Course FAT
Fatigue, Damage Tolerance, & Airworthiness of Aging Aircraft

Course Summary

This course is **offered by Fatigue Concepts** at Abaris' Reno, NV facility. It is designed for anybody interested in learning about aging aircraft, metal fatigue, corrosion, and many other related issues.

Please visit this link to enroll: **https://flipt.wufoo.com/forms/fatcon-enrollment-and-payment-form-4-day-course/**

Introduction

Topics

- **Prologue**
- **Cost of Fracture**
- **The Danger of Metal Fatigue**
  - Early transportation failures from centuries past
    - Bridges
    - Trains
    - Titanic and Liberty ships
    - Wright Flyer, Comet, …
    - F-111 crash
  - What is a Failure? USAF-Navy-FAA-NASA Guidelines
  - Structural Failure Modes
  - Environmentally induced and/or time-dependent failure modes
    - Creep, Fatigue, Corrosion, Wear, Fretting, Hydrogen Embrittlement
  - Synergistic processes
    - Corrosion fatigue, fretting fatigue, SCC, high temperature fatigue
  - Why High Strength materials are weak in fatigue!
  - Crack Initiation and Propagation
  - Design Strategies to combat Metal Fatigue
    - Safe Life
      - Safety Factor fantasies
    - Fail Safe
      - 1. Crack Arrest
      - 2. Multiple Load Path (Structural Redundancy)
      - Design for inspectability
- **Fractography**
  - What does a fatigue crack look like?
  - Macro and Micro Aspects
  - Striations and Beach Marks
  - Quantitative and qualitative use
    - Ratchet lines
  - Marker cycles
  - Guides on using Fractography
  - Scanning Electron Microscope
  - Use of fractography to perform failure analysis
- **Stress Concentration K_t, Finishes**
  - Stress Concentrations
    - Load Flow Lines (Streamlines): a useful analogy
  - Surface finish
    - Pitfalls in grinding
    - Chrome-plating dangers, zinc and other platings
  - Size effects
    - Leonardo da Vinci
    - Similitude or lack thereof
  - Scatter, Reliability
  - High Temperature Effects
- **Fatigue Life Prediction**
  - Cycle parameters
    - Range, amplitude, mean stress, R ratio
  - S-N Curves
    - Endurance Limit is largely a myth: Use Fatigue Strength
    - Fatigue Strength
    - Mean stress effects
    - Constant Life Diagrams, Haigh Diagrams
  - Low cycle fatigue
    - Neuber’s Notch strain analysis
  - Miner’s Myth
    - Extremely limited applicability and lack of defensibility
    - It is not a RULE
  - Fracture Mechanics
    - Griffith Criterion
    - George Irwin, Naval Research Lab: Father of Fracture Mechanics
    - Stress intensity factor SIF K_I
    - Beta factors
    - Residual strength
    - Fracture toughness
      - Effect of thickness, orientation, impact, temperature

            - Dynamic fracture toughness and crashworthiness
        - Crack propagation
        - Thresholds
        - Inspection intervals
        - Classroom problem-solving exercises
        - NDE, detectable crack sizes
            - Visual, eddy current, radiographic, ultrasonic, penetrant, magnetic particle
            - Applicability, comparison
            - POD (Probability of Detection)
            - Reliability of Inspections
            - Case Study: MD-88 uncontained engine failure
        - Initial quality, EIFS equivalent initial flaw size
        - Multiaxial stresses, Mixed mode cracking
    - Short cracks
        - Can be deadly
    - Classroom tutorials in Fracture Mechanics
        - Rigorous, parametric evaluations of various interconnected variables: fracture toughness, initial flaw size, inspection interval, fastener holes, corrosion effects, coldworking, shot-peening, da/dN, material properties C, m, …
    - Damage Tolerance
    - MIL-A-83444 -> MIL-A-87221 -> JSSG2006
        - 1. Fail-safe structure
            - Arrest of a rapidly running crack
            - Safe partial failure of a load path
                - Skin-stringer partnership
                - Titanium crack stoppers
        - 2. Slow crack growth structure
            - Degree of inspectability
        - Initial flaw assumptions
    - Retardation Models
        - Willenborg
        - Wheeler
        - Closure
        - Onera…
    - Continuing damage
    - ASIP, IATP
- **Environmentally Assisted Cracking**
    - Corrosion Fatigue
        - Effect of frequency, waveform, hold-time, …
    - Stress Corrosion
        - K_{Iscc}
        - SCC ratings for aircraft alloys
        - Case study: SCC of a High Strength Steel Frame in a USNavy Fighter
    - Fretting Fatigue
        - How surface finish, similar materials in contact, slip amplitude, temperature, and environment affect Fretting Fatigue
    - Contact fatigue
        - Gear failures
    - Aging aircraft issues
        - Durability vs Damage Tolerance
        - Multi-Site Damage, Widespread Fatigue Damage
        - The Aloha accident
        - Continued airworthiness
        - Supplemental inspection programs
        - Limit of Validity (LOV)
- **Testing for Substantiation and Data accumulation**
    - Cycle Counting methods
        - Rain flow method
    - In-flight loads monitoring
    - Testing
    - Coupons, specimen, component, and Full-Scale
        - Standardized Testing
        - Coupon preparation, precracking guidelines
        - E-399 K_{Ic}
        - E-647 da/dN
        - Service duplication Testing
        - Environmental chambers
        - Time compression issues in corrosion fatigue testing
    - Load Spectrum Generation
        - Canned Spectra
            - TWIST, MINITWIST, TURBISTAN, HELIX, FELIX, …
        - Sequence effects

        - Truncation, clipping
    - Scatter, Reliability, Risk management
        - Weibull Paper, Example problem
    - Material Properties & Useful Data handouts and Sources
        - S-N curves
        - Crack initiation data
        - da/dN crack growth data
        - Fracture Toughness K_cs
        - Data sources and handbooks
        - Journals
- **Special Topics (Optional)**
    - Cracking in aircraft engine components
        - ENSIP
        - Sioux City DC-10 crash landing
        - Thermo-mechanical Fatigue
    - Creep Fatigue
    - Thermal Fatigue
        - Concorde
    - Sonic fatigue (Acoustic Fatigue)
    - Fatigue of composites
        - Polymers
    - ARALL, GLARE and other newer materials to fight fatigue
- **Do’s and TABOOs**
    - Methods to improve fatigue resistance
    - Clever use of favorable residual stresses
        - Cold-working of holes
        - Shot Peening
        - Residual Stress control measures
    - Bolts, Rivets, Springs, Bearings, Welds, …
    - Failure Analysis: useful learning tool
        - Care and handling of fractures
    - Repair techniques
        - Japan Air Lines 747 crash
    - “stop”-drill?
    - Helpful treatments and processes
        - plating
    - Hi-Tigue and other fatigue rated fasteners
    - Guidelines based on experience
- **Epilogue**
- **No highway**

Course Benefits

Attending Delegates will

• Gain solid understanding of the fundamentals of Metal Fatigue, Corrosion, and Aging Composites

• Receive knowledge and tool that'd enable them to operate aging fleet of aircraft and helicopters in an economical, yet safe fashion

• Study very practical case histories in a relaxed setting with interactive facilitation and be able to learn extremely valuable and real-life lessons

* Understand technical expertise required to minimize the probability of a catastrophie or accident

* Perform in-class fracturem mechanics calculations with instructor's individual attention

Prerequisites

None

Teaching Method

Classroom instruction

CEU