A numerical approach to the disbonding mechanism of adhesive joints

Zavatta, Nicola [1], Troiani Enrico [1]
[1]*University of Bologna, Forlì, Italy*

The need for lightweight structures in aeronautics is leading to a strong interest in adhesively bonded joints. However, the difficulties in analyzing adhesive joints are a major obstacle to their use in practical applications. From the point of view of a damage tolerant design, current prediction capabilities of their fracture mechanisms lead to the necessity of designing heavy, sub-optimal structures.

This work aims at contributing to the understanding of disbonding of adhesive joints from a numerical point of view. A numerical model for disbonding propagation under mode II and mixed-mode loading conditions has been developed, taking into account the thickness of the adhesive.

Mode II disbonding poses several difficulties with experimental measurements, which motivated the development of a numerical model. It is expected that numerical results could provide useful information for proper experimental set-up. Additionally, stress and strain distributions can be computed and input to analytical models for fatigue disbonding.

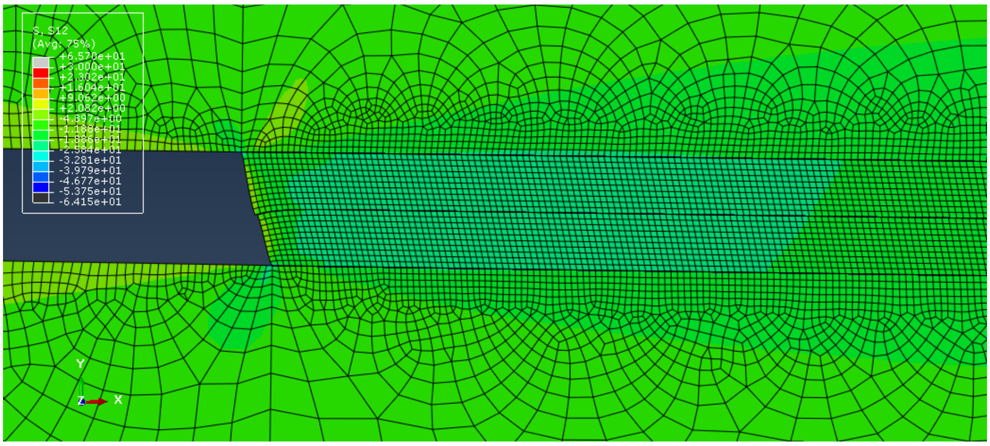

Figure 1. Shear stresses in the adhesive layer of a ENF specimen under mode II loading.

Disbonding growth is taken into account by introducing a Cohesive Zone Model (CZM), which is able to capture the process zone around the crack tip and to enforce an energy-based failure criterion. The model, which had originally been developed for DCB specimens under mode I, was then extended to consider more general loading conditions.

Fatigue in adhesively bonded joints is usually related to parameters from Linear Elastic Fracture Mechanics (LEFM), such as the stress intensity factor or the strain energy release rate, as discussed in [1]. The computation of these parameters from experimental data in mode I is relatively easy. On the contrary, their evaluation under mode II is made difficult because of the different propagation mechanism. In fact, the closure of the crack and the contact between the crack surfaces, as well as the complex crack patterns that are found in tests hinder accurate measurements of the disbond length, introducing a large scatter in the data [1]. The crack length predicted from the numerical model can be employed to estimate the disbond length in the real specimens and compute the energy release in the propagation process. This also provides useful information on the residual strength of the specimen and can be extended to geometries which are closer to in-service components.

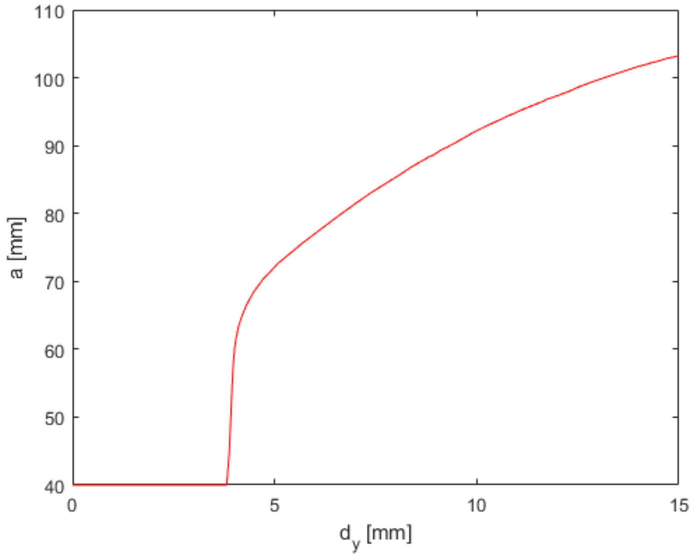

Figure 2. Disbonding length as a function of the applied displacement in mode II. Unstable propagation can be observed at the beginning of crack growth.

Another approach to fatigue has been proposed in [3]; a correlation is established between the crack growth rate and the energy dissipation per cycle, in an attempt to improve the physical understanding of the fatigue phenomenon. A practical implementation requires an estimate of the dissipated energy, which could also encompass some plastic deformation. The cohesive model is a suitable way for estimating the energy under conditions like mixed-mode loading or when significant plasticity is present.

The model developed here is a suitable option for the estimation of fracture mechanics parameters in cases in which complex geometry and loads prevent the application of analytical theories. The final goal is to include progressive degradation of the cohesive properties, thus directly modelling fatigue disbonding in the adhesive.

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