Analysis of Kissing Bonds in Metallic Joints

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AIRBUS
Imperial College London

Our Objectives

1. Produce reliable and repeatable kissing bonds

2. Investigate changes in their surface chemistry and morphology * Zofia Luklinska

3. Establish the effects of kissing bonds on joint strength

4. Correlate experimental measurements in terms of bond strength and local strains for kissing bonds with numerical predictions

5. Investigate means of detection of kissing bonds

*C.Jeenjitkaew, Z. Luklinska and F.J. Guild, Morphology and surface chemistry of kissing bonds in adhesive joints produced by surface contamination, *IJAA,* 30 (2010) 643-653

C.Jeenjitkaew, Z. Luklinska and F.J. Guild, Morphology and surface chemistry of kissing bonds in adhesive joints produced by using ElectRelease™ adhesive, *J. Adhes.* 87 (2011) 291-312

This Presentation

Production of reliable and repeatable kissing bonds

(1) Surface contamination

(2) ElectRelease™ adhesive

Failure mechanisms (Experimental and FEA)

Failure strength

Mode of failure

Local strains

Future detection of kissing bonds?

I Producing reliable and repeatable kissing bonds

(1) Surface contamination

Hardened steel (HDS) - solvent degreasing+SiC papers+solvent degreasing

Al 2014 T6 - CAE (DEF standard)

High temperature cure adhesive - Redux® 319 (Modified epoxy film adhesive)

Room temperature cure adhesive - E3348 (2 part epoxy adhesive)

Set	1				2				3			
Adherend	HDS	HDS	HDS	HDS	Al 2014 T6	Al 2014 T6	Al 2014 T6	Al 2014 T6	Al 2014T6	Al 2014 T6	Al 2014 T6	Al 2014 T6
Adhesive	Redux 319	Redux 319	Redux 319	Redux 319	Redux 319	Redux 319	Redux 319	Redux 319	E3348	E3348	E3348	E3348
Contaminants	-	PTFE film	PTFE spray	Frekote	-	Frekote	Sweat	Cutting Oil	-	Frekote	Sweat	Cutting oil

DLJ specimens – contaminated surface in the middle of the joint (25% of effective bonded area)

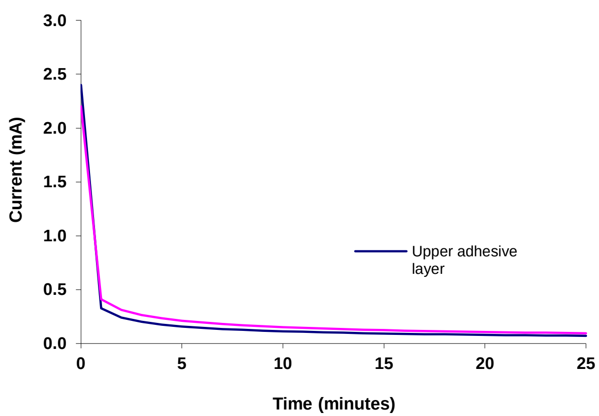
I Producing reliable and repeatable kissing bonds

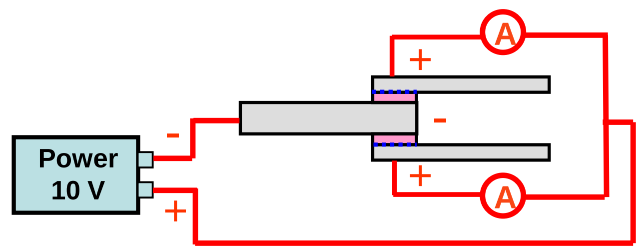
(2) Using ElectRelease™ adhesive

HDS - solvent degreasing+SiC papers+solvent degreasing

Electrically debonding adhesive – ElectRelease™ (2 part amine cured epoxy adhesive)

Set	A	
Adherend	HDS	HDS
Adhesive	ElectRelease™	ElectRelease™
Electric field	-	10 V DC

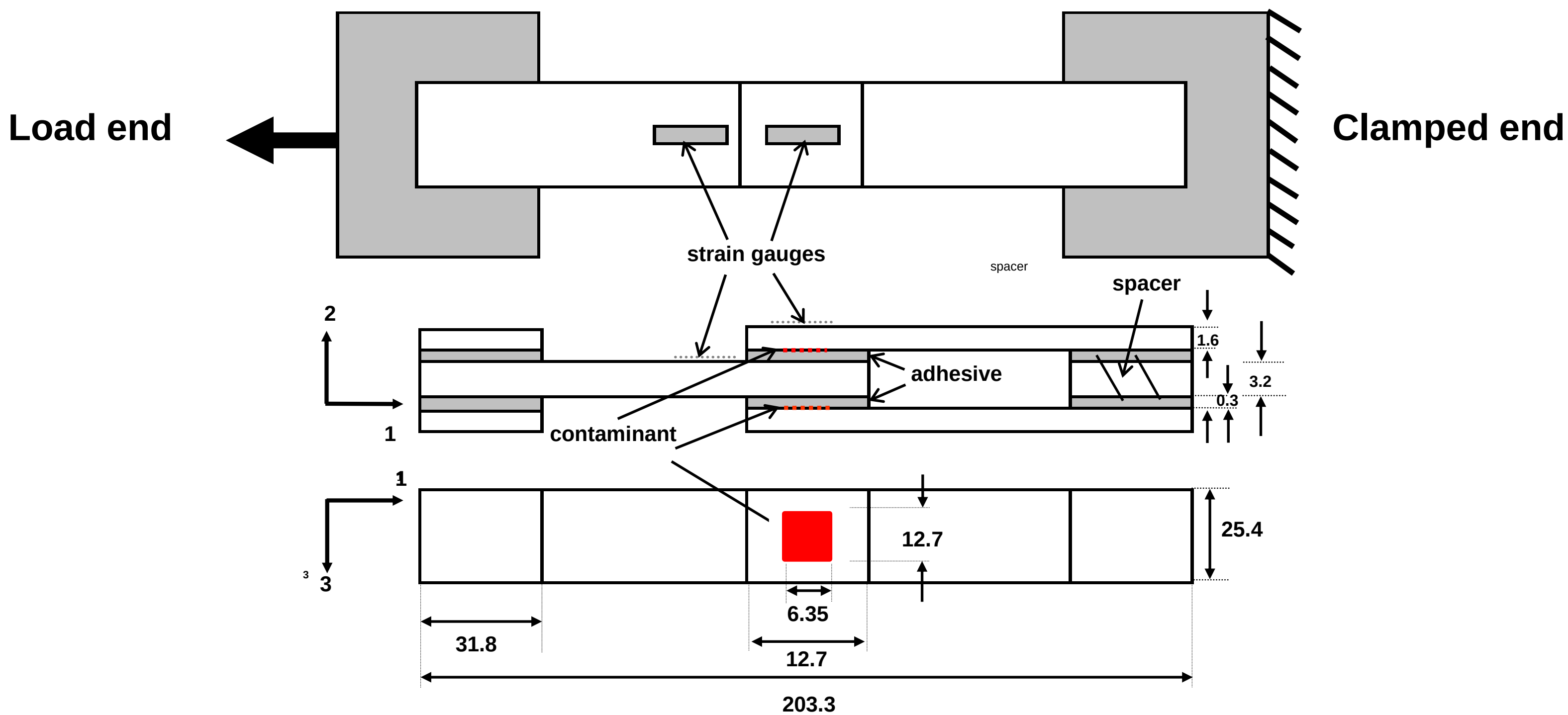




...... Weakened interface

DLJ specimens – weakened interface by applying 10 V DC for 25 mins

Double-lap joint

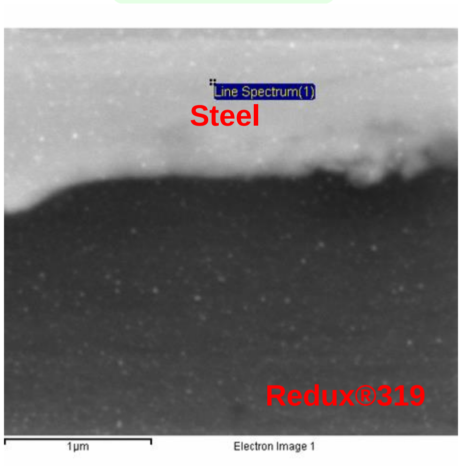


All dimensions are in mm and not to scale

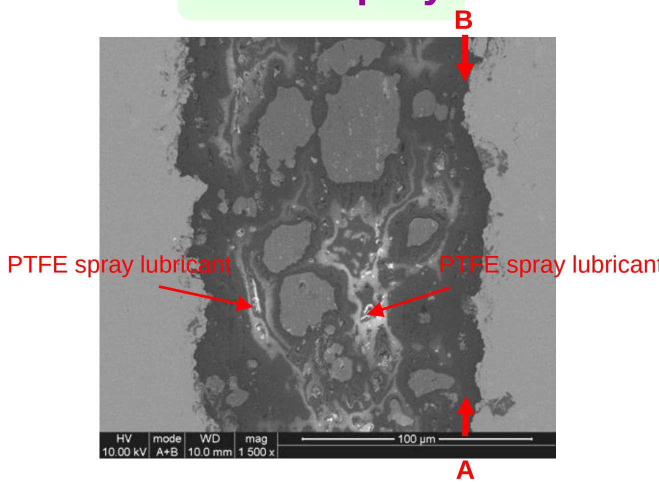
Surface Chemistry : SEM with EDS

- **Surface contamination - (HDS+Redux®319)**

Control

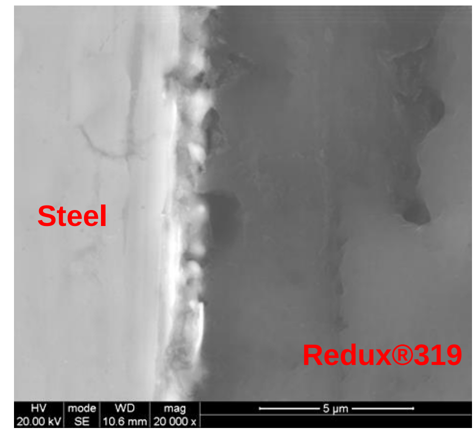


PTFE spray



AB = contaminated interface

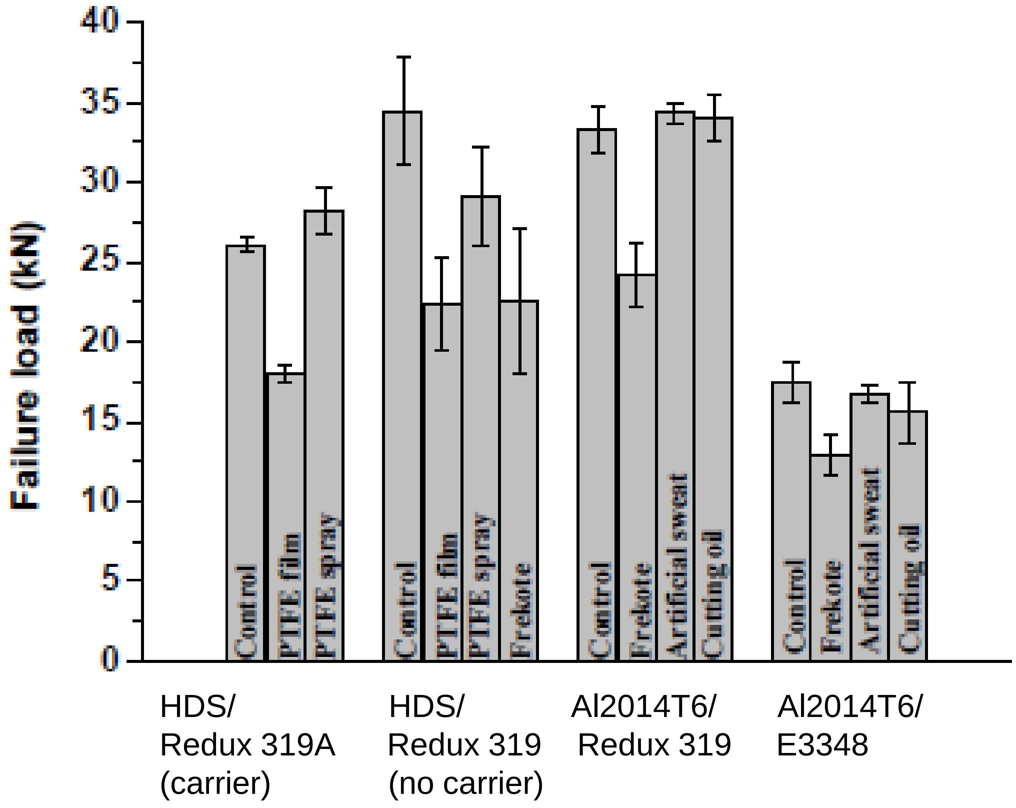
Frekote



- Migration of PTFE spray is evident
- Similar migration observed for sweat
- Cutting oil appears to be absorbed by adhesive
- Frekote tends to remain at /near the interface

Comparison of Failure Loads

Contaminant



- Effect of Carrier
- Effect of Adhesive

Redux® 319

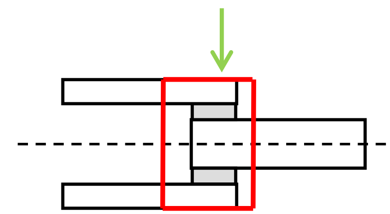
- Effect of PTFE spray/sweat/cutting oil
- Effect of PTFE film/Frekote

Frekote

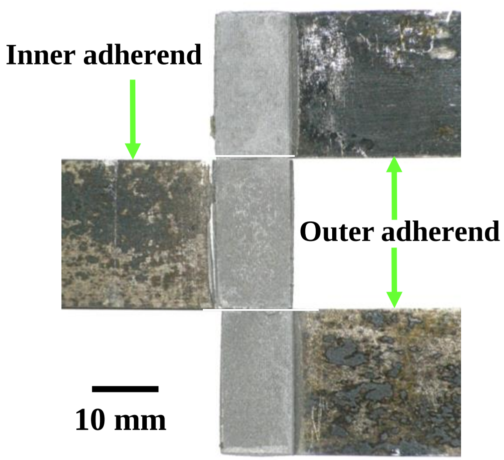
Failure mechanisms

Contaminant

(HDS+Redux®319)

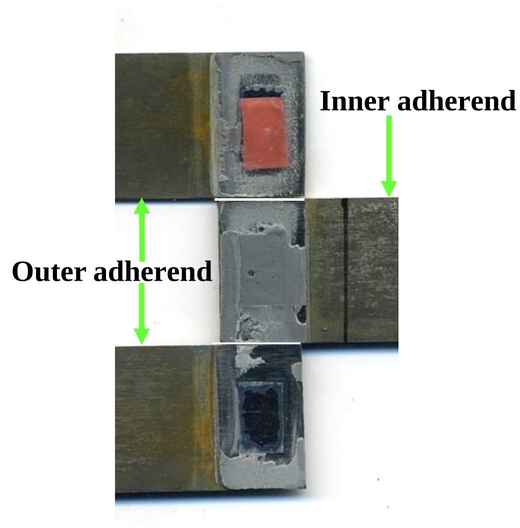


Control



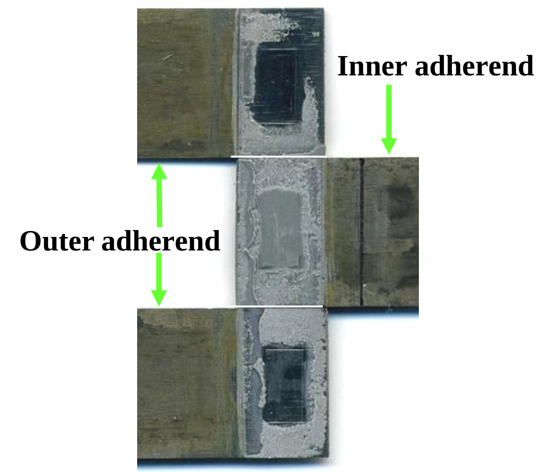
Cohesive failure

PTFE film



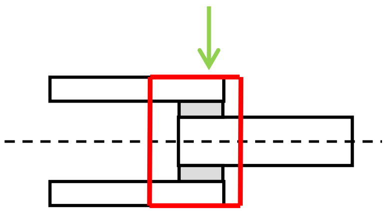
Adhesive failure at the position of PTFE film and mixed mode at noncontaminated area

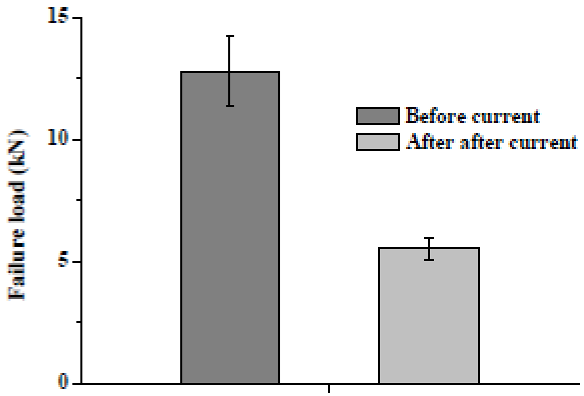
Frekote



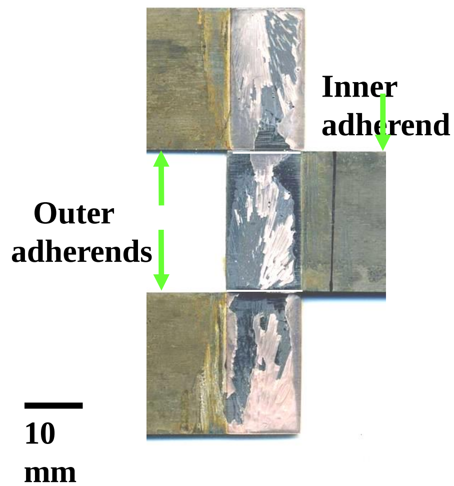
Adhesive failure at the position of Frekote and mixed mode at noncontaminated area

Failure of ElectRelease® Bonds



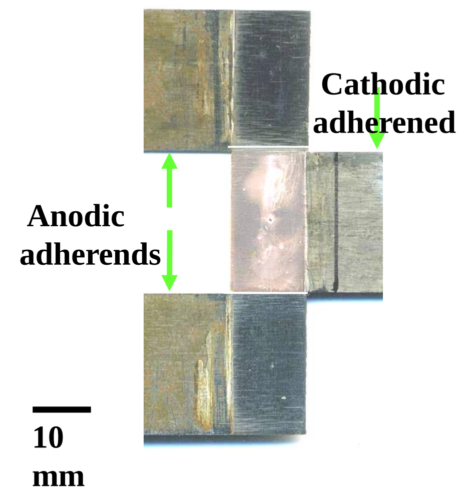


Without electric field



Cohesive failure dominates

With electric field

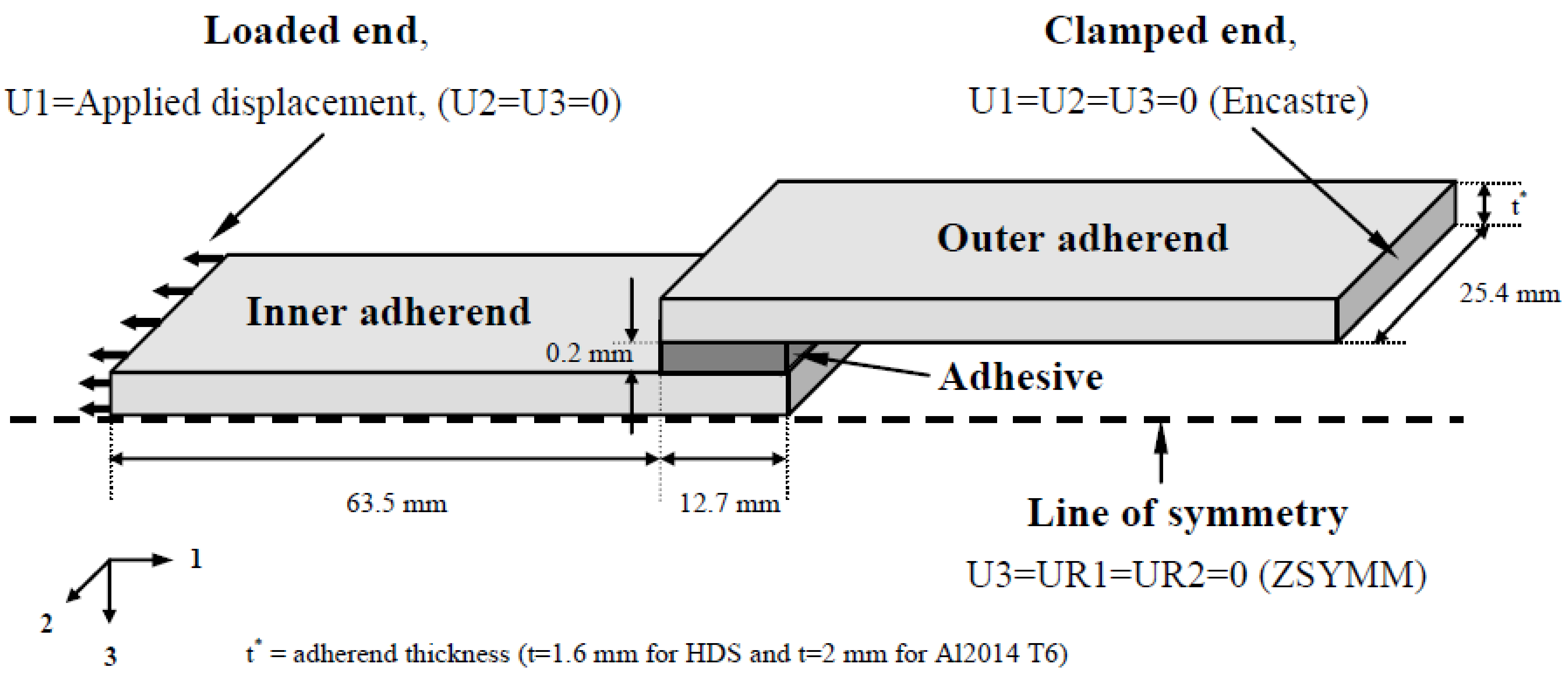


Adhesive failure at anodic surfaces

Value of average failure load reduced by 57%

Change in Failure mechanism

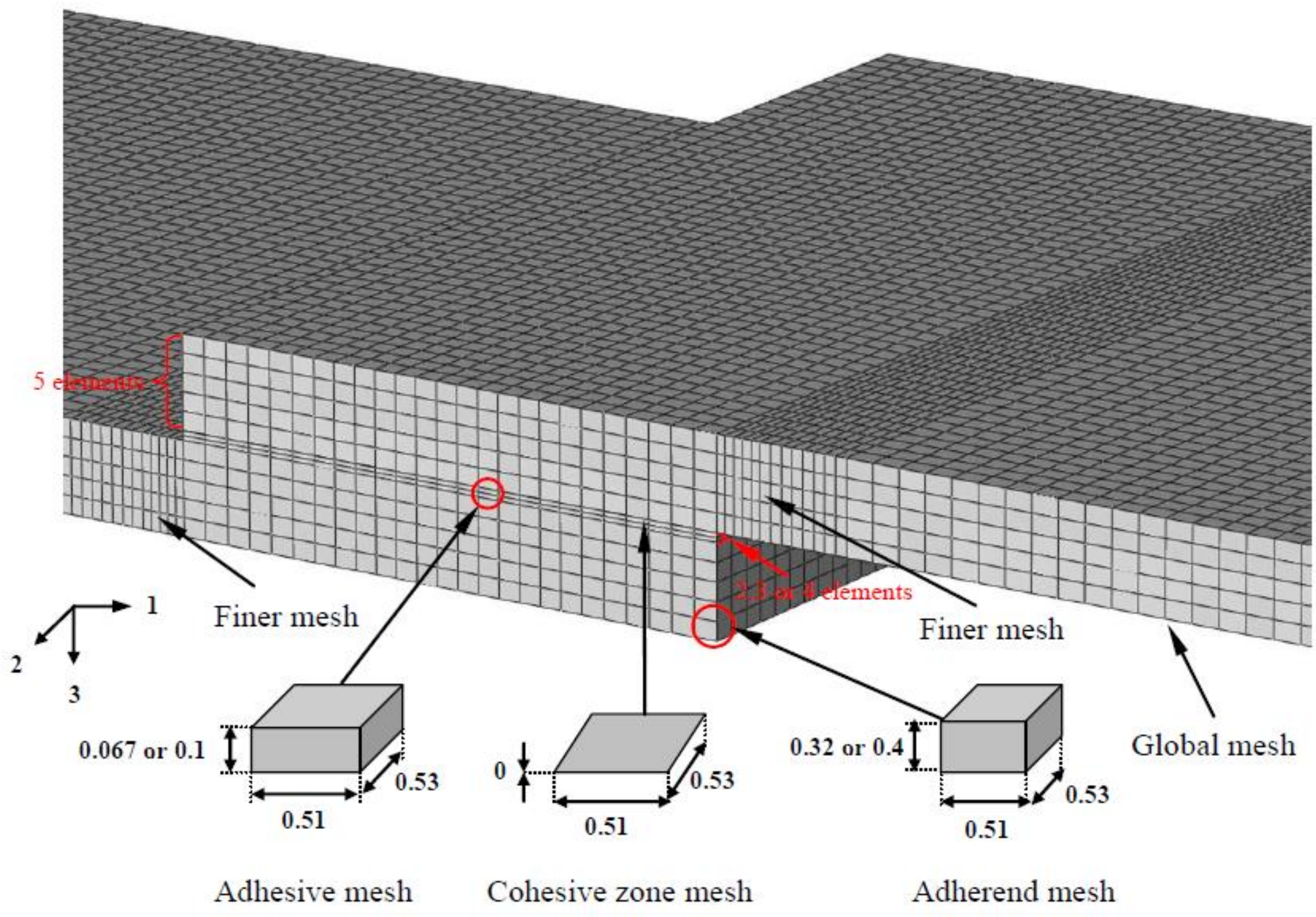
Finite Element Model



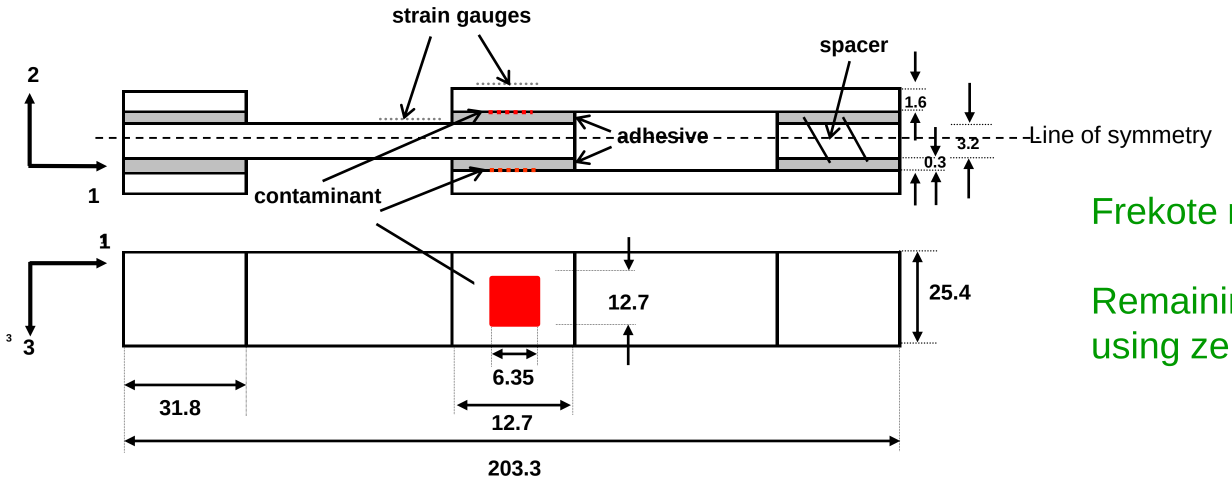
Material Models

- Adherends simulated as elastic/plastic materials assuming von Mises yield criterion
  - Failure occurred in elastic region for HDS but AL2014 T6 within plastic region
- Simulation of adhesives more complex
  - Isotropic
  - Shear behaviour not accurately derived from tension behaviour (as assumed for von Mises yield criterion)
- Use Exponent Druker-Prager model
  - Successful model derived for Redux®319
  - Model for ElectRelease® failed to converge – used elastic/plastic
- FEA models for ElectRelease® may not be fully accurate

Finite Element Mesh



Modelling of Contaminant



Frekote modelled as uncoupled surfaces

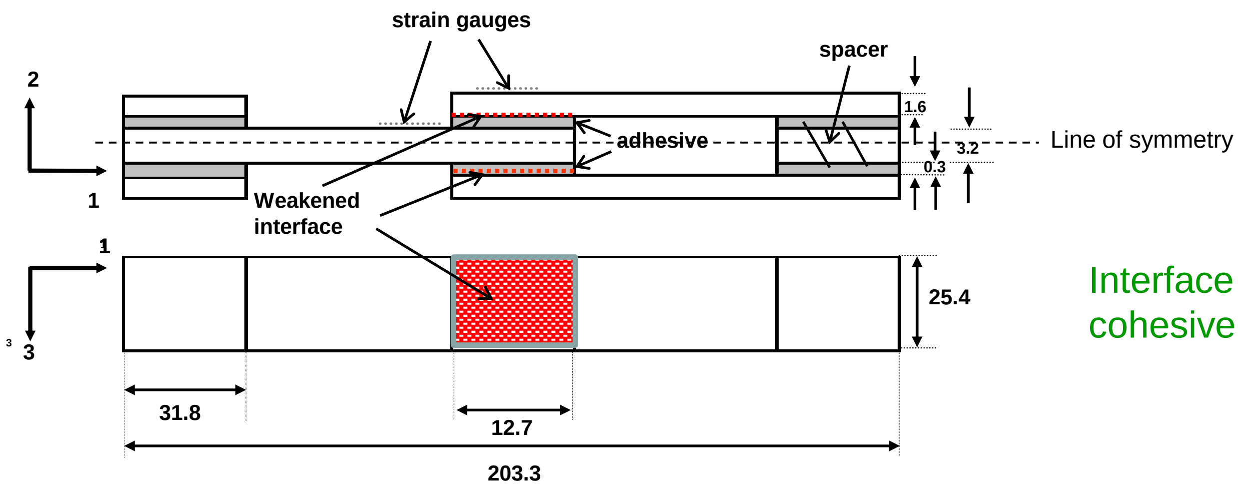
Remaining adhesive interface modelled using zero thickness cohesive elements

All dimensions are in mm and not to scale

Properties of cohesive zone gained from material tests
- Fixed arm peel tests (Mode I)
- Four point bend end notch flexure test – 4ENF (Mode II)
- Assumed Mode II and Mode III parameters identical

The cohesive properties are derived from independent material tests

Modelling of ElectRelease®



Interface modelled using zero thickness cohesive elements

All dimensions are in mm and not to scale

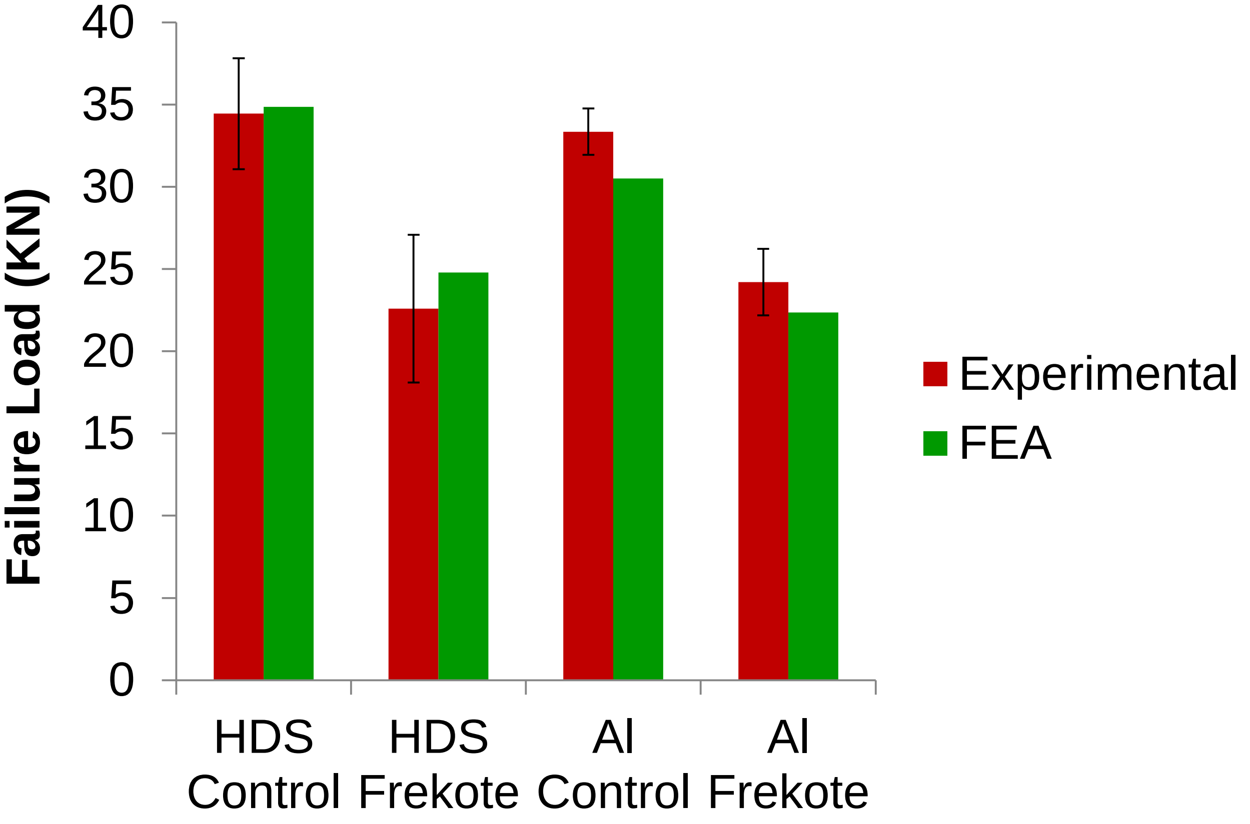
Properties of cohesive zone gained from material tests
Measured before and after application of the current

Fixed arm peel tests (Mode I)
Four point bend end notch flexure test – 4ENF (Mode II)
Assumed Mode II and Mode III parameters identical

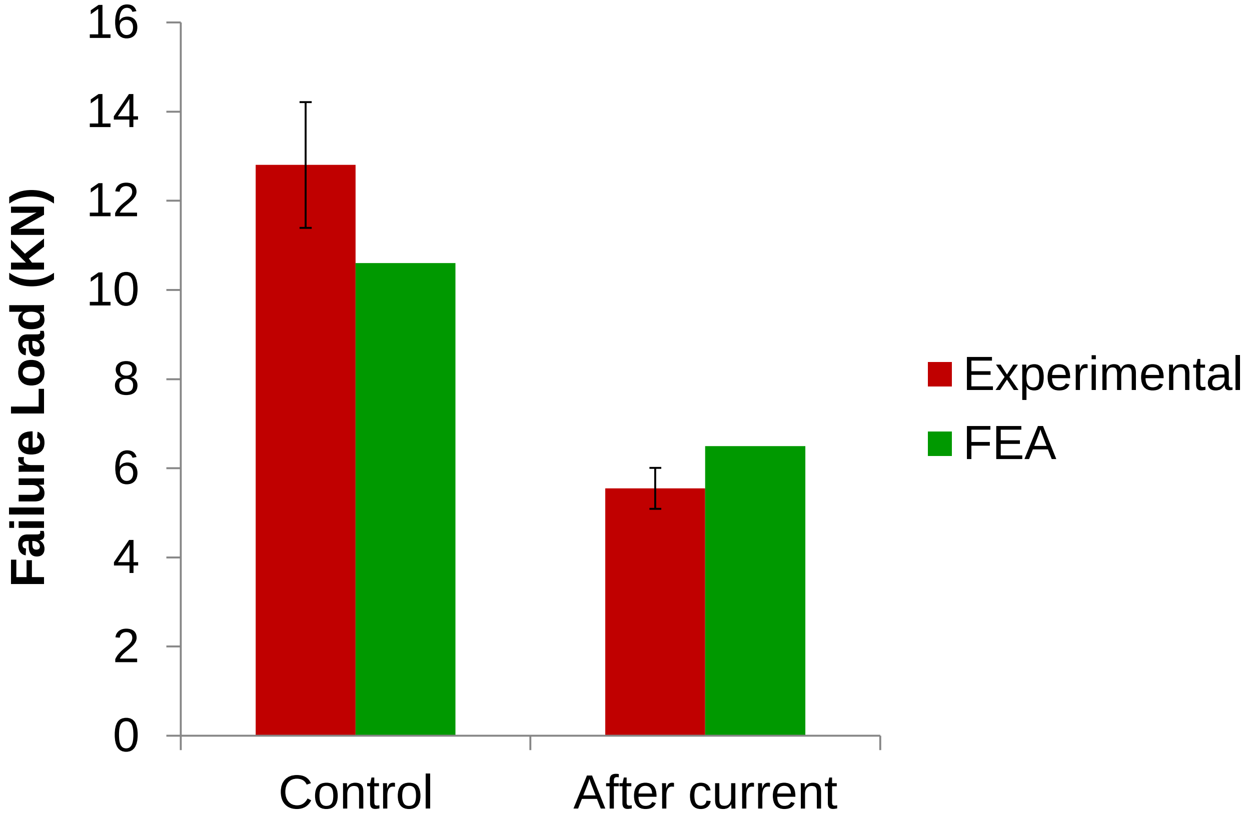
The cohesive properties are derived from independent material tests

Comparison of Experimental and Predicted Values of Failure Load

HDS/Al2014 T6 + Redux® 319



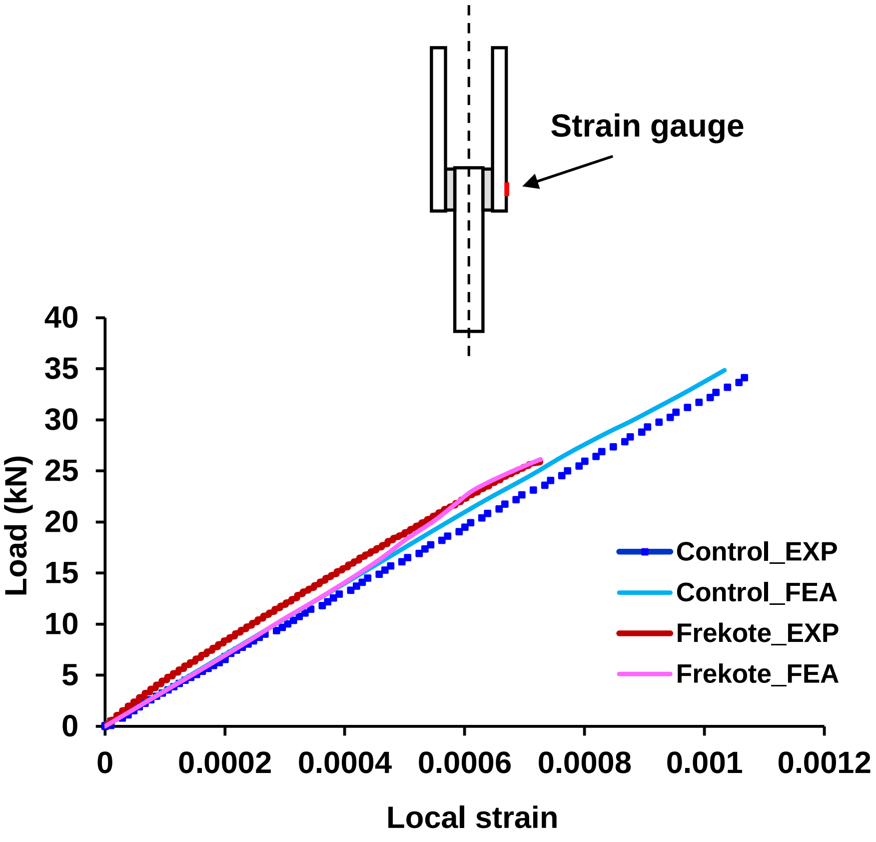
Comparison of Experimental and Predicted Values of Failure Load HDS/ElectRelease™



Comparison of Values of Local strain

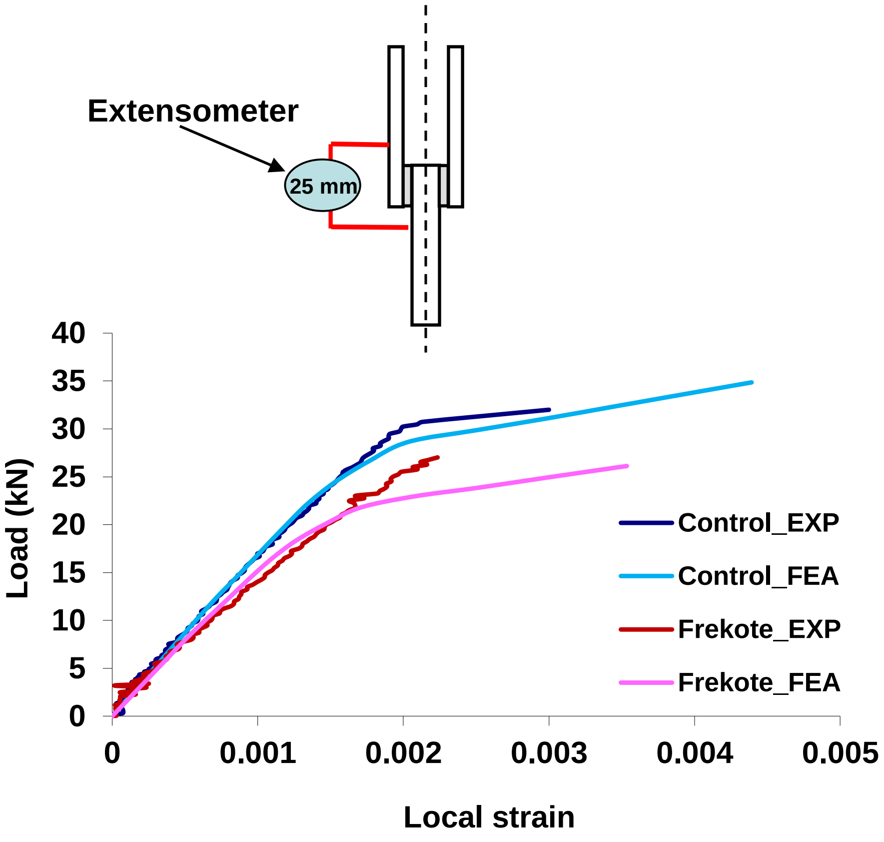
- **Surface contamination:** **HDS+Redux®319**

1 mm in the middle of bonded area



Good agreement between EXP and FEA for control and contaminated DLJ.

25 mm over bonded area

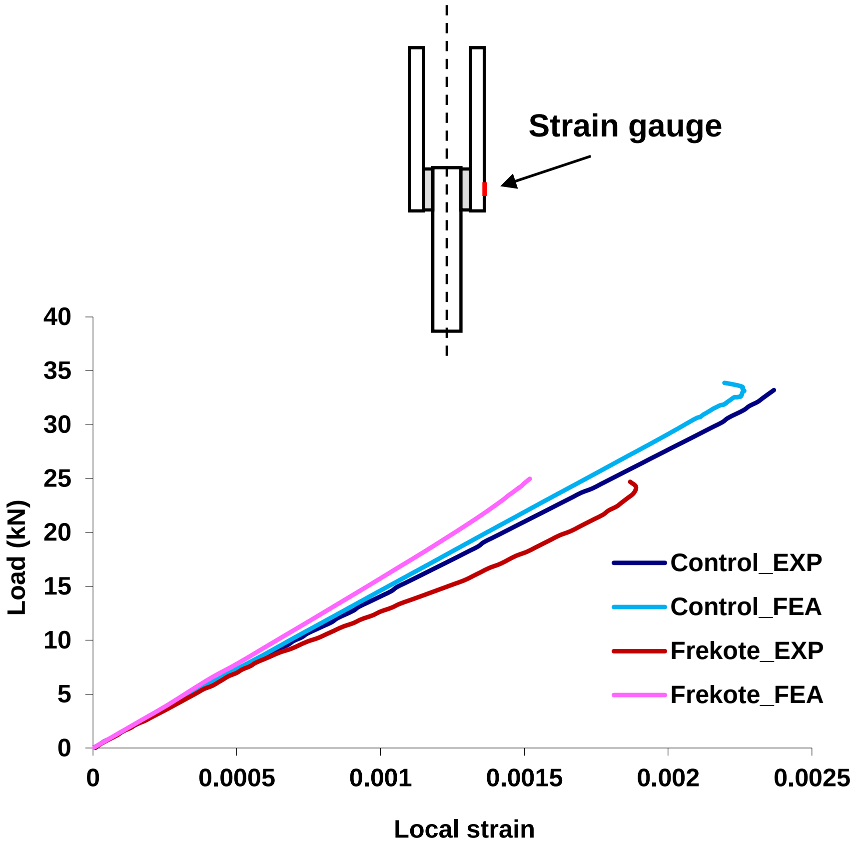


Good agreement between EXP and FEA for both control and contaminated DLJ

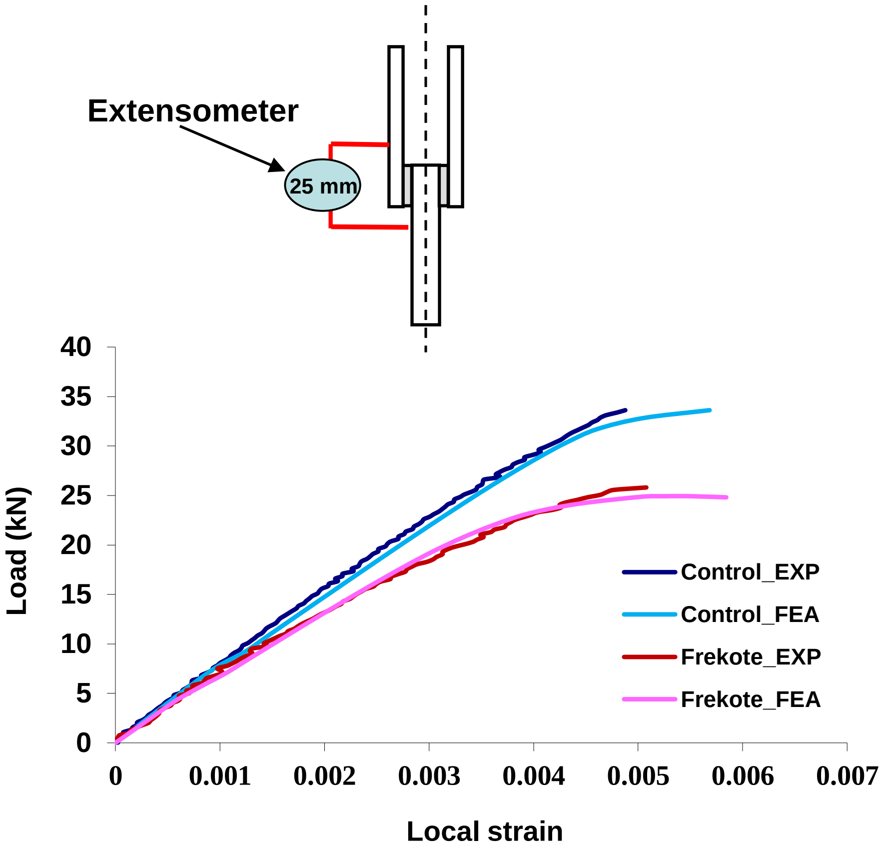
Comparison of Values of Local strain

- **Surface contamination:** **Al2014 T6+Redux®319**

1 mm in the middle of bonded area | **25 mm over bonded area**



Good agreement between EXP and FEA for control DLJ but less good for contaminated DLJ

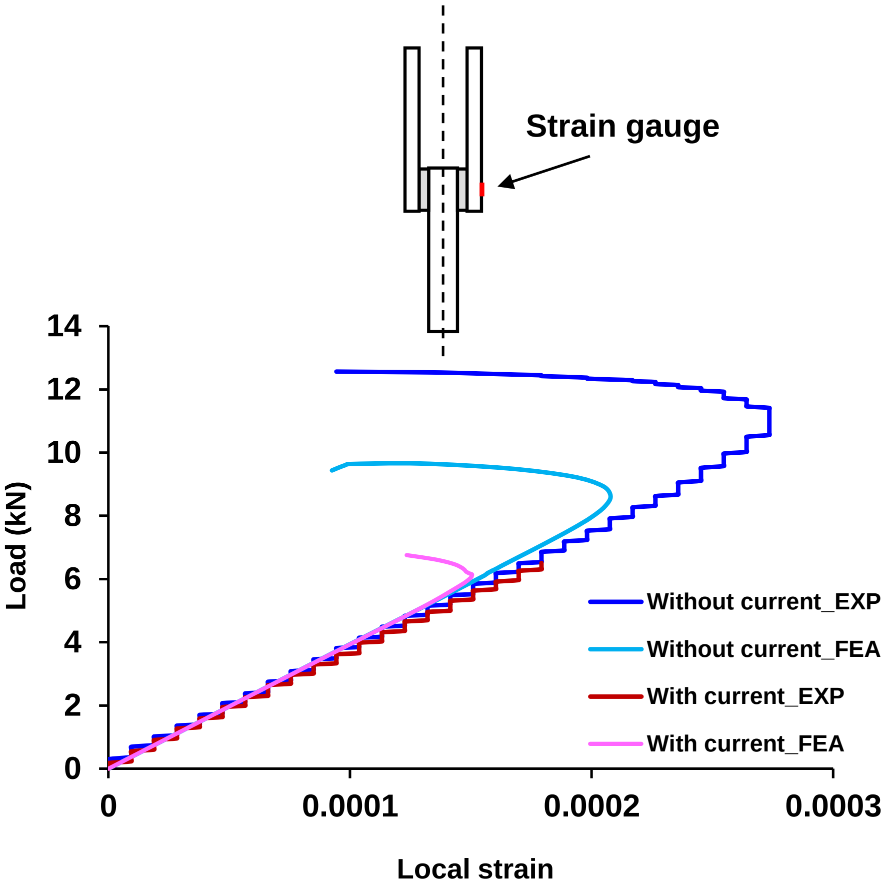


Good agreement between EXP and FEA for both control and contaminated DLJ

Comparison of Values of Local strain

- **Using ElectRelease™ adhesive:** HDS+ElectRelease™

1 mm in the middle of bonded area



Good agreement between EXP and FEA for control and contaminated DLJ at 1mm gauge length. Same local stiffness before and after current.

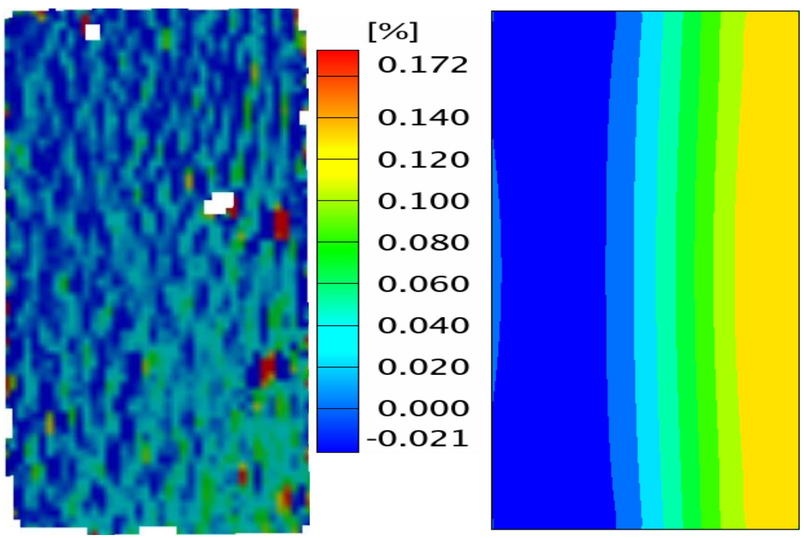
Comparison of DIC Results

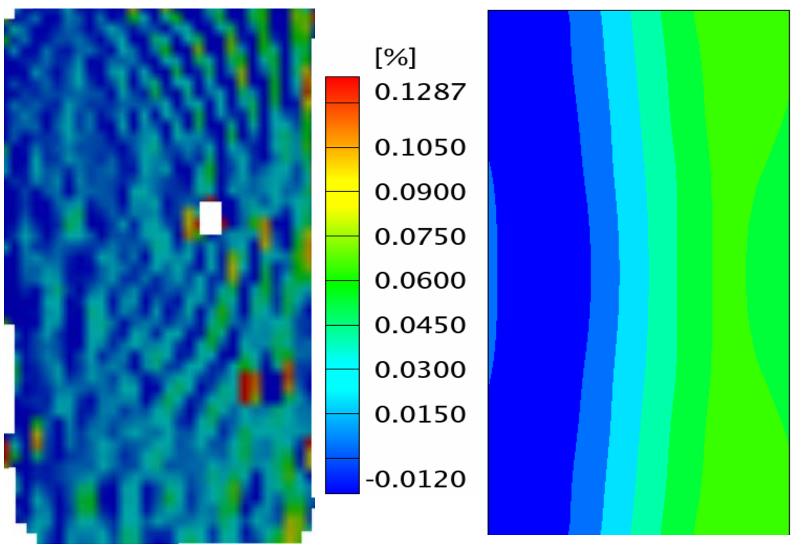
Axial (applied) Strain

Control Joint

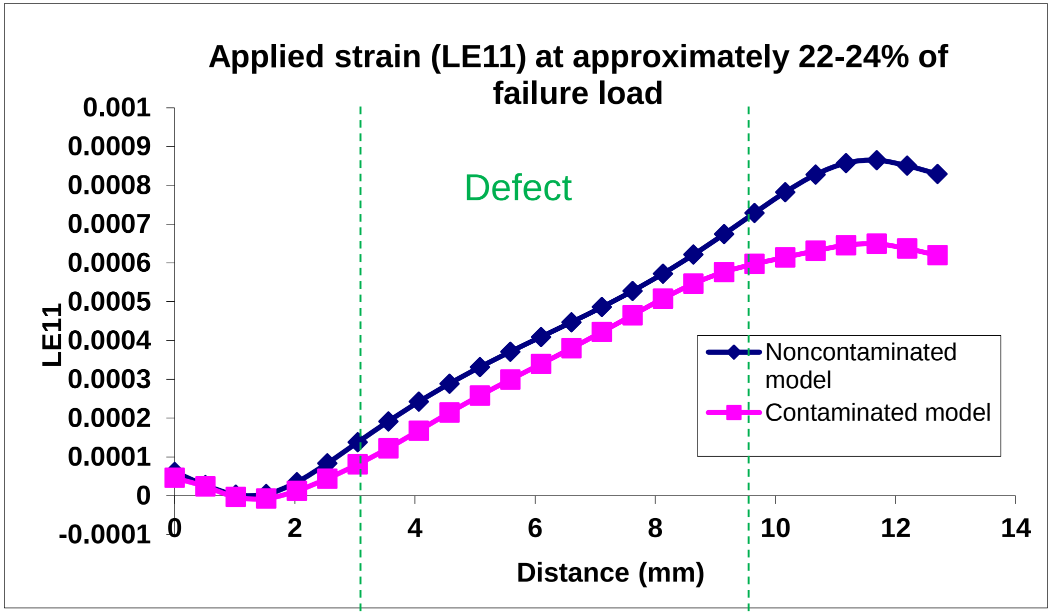
Contaminated Joint

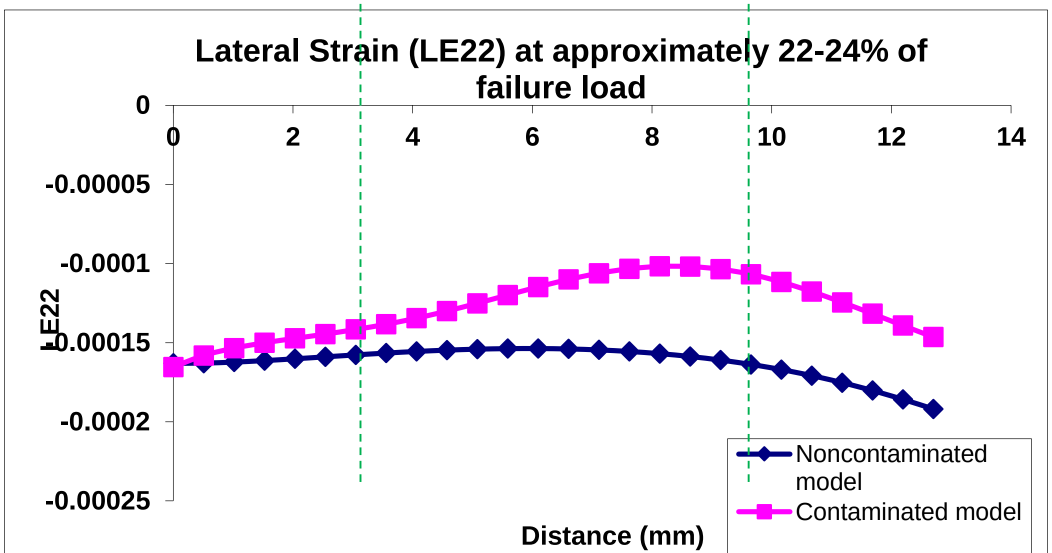
load

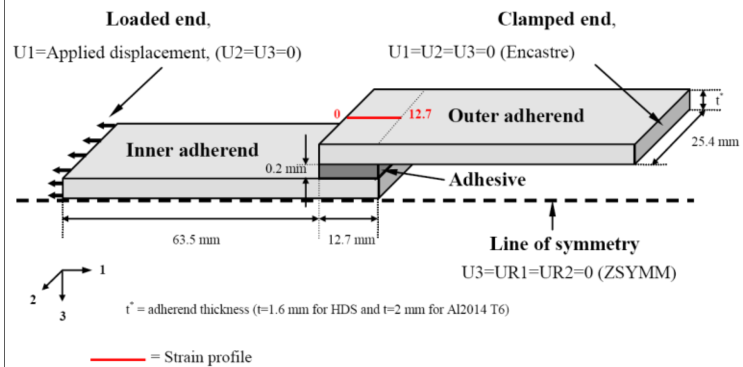




Failure mechanism: Possible Future detection of kissing bonds?







Strain profiles across top plane of adherend above the kissing bond

Presence of kissing bond changes the strain profiles

Could this be used as a means of detection?

Conclusions

- We produced reliable and repeatable kissing bonds
  - Contamination by Frekote
  - ElectRelease™ adhesive
- *We established the changes in surface chemistry and morphology at the interface/interphase for kissing bonds*
- We measured significant changes in joint strength and adhesive failure at the interface for kissing bonds
- We successfully modelled kissing bonds using finite element analysis and correlated the reduction in joint strength with the change in adhesive strength at the interface
- We propose that a future method of kissing bond detection could be based on measurement of strain in the adherends, particularly lateral strain