Basic Information:

Course Title: Methods for computation of residual stresses and distortions by welding and post-processing

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Total Teaching Hours: 30

Annotation (up to 150 words)

The aim of the course is to deepen the basic knowledge and skills in the application of approaches and methods for the calculation of residual welding distortions and stresses in structures during welding, thermal straightening and stress relief processing. Particular emphasis is given to analytical and numerical (FEM) methods, and their combination in solving large-scale problems. The course is intended for PhD students in mechanical engineering (02.01.00.) and metallurgy (02.09.00.), but is also applicable to other specialties of technical sciences (02.00.00.).

The content includes the basic principles for conceptualization, classification of approaches and methods for computation, and aspects for practical application. In particular, it covers: dimensioning and scaling of the problem; thermal deformation processes; influence factors and their interactions; numerical (FEM) solutions; the coupling of thermal and deformation numerical analysis; analytical solutions; various applications of the inherent strain method. Additionally, aspects in interpretation and critical evaluation of results are discussed.

Course content (brief description by topics or modules)

Topic 1. Modeling and simulation, definitions, classification, general approach, physical characterization of processes
Topic 2. Temperature field during welding and related processes – general concepts, differential equation of heat conduction, thermophysical properties, and model parameters
Topic 3. Classification and characterization of heat sources, heat flux distribution, models and parameters
Topic 4. Functional-analytical solutions, fundamental solution, boundary and initial conditions, superposition method, reflection method
Topic 5. Numerical solutions by FEM, implicit and explicit analysis, spatial and temporal discretization, h- and p-method
Topic 6. Application for solving specific problems, peculiarities in the application and comparison of numerical and analytical solution methods, determination of the field of maximum temperatures
Topic 7. Residual welding displacements and stresses, definitions, classification and characterization, influence on technological and operational strength
Topic 8. Models of plastic deformation, deformation hardening, influence of temperature, deformation rate, and phase composition
Topic 9. Dilation during phase transitions in the solid state, plasticity during phase transition, models, and parameters

Topic 10. Factors of influence, dependencies and interrelationships, thermo-mechanical properties and model parameters
Topic 11. Mechanism of deformation and stress occurrence – simplified models, Relationship between the temperature cycle, thermal deformation, stress-strain curve, and stress development (for linear and point heating)
Topic 12. Influence of stiffness and initial and accompanying deformations on the development of plastic deformations
Topic 13. Practical implementation of coupled thermal-deformation numerical (FEM) analysis, dimension of the field of plastic deformations and stresses, field of displacements
Topic 14. Analytical models for calculating residual welding displacements, input data, consideration of influencing factors
Topic 15. Calculation of residual welding displacements and stresses in complex structures, method of inherent strain, applied models

Teaching and assessment methods
hybrid

Competencies acquired as a result of training (3–5 points)
The expected outcome is an enhanced theoretical background and practical skills in the conception, calibration and application of models for computer simulation of processes in the fabrication and repair of welded structures.

Literature:
1. Michailov V. et al.: Principles of welding, Politech. Uni. Publ. St. Petersburg, 2016
2. Radaj D.: Heat Effects of Welding, Springer-Verlag, Berlin, 1992
3. Radaj D.: Eigenspannungen und Verzug beim Schweißen, DVS Verlag,Düsseldorf, 2002
4. Radaj D.: Schweißsimulation, DVS-Verlag, Düsseldorf 2000
5. Желев, А., Христов, С.: Заварени конструкции, том 1, изд. Техника, 1988
6. Lindgren, L.-E.: Computational Welding Mechanics, Woodhead Publishing, 2007
7. Doynov, N. et al.: Sensibilitätsanalyse der thermomechanischen FE-Schweißsimulation, Shaker Verl., 2012
8. Doynov, N.: Hybride Modelle für Verzugs- und Eigenspannungsberechnung von großen und komplexen Schweißkonstruktionen, Rep. BTU Cottbus, 2012, DOI: 10.26127/BTUOpen-6453

Additional information (optional) (e.g., special requirements, laboratory equipment, prior knowledge)
This course may also be held in English or German, upon request