MEMORANDUM FOR PRS (Contractor Publication)

FROM: PROI (TI) (STINFO) 18 May 1998

Tim Miller (SPARTA) "Modeling of Interfacial Fracture in Photelastic Specimens"

Vugraphs

(Statement A)
Modeling of Interfacial Fracture in Photoelastic Specimens

T.C. Miller
Sparta, Incorporated
Air Force Research Laboratory
Edwards Air Force Base, California

DISTRIBUTION STATEMENT A
Approved for Public Release
Distribution Unlimited

June 1998
Introduction

Applications to Composite Structures

Related Photoelastic Stress Freezing Experiments

Casing
Insulator
Liner
Propellant

Specimens are glued to aluminum grips
Aradite
Aradite and aluminum powder

(All thicknesses are 12.7 mm)

Loading point
Incompressible Bimaterial Paris Under Plane Strain Conditions

General Interfacial Fracture

\[ \epsilon = 0 \quad \beta = 0 \]

\[
\sigma_{pq} = \frac{1}{\sqrt{2 \pi r}} \left[ Re(Kr^i) \Sigma_p^i(\theta) + Im(Kr^i) \Sigma_p^u(\theta) \right]
\]

\[
(\sigma_{yy} + i \sigma_{yx})_{\theta = 0} = \frac{K_r^i}{\sqrt{2 \pi r}} = \frac{K_1 + i K_2}{\sqrt{2 \pi r}} \left[ \cos(\epsilon L \pi) + i \sin(\epsilon L \pi) \right]
\]

\[ J = G = \frac{\Lambda_1 + \Lambda_2}{16 \cosh^2(\pi \epsilon)} |K|^2 \]

Plane Strain/Incompressible Materials

\[ \epsilon = 0 \quad \beta = 0 \]

\[
\sigma_{pq} = \frac{1}{\sqrt{2 \pi r}} \left[ Re(K) \Sigma_p^i(\theta) + Im(K) \Sigma_p^u(\theta) \right]
\]

\[
(\sigma_{yy} + i \sigma_{yx})_{\theta = 0} = \frac{K}{\sqrt{2 \pi r}} = \frac{K_1 + i K_2}{\sqrt{2 \pi r}}
\]

\[ J = G = \frac{K^2}{E}, \quad \frac{1}{E'} = \frac{1}{2} \frac{1}{E_1} + \frac{1}{E_2}, \quad \bar{E}_1 = \frac{E_1}{1 - v_1^2}, \quad \bar{E}_2 = \frac{E_2}{1 - v_2^2} \]
Hybrid Elements and Mixed Formulation Prevent Ill-Conditioning Problems

Conventional Formulation

Mixed Formulation

Shear Stress

KPa

-1579

-169

-194

-256

-132

-56

-1

1

94

169

207
A Refined Mesh is Used to Provide Accurate Bond Line Traction
Contour Plots of In-Plane Shear Stress for Various Mode Mixities
Contour Plots of $\sigma_{yy}$ Stress Component for Various Mode Mixities

Crack angle = 0 deg.

Crack angle = 15 deg.

Crack angle = 30 deg.

Crack angle = 45 deg.
Contour Plot of Maximum In-Plane Shear Stress Component for Various Mode Mixities

Shear stress levels:
- INF
- +0
- +19
- +38
- +56
- +75
- +94
- +113
- +132
- +150
- +169
- +188
- +207
- + INF

Crack angles:
- Crack angle = 0 deg.
- Crack angle = 15 deg.
- Crack angle = 30 deg.
- Crack angle = 45 deg.
Results

Magnitude of Complex Stress Intensity Factors

Phase Angle of Complex Stress Intensity Factors

Stress intensity factor magnitude [psi in**1/12]

Stress intensity factor phase angle [degrees]

Crack orientations [degrees]

[charts with data points indicating computational and experimental results]
Conclusions

• Area integration and bond line traction regression is a simple and accurate way of determining the magnitude and phase angle of $K$ for cracks along the interfaces between two incompressible materials under plane strain conditions.
Acknowledgements

• Experimental results and data - Dr. C.W. Smith, Virginia Polytechnic Institute and State University

• Funding and Computational Facilities - Dr. C.T. Liu, Air Force Research Laboratory, Edwards Air Force Base, California