

Damage tolerance of adhesively bonded structures

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Background

Adhesive bonding promises to allow the design of lighter weight structures.

Before adhesive bonding can be more widely applied, more knowledge is required about its damage tolerance characteristics.

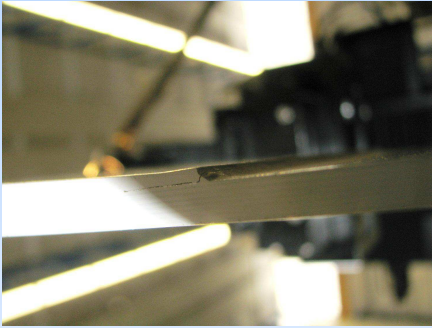
One of the most important damage modes is disbonding, especially due to fatigue load cycles.



Schematic example of disbonding

Aim

The goal of this project is to gain a better understanding of the mechanisms governing disbond growth, in order to develop more accurate prediction models.



Disbonding of a bonded patch

Research questions

In order to understand the disbond growth behaviour, the following sub-questions will be addressed during this research:

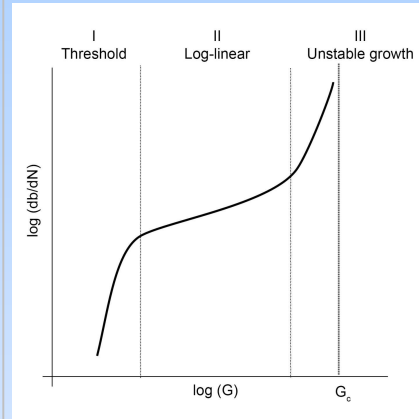
- Are fatigue disbond growth and quasi-static failure driven by the same mechanism?
- Why does the growth rate vs strain energy release rate (SERR) behaviour deviate from log-linearity approaching the critical SERR value (G_c)?
- Is there both a mechanism that is dependent on the maximum SERR G_{max} and a mechanism that is dependent on the SERR range ΔG , or is there only one mechanism that depends on both?
- What is the effect of temperature on disbond growth?
- When subjected to variable amplitude loading is there a history or interaction effect?

Theory

It is known that the disbond growth rate is correlated with the strain energy release rate (SERR). In general:

$$\frac{db}{dN} = C f(G)^n$$

Here db/dN is the disbond growth rate, and C and n are empirical parameters, generally determined by curve fitting.



Disbond growth as a function of SERR

Methodology

The SERR is a function of geometry and load and can be found by one of several finite element techniques.

Physical specimens will be subjected to different loading conditions in order to attempt to isolate the various mechanisms though to be involved in disbond growth.

Fractography, using optical and scanning electron microscopy, will be employed to relate the SERR state to the observed mechanisms.

Apart from the Paris relation, it appears there is also a relation between the disbond growth rate and the total strain energy released during a fatigue cycle:

$$\Gamma = \int_{b_N}^{b_{N+1}} G(b) db$$

$$\frac{db}{dN} = f(\Gamma)$$

This idea will be investigated further.



Preparation of the first specimens

Progress and Objectives

Achieved so far:

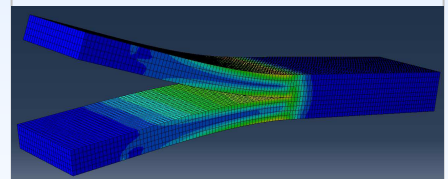
- Formulation of research questions.
- Completion of research plan.
- Completion of literature review (submitted for publication).

Highlights of the literature review:

- A historical overview of delamination growth methods is critically discussed.
- 4 classes are defined: stress/strain based, LEFM based, CZM based, XFEM based.
- It is shown most models are in essence phenomenological.
- It is argued a stronger connection with the physical mechanisms is needed.

Further objectives for the 1st year:

- Investigate fatigue vs quasi-static growth.
- Investigate G_{max} vs ΔG behaviour.



Finite element analysis of a typical test specimen

Journal papers

- J.A. Pascoe, C.D. Rans, R. Benedictus (2013), "Characterizing fatigue delamination growth behaviour using specimens with multiple delaminations: the effect of unequal delamination lengths", *Engineering Fracture Mechanics*, article under review
- J.A. Pascoe, R.C. Alderliesten, R. Benedictus (2013), "Methods for the Prediction of Fatigue Delamination Growth - A Critical Review", *Engineering Fracture Mechanics*, article under review

Conference papers

- J.A. Pascoe, C.D. Rans, R.C. Alderliesten, R. Benedictus (2013), "Fatigue Disbonding of Bonded Repairs – An Application of the Strain Energy Approach", 27th ICAF Symposium, Jerusalem.

