DURABILITY AND LIFE EXTENSION

October 9th 2003 – NOORDWIJK - NL

FENET Workshop

MODELLING FATIGUE OF METALS

DLE

BACKGROUND

Four previous workshops on the FENET technology theme of Durability and Life Extension:

- **Contact analysis (Copenhagen, February 2002),**
- **Structural integrity (Zurich, June 2002),**
- **Fracture and crack growth (Trieste, September 2002),**
- **Finite Element Simulation of Welds and Joints (Barcelona, February 2003).**

Modelling the fatigue behaviour of metals of fatigue was confirmed as a major problem and it was decided to held a further meeting, Oct. 2003

Workshop Objectives (I)

- To provide an overview of current practice in modelling fatigue of metals using FE analysis.

- To identify current limitations and difficulties in FE modelling of metals fatigue .

- To create the opportunity of a mutual sharing of experiences, either successful or unsuccessful, for increasing the degree of competence and awareness on the topic.\

Workshop Objectives (II)

- To provide a forum for discussion on “Guidelines” and “Best Practice ”on using FE in modelling Fatigue of Metals.
- To present current techniques and advances in Modelling Fatigue of Metals.
- To discuss the need for benchmarks for the FE modelling of metals fatigue.
- To propose a set of actions to be adopted by the users and the software developers to solve the problems and spread the adoption of FE simulations in the field of FE fatigue analysis of metal components.

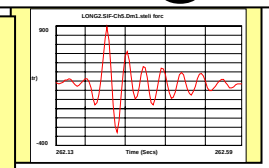
Modelling fatigue of metals

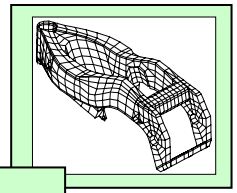
Analysis of the state of the art

- **General overview of modelling of metals fatigue by FE analysis.**
- **Modelling fatigue behaviour of metals and comparison with experiments.**
- **Modelling multiaxial fatigue problems in metals.**
- **Modelling notch, surface, heat treatments and size effects in the fatigue behaviour of metals and components.**
- **Modelling crack initiation and crack paths during fatigue in metals.**
- **……**

Fatigue Life Prediction

LOADS
- Mission
- Load components
- Load spectrum
- Special events





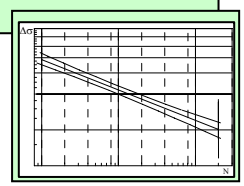
GEOMETRY
- Shape
- Dimensions
- Notches

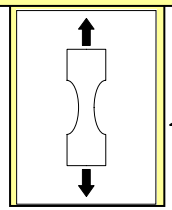
STRESS STRAIN ANALYSIS
- Analytical method
- Numerical method
- Experimental Strain analysis

MODELLING FATIGUE OF METALS
- Stress/ Life **σ-N**
- Load / Life **P-N**
- Strain / Life **ε-N**
- Fatigue Life Prediction

MATERIAL
- Fatigue basic properties
- Heat treatments
- Surface treatments
- Residual stresses

FATIGUE TESTS
- Material
- Components

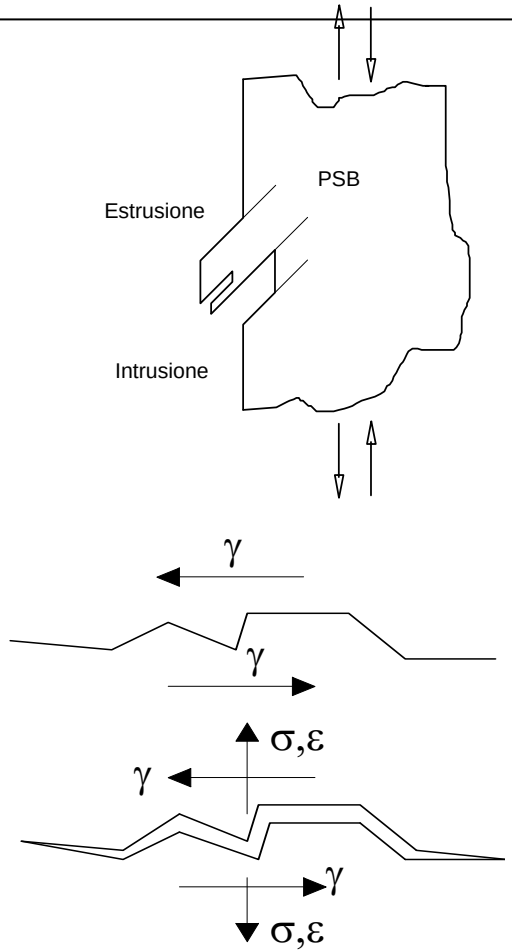




EXPERIMENTAL VALIDATION
- Standard Constant Amplitude tests
- Variable Amplitude tests
- Multi-Channel Variable Amplitude tests

OPTIMIZATION
- GEOMETRY
- MATERIAL
- (LOADS)

Multiaxial fatigue: experimental evidences



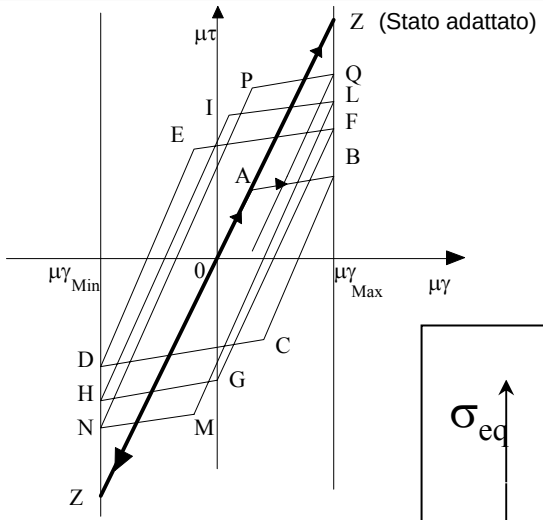
Evidences:

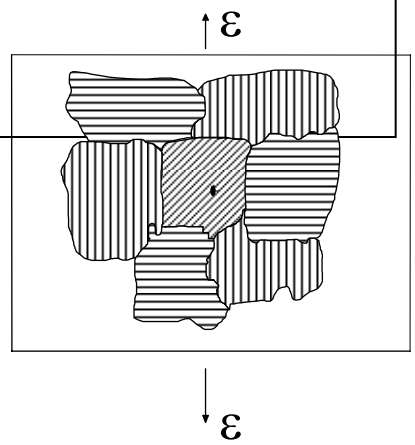
- Out-of-phase σ and τ stress (strain) components are more damaging than in-phase.
- In torsion fatigue, a mean tensile load reduce fatigue life. In bending fatigue, the presence of a mean torsion load is not reducing fatigue life.
- Crack nucleation is in shear and is related to a critical plane subjected to maximum shear stress (strain) amplitudes.
- Normal stress (strain) on the critical plane reduces fatigue life if tensile.

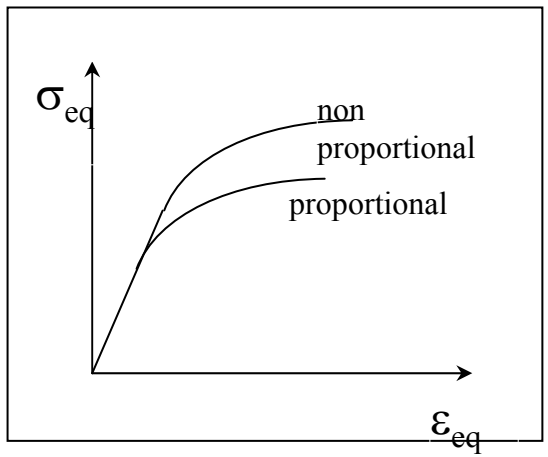
Modelling multiaxial fatigue

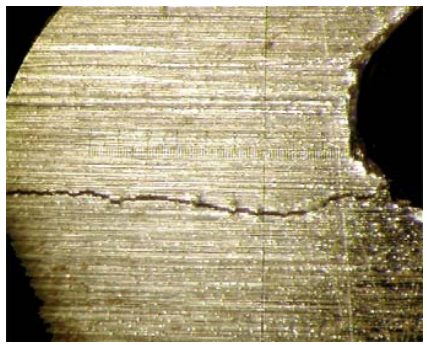
Correct model should be able to take into account:

- **Crack initiation (shake down)**
- **Incremental plasticity model**
- **Non-proportional strain hardening**
- **Crack paths during propagation**







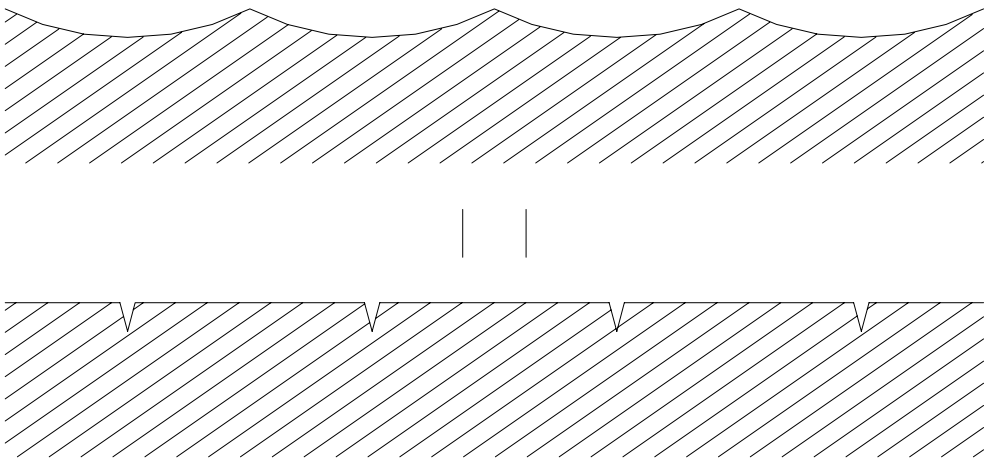


D.F. Socie, G.B. Marquis, "Multiaxial fatigue", SAE International, 2000.

Modelling surface effects in the fatigue behaviour of metals.

- Equation valid for a series of notches or cracks
- Surface roughness as a series of cracks

$$\sigma_{a\infty} = \frac{1{,}43\left(Hv+120\right)}{\left(\sqrt{area_R}\right)^{1/6}}$$

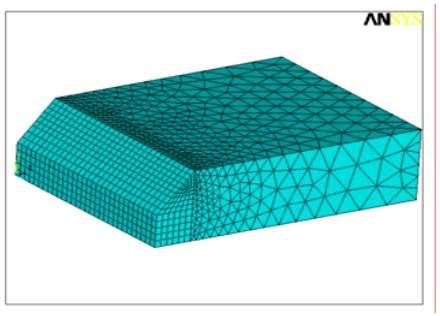


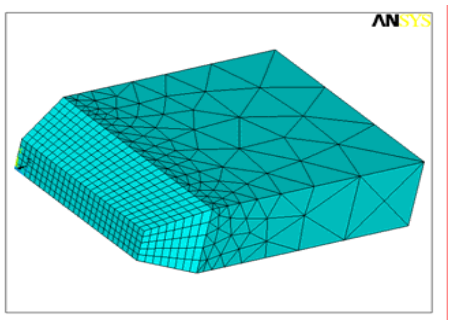
H_v= Vickers hardness

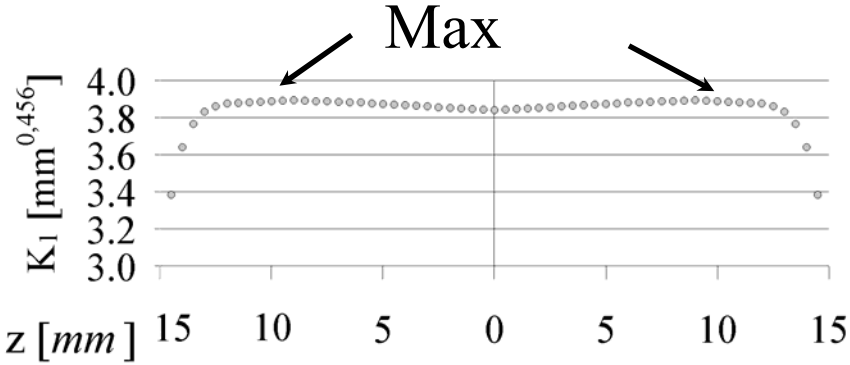
$\sqrt{area} < 1000\ \mu m$

Y. Murakami "Metal Fatigue. Effect of small defect and non metallic inclusions" ELSEVIER 2002

Modelling crack initiation and crack paths during fatigue in metals.







$$\eta = \frac{K_1}{\sigma_p} \qquad \eta = 0{,}87\ mm^{0{,}456}$$

Courtesy: Atzori-Meneghetti, 2003

Modelling fatigue of metals

Technical advances

- **Development of “Guidelines ”and “Best Practice ” on using FEA in fatigue of metal components.**
- **Development of FE fatigue benchmarks for metal components.**
- **Integrating materials fatigue database, load history data and fatigue life prediction tools in FE codes.**
- **Implementing FE solutions in fatigue design codes for metals.**
- **……..**

Workshop program

- **RECENT DEVELOPMENTS IN 3D FATIGUE CRACK GROWTH PREDICTION USING THE FINITE ELEMENT METHOD**

Ramesh Chandwani, ZENTECH INTERNATIONAL LTD.,UK

- **INFLUENCE OF TRANSIENT AND RATE DEPENDENT EFFECTS ON THE ESTIMATED LIFE TIME OF LIQUID ROCKET COMBUSTION CHAMBER WALLS**

Jörg Riccius – DLR e.V., Germany

- **FATIGUE OF WELDED STRUCTURES**

Paul Melleney– CAE, nCode International Ltd.

- **Discussion**
- **A REVIEW OF FE CONTACT BENCHMARKS**

Adib A. Becker, University of Nottingham