Multiaxial Fatigue and Fracture Analysis Computational Aspects

Lecturer : Domenico Quaranta

(MSc, Aerospace Engineering – Pilatus Aircraft Chief Structural Engineer Trainers Department)

Abstract

The principal topics involved in Fatigue and Damage Tolerance assessments based on FEM are discussed.

The seminary opens (Introduction) with a short description of what a fatigue failure is and what are the main design criteria against fatigue (Safe Life, Fail Safe, Damage Tolerance).

The Uniaxial fatigue analysis, crack initiation, process is described, highlighting the main 'actors': stress concentration and notch factors, rainflow counting, cumulative damage, stress based and strain based approaches (S-N and ε-N curves). The Neuber and Glinka's Equivalent Strain Energy Density methods are shown for the calculation of the elastic-plastic stress-strains. The principal sequence effects induced by plasticity are shown.

The central part of the seminary provides an insight of the main challenges involved in a FEM assisted fatigue analysis, typically in multiaxial regime, are introduced. An overview on most commonly used approaches and parameters is given. A description of the principal issues involved in Cyclic Plasticity are described. In particular the Critical Plane approaches with fatigue parameters of Brown-Miller, Fatemi-Socie, Smith-Watson-Topper are described, with elastic-plastic stress tesnor sequence derived with the Pseudo-Material approach of Köttgen-Barkey-Socie, in combination with the Mroz-Garud Multi-Yield Surface cyclic plasticity model.

Finally the fracture mechanics and crack growth aspects are discussed. The concepts of Linear Elastic Fracture Mechanics are deployed and Stress Intensity Factors are introduced. Some of the methods to calculate SIFs from FEM, with their own pro and cons, are shown (emphasis on J-Integral and quarter point FEM elements). Crack growth models (Paris, Walker, Nasgro) are shown and the algorithm to calculate crack growth life curve is briefly discussed. Some basic topics on crack closure and retardation effects are shown.

Note: the lecturer has extensive experience in computer coding and all the topics are discussed with emphasis to the computational aspects.

Duration : 3 hours

Language: English, Italian

Table of Contents (Preliminary)

Curriculum Vitae - Domenico Quaranta

Domenico Quaranta has extensive experience in the following fields:

- Stress Analysis, with both standard practice hand calculation and FEM
- FEM numerical methods (vast experience with NASTRAN)
- Fatigue Analysis, with standard methods (hand calculation) and FEM assisted methods
- Crack Growth and Damage Tolerance, with standard methods and FEM assisted methods
- Computational Fracture Mechanics
- Computer coding

From 2006 to now

- *Pilatus Aircraft Ltd. (Stans, Switzerland)*
  - Chief Stress Engineer for the Pilatus Trainers Engineering Structures Department (supporting the products PC-7, PC-9, PC-9(M), PC-MkII, PC-21).
  - Leader of the Fatigue Specialists Group.
  - Stress signatory authority for design.
  - Personnel trainer (static analyses using both FEM and hand calculation and for fatigue and damage tolerance analyses).

  Relevant projects:

  - PC-7MkII Trainer Life Extension: +50% Landings
  - PC-9 Aft Fuselage Relifing: FEM assisted Fatigue Analysis aimed to justify/calibrate structural integrity and inspection regimes
  - Several re-design optimization aimed to improved durability

From 2000 to 2006

- *Client SICAMB-EUROCOPTER (Latina, Italy – Donauwörth, Germany)*
  Responsible for the preliminary sizing and the stress analysis methodology definition of the AIRBUS A-380-800F Main and Upper Deck Cargo Doors.

- *Client AERMACCHI (Varese, Italy)*
  Analysis, support to design, and certification reporting of the AIRBUS A-380 Trent 900 Nacelles (both Fixed Fan Duct and Thrust Reverser configurations)

- *Client AERMACCHI (Varese, Italy)*
  Analysis and design of the M-346 front fuselage structures work package: stress analyses of frames and bulkhead frames, spars and longerons, stringers, metallic and composite skins and panels, brackets, junctions.

- *Client ALENIA SPAZIO (Torino, Italy)*
  Analysis and design of the MDPS (Meteoroids and Debris Protection System) of the International Space Station – Node 2: stress analysis of mixed composite and metallic structures having “external shield” requirements for space debris and extra vehicular activities.

Education

- MSc - Aerospace Engineering at Politecnico di Torino, marks 110/110, in 1998.
- Computational Fracture Mechanics Advanced course at Cornell University (NY – USA)
- Fatigue – Numerical aspects by G.Glinka (University of Waterloo, Canada)