

# REPORT DOCUMENTATION PAGE

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1011CH qf

MEMORANDUM FOR PRS (Contractor Publication)

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18 May 1998

SUBJECT: Authorization for Release of Technical Information, Control Number: **AFRL-PR-ED-TP-1998-104**  
Tim Miller (SPARTA) "Modeling of Interfacial Fracture in Photoelastic Specimens"

**Vugraphs**

(Statement A)



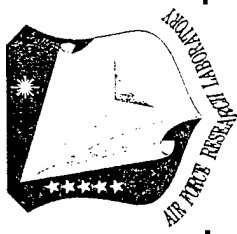
# Modeling of Interfacial Fracture in Photoelastic Specimens

T.C. Miller

Sparta, Incorporated  
Air Force Research Laboratory  
Edwards Air Force Base, California

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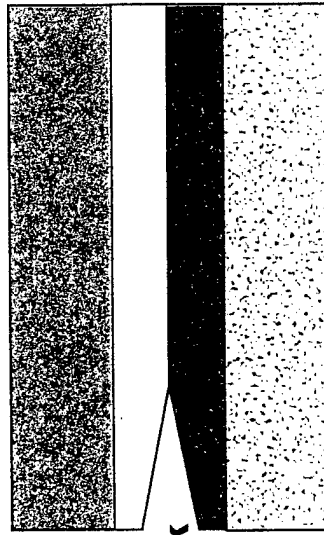
June 1998



# Introduction

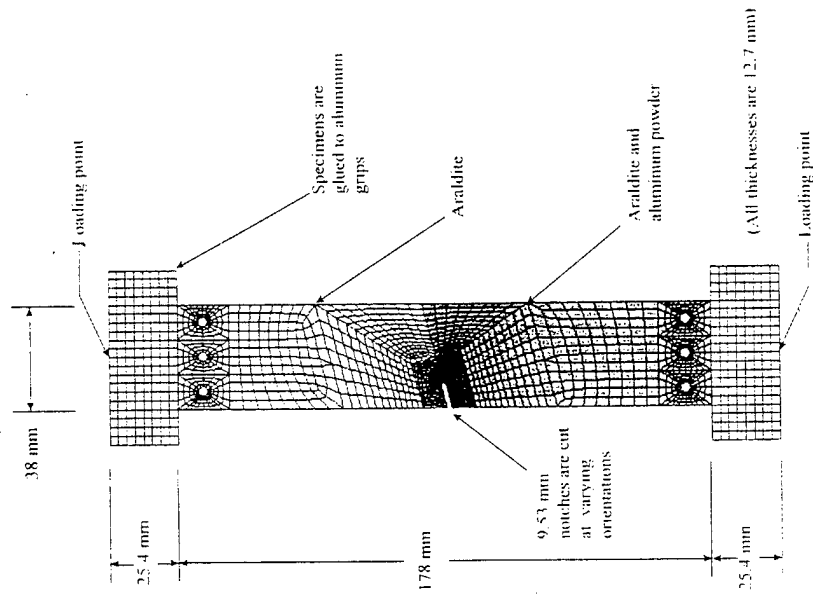
## Applications to Composite Structures

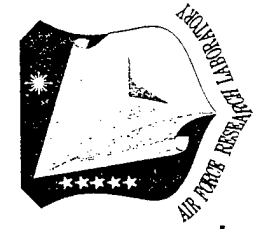
## Related Photoelastic Stress Freezing Experiments



crack

**Casing**  
**Insulator**  
**Liner**  
**Propellant**





# Incompressible Bimaterial Paris Under Plane Strain Conditions

## General Interfacial Fracture

## Plane Strain/Incompressible Materials

$$\epsilon \neq 0 \quad \beta \neq 0$$

$$\sigma_{pq} = \frac{1}{\sqrt{2\pi r}} \{ \text{Re}(K r^{i\epsilon}) \Sigma'_{pq}(\theta) + \text{Im}(K r^{i\epsilon}) \Sigma''_{pq}(\theta) \}$$

$$(\sigma_{yy} + i\sigma_{xy})_{\theta=0} = \frac{K r^{i\epsilon}}{\sqrt{2\pi r}} = \frac{K_1 + iK_2}{\sqrt{2\pi r}} [\cos(\epsilon Lnr) + i \sin(\epsilon Lnr)]$$

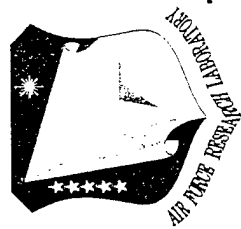
$$J = G = \frac{\Lambda_1 + \Lambda_2}{16 \cosh^2(\pi\epsilon)} |K|^2$$

$$\epsilon = 0 \quad \beta = 0$$

$$\sigma_{pq} = \frac{1}{\sqrt{2\pi r}} \{ \text{Re}(K) \Sigma'_{pq}(\theta) + \text{Im}(K) \Sigma''_{pq}(\theta) \}$$

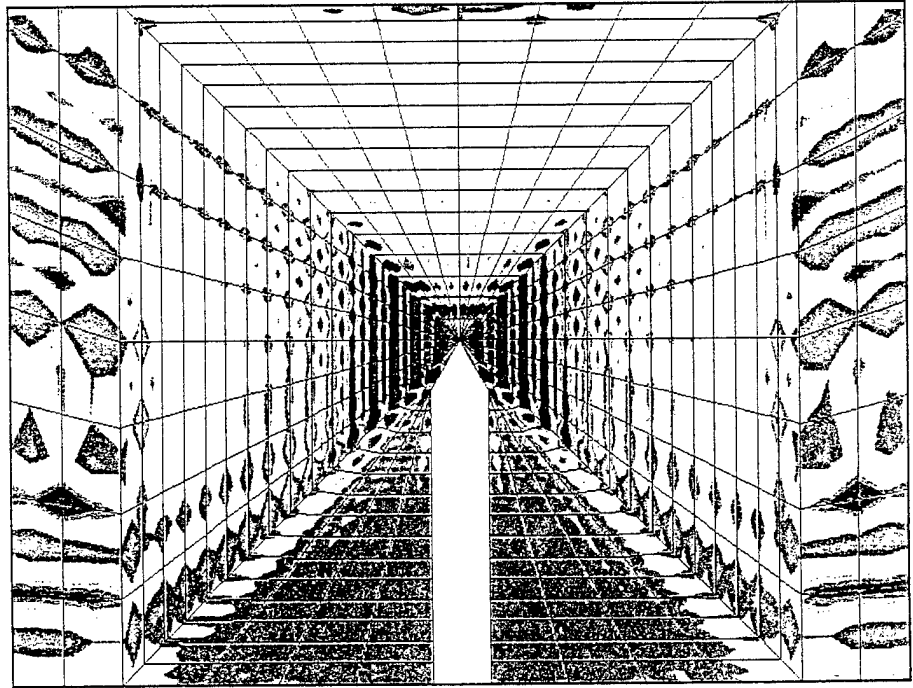
$$(\sigma_{yy} + i\sigma_{xy})_{\theta=0} = \frac{K}{\sqrt{2\pi r}} = \frac{K_1 + iK_2}{\sqrt{2\pi r}}$$

$$J = G = \frac{K^2}{E^*}, \quad \frac{1}{E^*} = \frac{1}{2} \left[ \frac{1}{E_1} + \frac{1}{E_2} \right], \quad \bar{E}_1 = \frac{E_1}{1 - \nu_1^2}, \quad \bar{E}_2 = \frac{E_2}{1 - \nu_2^2}$$

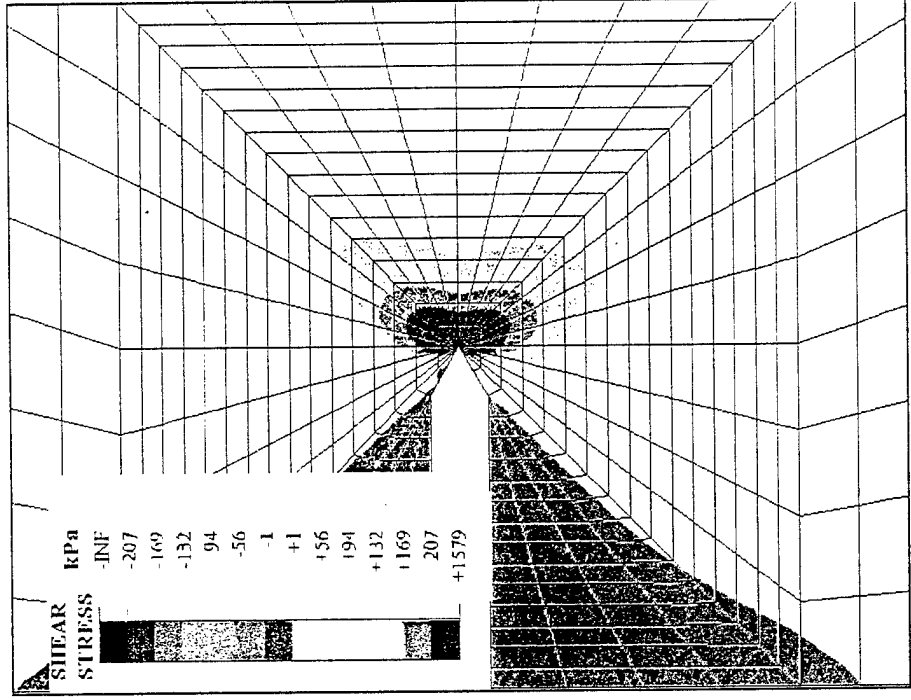


# Hybrid Elements and Mixed Formulation Prevent Ill-Conditioning Problems

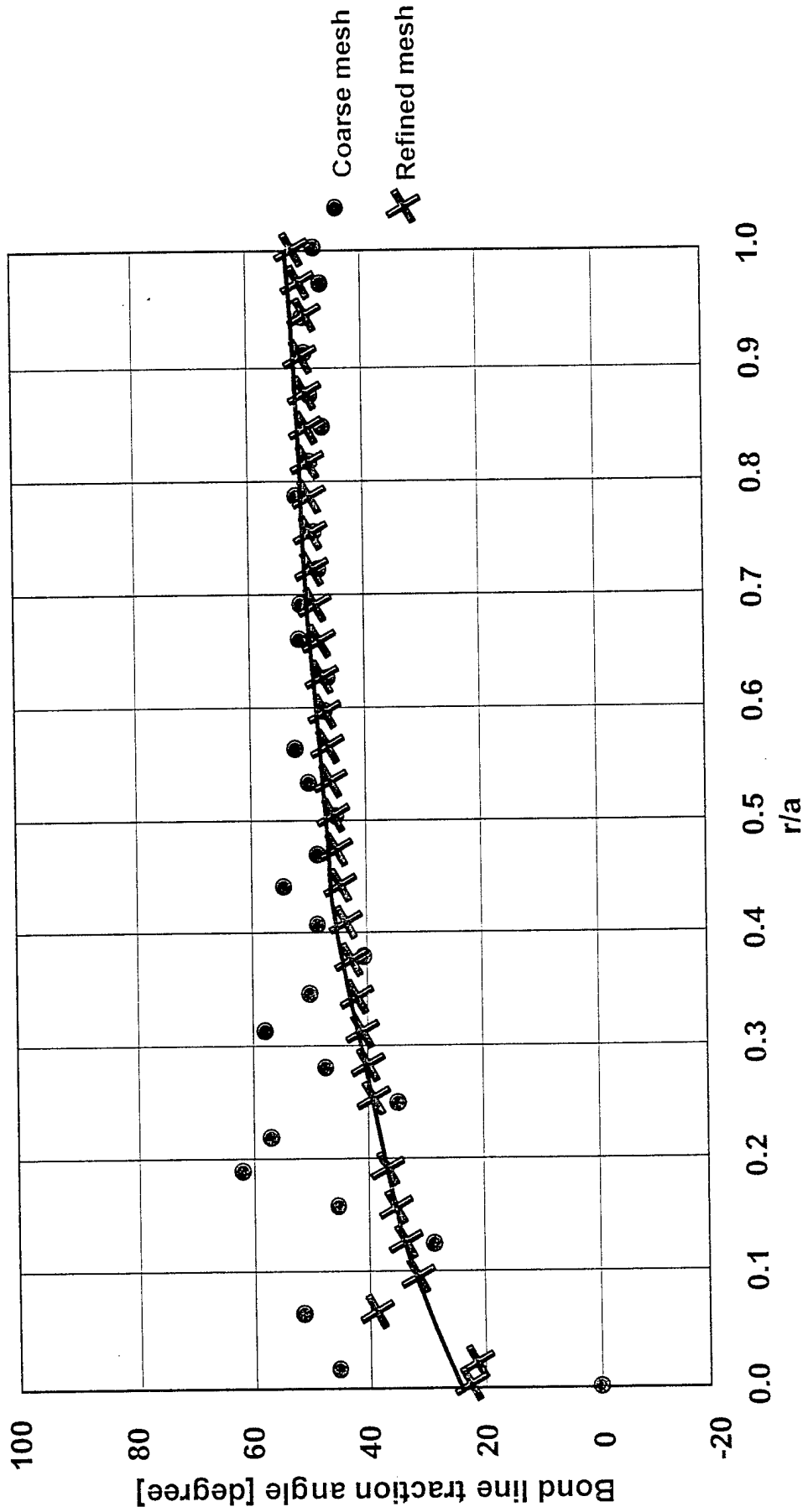
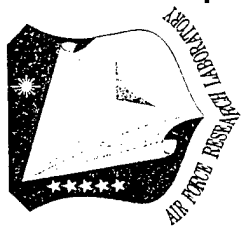
Conventional Formulation



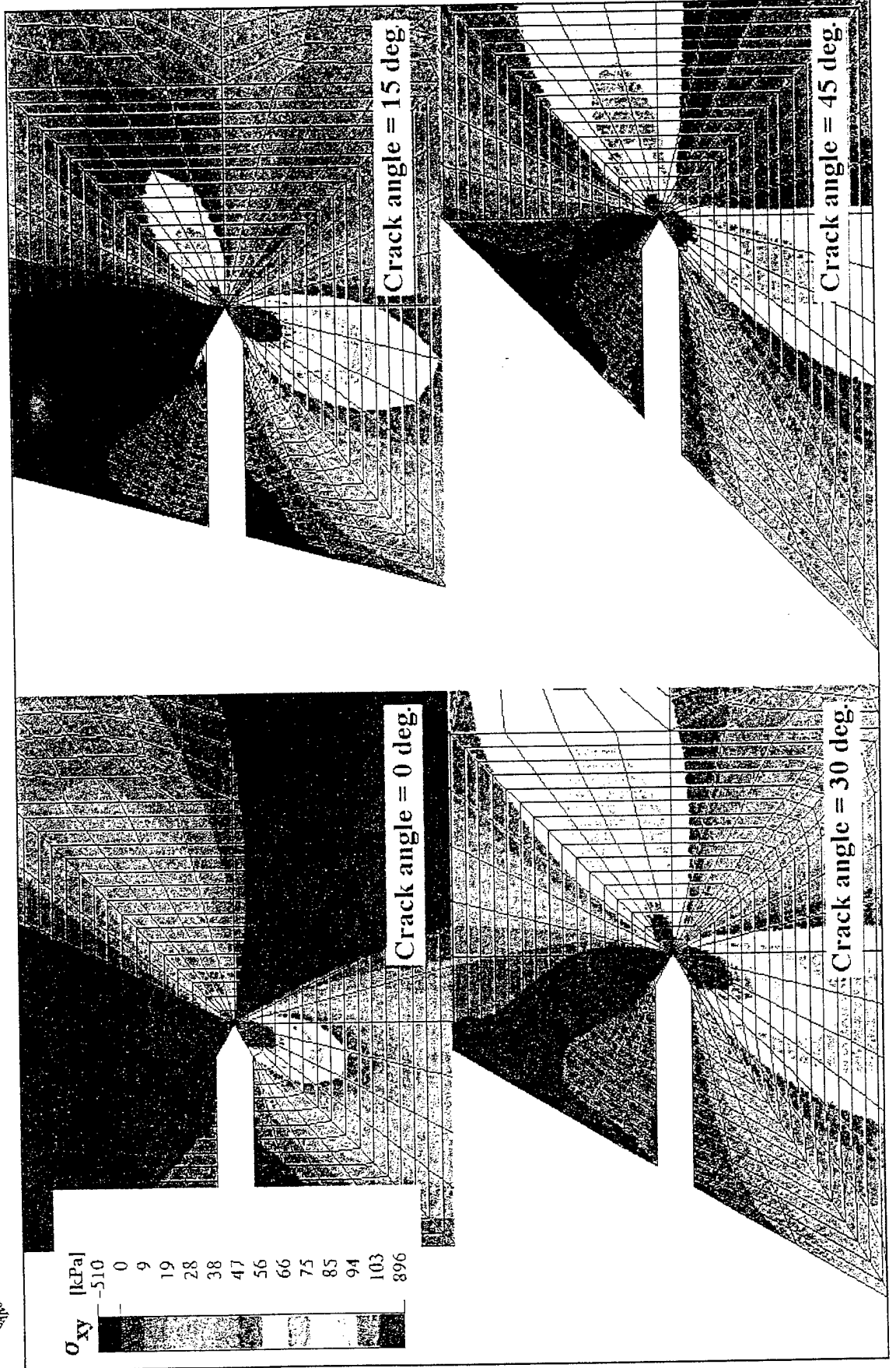
Mixed Formulation



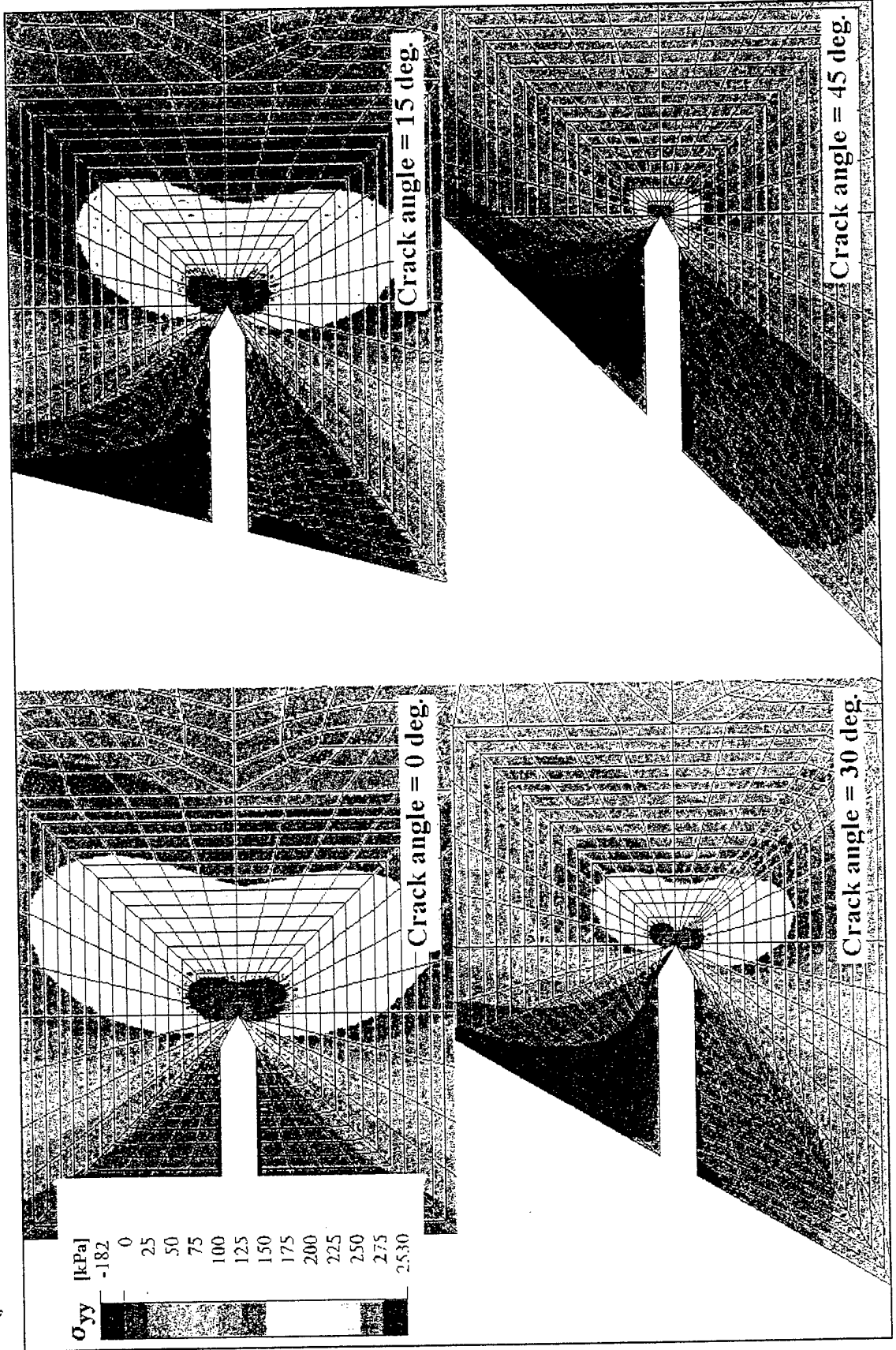
# A Refined Mesh is Used to Provide Accurate Bond Line Traction



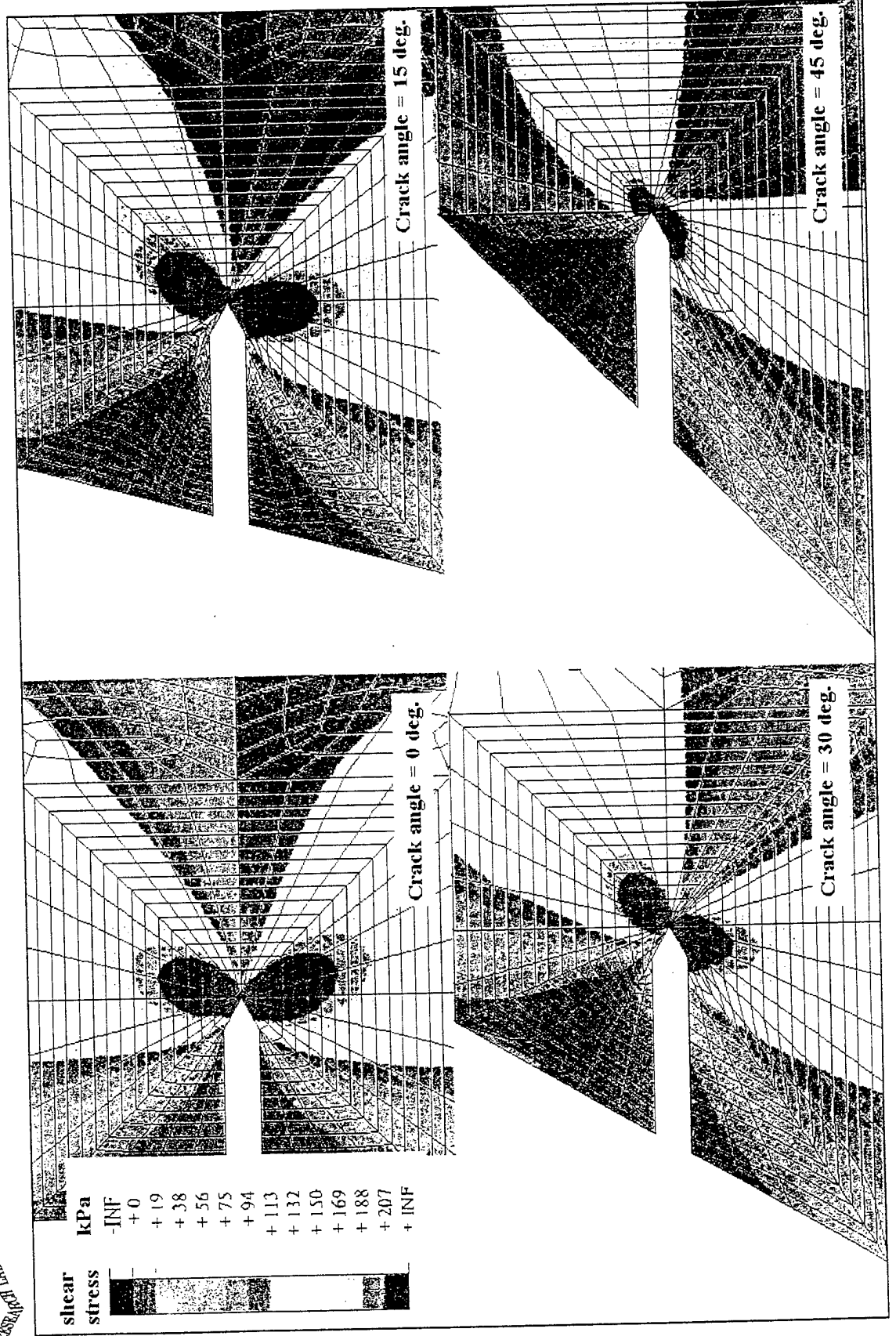
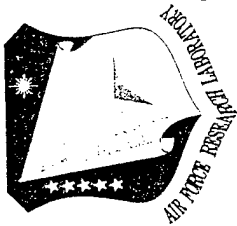
# Contour Plots of In-Plane Shear Stress for Various Mode Mixities

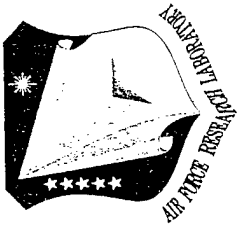


# Contour Plots of $\sigma_{yy}$ Stress Component for Various Mode Mixities



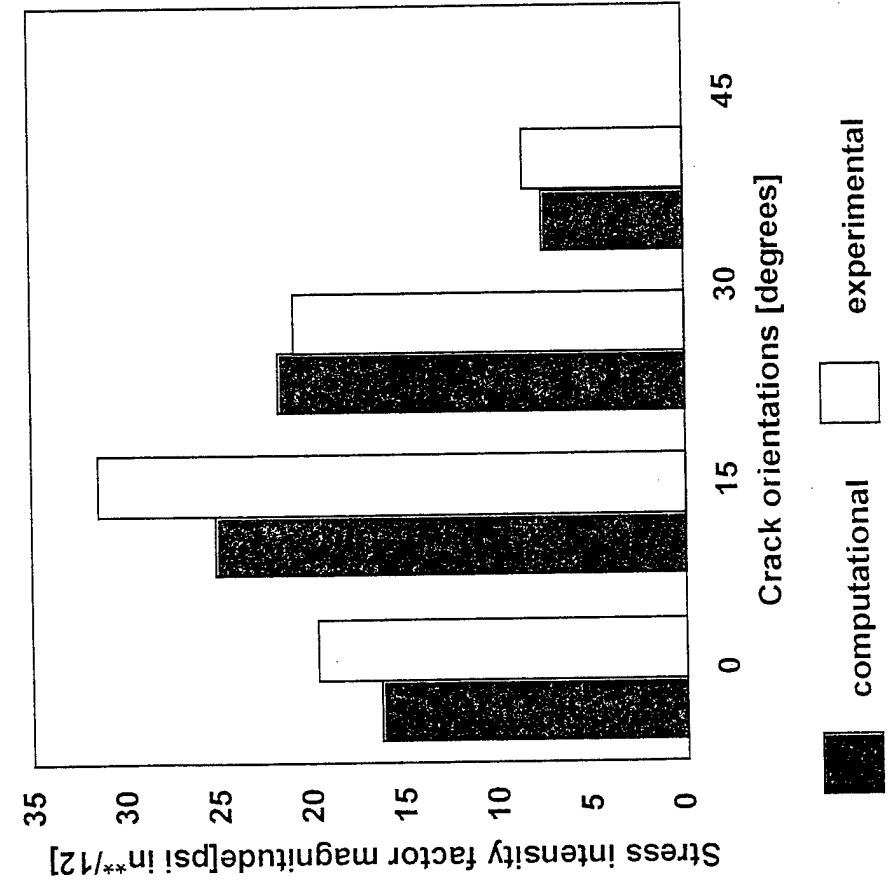
# Contour Plot of Maximum In-Plane Shear Stress Component for Various Mode Mixities



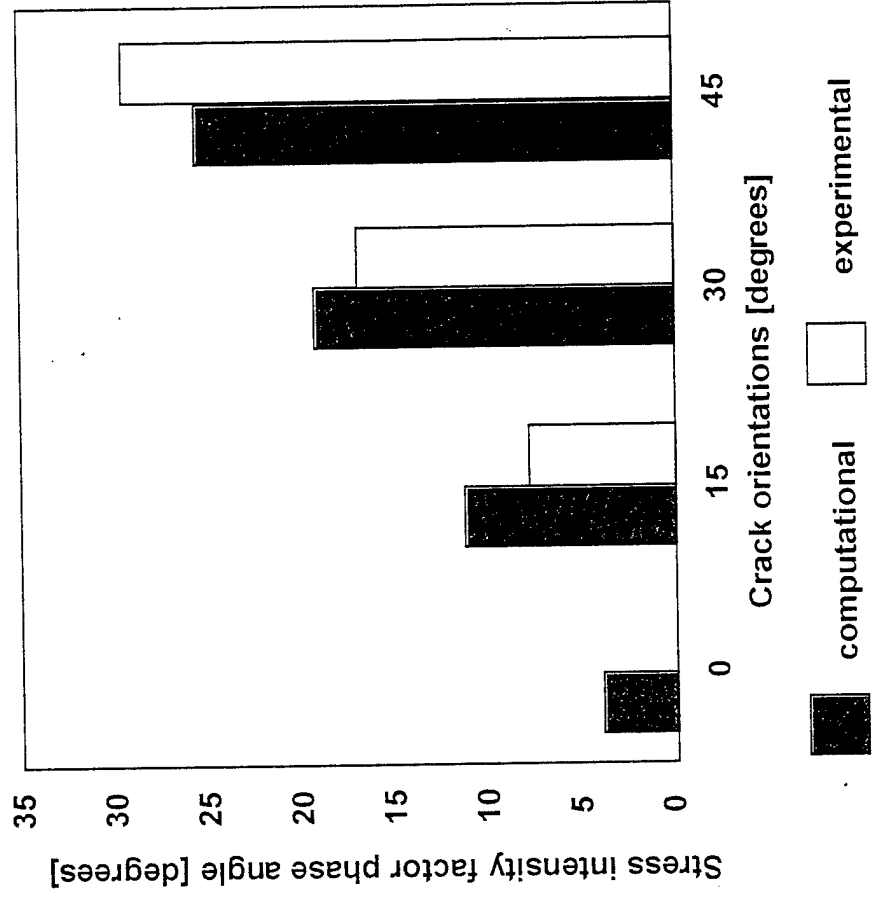


# Results

## Magnitude of Complex Stress Intensity Factors



## Phase Angle of Complex Stress Intensity Factors





# Conclusions

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- 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.



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Base, California