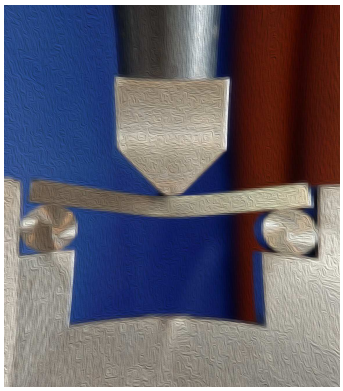
The Italian Scientific Society of Mechanical Design

PhD Summer School AIAS

Non-linear behaviour of materials
Theory and Applications

Ferrara (Italy)
June 13-16, 2016



University of Ferrara

università di ferrara
DA SEICENTO ANNI GUARDIAMO AVANTI.

In collaboration with:

IUSS - Ferrara 1391

LIMES
LAB INTEGRITY MECHANICAL STRUCTURES
DEPT OF ENGINEERING UNIFE.IT

Non-linear behaviour of materials
Theory and Application

AIAS Summer School
For PhD students and young researchers
Ferrara, June 13-16, 2016 – AIAS (The Italian Scientific Society of Mechanical Design)

	Monday	*Tuesday*	*Wednesday*	*Thursday*
	June 13, 2016	June 14, 2016	June 15, 2016	June 16, 2016
		9:30-13:00	9:30-13:00	9:30-13:00
morning		***Prof N. E. Dowling***	***Prof N. E. Dowling***	***Prof. G. Mirone***
				Experimental approches
		Low cycle fatigue	*Creep, non linear fracture mechanics*	***Ing. S. Filippi***
				Industrial cases studies
	14:00 *Registration, Opening of course*	13:00 – 14:00 *lunch*	13:00 – 14:00 *lunch*	13:00 – 14:00 *lunch*
afternoon				
	14:30-18:30	14:30-18:00	14:30-18:00	14:00-16:30
	Prof F. Berto	***Prof. M. Vormwald***	***Prof. S.A. Meguid***	***Prof. L. Vergani***
	General introduction			
	Prof. P. Livieri			
	Introduction to non-linear behaviour of materials	*Non linear simulations in welded structures*	*Numerical applications*	*Final test and Ph.D.* activity *presentation*

Conference Venue, IUSS – Ferrara 1391 - via delle Scienze, 41/B

Local Organising Committee

Prof. F. Berto – *Università di Padova*
Prof. P. Livieri – *Universita di Ferrara*
Prof. R. Tovo – *Universita di Ferrara*
Prof. L. Vergani – *Politecnico di Milano*

Secretary

Prof. P. Livieri
Engineering Department of Ferrara
University of Ferrara
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Program of Monday 13 June

Monday Afternoon

Prof. Filippo Berto
Università di Padova-Italy
14:30 – 15:00 **Introduction to the course**

In this opening lecture, an introduction to the summer school topics is provided. The aims and the outline of the school are presented.

Prof. Paolo Livieri
Università di Ferrara-Italy
15:00 – 18:00 **Introduction to non-linear behaviour of materials**

The subject of the lecture will be divided into two parts: in the first part will be recall many fundamentals topics, in the second an introduce to the non-linear behaviour of material will be made. Finally, a more detailed section will be dedicated to autofrattage.

General topic:
-Introduction to fatigue
-Palmgren-Miner rule
-Rainflow cycle counting
-Cyclic stress-strain and strain-life curves
-Linear-elastic fracture mechanics
-Linear-elastic stress intensity factor
-Fracture toughness concept, testing in linear-elastic regime
-J-Integral

Elementary plasticity:
-monoaxial cases
-Neuber's rule for notch stress-strain
-Yield criteria of metals
-Hardening Role
-Flow rule
-Prandlt-Reuss equations

Autofrettage:
-loading phase
-unloading phase
-residual stresses

Program of Tuesday 14 June

Tuesday Morning

Prof. Norman Dowling
Virginia Tech-USA
9:30 – 13:00 **Advanced testing in the automotive industry: evolution of metallic material characterization**

Low Cycle Fatigue - Part 1
- Introduction
- Palmgren-Miner Rule
- Cycle Counting

Student Exercise: Cycle counting for Ex. 9.9

Low Cycle Fatigue – Part 2
- Plastic Deformation Behavior and Models
- Local Stress-Strain Estimates at Notches

Student Exercise: Cycle counting for Ex. 14.4
Student Exercise: Do Prob. 14.44(a)

Low Cycle Fatigue – Part 3
- Strain-Based Approach to Fatigue
  - Strain-Life Curves
  - Mean Stress Effects
  - Life Estimates for Structural Components
  - Discussion

Student Exercise: Do Prob. 14.44(b)

Tuesday Afternoon

Prof. Michael Vormwald
Technische Universität Darmstadt-Germany
14:30 – 18:00 *Non linear simulations in welded structures*

1 Introduction - Approaches for the assessment of fatigue of welded joints
1.1 Nominal stress approach1.2 Structural stress approach
1.3 Local stress approach
1.4 Local strain approach
1.5 Fracture mechanics approach
2 Overview of the Local Strain Approach
2.1 Deformation behaviour
2.2 Damage behaviour
2.3 Application example for welded joints
3 Fracture mechanics based approach according to the IBESS procedure
3.1 Mechanically and physically short cracks
3.2 Cyclic R curve
3.3 Initial crack size and its statistical distribution
3.4 Varying local geometry
3.5 Residual stresses
3.6 Stress intensity factors and cyclic Delta J-intergral
3.7 Validation examples

Program of Wednesday 15 June

Wednesday Morning

Prof N. E. Dowling
Virginia Tech -USA
9:30 – 13:00 *Creep, non linear fracture mechanics*

Creep - Time-Dependent Stress-Strain Behavior
- Introduction
- Creep Testing
- Physical Mechanisms of Creep
- Time-Temperature Parameters and Life Estimates

Student Exercise: Do Prob. 15.18(a), (b), and (c)

Fracture Mechanics – Part 1
Introduction to Linear-Elastic Fracture Mechanics (LEFM)
- Mathematical Concepts
- Application of *K* to Design and Analysis
- Fully Plastic Yielding Loads

Student Exercise: Do Prob. 8.10

Fracture Mechanics – Part 2
Fracture Toughness Values and Trends
Non-Linear Fracture Mechanics
- Plastic Zone Size, and Plasticity Limitations on LEFM
- Extensions Beyond Linear Elasticity

Wednesday Afternoon

Prof. Shaker A. Meguid
University of Toronto-Canada
14:30 – 18:00 *Numerical applications*

In this lecture, an overview of numerical techniques to characterize the non linear behaviour of material is presented. Examples of non-linear FE analysis are presented.
- Theory in numerical non-linear FE analysis
- Numerical example of Engineering interest.

Program of Thursday 16 June

Thursday Morning

Prof. Giuseppe Mirone
Università di Catania -Italy
9:30 – 11:00 ***Experimental characterization of the nonlinear stress-strain behavior of metals***

In this lecture, a review of experimental techniques to characterize the mechanical behaviour of material at high strain rates is presented. In this session, a real experimental test will be presented in the classroom.

- Isotropic hardening. quasitatic and dynamic strain rates
- Engineering, True and
post-necking flow curves
- Experimental procedures for the quasistatic characterization
- Experimental procedures for the dynamic characterization
- Analysis of raw experimental data and derivation of flow curves

Tools for class exercises
- A laptop should be available for small groups of 2-3 students each;
- Installation of Microsoft Office and Autodesk Autocad is required;
- The freeware Virtual Dub can be downloaded @ http://www.virtualdub.org/

Ing. Stefano Filippi
OMERA-Vicenza-Italy
11:30 – 13-00 *Industrial cases studies*

The lecture will show an industrial application of advanced non-linear techniques in the field of materials and components:
- Local Elasto plastic stress fields: the HRR solution in closed form
- Fragile/Ductile behavior: experimental response of plane and round specimens
- Discussion on Static and fatigue behavior of bolt/nut connections: some practical examples

Thursday Afternoon

Prof Laura Maria Vergani
Politecnico of Milano –Italy
14:00 – 16:30 ***Final test and PhD activity presentation***