6th European Solid Mechanics Conference
ESMC 2006
28 August – 1 September, 2006
Budapest, Hungary

EFFICIENT MODELING OF ADHESIVELY BONDED JOINTS WITH INTERFACIAL MECHANICS FOR CRASH ANALYSIS

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Keywords: Structural bonding, crash analysis, interface element, traction-separation models

Summary. *The modeling of ductile, toughened adhesives is currently an active field of research in interfacial mechanics, since the recently developed adhesives are suitable to bond structural components of automotive bodies. For the practial simulation of bonded car structures there is still a need of a kinematic substitute element, as well as suitable material models for the adhesive. In this contribution an interface element and traction-separation models for brittle and ductile materials are presented. The finite element analysis of fracture or delamination of specimen in various modes under crash loading is demonstrated at various examples.*

1 INTRODUCTION

The failure analysis of adhesive bonds in structures requires a fine discretisation of the adhesive layer in thickness direction in order to approximate the state of stress exactly. For the crash analysis of complete vehicle bodies small finite elements are undesired, since they require a small critical time step for the simulation of the entire structure. If only one finite element is used over the thickness of the adhesive layer, the smallest element edge length is in the range of 0.05 to 0.2 mm. The resulting critical time step of the classical volume elements for the explicit integration of the equations of motion reached is still too small for the FE-simulation of a complete vehicle.

Thus, interface elements are developed to be used for the modeling of the adhesive layer. Then the critical time step is no longer controlled by the interface elements but by the adjacent elements, describing the adjacent steel structures. Due to the analogy of adhesive structural components and laminated fiber structures the analysis methods can be transferred. Instead of an approximation of the three-dimensional stress and strain state by volumetric continuum elements, the adhesive is discretized by interface elements, which describe the effective in-situ behaviour of the adhesive between the two adherents.

2 INTERFACE ELEMENT

Interface elements were originally developed for the description of the delamination process in composite materials [1]. With the modelling of interfaces within continuous bodies, the work in the interface must be considered. The work of the interface consists of the vector of the interface traction and the associated displacement jump. Contrary to the usual finite elements the interface element is formulated with the displacement jump. The displacement in lengthwise and transverse direction to the interface is carried out bilinear and the element is full integrated with four integration points of the surface. The element has no stiffness in the membran direction, pronounced locking effects could not be observed so far.

3 TRACTION-SEPARATION MODELS

The constitutive behaviour is formulated between the interface tractions and the displacement jumps, which represent the differences of the displacement components in normal and tangential direction of the two neighbouring surfaces of the adherents. For the softening behaviour of interfaces different models were published in the literature, e.g. Barenblatt developed a fracture model for ideally brittle interfaces. Dugdale proposed a fracture model for ductile interfaces. The traction-separation equations are formulated for the three fracture modes of fracture mechanics. The interaction of the three modes of fracture is accounted for. The course of the interface traction as a function of the crack opening in the process zone is unknown and must be supposed. Two assumptions for the distribution of the interface tractions are presented. In the first, the bilinear model for brittle interfaces, combines ideal-elasticity behavior with an ideal-brittle behavior. A Mixed-Mode formulation is presented by Camahno/ Dávila [2]. Secondly, the model of Tvergaard and Hutchinson [3] possesses a trilinear distribution of the interface traction with regard to the crack opening displacement. The model was developed for ductile interfaces, however it is not a complete plastic interface model, since no permanent displacement jumps are taken into account. An interaction of the various modes of fracture is inherent in the model.

4 NUMERICAL EXAMPLES

The interface elements and traction-separation models are implemented into the FE code FEAP and the commercial code LS-DYNA. The performance of our approach is demonstrated at different benchmark exampels like the peel test, the shear lap specimen, the KSII test and a T-section component. The rate dependent behaviour of the thoughened adhesives is added to the models. The first fracture specimen to be examined is a peel test. It resembles to the DCB specimen, which is well known from the testing of composites in mode I failure - see fig. 1. Besides the analytic solution of the DCB specimen the numerical results of an implicit static, implicit dynamic and explicit dynamic computation are presented and compared.

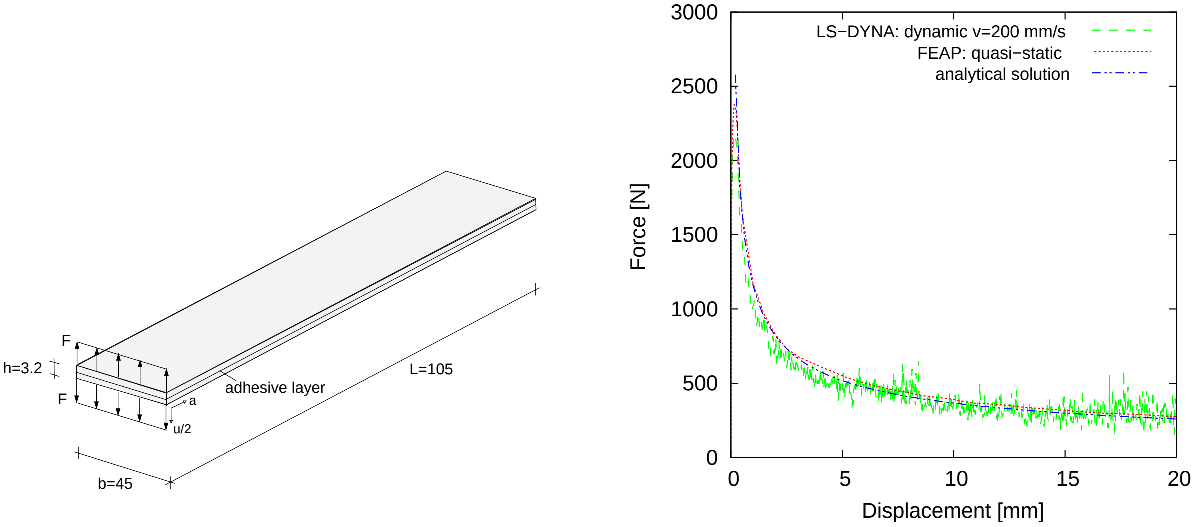

Figure 1: Geometry and computation results of the DCB specimen

ACKNOWLEDGMENT

The authors thanks all participants of the research project ”Methodenentwicklung zur Berechnung von höherfesten Stahlklebverbindungen des Fahrzeugsbaus unter Crashbelastung” (Projekt P676) coordinated by the FOSTA - Forschungsvereinigung Stahlanwendung e.V.

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