. For that, the critical notch areas were investigated by scanning electron microscopy (SEM).

1.1 State of the art for dimensioning of components made of short fiber reinforced polymers

The state of art shows that in the field of polymers the investigations of material properties, which are applied to the component dimensioning, are often performed with unnotched specimens. But normally structural durability components have notches, which changes the material behavior caused by the effected local stress concentration according to the loading of component.

One method for the consideration of the local stresses is the method of the highly stressed material volume V [2, 3]. This volume can be determined by Finite-Element calculation and varies with the geometry of the component. In previous publications [2, 4] was confirmed that the highly stressed material volume V_{80} (80 % of the highest stress in the notch root) is applicable for the dimensioning of components made of short glass fiber reinforced polyamide.

In a previous work [4] the highly stressed material volumes V_{80} were calculated for three different theoretical notch factors by Finite Element simulation see Table 1. The theoretical notch factors were K_t=1.0 (unnotched), K_t=2.5 (mild notched) and K_t=9.8 (sharp notched). The sharp notched specimen were the same specimen, which were investigated in this paper by SEM. However, the values in Table 1 show obviously, that the highly stressed material volume is reduced with the increase of the theoretical notch factor K_t and accordingly with the sharpness of the notch.

K_t	V_{80} [mm^3]
1.0 (unnotched)	4807
2.5 (mild notched)	9
9.8 (sharp notched)	0.02

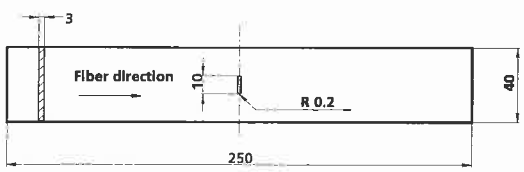
Table 1. Results of the highly stresses material volume V_{80} of unnotched and notched flat specimen [4]

As already mentioned above the short glass fibers are oriented around the notch due to the manufacturing process. Fibers can sustain loads best in the direction of fiber length. Because of this two attributes the question occurs: How are the fibers aligned around the notch and does the method of the highly stresses material volume can be used for the dimensioning of sharp notched components made of short fiber reinforced polymers.

2 Experimental section

2.1 Specimen

For this investigation sharp notched specimens with their respective theoretical notch factors K_t=9.8 were used, see Figure 1. These flat specimen were made of polyamide 66 with 50 % short glass fiber reinforcement (PA66-GF50). They were manufactured by injection molding. The flat specimen were produced in the way that the fibers were mainly aligned in the loading direction. The notches of specimens were produced during the injection molding process by an insert in the mold, which lead to a reorientation of the fibers around the notch.



Sharp notched specimen
K_t = 9.8 (r = 0.2 mm)

Figure 1. Specimen geometry

The investigated flat specimen were undergone uniaxial fatigue testing (Woehler) at room temperature with stress ratio R=0 until the fracture of specimen.
The fracture surfaces of the specimen were prepared due sputtering for the analysis with scanning electron microscopy (SEM).

3 Results

The Figures 2 to 5 show the fracture surface of one sharp notched specimen made of short fiber reinforced polyamide 66 with 50 % fiber content.
Figure 2 presents an overview about the two sides A and B and the three points 1, 2 and 3 of the enlarged details in the critical notch area. The fracture surface was enlarged 30-times. The

boundary areas of the specimen with the position numbers 1A, 1B, 3A and 3B are shown in the Figures 3 and 5. The middle area with the position numbers 2A and 2B is shown in Figure 4. These detail pictures shows a 500-times enlargement of the fracture surface.

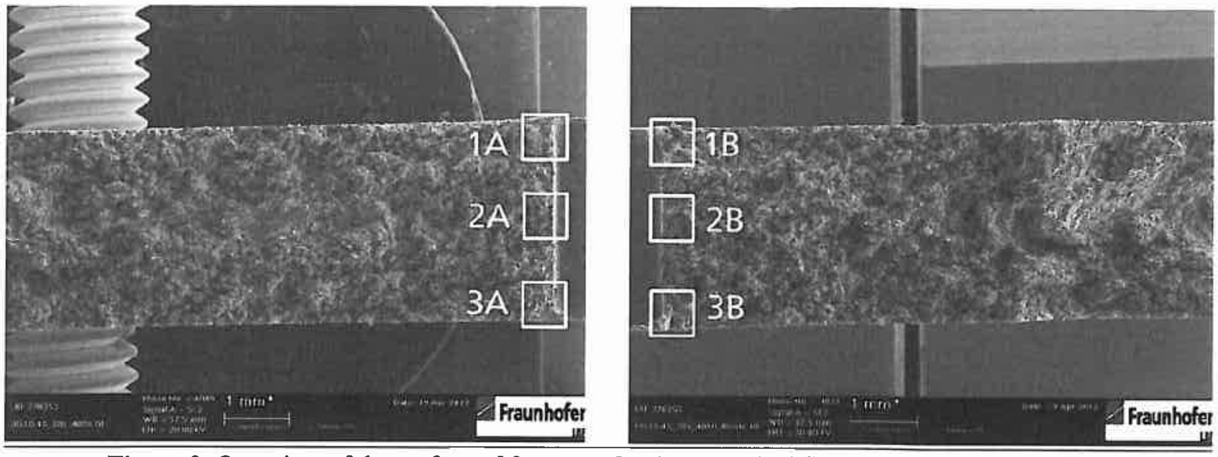


Figure 2. Overview of the surface of fracture of a sharp notched flat specimen made of SFRP

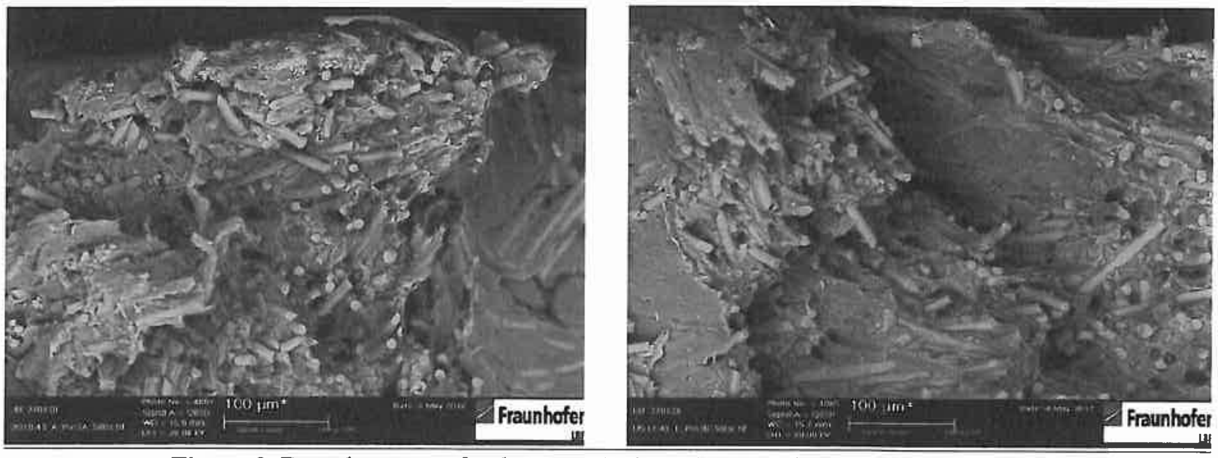


Figure 3. Boundary area of a sharp notched specimen made of SFRP (Position 1)

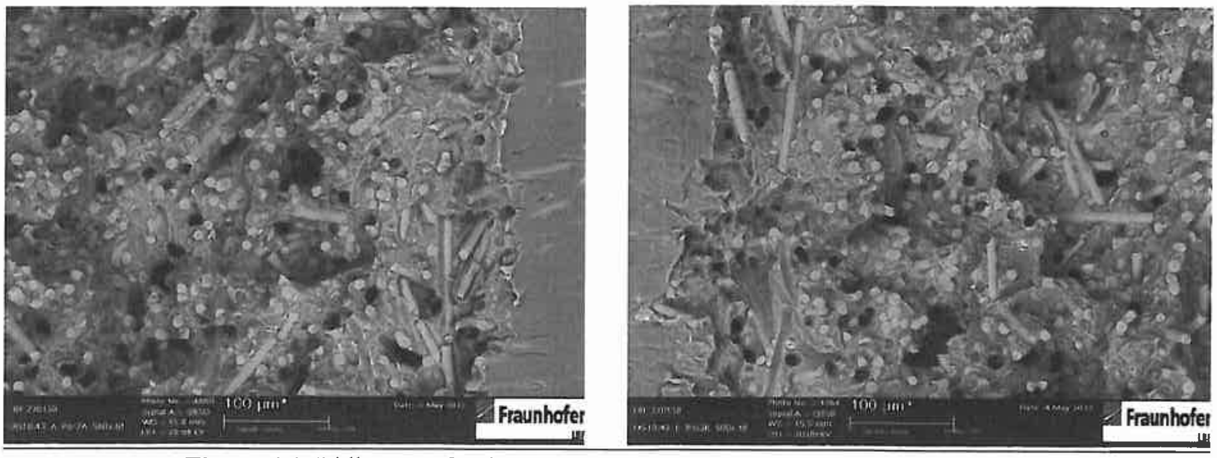


Figure 4. Middle area of a sharp notched specimen made of SFRP (Position 2)

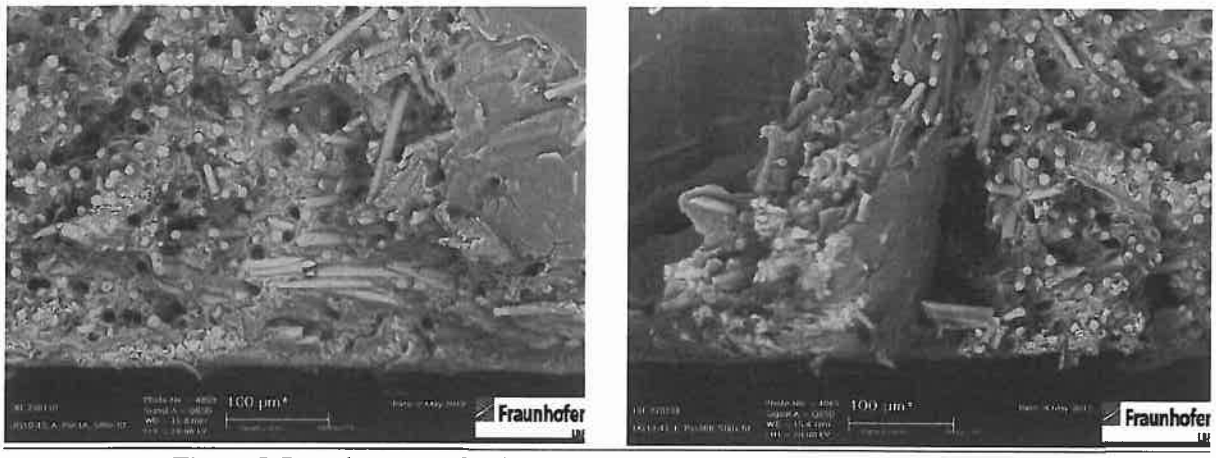


Figure 5. Boundary area of a sharp notched specimen made of SFRP (Position 3)

These SEM pictures show simplified the classical 3-layer-model of an injection molded plate.[5] The fibers in the boundary area seem to be aligned, see Figure 3 and 5. However, it can be shown very clear, that fibers exist in the critical notch area.

4 Summary and outlook

One purpose of this paper was to investigate the availability of short fibers in the critical area of sharp notched flat specimen made of short fiber reinforced polyamide, which were manufactured by injection molding. SEM-pictures showed that fibers were available in this area. In addition, the applicability of the local concept, the highly stressed material volume, should be discussed for components made of short fiber reinforced polymers. The conclusion that this local concept can be used for such material can be done based on the SEM-pictures. Continuative, the performance of numeric calculations about the highly stressed material volume, which consider the fiber alignment and its resulting stiffness anisotropy, are recommended.

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