FINITE ELEMENT MODELING OF WELDING PROCESSES

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INTENDED AUDIENCE : Bachelor/Master/PhD students having background in Mechanical/Material Science/Metallurgical engineering/ Production Engineering/Manufacturing Technology
The faculty of different institutes can attend this course as a part of FDP.

COURSE OUTLINE :
The welding process involves complex interaction of several mechanisms. The fundamental understanding relied on basic mechanisms such as heat transfer and/or fluid flow, and associated distortion and residual stress generation including the effect of metallurgical transformation for a welding process is the focus of this course. It helps to develop the numerical model, and makes the foundation for analysis and experimentation for the process. The development of computational models for welding process relies on mathematical expression of the governing mechanism. It helps to design relevant experiments and drives to find the data to be obtained. Mutual understanding between numerical and experimental results leads to better insight of the welding processes that impact on the improvement of existing process and directs to the development of new process. This course emphasized on the development of finite element based numerical model of both fusion and solid state welding processes. The development of FE-based model is presented in a simplified way to understand the subject at elementary level. The broad impact is that the students will be able to develop FE-based heat transfer, fluid flow and stress analysis model of welding process using standard commercial package. However, this course does not intend to cover the learning of the commercial software.

ABOUT INSTRUCTOR :
Prof. Swarup Bag's The broad area of instructor is teaching and research interest of materials and manufacturing processes through computational models using finite element method and experiments. The instructor completed his Ph.D on “Development of bi-directional heat transfer and fluid flow model for reliable design of GTA and laser welding processes” from Indian Institute of Technology Bombay. Later he has worked at the Center for Material Forming (CEMEF), MINES Paris Tech, France in Metallurgy, Structure and Rheology (MSR) group. Soon after post-doctoral research experience, he joined in the Department of Mechanical Engineering, Indian Institute of Technology Guwahati as a faculty member. His primary area of research is fundamental process modeling of welding and joining technologies, optimization of manufacturing processes and recrystallization in metal forming processes. Dr. Bag has published about 56 journal papers, 45 Conference papers, and 18 book chapters related to welding and joining processes. He is the author of the book ‘Computational models for GTA and laser welding processes’ and recipient of ‘Royal Arc Award 2009’ from Indian Institute of Welding for the best PhD thesis in welding. The instructor is involved in teaching the subjects like ‘Physics of Manufacturing Processes’, ‘Engineering Materials’, ‘Advanced Welding Processes’, ‘Mechanical Behavior of Materials’, ‘Solidification Processes’ and ‘Manufacturing Technology’ at IIT Guwahati. The subjects broadly covers the fundamentals of manufacturing processes, mechanical metallurgy, theory of plasticity, heat transfer in manufacturing processes, crystallography, dislocation mechanism, phase transformation and solidification.

COURSE PLAN :

Week 1-2:Introduction to welding processes

Classification, fusion welding, brazing and soldering, solid state welding processes, advanced welding processes, wire additive manufacturing processes

Week 3-4: Fundamentals of finite element (FE) method
Elastic stress Analysis, Weighted residue technique, Material non-linearity, Heat conduction, Fluid flow, Structure of a FE model, Steps of a FE model, Introduction FE solver, X-FEM and other interface tracking methods

Week 5: Heat source model in conduction mode welding processes
Representation of heat source, Surface heat source model, Volumetric heat source model, Heat source model for solid state welding, Heat source model for keyhole mode laser and electron beam welding processes

Week 6-7:Application of FEM to model welding processes
Fusion welding: laser, arc, electron beam and resistance spot Solid state welding: Friction, FSW and hybrid FSW Representation of welding processes by governing equations and boundary conditions, Incorporation of heat source, Difference between linear and spot welding, FE formulation, Incorporation of temperature dependent properties, Incorporation of latent heat of melting and solidifications, Demonstration of thermal model development using commercial software

Week 8: FE-based fluid flow model in fusion welding processes
Surface active elements and fluid flow, Allied welding processes, Governing equations and boundary conditions, FE formulation, Solution strategy, Prediction of free surface profile

Week 9: FE-based elastic-plastic stress model of welding processes
Yield criteria, Hardening rule, Flow rule, Material models, FE formulation, Prediction of residual stress and distortion, Solution strategy, Incorporation of phase transformation effect Demonstration of thermo-mechanical model development using commercial software

Week 10: FE model of metal transfer in welding
Fundamentals of metal transfer in arc welding, FE-based modelling approaches

Week 11: FE model of non-Fourier heat conduction
Ultra short pulse laser welding, Heating of nano-film, lattice distortion

Week 12: FE model of wire-additive manufacturing processes
Fundamentals of wire additive manufacturing processes, Modelling approaches of additive manufacturing, FE formulation, Solution strategy