Approval: 9th Senate Meeting

Course name: Applied Finite Element Method

Course no.: ME505

Credits: 2-0-2-3

Pre-requisites: ME 352 Finite Element Methods in Engineering

Intended for: UG/PG

Distribution: Electives for EE/ME/MS/PhD

Semester: Odd/Even

Course Preamble: Graduate students including masters and PhD students study lots of theory of Finite Element Method but when comes to the application of theory in solving real world problems, they either lack the skill and/or don't know how to approach the problem. A real world problem involve all kind of physics and complex geometry simultaneously, for example, a car undergoes thermal, NVH, CFD, static loads, fatigue, linear and non-linear dynamics with various geometric shapes such as thin and thick sheets, thin and thick beam etc. Hence, students' needs practical exposure to such multidisciplinary problems. Keeping this in mind, this course has been designed to provide SKILL to the students on industry standard tools and practices using Applied FEM. At the end of the course, the students are expected learn the theory as well as quality meshing and analysis techniques of various types (1D, 2D, 3D) using variety of element types. Students will be given design problems and they are expected to solve it using FEM tools. This course is expected to provide hands-on experience to the students.

Course outline: The objective of this course is to introduce FEM as tool and how it can be used to analyze designs in various fields. This course would aid students in understanding the practical aspect of courses like FEM, design of machine elements, theory of machines, heat transfer etc. The course will also be taught be experts from various industries who have extensive experience in handling FEA tools and design processes.

Modules:

Module 1 [3 Lectures]

Introduction to FEM: Basics of statics, strength of materials and FEM, CAE driven design process, Analysis types: linear, non-linear, dynamic, buckling, thermal, Fatigue, optimization, CFD, NVH etc, 1D, 2D, 3D methods, Degree of freedom, Advantages of FEM, Modeling/Preprocessing techniques, introduction to meshing, common mistakes and errors, Application of analysis types in various engineering fields.

Module 2 [14 Lectures]

FEM-Weighted Residue Approach: Non-weak type methods- methods adopted to minimize errors: Subdomain, Galerkin, Petrov-Galerking, Least Square, Collocation; Weak form type method: Rayleigh-Ritz method, Finite element method, Global stiffness matrix, Shape functions, Direct application of element matrix equations, Compatibility, Convergence criteria, Sources of errors, Types of PDE: elliptic, parabolic and hyperbolic and their solution approach, 1D problems in heat transfer, fluid flow, vibration etc. and comparison with exact solution.

Module 3 [8 hours]

Introduction to Meshing: 1-D Meshing- Introduction to meshing, when to use 1-D meshing, meshing in critical areas, element section, stiffness matrix derivation (direct method) and its properties, element types: beam element, rigid elements, fasteners, problems based on 1-D FEM and comparison with exact theory, 2-D Meshing: When to use 2-D elements, mid-surface, Constraint strain triangle, different types of element and their displacement function, Family of 2D elements: plane stress, plan strain, plate, membrane, thin shell etc., effect of mesh density, effect of biasing in critical region, boundary conditions, how not to mesh, shrink wrap meshing, problems based on 2-D FEM and comparison with exact theory. 3-D Meshing: When to use 3-D elements, DOF for solid elements, Algorithms, brick meshing, how not to mesh, Hexa and Penta elements, solid map meshing. (8 hours)

Module 4 [5 Lectures]

Element Quality and Checks: Compatibility and mechanisms, spring elements, shells to solids, beam to solids, beams normal to shells, beam to shell edge, General element quality checks: skewness, aspect ratio, warpage, jacobian; 2-D quality checks, quality checks for tetra meshing, brick mesh quality checks, student projects on mesh quality, Weld, Bolt and Shrink Fit Modeling: Welding simulation-modelling spot and arc welding, bolted joints, bearing simulation, shrink fit simulation.

Module 5 [12 Lectures]

Linear Static and Dynamic Analysis: Stiffness matrix, stress and strain calculations, FEM model for linear analysis, error analysis, design problems based on linear analysis, Theory of dynamic analysis: forced and free vibration, mode shapes, harmonic analysis, design for avoiding resonance, Thermal Analysis: Conduction, convection and radiation heat transfer, structured and unstructured meshing, IC engine block thermal analysis, Introduction to CFD, Nonlinear analysis: Introduction to nonlinearity, types of nonlinearity: geometric nonlinearity, material nonlinearity, boundary nonlinearity/contact nonlinearity, stress-strain measures, general procedures for nonlinear static analysis, plasticity.

Applied FEM: Projects based on thermal analysis, CFD, Fatigue analysis, NVH analysis, Crash analysis etc., application of FEA in biomedical, implant designs such as Orthopaedic Implants, Spine Implants, Cardiovascular Implants, medical device components, automotive, aerospace, civil etc.