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ADVANCED JOINING PROCESSES COURSE

COURSE STRUCTURE

Online / Live Stream

6, 7, 8 and 12, 13, 14 april 2021

U.PORTO

Part A – Welding (2 days)

1. Laser welding (8h - 6th April) - Arnold Gillner

Laser welding fundamentals - Arnold Gillner • Laser radiation • Laser types • Laser beam propagation • Interaction between Laser radiation and materials	90min
Break	10min
Laser beam welding of metals - micro and macro - Arnold Gillner and Olowinsky • Laser welding principles for metals • Process variants • Basic conditions • Requirements for metal components • Typical applications	90min
Break	45min
Laserwelding of polymers - Arnold Gillner and Brosda • Optical properties of polymers • Process variants • Possible combinations of polymer • Applications	30min
Hybrid joining processes - Arnold Gillner and Van der Straeten • Special aspects of a hybrid connection • Physical and mechanical requirements • Technical approaches • Applications	45min
Break	10min
Process monitoring - Arnold Gillner and Abels • Goal of process monitoring • Introduction to error definitions • Suitable approaches and sensors for process monitoring • Industrial implementation	45min
Break	10min
LIVE - Labtour laser welding - Arnold Gillner and Brosda • Guided tour through the laboratories • Explanation of typical laser welding equipment • Demonstration of a LIVE welding • Explanation and demonstration of analysis methods • Questions and answers	60min
Conclusion and Outlook - Arnold Gillner • Laser safety • Future developments • Summary • Discussion	45min

2. Weld manufacturing, design and analysis (8h - 7th April) - Gregory Glinka and Rakesh Goyal

Weld Manufacturing - Rakesh Goyal • Overview of welding processes • Welding Symbols – Interpretation and most common challenges • Welding Standards – Brief overview of various International Weld Standards • Welding Terminology – Weld joint types • Evaluate design for manufacturing/welding • Weld Quality and WPS/PQR	80min
Break	10min

Static Design Welded Structures - Rakesh Goyal • Static Strength analysis of welded joints • Stress concentration and stress distribution in welded joints • Weld design – International standards (AWS and ISO) • Determination of weld size – Butt, lap and T-joint	45min
Residual Stress and Distortion - Rakesh Goyal • Residual Stress and distortion – What, how and why • Controlling residual stresses and distortion in Welds • Modeling and simulation to determine residual stress and distortion • Systematic accounting of residual stress in fatigue design	45min
Break	30min
Fatigue Design of Welded Structures - Gregory Glinka • Introduction to modes of failure • Loads and Stresses in welded structures • Stress concentration for welded joints • Contemporary fatigue analysis methods	90min
Break	10min
Nominal Stress Method - Gregory Glinka • Wohler's Fatigue Test • The Minor's rule • Fatigue design codes and standards for weldments • Ambiguity of the Nominal stress defintion for weldments	30min
Local Strain Life Method - Gregory Glinka • The Basic Concept of the ε-N Method • The mean stress effect • The Neuber and ESED rule • The load sequence effect • Example case study	45min
Break	10min
Fracture Mechanics Method - Gregory Glinka • Basics of Linear Fracture Mechanics • Determination of Stress Intensity Factors • Fatigue Crack Growth Analysis • Example case study	45min
Fatigue Life Improvement of Welded Joints - Rakesh Goyal • Critical factors affecting fatigue life of weld joints • Design against fatigue fracture • Fatigue life improvement techniques - Brief • High Frequency Mechanical Impact Treatment • Ultrasonic Impact Treatment (UIT) • Design, Manufacturing and Quality considerations	40min

Part B – Mechanical Joining (2 and 1/2 days)

3. Friction stir welding (8h - 8th April) - Reza Beygi and Krishna Kishore Mugada

Introduction - Reza Beygi • Process definition • Applications • Comparison with fusion welding • Load and torque during welding • Heat generation during welding • Weld structure • Material flow • Advantages	50min

Break	10min
FSW tools - Krishna Kishore Mugada • Tool materials • Tool geometries • Tool Design-Shoulder design, pin design, and geometric parameters • Case study: Tool geometry effect on material flow in FSW of 6082 Al alloy	50min
FSW variants - Reza Beygi and Krishna Kishore Mugada • COM-stirTM • Skew-stir and its variants • Dual-stir • Re-stir • twin-stir™ • Stationary shoulder FSW • Bobbin tool FSW	20min
Friction stir based processes - Krishna Kishore Mugada • Friction stir processing • Friction stir additive manufacturing • Friction stir forming • Friction stir spot welding • Friction stir channeling	40min
Applications - Krishna Kishore Mugada • FSW applications	10min
Weld design - Reza Beygi • Weld configuration • Adjusting the process for each configuration	20min
Break	10min
Industrial Lecture or Lab demonstration - Industry • Practical case study	30min
FSW machines - Reza Beygi • Types of machines • Load and torque measurement techniques • Controlling techniques	20min
Friction stir spot welding - Reza Beygi • Basic FSSW • Refill FSW • Stich FSSW • Swept FSSW	20min
Break	30min
Joining of similar materials - Reza Beygi • Aluminum alloys • Copper alloys • Magnesium alloys • Steels	60min
Simulation of FSW - Krishna Kishore Mugada • Simulation of FSW	30min
Break	10min
Joining of dissimilar materials - Reza Beygi and Krishna Kishore Mugada • Aluminum-steel • Aluminum-copper • Aluminum-magnesium • Aluminum-titanium	70min

4. Design and analysis of bolted joints (8h - 12th April) - Sayed Nassar

Torque-Tension Relationship • Bolted System Variables • Brief overview of Bolting Terminology and specifications • Motosh Model, Torque Components • Joint Testing, signature, and Joint Diagram	70min
Break	10min
Process Control Methods • Torque-control • Torque-Angle control • Torque-to-yield control • Bolt stretch control	50min
Break	10min
Analysis of Bolted Systems • Elastic Interaction (1-pass, 2-pass) • Static Loading of Bolted Systems • Joint Diagram • Fatigue Loading of Bolted Systems	60min
Break	30min
Fatigue Design of Bolted Systems • Brief Overview of Metal Fatigue • Effect of Bolt Mean Stress • Fatigue Stress Concentration in Threaded Fastners • Importance of Initial Bolt Preload • Fatigue Safety Factor	70min
Break	10min
Vibration Loosening of Bolted Systems • Intro to Vibration Loosening • Junker Test • Analytical Models for Bolt Loosening • Loosening variables (preload level, pitch, clearances, friction, ...) • Loosening Analysis Software	70min
Break	10min
Corrosion of Bolted Systems • Concept of Corrosion Battery • Types of Corrosion Battery • Stress Corrosion Cracking (SCC) • Corrosion Protection	50min
Break	10min
Selection of Bolt Preload Level • Strength consideration (service loads, static, fatigue, SCC, ...) • Reliability of Control Method at initial assembly • Type/nature/consequnce of failure	30min

5. Deformation assisted joining - overview (4h - 13th April) - Paulo Martins

Introduction	10min
Joining mechanisms • Force-closed	50min
Break	5min

Joining mechanisms • Form-closed • Material-closed	50min
Break	5min
Joining of tubes • Rolling • Crimping • Hydroforming • Electromagnetic forming • Plastic instability	25min
Joining of sheets • Hemming • Clinching • Sheet-bulk forming • Magnetic pulse welding	25min
Break	10min
Joining of sheets to tubes • Rolling • Ironing • Electromagnetic expansion • Hydroforming • Plastic instability • Boss forming and upsetting • Sheet squeezing	20min
Joining of sheets to rods • Thermal expansion-contraction • Boss forming and upsetting • Sheet squeezing • Cross rolling	20min
Riveting • Solid punch riveting • Self-pierce riveting • Double-sided self-pierce riveting	20min

Part C – Adhesive Bonding (1 and 1/2 day)

6. Introduction and overview (4h - 13th April) - Lucas da Silva

Introduction • Applications • Technologies involved • Advantages • Disadvantages	30min
Theory of Adhesion • Forces involved • Surface roughness • Phase change • Wetting • Spreading • Theories of adhesion	30min
Break	20min

Adhesive selection • Classification • Composition • Hardening • Epoxies • Polyurethanes • Acrylics • Phenolics • Polyaromatics • Selection process	40min
Joint design • Stress analysis • Failure modes • Failure criteria • Optimisation • Tubular joints • T joints • Corner joints • Jointdesigner	40min
Break	20min
Surface treatment • Characteristics that affect adhesion • General principles • Importance • Assessment • Selection • Methods	20min
Fabrication • Steps • Storage • Metering and mixing • Adhesive application • Fixturing of parts • Hardening • Safety and environment	20min
Control • Destructive tests • Non-destructive tests • Post-fracture tests	20min

7. Functionally graded joints (2h - 14th April) - Eduardo Marques

Introduction • Concept definition • Ideal stress distributions • Substrate vs adhesive grading • Main advantages and limitations • Practical uses	30min
Graded joint design theory • Analytical models • Numerical models • Optimization strategies	30min
Break	10min

Comparison of practical techniques — 50min

- Mixed adhesive joint
- Differentiated adhesive curing
- Resin/hardener ratio control
- Particle addition
- Adherend toughenening
- Composite layup control
- Additively manufactured substrates

8. The behaviour of adhesives under impact loads (2h - 14th April) - Eduardo Marques

Introduction — 10min

- Impact loads in adhesive joint
- Bonded structures in the automotive industry
- The challenge of modern adhesives
- Key competences for designing impact resistant joints
- Design of impact testing equipment

Adhesive characterization and joint testing under impact loads — 30min

- Tensile testing under impact
- Shear testing under impact
- Fracture toughness testing under impact
- Mixed mode fracture toughness testing under impact
- Single lap joint testing
- Component level testing

Break — 20min

Numerical simulation under large strain rates — 30min

- Strain rate definition
- Strain rate in material characterization tests
- Procedures for strain rate control
- Cohesive zone modelling under impact
- Strain rate dependent cohesive zone element design

Case study in joint design for the automotive industry — 30min

- Typical design brief
- Adhesive selection
- Surface treatement selection
- Material property determination
- Joint design using numerical tools
- Design validation activities
- Design for manufacturing

9. Fatigue of adhesive joints (4h - 14th April) - Alireza Akhavan-Safar

S-N metodology in fatigue life assessment of adhesive joints — 70min

- Experimental procedures (Different test approaches, Effects of load level, mode mixity, Properties degradation, etc.)
- Post processing approaches (L-N and S-N diagrams, Effective stresses and how they should be obtained, and how to construct a master curve out of the raw data?
- Total fatigue life estimation in real adhesive joints using S-N approach by direct and indirect methods
- Theory of critical distances in adhesive joints
- Multiaxial fatigue life prediction models using the critical plane technique

Break — 20min

Fatigue crack growth in adhesive joints • Experimental procedures (Different test specimens, Effects of load level, Frequency, Mode mixity, R ratio). • Data reduction technique. • Post processing approaches: Paris law curves (different paris law relations, how to define a master paris law curve for adhesive joints, how the threshold condition is obtained. • Fatigue life estimation using Paris law curves.	70min
Break	20min
Numerical simulatioin • Cohesive elements and cohesive zone modelling • Degradation of adhesive properties (which properties should be degraded and how?, Different models for degradatoin of the cohesive properties) • How to simulate the fatigue response of adheisve joints (cycle by cycle sterategy, cycle jumping technique) • Damage initiation and damage propagation as a function of load cycle and nodal stress state. • How to implement the method in Abaqus	60min