LIGHTEN

Ultralight membrane structures towards a sustainable environment

H2020-MSCA-ITN ◆ ITN - Innovative Training Network ◆ EID - European Industrial Doctorates

First Training School

Characterisation and modelling of structural membranes

6th – 8th September 2021
From 9:00 to 17:30 BST

Registration requests should be sent to: lighten.project@ucl.ac.uk

Time (BST)	Monday 6th	Tuesday 7th	Wednesday 8th
9.00 – 10.30	Introduction to nonlinear solid mechanics (F. Dal Corso - UNITN)	Linear and nonlinear viscoelasticity (F. Bosi - UCL)	An introduction to tensile structures (A. Bown - Tensys)
10.30 – 11.00	Coffee break		
11.00 – 12.30	Introduction to nonlinear solid mechanics (F. Dal Corso - UNITN)	Introduction to plasticity (M. Bessa - TU Delft) *starts at 10.45	Tension structures: worked examples and case studies (A. Bown - Tensys)
12.30 – 14.00	Lunch break		
14.00 – 15.30	Introduction to viscoelasticity (M. Bessa - TU Delft)	Plasticity and nonlinear material models (M. Penasa - CAEmate)	Virtual Lab: structural membranes characterisation (K. Suleman - UCL)
15.30 – 16.00	Coffee break		
16.00 – 17.30	Linear viscoelasticity (F. Bosi - UCL)	Plasticity and nonlinear material models (M. Penasa - CAEmate)	Virtual Lab: structural membranes characterisation (K. Suleman - UCL)

Organised by:

UCL, TENSYS Engineering • Analysis, University of Trento, CAEmate Engineering, Made Easy, TU Delft, sbp schlaich bergermann partner

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Monday 6th | 9.00 – 10.30 and 11:00 – 12:30 BST

Introduction to nonlinear solid mechanics
by *Francesco Dal Corso* – University of Trento

An overview will be given on the main aspects of nonlinear solid mechanics, with particular reference to:

- Kinematics and stress
- Constitutive equations, hyperelasticity
- Föppl–von Kármán model of plates

Reference:

- D. Bigoni (2012). *Nonlinear Solid Mechanics: Bifurcation Theory and Material Instability*. Cambridge University Press.

After earning a PhD in Materials and Structural Engineering at the University of Trento, Italy, Francesco Dal Corso won a postdoctoral fellowship at the Department of Applied Mathematics and Theoretical Physics, University of Cambridge. He is currently an Associate Professor of Solid and Structural Mechanics at the University of Trento. His research activity is devoted to the Mechanical behaviour of Solid and Structures. He has co-authored over 40 journal papers and has co-guest edited a Special Issue of the Journal of the Mechanics and Physics of Solids in 2020.

Monday 6th | 14:00 – 15:30 BST

Introduction to viscoelasticity
by *Miguel Bessa* – TU Delft

The lecture aims to give an introduction to the viscoelastic behaviour of engineering polymeric materials.
The following topics will be covered:

- Different classes of polymers: thermoset, thermoplastic and elastomers
- Characterisation of the mechanical response of viscoelastic materials: stress relaxation, creep and dynamic mechanical analyser (DMA) tests
- One-dimensional viscoelasticity and phenomenological models

Reference:

- D. Roylance (2001). *Engineering viscoelasticity*. Department of Materials Science and Engineering, Massachusetts Institute of Technology, Cambridge MA 2139: 1-37.

Miguel Bessa is an Associate Professor in the Materials Science and Engineering Department at Delft University of Technology. He is also the director of an inter-faculty Artificial Intelligence lab called MACHINA, dedicated to machine intelligence advances for materials design. In addition, he was the recipient of a Veni personal grant (2019). Prior to coming to the Netherlands, he was a postdoc scholar in Aerospace at the California Institute of Technology (2017), and received his PhD (2016) in MechEng at Northwestern University as a Fulbright scholar. He has 25 publications and envisions a new era in relation to the design of materials and structures through AI.

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Monday 6th | 16:00 – 17:30 BST and Tuesday 7th | 9:00 – 10:30 BST

Linear and nonlinear viscoelasticity
by *Federico Bosi* – UCL

The two lectures will cover the main aspects of engineering viscoelasticity, with a focus on the linear and nonlinear modelling of viscoelastic materials. Covered topics include:

- Mathematical models for linear viscoelasticity
- Hereditary integral and Boltzman superposition principle
- Time-Temperature Superposition Principle and shift factor
- Creep compliance and relaxation modulus master curves
- Introduction to nonlinear viscoelasticity
- The Schapery approach and the free volume model for nonlinear viscoelasticity
- Viscoelasticity for membrane materials

Federico Bosi is an Associate Professor in the Department of Mechanical Engineering at UCL. Prior to joining in 2017, he was a postdoctoral scholar (2015-2017) in the Space Structure Laboratory at the California Institute of Technology, USA. He earned his PhD degree (2014) in Engineering of Civil and Mechanical Structural Systems from the University of Trento, where he was a Marie Curie Early Stage Researcher in the Solid and Structural Mechanics Group. His research activity is devoted to studying the mechanics of solids and structures, with a particular interest in the nonlinear, time-dependent, and thermo-mechanical response of highly deformable materials and flexible mechanical systems.

References:

- H. F Brinson, L. C. Brinson (2008). *Polymer engineering science and viscoelasticity. An introduction*. Springer.
- I. M. Ward, J. Sweeney (2004). *An Introduction to the Mechanical Properties of Solid Polymers*. Wiley.

Tuesday 7th | 10:45 – 12:15 BST

Introduction to plasticity
by *Miguel Bessa* – TU Delft

The lecture aims to give an introduction to the plastic behaviour of materials.
The following topics will be covered:

- Yield criteria for ductile material in 2D and 3D
- Plastic flow and consistency condition
- Perfect plasticity and strain hardening materials

Reference:

- Hosford and Caddell (2006). *Metal forming: Mechanics and metallurgy*. Oxford university press. Chapter 2.
- Krabbenhoft (2002). *Basic computational plasticity*. Lecture Notes, chapter 2.

Miguel Bessa is an Associate Professor in the Materials Science and Engineering Department at Delft University of Technology. He is also the director of an inter-faculty Artificial Intelligence lab called MACHINA, dedicated to machine intelligence advances for materials design. In addition, he was the recipient of a Veni personal grant (2019). Prior to coming to the Netherlands, he was a postdoc scholar in Aerospace at the California Institute of Technology (2017), and received his PhD (2016) in MechEng at Northwestern University as a Fulbright scholar. He has 25 publications and envisions a new era in relation to the design of materials and structures through AI.

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Tuesday 7th | 14:00 – 15:30 and 16:00 – 17:30 BST

Plasticity and nonlinear material models
by *Massimo Penasa* – CAEmate srl

Two lectures aiming to provide an overview of the computational approaches for the modelling of materials nonlinearity and plasticity. They will cover the following topics:

- Elastoplasticity: yield function, hardening, softening, examples
- Thermoplasticity and viscoplasticity: thermal softening, rate-dependent analysis, examples
- Integration algorithms for plasticity: newton method, return mapping and custom numerical strategies
- Typical elastoplastic models
- Constitutive parameter identification by multi-objective optimisation
- Overview of optimisation methods

Dr Massimo Penasa is co-founder and director of CAEmate SRL, an innovative software company focused on the development of the cloud-based platform WeStatiX for structural design, engineering workflow automation and structural health monitoring. He has wide experience as structural designer and project manager in international infrastructure projects. He is also a lecturer for international engineering chambers and for the courses of Computational Mechanics at the University of Trento. Dr Penasa has been responsible for tutoring a number of University students during his doctorate programme, together with teaching activities and scientific advisory.

Wednesday 8th | 9:00 – 10:30 and 11:00 – 12:30 BST

Tension structures: introduction, worked examples and case studies
by *Adam Bown* – Tensys ltd

The two lectures will cover an introduction to the engineering design of tensile structures and examples of permanent and temporary tension fabric structures from around the world:

- Fabric structures: advantages & drawbacks
- Form finding and typical shapes
- Tools and approaches to design & analysis
- Dynamic relaxation, structural analysis approach and standards
- Material types, properties and models
- Connection details, pattering, compensation and installation
- Single skin vs full building envelope
- Permanent vs retractable
- Temporary and inflatable structures
- ETFE: single skin, cushions and sculptures.
- Failure cases
- Hybrid Air Vehicles & viscoelastic modelling of high altitude balloons

Adam Bown, a Director of Tensys Ltd, has over twenty years of experience in the design, form-finding, static and transient analysis and provision of fabrication data for a variety of tensile structures from around the world. Working in the fields of architecture, aerospace, and artistic installations. Notable projects and experience being: *Architecture*: BC Place Stadium, Vancouver; Suvarnabhumi Airport, Bangkok; M11 Monument, Madrid; Munich Olympic Swimming Pool; Waldstadion Frankfurt. *Aerospace 'lighter than air' craft*: Project Loon communication balloons and the NASA high altitude super pressure balloon program. *Artistic installations* by artist Anish Kapoor: Sectional Body preparing for Monadic Singularity, Palace of Versailles, France; 'Ark Nova' – Japan; 'Leviathan' – Grand Palais, Paris; 'Marsyas' Tate Modern, London.

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Wednesday 8th | 14:00 – 15:30 and 16:00 – 17:30 BST

Virtual Lab: structural membranes characterisation

by *Khurram Suleman* – UCL

The two lectures will show the experimental tools and approaches to characterise the mechanical response of membrane materials, with a focus on the uniaxial tensile test. The topics covered are:

- Introduction to membrane testing
- Standards for uniaxial tensile test of thin films
- Digital Image Correlation (DIC) technique
- Sample preparation and installation
- Data analysis and postprocessing through Correlated Solution VIC software
- Examples and results for different thin-film materials.

Khurram Suleman is a senior PhD student in the Department of Mechanical Engineering at University College London (UCL), working with Prof. Federico Bosi on the characterisation and modelling of inflatable thin films and the development of a novel imaging approach to assess the onset of plasticity in structural membranes. Prior to joining UCL, Khurram obtained MSc and BSc degrees in Mechanical Engineering from Imperial College London and National University of Science and Technology (NUST), respectively.

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