

REPORT DOCUMENTATION PAGE

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36 separate items are enclosed
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MEMORANDUM FOR PRS (In-House Publication) Propulsion Science and Advanced Concepts Division

FROM: PROI (TI) (STINFO)

30 Nov 2000

SUBJECT: Authorization for Release of Technical Information, Control Number: AFRL-PR-ED-TP-2000-227
Miller, T. C., "Fracture Mechanics Research at Air Force Research Laboratory"

Visit by Swedish Diplomats to AFRL
(AFRL/Edwards, 05 Dec 2000)

(Statement A)

1. This request has been reviewed by the Foreign Disclosure Office for: a.) appropriateness of distribution statement, b.) military/national critical technology, c.) export controls or distribution restrictions, d.) appropriateness for release to a foreign nation, and e.) technical sensitivity and/or economic sensitivity.

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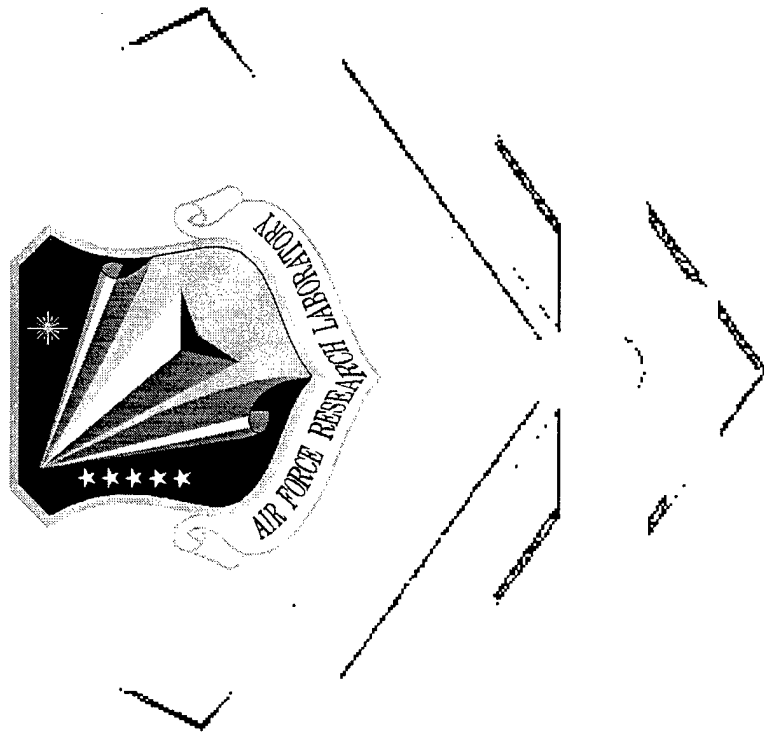
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PHILIP A. KESSEL Date
Technical Advisor
Propulsion Science and Advanced Concepts Division

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Fracture Mechanics Research at Air Force Research Laboratory

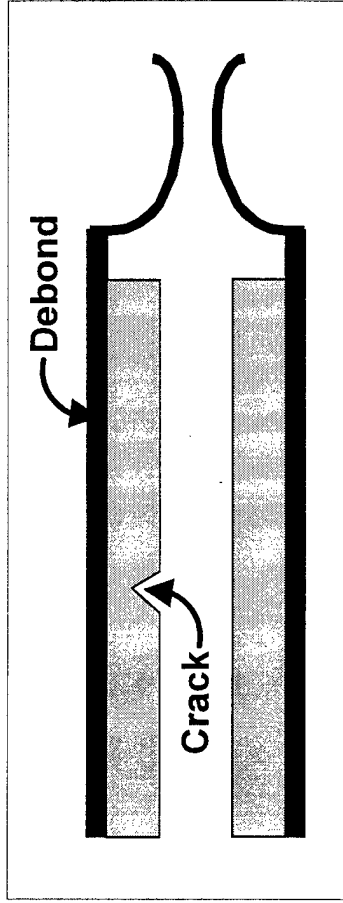


December 5, 2000

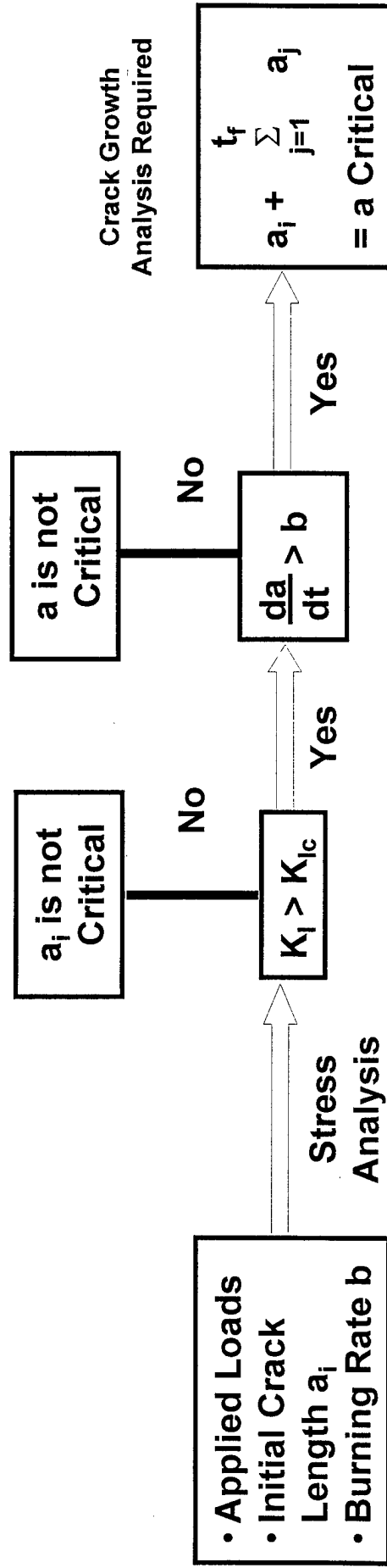
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Two Crack Failure Modes in Solid Rocket Motors



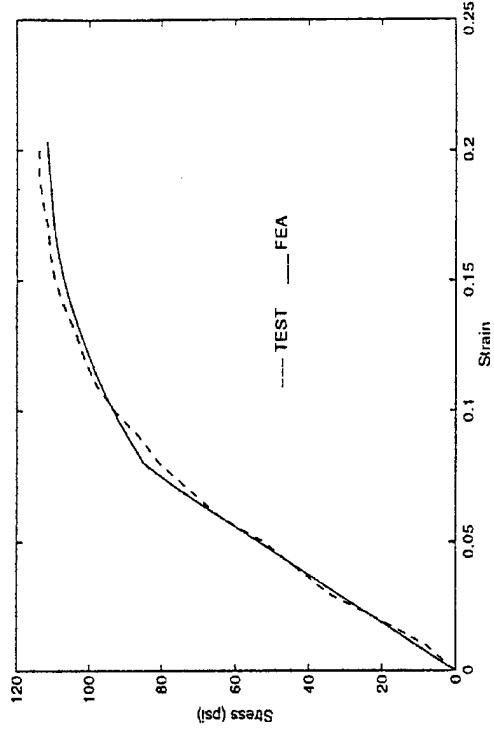
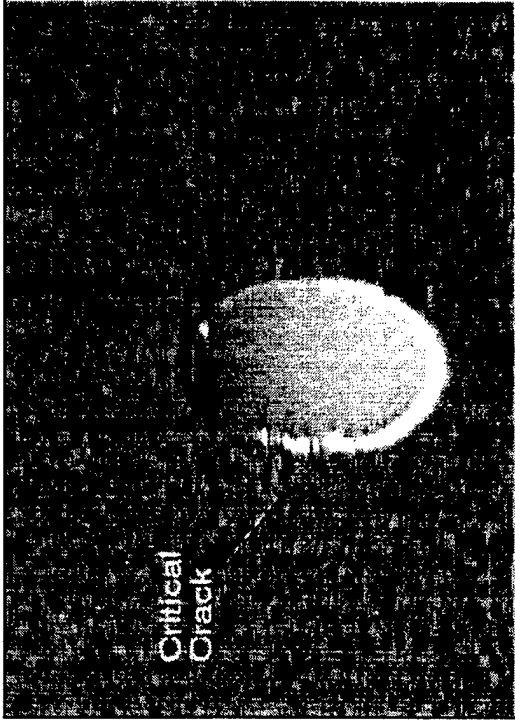
- Does Crack Propagate Under Service Loads?
- If the Crack Propagates, How Does it Propagate?





Good Correlation Exists Between the Predicted and the Measured Crack Initiation Load and the Initial Crack Length

- Based on a Micro-Macromechanical Model and a Stress Instability Criterion, the Predicted and Measured Average Initial Crack Lengths are 1.2 mm and 1.0 mm for $D = 0.25$ inch Hole and 1.5 mm and 1.3 mm for $D = 0.5$ inch Hole.

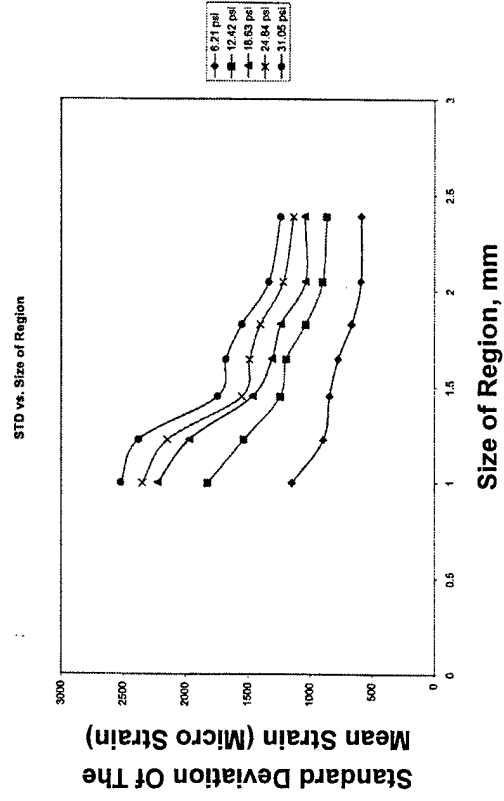
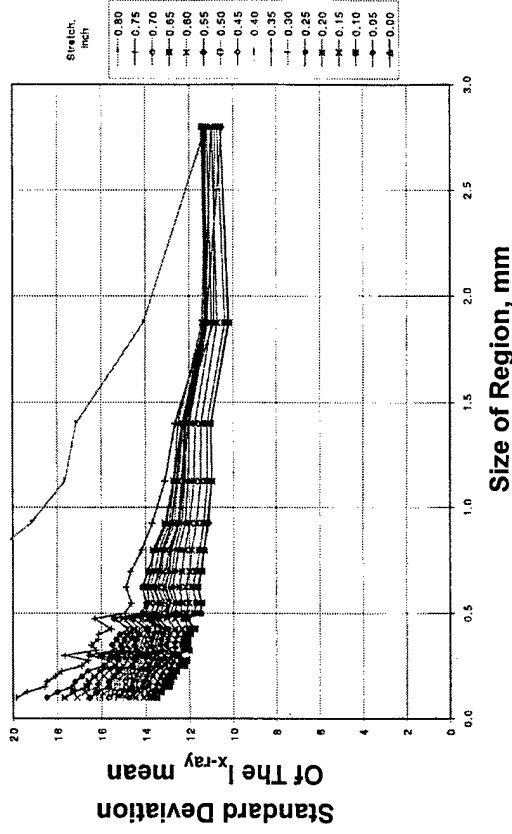


Stress-Strain Curve at Strain Rate 0.02/min

There Exists a Representative Area for a Valid Continuum Assumption of Solid Propellant



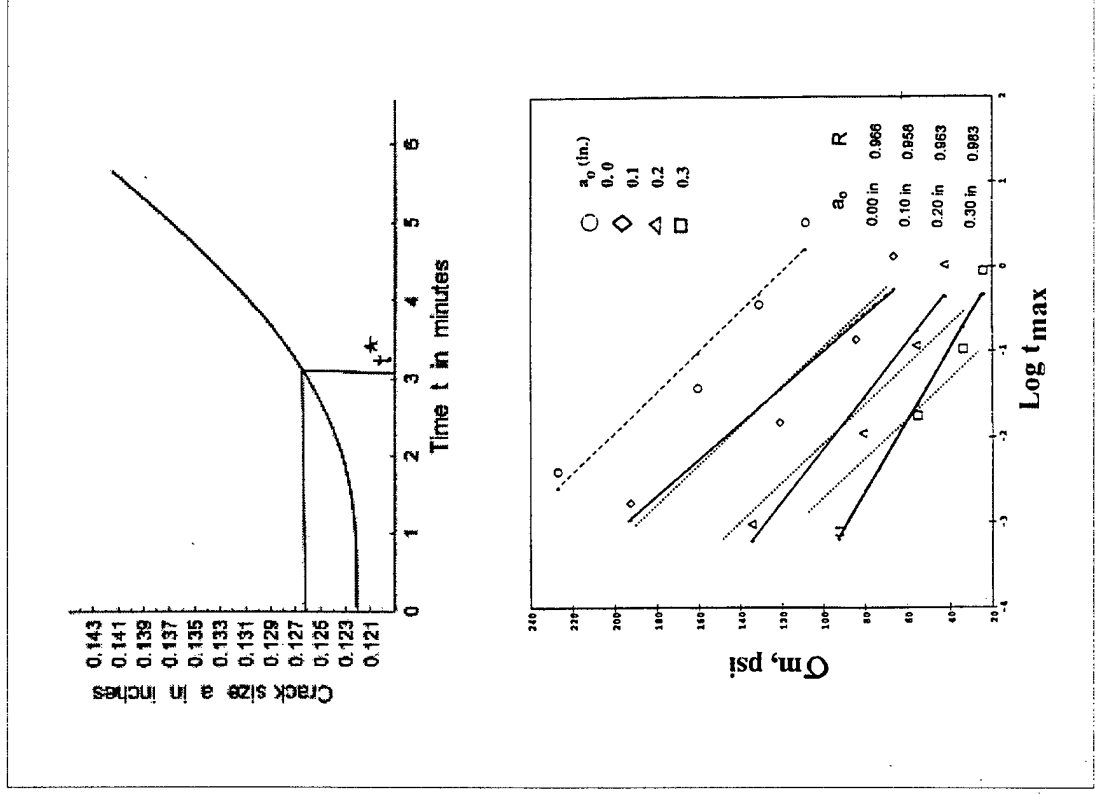
- Based on micro-measurements, the representative area is 2 mm x 2 mm.
- The existence of the representative area provides a basis for conducting stress analysis of solid rocket motors from nondestructive testing data.





A Technique is Developed to Predict the Initial Crack Length in Solid Propellants

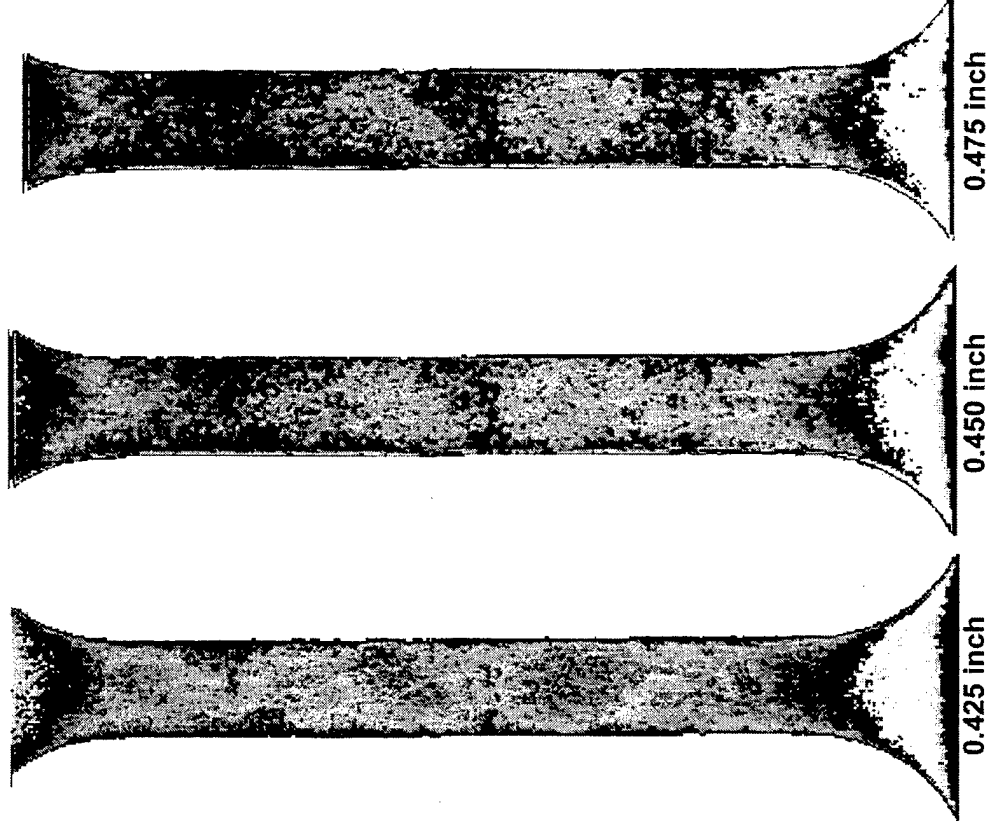
- Based on fracture mechanics and fracture data, the predicted and the estimated initial crack lengths are 3.3 mm and 2.5 mm, respectively.
- The initial crack size follows the second asymptotic distribution of the maximum value.
- The determination of the statistical distribution function of the initial crack makes statistical analysis of crack growth feasible.



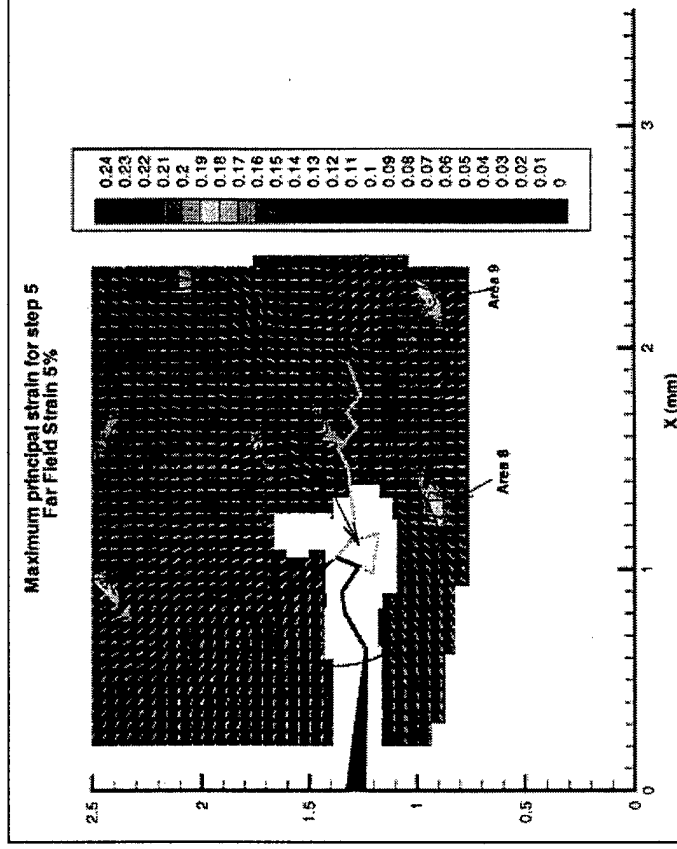
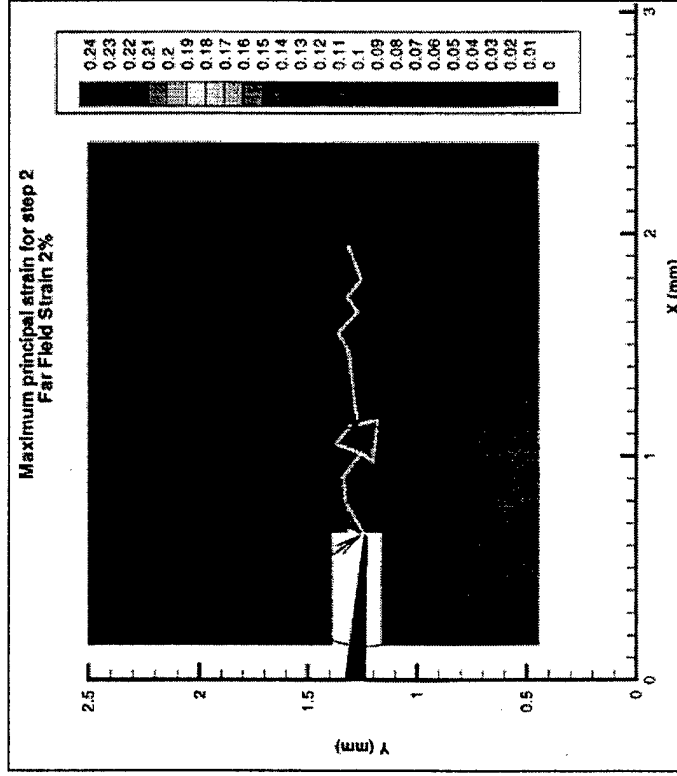
The Inhomogeneity of Microstructure Plays a Key Role in Crack Initiation and Growth



- Non-propagating cracks are formed in weak regions with a mean crack length of 1.5 mm
- In general, a critical crack is formed by the coalescence of small non-propagating cracks with an average critical crack length of 3.15 mm



Microstructure Induces a Large Inhomogeneous Variation in the Strain Field Near the Crack Tip

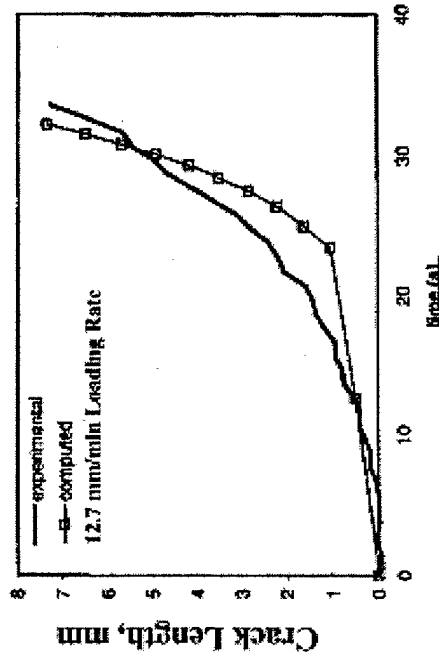
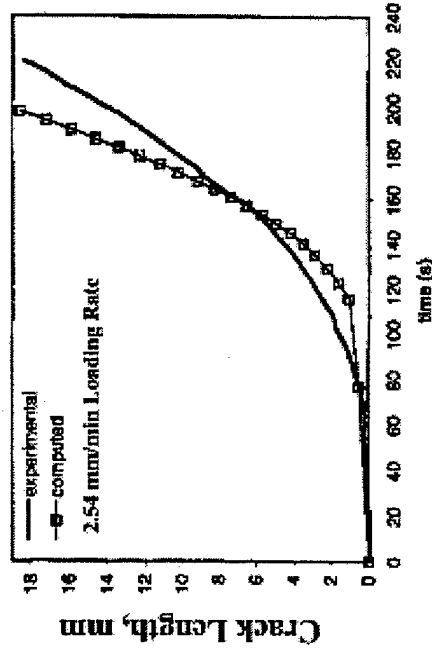


- The Interaction Between Large Deformation and Crack Propagation Process Localizes around The Crack Tip Regions

The Predicted Crack Growth Behavior Compares Well with Experimental Observation



- The variation of the strain rate near the crack tip was included in computer simulations of crack growth.
- The realistic modeling of crack growth can be a useful tool in predicting service life of solid rocket motors





Critical Defect Assessment (CDA) Program Introductory Information



Objectives:

Enhance the capabilities of the existing service life prediction methods of the Structural/Ballistic Analysis System (SBAS) in three areas:

- Fracture mechanics**
- Coupled analyses between structural mechanics and Computational Fluid Dynamics (CFD) codes**
- Automated geometric modeling of known flaws using non-destructive evaluation (NDE) data**



CDA Task 1: Fracture Mechanics



Objectives:

Conduct exploratory development effort to enhance existing fracture mechanics models of:

- Development of the initial crack - its geometry and size (continuum failure)
- Growth initiation threshold
- Fracture growth propagation -- the direction and speed of propagation

Develop algorithms for building fracture modules into existing capabilities, such as SBAS



CDA Task 1.1: Initial Crack Development



Analytical Methods:

- **Coalescence of local load-induced damage zones forms a crack**
 - **Continuum failure criterion will be used to determine when local material elements will fail**
 - **Experimental data will show the contour of the damage zone formed by coalesced failed elements**
 - **The coalesced damage zone represents the initial crack**
- **When possible, the micromechanics model in the SLPT program will be employed**

CDA Task 1.2: Crack Growth Initiation Threshold or Onset



Crack Growth Initiation Threshold or Onset

- The predictive method on this subject is reasonably developed (e.g. NASA SPIP, AF S/BRAM programs)
- The analysis method is built upon a linear elastic model. Exploratory effort on using non-linear viscoelastic (NLVE) models are also being examined
- Fracture mechanics parameters, stress intensity factor (K), strain energy release rate (G), and the J-integral, are interchangeably used
- Satisfactory predictions of crack and debond growth onsets have been made (e.g. CPIA publications)

CDA Task 1.3: Crack Growth Propagation



Characteristic Relationship Between Crack Speed and Stress Intensity Factor "K"

