Studies of Interfacial Fracture Analysis

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Abstract-We study understanding the Fracture behaviour of adhesively bounded. Joints is important from two points of view. It is essential to be able to redict the onset and propagation of Frscture for engineering design purposes.

Keywords: Fracture, Bound strength, Mechanical interface

1.**Introduction**-Adhesive bonds for structural purposes are typically fonned through heating the adhe rends together with the interspersed adhesive layer under moderate pressure from a ternperature above the glass transition of the polymer to the use temperature (substantially) below the latter. It is thus inevitable that, depending on the processing conditions, residual stresses are generated to varying degrees . During use these residual stresses act in addition to those induced by the loading so that the final load carrying ability of the bonded joint may be materially impaired. ln fact, it is believed that in many cases ari apparent bond weakness observed in laboratory tests is primarily the result of residual stresses rather than an intrinsically weak chemical/mechanical interface connection.

2.**Discussion**:Fractute behavior of adhesively bonded joints is important from two points of view. First, it is essential to be able to predict the onset and propagation of (interfacial) fracture for engineering design purposes. Second, in pursuing the understanding and evaluation of the physie-chemical aspects of bonding. it is mandatory that one be able to fully evaluate the relation between the past (formation) history of the bond and its strength. In terms of the surface chemistry or physics. Thus, an. evaluation of the "bond strength" may attribute unfair low strength to a particular interface chemistry unless residual stresses are In the following development we are, therefore, concerned only with the examination of the available energy for fracture and investigate the change in the residually stored energy with a small advance of the crack along an interface.

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With this idea in mind we consider the effect of inhomogeneous; stresses introduced during the thermal bond formation process. Because of the already large numbeinof variables accounted for in this analysis we exclude the effect of pressure during the bond formation from consideration here, although this effect is within the scopetof the analysis and material model employed here. We point out that the requisite material characterization, which involves thermal rate effects as well as other thermoviscoelastic responses of the adhesive polymer, is not generally practiced and thus an appropriate characterization is not available for even a limited number of materials. For this reason we draw on the computations of the residual stresses in a bonded joint, the adhesive for which has been modelled by a relatively simple polymer, Polyvinylacetate (PVAs) as outlined in chapter 2 delineating the stress analysis aspect of this problem. We expect that while the resulting values are not necessarily directly applicable to arbitrary commercial adhesives, the results are nevertheless indicative of the phenomena one needs to be concerned wiuthin this context.

Because adhesive bonds are typically used at temperatures considerably below the glass transition the fracture process. occurs in what, in viscoelastic parlance, is called the "glassy state."As a consequence we assume that all stress changes related to fracture occur elastically, with the corresponding properties of the polymer being its glassy or‘ short term ones. ln addition, we follow linearly elastic fracture analysis concepts to determine then the energy release rate associated with crack advancealong an interface, taking into account the special deformations of the adherend(s) that result from such an adhesion breakdown, namely crack closure away from the crack tip.

3. **Computing Algorithm**-The iterative procedure for the solution of the contact (fracture) problem deserves special consideration. Also, the computation of the energy release rate warrants discussion. Both of these topics are addressed briefiy in the sequel.

3.1 **Iterative procedure for the contact problem**-Since both the adherend and the polymer are considered to be linearly elastic for the present problem, the formulated problem can be analyzed within the context -of linear fracture mechanics for dissimilar materialii

It is well known from previous work [1, 2, 3] that the linearly elastic asymptotic solution to the interface crack problem has various undesirable consequences for the predicted near tip field. crack faces can overlap and the stress components change sign alternately. Since our concern here is only with the (global) energy release rate without recourse to the detailed near tip stresses and displacement, this (near tip) contact zone is completely ignored in modelling the present problem. in addition, when tractions on the crack line are completely released, the crack surfaces interpenetrate over a small domain at the free edge; the residual normal stress. The crack surfaces are, therefore, modelled to be in contact but free to slide over the interpretation domain near the free edge. Thus the basic difficulty for the present problem consists of the determination of the stress and displacement fields which satisfy (a) the stress free condition on the open pan of the crack and (b) the vanishing condition of the "relative" normal (y) displacement of the erack surfaces (which are free of shear stress) on the contact domain. It should be emphasized that thet (boundary) conditions (a) and (b) prescribed on the erack surfaces depend on the displacements of these surfaces according to whether the surfaces are pressed together or separate in the (stress) unloading process. The present problem is, therefore, "geometrically" nonlinear and is solved by an iterative procedure. The discussion of this iterative procedure necessitates introducing an alternately crack surface loading problem.

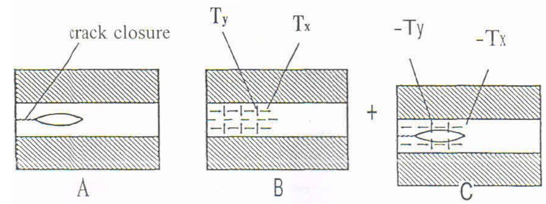
We outline next the iterative procedure. The open portion of the crack is first assumed. The stress solutions of the crack surface loading problem is obtained and is then added to the corresponding original residual stresses. The superimposed iterated solutions must satisfy two conditions. First, the released crack faces must separate along an "open" portion; second, the superimposed normal traction ((1)) must be compressive everywhere in the contact zone. If one of these two conditions is violated, another guess will be. used, and the whole procedure is repeated until both conditions are satisfied.

3.2 **Computation of the energy release rate**-It was pointed out in the previous section that the energy release rate in a residualstress crack problem is identical to that in a crack surface loading problem. It suffices here to show the computation ofthe energy release rate in a crack surface loading problem.

On the other hand. the energy release rate in a finite dimensioned sandwich is determined by way of the finite element method with the crack tip path (or area) indebtness integral. Based on the mechanical energy balance and the local steady state condition at the crack tip, the energy release from a homogeneous body per unit crack advance defined

$$g = \lim_{r \to a} \int_{r} [Wb_i - a_i u_i] \, nidf$$

where W is the stress work density r is a small contour which is fixed in size and orientation with respect to the crack tip and translates with the crack tip. g must be independent of the shape of r as r is shrunk to zero.



4. **Results and discussion**

In this section the computation of the energy release rates are detailed. We also illustrate several important results for assessing the durability of bonded joints such as the potentially failure (fracture) location in the adhesive polymer, the critical crack length for maximum energy release rate in finite bonded plates, and the effect of the cooling rates on the energy release rate. In the sequel, the energy release rates for an in infinite sandwich is first delineated, followed by the results for the finite configuration.

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