Consequences of Fracture

Aloha Airlines 737
April 1988
Hawaii
Consequences of Fracture

United Airlines DC-10
July 1989
Sioux City, Iowa
NASA Fracture Control Requirements

  - Establishes requirements for fracture control of all NASA manned spaceflight systems and payloads on manned spaceflight systems
  - Mandatory for manned systems; optional for unmanned systems
  - Fracture control process includes non-destructive evaluation as well as analyses of fracture-critical parts
  - Fracture mechanics & fatigue crack analysis software package NASGRO meets the analysis requirements
**NASGRO® Reduces Risk**

- Fracture mechanics & fatigue crack analysis software
  - Provides optimal design of fracture-resistant structures
    - Determines safe stresses for a specified lifetime
  - Provides specification of fracture control plans at the design stage
    - Determines safe lifetime for a specified design
    - Determines required inspection intervals (if any) to maintain safety
  - If damage is discovered...
    - Determines safe remaining life (if any)
    - Determines required inspection intervals (if any) to maintain safety
  - Accurately simulates crack growth and failure in real structures
    - Calculate fatigue crack growth rate and remaining life
    - Calculate conditions (loads, crack sizes) that cause failure
NASGRO® Use Inside NASA
NASGRO® Components: Crack growth module

- Calculate fatigue crack growth or component life, critical crack sizes, or stress intensity factors for a library of 50+ different crack configurations
- Multiple crack growth equations
- Elastic-plastic crack growth analysis
NASGRO® Components: Material property module

- Store, retrieve, and curve-fit fatigue crack growth and fracture data
- NASA database:
  - 476 different metallic materials
  - 3000 sets of fatigue crack growth data
  - 6000 fracture toughness data points
  - Statistically-derived crack growth equations for all materials
- Users can create their own database
Typical NASGRO® analysis:
Crack growth or component life calculation

- **Problem:**
  - Actual crack or flaw is reported in component
  - Hypothetical flaw: assume worst-case scenario based on applied loading, component geometry, and crack location

- **Analysis input:**
  - Crack and component geometry
  - Component material
  - Load type and spectrum

- **Analysis results:**
  - Fatigue crack growth rate and remaining life
  - Conditions (loads, crack sizes) that cause failure
  - Safe stresses to attain a specified lifetime
  - Component inspection intervals for safe operation
Objective: To determine the service life of the Shuttle Orbiter flowliners containing cracks by using a fracture-based assessment to account for crack propagation.
Problem: Flowliner crack geometry not easily represented by any of 50+ standard cracks in NASGRO crack library.
Solution: Use NASGRO's Boundary Element Analysis module for its
- CAD-like drawing tools to custom-build crack model
- Computational core to calculate crack driving force $K$
NASGRO Sample Application:
Orbiter feedline flowliner crack analysis

- NASBEM results used in concert with other tools (e.g. NASTRAN structural analysis code) to determine:
  - crack growth between flowliner holes as function of flight service history
  - flowliner service life
Summary and Challenges for the Future

- NASGRO® reduces the risk of fracture
- NASGRO is used extensively around the world
  - Standard code for analysis of space hardware for NASA and its international partners
  - Supported and used by DoD, FAA, and private industry in aircraft, rotorcraft, turbine engines, and many others

- Spaceflight systems for future space missions will use innovative materials and methods of construction
  - New materials will require testing and characterisation for their properties for use in fracture analyses
  - New systems, components, configurations, and manufacturing techniques will need to be certified for flight