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# **AG27 - Fractographic Aspects of Fatigue Failure in Complex Laminates and Components**

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# Objectives

- Establish how findings of previous AG20 activity can be applied to analysis of failures in multi-directional and woven laminates.
- Identify macroscopic & microscopic features associated with static and fatigue damage growth in such laminates.
- Establish relation between fractographic features and direction of crack growth.
- Establish microscopical mechanisms by which features above occur under different loading modes.

# Objectives - continued

- Establish material dependency, in particular the effect of brittle and tough matrices on the fractographic features identified.
- Establish the read across between the fatigue failure processes occurring in coupons and those observed in structural components.

# Plan

- Ten organisations participating in AG27 (DGA/CEAT, CETIM, CSM Materialtechnik, QinetiQ, BAE Systems, INTA, NLR, FOI/FFA, EADS France, EADS Germany) from six countries.
- Plan to address objectives by performing 4 round robin exercises, involving the 'blind' assessment of failed specimens and structural elements.
- Round robins to include assessment of mode I, mode II & mixed mode (I +II) interlaminar fractures. Fractures will be generated statically and in fatigue. Multidirectional, woven and RTM materials to be studied.

# Progress

- 1st round robin completed
- Involved the assessment of mode I and mode II fatigue fractures in 32 ply laminates made from T800/8552 and AS4/8552 carbon/epoxy.
- Specimens manufactured consisted of a multidirection laminate containing -45, +45, 0 and 90 plies manufactured from U.D prepreg.
- Delaminations grown at the mid-plane between +45°/0° interface, in fatigue, using R-ratio of 0.1 .

# Findings of 1st round robin

- Meeting of group held in October 2001 at DGA/CEAT, France to discuss the findings of the 1st round robin exercise.
- It was found that the characteristic fracture features of each mode, identified for  $0^\circ/0^\circ$  interfaces in the previous AG20 group, were also present in laminates containing a  $0^\circ/45^\circ$  interface.
- Striations in the fibre imprints (but not surrounding matrix) were observed in both mode I and mode II fractures, the former usually occurring only next to the PTFE insert.

# Findings of round robin 1 -continued

- Work in AG20 suggested shear stresses are required to cause striation formation. It is unclear whether the mode I striations observed in the multidirectional laminates are genuine, or caused by localised shear stresses occurring in the laminates.
- There appeared to be some correlation between the appearance of the striations (light or dark) and crack growth direction, but exceptions were still observed. Fibre bridging effects may be responsible for this.

# Findings of round robin 1 -continued

- In specimens tested at low strain energy levels, the correlation between the striations and globally measured crack growth rate was not good. At higher strain energy levels the correlation was better.

# Current studies - round robin 2

- Round robin split into two parts.
- Part A involves the investigation of R-ratio and strain energy level  $G$ , on the fracture features occurring in multidirectional laminates based on U.D prepreg ( $0^\circ/45^\circ$  interface).
- Two levels of  $G$  selected in mode II (high and low) and two R-ratios (0.5 and -1). In Mode I only 1 R-ratio (0.5) selected at two strain energy levels.
- Material AS4/8552.

# Current studies - round robin 2 - continued

- Part B examining static fracture in woven laminates.
- Two materials selected AS4/8552 (5-harness satin weave) and Carbon/920 (2:2 twill weave).
- Specimens to be tested in mode I, mode II and mixed mode (I +II).
- After testing only the fractured section is to be distributed to members for assessment. All evidence on the specimens which might give clues as to the mode of testing and direction of crack growth (i.e insert) first being cut away.

# Current studies - round robin 2 - continued

- Cutting away the periphery of the specimens means that investigators will have to rely solely on the fractographic features available to determine the mode and direction of fracture.
- Determining both the mode and direction of fracture in woven laminates is difficult, since the discontinuous nature of these materials often promotes many localised fracture sites near the crack tip.
- By mapping the direction of the localised fractures, it is hoped the global crack growth directions can be determined.

# Current studies - round robin 2 - progress

- Part A of round robin 2 has been delayed due to material supply problems. It now looks like this activity will not be completed until towards the end of 2002.
- Part B is progressing well, but a delay of approximately 10 weeks has also been incurred due to material supply problems . Specimens have been manufactured and passed to the testing labs. Testing and distribution of the fractured samples should be completed towards the end of April 2002.

# Meetings

- Last meeting was held at DGA/CEAT, Toulouse, France on 01/02 October 2002.
- The next meeting was originally scheduled to take place at the beginning on April 2002 at NLR in Amsterdam.
  - This meeting has now been rescheduled for July due to material supply problems.
  - However, recently Arne Skontorp (the groups secretary) had a heart attack, which may affect arrangements