



## 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
    - $K_{Isc}$
    - SCC ratings for aircraft alloys
    - Case study: SCC of a High Strength Steel Frame in a US Navy 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  $K_{Ic}$ s
  - 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 catastrophe or accident
- \* Perform in-class fracture mechanics calculations with instructor's individual attention

## Prerequisites

None

## Teaching Method

Classroom instruction

## CEU