Structuring and preparation of a lesson: **EAE module 3 (Construction and design)**

time	Theme, core information, statements or questions	Learning objectives [1]	Methods (e.g. presentation/ discussion/group work)	Media/ training material
8h	<u>Fundamentals of strength of materials:</u> Review of the mechanical properties of the main classes of materials (metals, plastics, ceramics, composites) Relationships between stress and strain. Theories to predict the yielding of materials and criteria to predict the strength of materials. Different behaviors presented by materials (elastic, elastic-plastic, plastic, viscoelastic, viscoplastic, elastomeric). Behaviors of materials under different conditions of temperature and load	Explain the fundamental principles and concepts of the strength of materials and how these apply for a variety of materials. (1) Explain the different types of stresses and deformations. (1) Define the stress-strain relationships. (1) Determine the values of mechanical properties from mechanical testing. (3) Detail different yielding theories and criteria used to predict the strength of materials. (1) Explain the different types of mechanical behavior that materials can exhibit. (1) Detail the different behaviors that a material	Demonstration of different behaviors with a metallic spring and/or plasticine. Perform tensile tests to show the stress-strain curve of different types of materials (metal, polymer, ceramic and composite) and of bonded joints. Demonstration and analysis of different fracture surfaces.	White board. Slides presentation. Demonstration objects (e.g. tested specimens with different types of fracture surfaces). Laboratory equipment to manufacture and test materials and adhesive joints.

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	Types of fracture	can present under the influence of varied temperature and load conditions. (1) Differentiate the types of fracture that can occur when a joint fails. (2)		
10h	<u>Joint design:</u> Considerations unique about adhesives and sealants and their advantages and disadvantages when compared to other joining materials techniques. Presentation of rules and standards related to the design principles of bonded joints. Design examples of bonded structures in various areas of application Considerations about the design for mechanized and automated fabrication of bonded joint using different types of adhesives and sealants	Explain the fundamental principles of design of bonded joints. (1) Compare the advantages of bonding when against other types of joining methods such as welding, spot welding, riveting, screwing, etc. (1) Check the specifications and requirements related with the design of bonded joints. (2) Interpret in detail different bonded structures used in specific areas/industries. (1) Outline the design characteristics that makes a joint most suitable for a given application. (1) Outline the manufacturing	Mechanical testing of different joints (bonded, welded, etc.) and comparison between these methods. Perform control measurements of bonded joints and verify if they are within given tolerances. Demonstration of calculation of stresses in bonded joints using analytical methods. Demonstration of calculation of	White board. Slides presentation. Laboratory equipment to manufacture and test joints. Laboratory equipment to control joint dimensions and verify tolerances. Demonstration objects (e.g. bonded joints with different geometries). Laboratory equipment to manufacture and test adhesive joints.

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	Access and tolerances Conditions of equilibrium Considerations about some physical concepts (stiffness, moments of inertia, etc.) Different types of stresses on bonded joints (tensile, shear, peel, multiaxial stresses and combined stresses) Stresses induced by differential straining (heterogeneous joints) Measurement of stresses in bonded joints	parameters and types of adhesives that enable the use of adhesive joints in an automated process. (1) Design joints that are able to be accessed for manufacture, inspection and repair. (2) Explain the tolerance requirements of different types of joints taking into account the application under analysis. (3) Illustrate the conditions of equilibrium that enable the transfer of forces in an adhesive joint. (1) Explain physical concepts like stiffness and moments of inertia. (1) Classify different types of stress that are present in an adhesive joint. (1) Compare the effect of the different types of stress on the strength of adhesive joints. (1) Explain how the use of heterogeneous materials in a joint can lead to	stresses in bonded joints using a numerical method (finite element method). Discussion about the types of bonded joints used in industrial applications. Discussion about the types of bonded joints produced in the practical course exercises. Practical demonstration (e.g. production and testing of joints with different geometries and/or different materials).	

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	Different types of bonded joints Classification of different types of bonded joints (lap joints, cylindrical and tubular joints...) Tolerance requirements Influencing factors (experimentally verified) Design proof testing	differential straining which induces additional stresses. (1) Outline different methods to measure the stress value in bonded joints. (1) Make use of different methods to measure the stress value in bonded joints. (2) Recognize what type of bonded joint is suitable for a given purpose. (1) Identify the different joint geometries. (1) Justify the usual applications and differences of the different joint geometries. (2) Design a joint able to respect given tolerance requirements (related to gap-filling ability of different types of adhesives). (2) Explain the different factors that can influence the performance of adhesive joints. (1) Clarify how these factors		

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		change the performance of a joint. (1) Carry out tests that validate the design decisions before the final joint design is implemented (2) Appraise all aspects of a given joint design project case study, such as defining the most suitable geometry, materials, selecting manufacturing parameters, identifying the major stresses acting upon the joint, checking tolerances and defining validation procedures. (2)		
12h	<u>Calculation of stresses in bonded joints:</u> Analytical methods Hypotheses - limitations	Define the different stress calculation methods. (1) Implement different stress calculation methods. (2) Identify the underlying hypothesis behind each of the stress calculation methods. (1) Outline the limitation of each of these methods	Discussion on the use of analytical and numerical methods for the calculation of stresses and strength of adhesive joints, its capabilities and its advantages and disadvantages.	White board. Slides presentation. Software for analytical calculations of the stresses in adhesive joints. Software for numerical calculations of the stresses in adhesive

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	Mechanical loadings Use of working examples with software Numerical methods Finite element method	(geometry of joint, materials of adherends, adhesives, loading conditions, etc). (1) Classify the different types of mechanical loadings that can act upon a joint and how to take into account the different mechanical responses that the joint materials can exhibit (elastic, elastic-plastic, visco-elastic). (1) Generate the model of the distribution of stresses in bonded joints with different geometries using numerical methods in an appropriate software. (2) Assess the influence of geometrical factors and the behaviour of materials in a variety of joint geometries. (3) Compare the numerical results with experimental data. (3) Define the advantages of numerical methods when	Perform simple calculations of stresses and loads in adhesive joints and compare the results with experimental results. Use analytical software to determine stress distribution of adhesive joints and compare the results with experimental data. Use of finite element software to determine stress distribution of adhesive joints and compare the results with existing experimental data.	joints.

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	Mechanical and thermomechanical analysis with different material behaviors for adherends and adhesives. Use of working examples with software	compared to analytical methods and also the limitations of each method. (1) Explain the main steps of a numerical analysis. (1) Explain the finite element method and its basic working principles. (1) Carry out mechanical and thermomechanical analysis considering materials with different mechanical behaviours. (2) Use appropriate software to assess the stress distributions in example joint configurations. (3) Act independently in the process of calculating the stresses in varied bonded joint geometries, using analytical and numerical models. (2)		
3h	<u>Hybrid joints:</u> Adhesive bonding associated with riveting, spot welding, screwing, clinching, setting, crimping, shrinking	Classify different types of hybrid joints. (1) Outline the main differences between the different types of hybrid	Discussion about practical examples of application of hybrid joints, focusing on the type of hybrid	White board. Slides presentation. Demonstration objects (e.g. different types of

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	Advantages and limitations of hybrid joints Rules for design of hybrid joints Comparison of the performance of hybrid joints with bonded joints Influence factors Practical examples in industry	joints. (1) Explain the advantages and limitations (e.g. production costs, equipment required for production, materials) of each type of hybrid joints when compared to bonded joints. (1) Outline the rules that should be considered for the design of the different types of hybrid joints. (1) Analyze the requirements of the rules related to the design to hybrid joints and transfer this knowledge to practical applications. (2) Explain the differences in performance (strength, durability) of each type of hybrid joint when compared to bonded joints (1) Define the different factors that can influence the performance of a hybrid joint. (1) Explain how each of	joint chosen and the motivations behind the non-application of bonded joints. Practical demonstration (e.g. tensile tests of different hybrid joints).	hybrid joints).

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		these factors change the performance of a joint. (1) Provide practical examples where hybrid joints are commonly used rather than bonded joints. (3) Justify why industrial applications might use hybrid joints instead of bonded joints. (3) Appraise the use of hybrid adhesive joints, checking their suitability for a given application and fully understanding the rules related to their design. (2)		

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