Effect of voids on interlaminar behaviour of carbon/epoxy composites

Iryna Tretiak

Luiz Kawashita
Stephen Hallett

bristol.ac.uk/composites
Introduction

Voids are a critical manufacturing defect:

- Difficult to eliminate
- Cause of other defects (e.g. delamination)
- Detrimental to mechanical properties

There is *no established model* to describe the relationship between void characteristics (e.g. size, shape, aspect ratio etc.) and mechanical properties.

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Objective

• To understand the failure behaviour of composite laminates with voids, using a combination of advanced testing and characterisation methods.

• Develop a process which will allow the manufacture of composites specimens with controlled void content

• Characterise voids (e.g. morphology, spatial distribution) and investigate the correlation of various parameters to ILSS
Materials and Methods

Introduction of voids in samples

- IM7/8552
- Pressure and temperature controlled method

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Characterisation of voids

- μ-CT scanning
- Voxel size 12.6-13 µm
- Post processing: VG Studio™ MAX defect detection plug-in

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Mechanical testing

- Short Beam Shear test
- Span/thickness ratio 4.5
- Load drop-off of 30%

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Void Feature / ILSS Correlation

Pairing of samples for correlation analysis
- Similar void content (± 0.08%)
- Different ILSS (difference > 2 MPa)
Presence of large (by volume) voids leads to reduction of the material strength.

BLUE – LOWER ILSS
ORANGE – HIGHER ILSS
Void Feature / ILSS Correlation

Behaviour 1

- ILSS=47.63MPa, Vv=7.47%
- ILSS=50.2283MPa, Vv=7.46%

Presence of large (by volume) voids leads to reduction of the material strength

Behaviour 2

- ILSS=49.9993MPa, Vv=7.06%
- ILSS=55.3808MPa, Vv=7.04%

There is a presence of one large void in the sample with the higher ILSS and the rest are negligibly small

BLUE – LOWER ILSS
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Void Feature / ILSS Correlation

Presence of large (by volume) voids leads to reduction of the material strength.

There is a presence of one large void in the sample with the higher ILSS and the rest are negligibly small.

Presence of large voids doesn’t lead to significant reduction of the strength.

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**Void Feature / ILSS Correlation**

**Behaviour 1**
- Void number: 1 2 3 4 5 6 7 8 9 10
- Void volume, $\text{mm}^3$: 0
- ILSS = 49.9993 MPa, $V_v = 7.06\%$
- ILSS = 55.3808 MPa, $V_v = 7.04\%$

**Behaviour 2**
- Void number: 1 2 3 4 5 6 7 8 9 10
- Void volume, $\text{mm}^3$: 0
- ILSS = 51.9103 MPa, $V_v = 6.37\%$
- ILSS = 57.343 MPa, $V_v = 6.37\%$

**Behaviour 3**
- Void number: 1 2 3 4 5 6 7 8 9 10
- Void volume, $\text{mm}^3$: 0
- ILSS = 51.9103 MPa, $V_v = 6.37\%$
- ILSS = 57.343 MPa, $V_v = 6.37\%$

10 largest voids in close proximity to mid-plane

**BLUE** – LOWER ILSS
**ORANGE** – HIGHER ILSS

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Conclusions (so far)

1. Proposed temperature and pressure-controlled manufacturing process allowed samples with a consistent level of porosity to be made.

2. Statistical analysis was performed to assess the effect of the void features on the ILSS.

3. Large voids are more critical than an equivalent volume of smaller voids.

4. Void location with respect to the critical region of the specimen has a significant effect on strength reduction.
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ig14476@bristol.ac.uk