ON THE DESIGN OF CRACK-ARRESTING LAYERS IN POLYPROPYLENE BASED MULTILAYER COMPOSITES

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Abstract

In natural materials, outstanding properties can be attained through an advantageous combination of different materials in intricate microstructures. Usually, a matrix material contributes high strength and stiffness ("hard phase"), while interlayer (IL) materials are often proteins with low strength and modulus ("soft phase") but high strains at break. The combination of both phases leads to crack arresting properties, thus dramatically increasing the fracture toughness and damage tolerance of the composite. Renowned examples of such effects are nacre as well as deep-sea sponges. The same concepts shall be mimicked to increase the fracture toughness of talcum reinforced polypropylene (PP). The challenge lies in preserving specimen stiffness while also utililzing the crack arresting properties of soft ILs. In this contribution, two types of PP with different mechanical properties are used as ILs. Normalized parameters for fracture toughness and specimen stiffness are used in order to assess the overall properties of multilayer composites. The trade-offs between stiffness and toughness are illustrated, while optimized structures also demonstrate that both properties can be attained simultaneously.

1. Methods

As a measure of fracture toughness, J_{exp} was assessed as stated in the ESIS TC4 recommendation [1] on single edge notched bending specimens. However, a corrected crack extension, Δa^*, according to Wiener et al. [2] was used for generating the *J*-*R* curves (Figure 1). From these curves, a parameter *Ω* was determined as the relative improvement in fracture toughness over the matrix material (Equation 3) at the position of the IL. Specimen stiffness was obtained by calculating an equivalent modulus on the basis of ASTM 1820 [3].

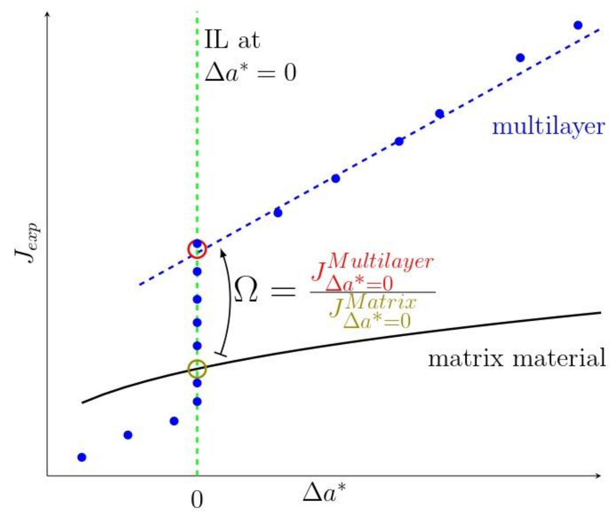

Fig. 1 – Adapted J-R curve for specimens with soft IL(s) within a brittle matrix [2].

2. Results

Several layer architectures were investigated regarding their relative fracture toughness *Ω* and specimen stiffness, which was also normalized to the value of the neat material for better comparison. The results, which are presented in Figure 2 and published in [2], show significant differences between layer configurations. ILs made of a soft type of PP (PP-Soft) showed increased *Ω* at the cost of stiffness, which can be attributed to the low stiffness of PP-Soft. Standard PP (PP-St) with higher strength could retain most of the stiffness, but did not exhibit crack arresting properties in most cases. However, one PP-St configuration achieved a considerable increase in fracture toughness while retaining high stiffness. Literature suggests [4,5], that the advantage of this configuration is a large enough layer size, which limits the detrimental effects of plastic deformation. More precisely, the plastic zone could be contained by the ILs in this optimal setup, while IL thicknesses were too small in other PP-St composites.

3. Conclusions

Inspired by damage-tolerant biological structures, soft ILs were used to increase the fracture toughness of a brittle type of reinforced PP. Two types of soft layer illustrated the challenges of this approach: Very soft PP always led to an increase in toughness, but also reduced specimen stiffness. A stronger grade of PP preserved stiffness, but did not increase toughness in many cases. This problem could be solved by adjusting the layer thickness of the stronger IL type. As a result, an optimum could be reached which combines increased fracture toughness with high stiffness.

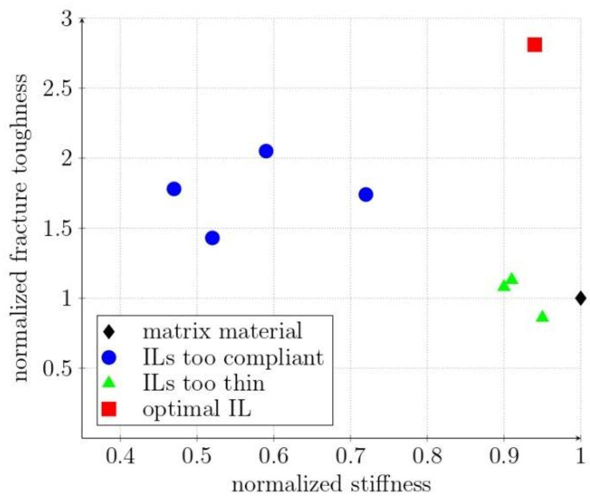

Fig. 2 - Normalized values for fracture toughness and stiffness for multilayer composites [2].

Acknowledgements

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