Analysis of Kissing Bonds in Metallic Joints

Felicity Guild* and Choothum Jeenjitkaew†

School of Engineering and Materials Science
Queen Mary, University of London
Department of Materials
Mile End Road
London E1 4NS

*Now at: Department of Mechanical Engineering
Imperial College London
London SW7 2AZ

† Now at: Element Hitchin [formerly: Materials Engineering Research Laboratory (MERL)]
Wilbury Way,
Hitchin, Hertfordshire, UK, SG4 0TW
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
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)

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<td>Contaminants</td>
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<td>PTFE film</td>
<td>PTFE spray</td>
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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)

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<td>Adhesive</td>
<td>ElectRelease™</td>
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<td>Electric field</td>
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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)

- 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

Inner adherend

Outer adherend

10 mm

Cohesive failure

PTFE film

Inner adherend

Outer adherend

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

Frekote

Inner adherend

Outer adherend

Adhesive failure at the position of Frekote and mixed mode at noncontaminated area
Failure of ElectRelease® Bonds

Value of average failure load reduced by 57%

Change in Failure mechanism
Finite Element Model

Loaded end,

U1=Applied displacement, (U2=U3=0)

Clamped end,

U1=U2=U3=0 (Encastre)

Inner adherend

Outer adherend

Adhesive

Line of symmetry

U3=UR1=UR2=0 (ZSYM)

t* = adherend thickness (t=1.6 mm for HDS and t=2 mm for Al2014 T6)
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

- Adhesive mesh
- Cohesive zone mesh
- Adherend mesh
- Finer mesh
- Global mesh

Dimensions:
- 0.067 or 0.1
- 0.51
- 0.53
- 0.32 or 0.4
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™

![Graph showing comparison of experimental and predicted failure loads.](image-url)
Comparison of Values of Local strain

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

1 mm in the middle of bonded area

25 mm over bonded area

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

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
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