A CRITICAL VIEW AT DIRECT APPLICABILITY OF THE STRAIN ENERGY RELEASE RATE DETERMINATION STANDARDS TO COUPLED COMPOSITE LAMINATES

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1. Introduction

The field of applications of composite laminates in contemporary engineering could be broadened of the coupled layups. In the papers by York, ex. [1], thorough analysis of possible couplings was presented. The author of the current article continues his attempts to apply directly the standardized strain energy release rate (SERR) determination procedures (ASTM D5528, ISO 15024, ISO 15114, ASTM D7905) by introducing additional parameters for the data reduction schemes [2-4]. For this purpose the finite element (FE) simulations were led on the multidirectional continuous fiber reinforced polymer (CFRP) beam models to obtain the distributions of the SERR along the front of delamination. The FE simulations preceded the experiments led by the author's team [5] in order to plan the tests properly. The virtual crack closure technique (VCCT) was used in the simulations performed with the Abaqus code. For the sake of generality, the Reeder Law has been chosen as the fracture criterion [6]:

$$G_{\mathrm{I}}+G_{\mathrm{II}}+G_{\mathrm{III}} \geq G_{\mathrm{Ic}}+\left(G_{\mathrm{IIc}}-G_{\mathrm{Ic}}\right)\left(\frac{G_{\mathrm{II}}+G_{\mathrm{III}}}{G_{\mathrm{I}}+G_{\mathrm{II}}+G_{\mathrm{III}}}\right)^{\eta}+\left(G_{\mathrm{IIIc}}-G_{\mathrm{IIc}}\right)\left(\frac{G_{\mathrm{III}}}{G_{\mathrm{II}}+G_{\mathrm{III}}}\right)\left(\frac{G_{\mathrm{II}}+G_{\mathrm{III}}}{G_{\mathrm{I}}+G_{\mathrm{II}}+G_{\mathrm{III}}}\right)^{\eta}.$$

2. Results and discussion

The material data used in the simulations were taken from the literature [7] for the SEAL's Texipreg HS160RM carbon-epoxy prepreg laminate – see Table 1.

Young moduli	[GPa]	Shear moduli	[GPa]	Poisson coeff.	[-]	Fracture const.	[N/mm]
E_1	109.0	G_{12}	4.3	ν_{12}	0.34	G_{Ic}	0.4
E_2	8.8	G_{13}	4.3	ν_{13}	0.34	G_{IIc}	0.8
E_3	8.8	G_{23}	3.2	ν_{23}	0.38	G_{IIIc}	0.8

Table 1: Material data used in the FE simulations.

In Fig. 1 an excerpt from the FE simulation results is presented. The SERR distributions for the double cantilever beam (DCB) test configuration exhibiting non-symmetries induced by the bending-twisting (BT) coupling at different fiber orientation angles θ in the 18-ply BT sequence: $[\theta/0/\theta/\theta/0/-\theta/0/-\theta/-\theta/-\theta/-\theta/0/-\theta/\theta/0/0/\theta/\theta]$. The plots are either contracted or deviated – depending on the value of θ; these effects can be described well by additional measures of the SERR distribution defined in one of the previous papers [2].

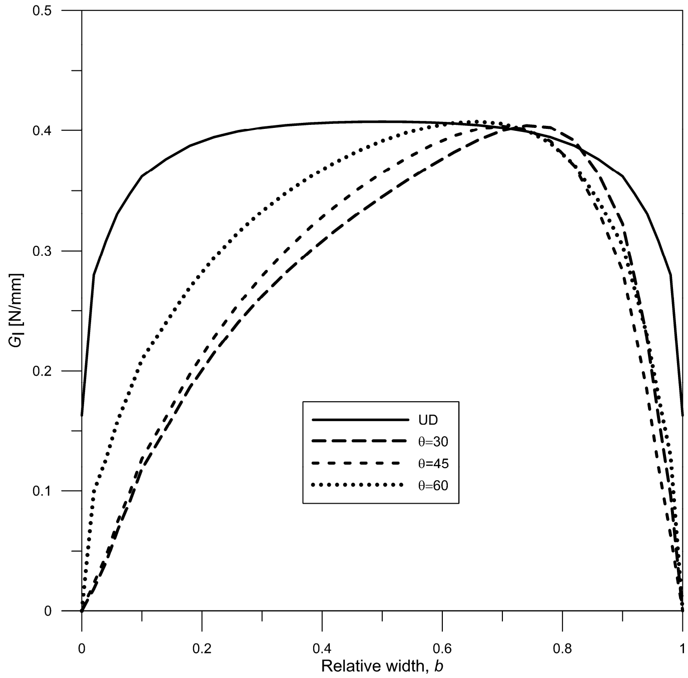

Figure 1: Skewness of the SERR plots induced by coupling.

5. Summary

The paper indicates possible difficulties in direct application of the standardized SERR determination methods. The presented results of the FEM simulations of delamination processes in laminated beams are a part of the study aimed at proper planning of the experiments on multidirectional layups. Additional parameters describing the distribution of SERR along delamination front were proposed in the previous stage of the study [2] in order to modify the data reduction schemes. The numerical outcomes are now being verified in laboratory tests with specimens of different couplings/delamination interfaces [5]. Further efforts to adjust the standards to the multidirectional laminates are being made [4].

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