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VIRTUAL DETERMINATION OF COHESIVE ZONE PARAMETERS FOR ADHESIVE JOINTS USING A HOMOGENIZATION APPROACH

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Lightweight materials, like fibre reinforced plastics (FRP), are important factors in the goal of reducing the weight in transportation application and thus to safe the limited natural resources. To fully exploit the potential of FRP materials, joining techniques have to be adapted. Compared to mechanical fasteners adhesive joining of FRP features several advantages, one of them being that fibres and surfaces are not disrupted.

For vehicle design and safety analyses, accurate simulation methods are mandatory for prediction of the load carrying and failure behaviour of adhesive joints in FRP components. On the other hand, simulation methods are required to be as efficient as possible. Cohesive zone models are often used to meet both requirements.

For a reliable and systematic characterization of the material behaviour of adhesive joints, extensive experimental investigations are required. Due to complex interactions of structural and material features, a separate treatment of the effects of structural parameters such as the thickness of the adhesive bond and the substrate geometry on one hand and the material parameters of the adhesive material and the substrate materials is not possible. All of these parameters affect the failure loads as well as the corresponding failure modes in a combined manner. Hence, all possible combinations of structural and material effects need to be considered in an experimental characterization of the joint design.

The experimental effort can substantially be reduced by a virtual determination of the cohesive zone parameters. For this purpose, a generalized homogenization approach enabling the virtual prediction of cohesive zone parameters rather than their experimental determination is proposed in the present contribution. In this approach, the progressive failure of the laminate joint is analysed using a detailed, very high resolution model, including particularly fine, 3D meshing of the adhesive layer. A continuum mechanics material model is used for describing the stiffness and failure behaviour of the adhesive material. The corresponding stiffness and strength parameters are derived from tensile and shear tests on bulk samples consisting of pure adhesive.

Using a generalized homogenization approach, the load-displacement and failure behaviour of the detailed joint model is mapped onto a numerically efficient cohesive zone model. The cohesive law parameters are determined by requesting a macroscopically equivalent mechanical response of both models.

The capability of the proposed approach is demonstrated in a number of parametric studies concerning the effective response of composite adhesive joints with different designs and different adhesive materials. By virtual variation of the adhesive layer thickness in the detailed model, the corresponding thickness-dependent cohesive zone parameters are derived without additional experimental effort. Moreover the detailed model allows an efficient and exhaustive analysis of local effects on the crack propagation, like stress concentrations at the adhesive-adherent interface which – in a natural manner – are fully accounted for in the corresponding cohesive zone model. Parameter studies for optimization of the adhesive joint design, e.g. regarding tapering of the adherents and/or adhesive can be carried out. Simulation of mode I and mode II fracture mechanics experiments on adhesively joint CFRP samples are used for validation of the concept.

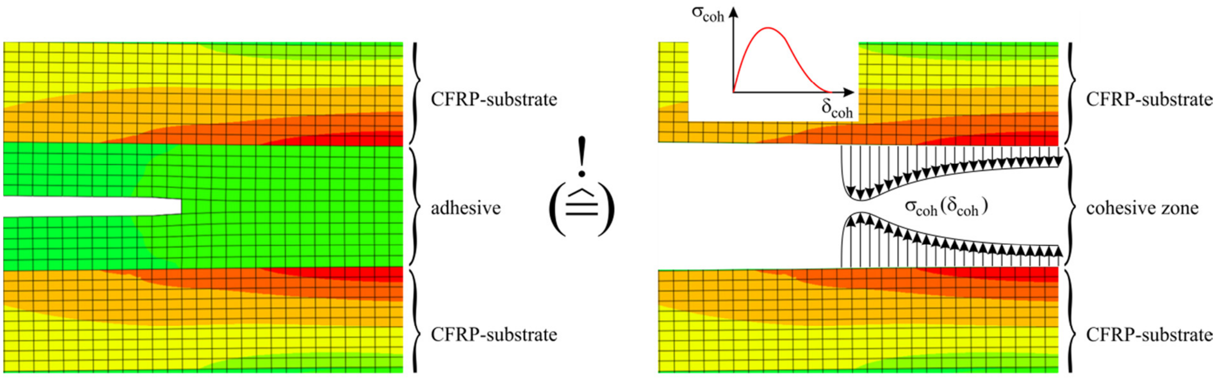

Fig. 1: Homogenization approach for determination of cohesive zone parameters.

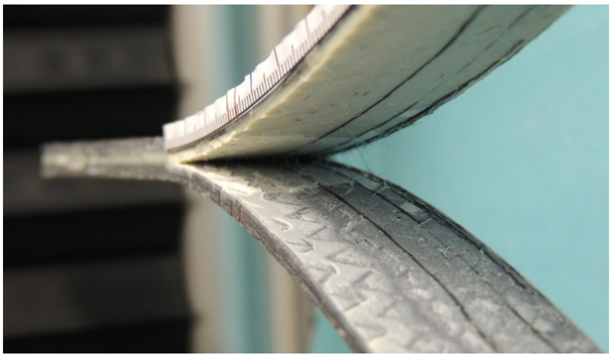

Fig. 2: Mode I fracture mechanics experiment on adhesively joint CFRP sample.