Finite Element Method Applied to Heat Transfer, Fluid Dynamics and Mechanics of Composite Structures

Overview

The Finite Element Method (FEM) is a numerical and computer-based technique of solving a variety of practical engineering problems that arise in different fields. It is recognized by developers and users as one of the most powerful numerical analysis tools ever devised to analyze complex problems of engineering. Finite element analysis is an integral and major component engineering design and manufacturing. Major established industries such as the automobile, aerospace, atmospheric sciences, chemical, pharmaceutical, petroleum, electronics and communications, as well as emerging industries such as biotechnology, nanotechnology, and information technology rely on finite elementanalysis capabilities to simulate and model complex systems for the design and manufacturing of high-technology products. The underlying theory of the finite element method is now well established, with many books and courses providing adequate explanations of the theory. However, most people using the method, via commercial software or in-house codes, do not often understand the method as applied to engineering problems, especially in generating input data and interpreting the results.

Structural elements (e.g., plates and shells) made of fiber-reinforced composite materials and functionally graded materials are used in a variety of engineering applications, such as medical prosthetics, off-shore oil drilling platforms, wings of airplanes, automobile parts, to name a few. The study of deformation and stresses developed in such structures subjected to thermo-mechanical loads is of practical significance, because even small changes in loads or temperatures, support conditions, or geometry can result in unpredictable deformations and stresses that can make the structure not functional. Experimental investigations of deformation and stresses are very expensive, time-consuming, and limited by the ability to measure various mechanisms of failure. Therefore it is of practical importance to develop the most accurate mathematical models and associated computational approaches to determine their response in different contexts, i.e., bending, buckling, vibration, and transient response.

Internationally renowned researchers and practitioners with proven knowledge, experience, and demonstrable ability in teaching, consultancy, research, and training in the field of finite element analysis and composite structures will deliver lectures and discuss cases in the course. The course is planned and will be offered as per the norms.

The present course is designed to bridge the gap between the theoretical finite element knowledge and its industrial applications by providing sufficient insights into the relationship between the physical phenomena, governing equations, problem data (e.g., loads, boundary conditions, constitutive behavior, etc.), and the finite element model. The course has two parts: Part A deals with an introduction to the finite element method as applied to heat transfer and other field problems. Part B is dedicated to the study of mechanics of laminated composite structures, where theories and finite element models of laminated plates and shells are presented.

This course is intended to provide graduate students, teachers, and researchers working in aerospace, automotive, chemical, civil, mechanical engineering, and applied mathematics, and engineering physics, as well as numerical analysts and materials scientists with the theory and applications of linear finite element analysis of problems from heat transfer and composite structures.

The primary objectives of the course are as follows:

- Provide the participants with a strong understanding of and the confidence in the formulative steps involved in the finite element model development of problems of heat transfer and composite materials
- Provide the participants the knowledge to generate finite element data (e.g., selection of elements and mesh, computation of nodal forces), imposition of boundary conditions, post-computation of stresses and strains, etc.), exploitation of problem symmetries, and interpretation and evaluation of the results
- Provide the participants with the knowledge to teach the finite element analysis procedures to others.
- Provide the participants with the theories governing the bending, buckling and vibration behavior of laminated composite plates

• Expose the participants to various analysis methods, analytical as well as the finite element method, to determine bending, buckling and vibration response of composite plates
• Educate the participants on the use of the finite element method in the stress analysis of laminated composite structures, including recent developments.

Modules	**A: Finite Element Method in Heat Transfer and Fluid Dynamics :July 25 – July 29** **B: Mechanics of Laminated Composite Structures :Aug 01 – Aug 05** **Number of participants for the course will be limited to fifty.**
You Should Attend If…	▪ you are an Engineer from industry and government organizations including R&D laboratories, who are involved with the analysis of heat transfer and like problems and laminated composite structures (plates and shells) in the aeronautical, automobile, mechanical, civil, chemical, and other engineering disciplines as well as in applied science. ▪ you are a student or faculty from academic institution interested in learning how to apply finite element analysis for a real problem
Fees	The participation fees for taking the course is as follows: **Participants from abroad(For both the modules)** : US $500 **Industry/ Research Organizations:** Any one of two modules : Rs. 10000/- Both modules : Rs. 15000/- **Academic Institutions:** Any one of two modules : Rs. 5000/- Both modules : Rs. 10000/- **Students of Constituent Units of JNTUH** Any one of two modules : Rs. 1000/- Both modules : Rs. 2000/- **SC/ST students** Any one of two modules : Rs. 500/- Both modules : Rs. 1000/- The above fee include all instructional materials, computer use for tutorials and assignments, laboratory equipment usage charges, 24 hr free internet facility, Tea, Snacks, Lunch. The participants will be provided with accommodation on payment basis.

The Faculty

ProfessorJ.N. Reddy is a Distinguished Professor, Regents Professor and the inaugural holder of the Oscar S Wyatt Endowed Professor at the Texas A&M University, College Station (TAMU). Dr. Reddy is the author of over 540 journal papers and 19 text books on theoretical formulations and finite-element analysis of problems in solid and structural mechanics (plates and shells), composite materials, computational fluid dynamics, numerical heat transfer, and applied mathematics. He is also internationally-recognized for his research on mechanics of composite materials and for computational methods. The shear deformation plate and shell theories that he developed bear his name (the Reddy third-order shear deformation theory and the Reddy layerwise theory) in the literature. The finite element formulations and models he developed have been implemented into commercial software like ABAQUS, NISA, and HyperXtrude. Dr. Reddy has received the1992 Worcester Reed Warner Medal and the 1995 Charles Russ Richards Memorial Award from the American Society of Mechanical Engineers (ASME); the 1997 Archie Higdon Distinguished Educator Award from the Mechanics Division of the American Society of Engineering Education; the 1998 Nathan M. Newmark Medal and 2014 Raymond D. Mindlin Medal from the American Society of Civil Engineers; 2000 Excellence in the Field of Composites and 2004 Distinguished Research Award from the American Society for Composites; 2003 Computational Solid Mechanics award from US Association of Computational Mechanics (USACM); 2014 IACM Award (Zienkiewicz Medal) from International Association of Computational Mechanics (IACM); and the 2016 Prager Medal, Society of Engineering Science. He is a member of the US National Academy of Engineering (2015) and a Foreign Fellow of the Indian National Academy of Engineering (2015). Received Honoris Causa from the Technical University of Lisbon, Portugal in 2009, and Honorary Doctoral Degree from Odlar Yurdu University, Baku, Azerbaijan, in 2011. He is an Honorary Member and Life Fellow of ASME, a fellow of AAM, AIAA, ASCE, ASC, IACM, USACM, the Aeronautical Society of India, and the Institution of Structural Engineers, U.K. Dr. Reddy serves on the editorial boards of about two-dozen journals, including International Journal for

Numerical Methods in Engineering, Computer Methods in Applied Mechanics and Engineering, Journal of Engineering Mechanics (Associate Editor), and International Journal of Non-Linear Mechanics. Currently, the Editor-in-Chief of Mechanics of Advanced Materials and Structures, International Journal of Computational Methods in Engineering Science and Mechanics, and International Journal of Structural Stability and Dynamics (served as the Editor of Applied Mechanics Reviews till 2012). Dr. Reddy is one of the original top 100 ISI Highly Cited Researchers in Engineering around world with over 17,300 citations (average citations of over 35 per paper) with h-index (h-index is the largest number h such that h publications have at least h citations) of over 63 as per Web of Science; as per Google Scholar the number of citations of nearly 40,000 with h-index of 83 and i10-index of 369 (i.e., 369 papers are cited at least 10 times).

Prof J Suresh Kumar is currently working as professor of mechanical engineering and had nearly 20 years of teaching experience in the field of machine design, composite structures, finite element methods etc. He published 130 technical works in various national/ international journals/conferences. 10 students are awarded doctoral degrees under his guidance and presently 10 more students are pursuing their Ph.D. work under his supervision.

Dr. P Bhramara is presently working as Associate Professor in the Department of Mechanical Engineering, JNTUHCEH. She has 16 years of teaching experience. She also had one of industrial experience in the system design of central and packaged air conditioners with M/s Voltas Ltd, Bangalore. Her subjects of interest include Computational Fluid Dynamics, Heat Transfer and Refrigeration and Air conditioning. Her major contribution is the development of research facility for the experimental evaluation of two phase heat transfer coefficient of refrigerants, which forms her doctoral work. She is the recipient of AICTE – RPS project of grant amount, Rs. 10.00 Lakhs and UGC Major research project of grant amount, Rs. 8.00 Lakhs, in addition to minor projects granted by University. Her research publications are essentially in the field of modeling of two phase flows using CFD analysis in horizontal pipe, two phase heat transfer, nanofluids and CFD analysis of Squirrelcage fans for inlet parameters.

Evaluation and Grading

There will be evaluation at the end of each module on the understanding of the concepts by the participant made during the course. Based on the evaluations finally a letter grade will be awarded to the participant. A completion certificate shall also be issued.

Course details

Module A: Finite Element Method in Heat Transfer and Fluid Dynamics

July 25 Monday

Lecture 1 : 9:30 to 11:00 AM
Governing Equations of Heat Transfer and Fluid Flow – Representation in Primitive Variables – Boundary and Initial Conditions
The basic concepts in FEM:
Strong and weak forms; Interpolation Functions; Library Finite Elements; Time dependent Problems and Axisymmetric Problems ;

Lecture 2 : 11.15 to 12.45 AM
Numerical/computational issues: Subparametric, isoparametric, and superparametric formulations; Numerical integration; General modeling considerations
Essential vs. natural boundary conditions; Methods of approximations (Ritz & Galerkin methods); Finite element approximation functions; Assembly of element equations;

Tutorial1: 2.00 to 4.00 PM
Illustrative examples and discussion of results in light of physical response; Numerical excercises

July 26 Tuesday

Lecture 3 : 9:30 to 11:00 AM
Heat Conduction:
Solution of Steady state and Transient Problems; Variable Properties;

Lecture 4 : 11.15 to 12.45 AM
Radiation solution algorithms; Advanced topics in Heat Conduction;

Tutorial2: 2.00 to 4.00 PM
Problem solving session with examples: heat transfer problems with convection boundary conditions;exploitation of symmetries; Post-computation of heat flow; Numerical excercises

July 27 Wednesday

Lecture 5 : 9:30 to 11:00 AM
Viscous Incompressible Flows**:**
Mixed Finite element models and Penalty Finite element models; Computational considerarions; Pressure calculation;

Lecture 6 : 11.15 to 12.45 AM
Solution of Non linear equations:
Fully coupled solution methods; Pressure correction/projection methods; Time – approximation schemes;

Tutorial3: 2.00 to 4.00 PM
Numerical excercises

July 28 Thursday:

Lecture 7 : 9:30 to 11:00 AM
Viscous Incompressible Flows and Solution of Non linear equations:
Stabilized Methods; Least Square Finite element models; Post processing.
Turbulence:

Lecture 8 : 11.15 to 12.45 AM
General Turbulence Models; One Point Closure Turbulence Models; Finite element modeling of Turbulence;

Tutorial4: 2.00 to 4.00 PM
Numerical excercises

July 29 Friday

Lecture 9 : 09.30 to 11.00 AM
Coupled heat transfer and fluid flow: governing equations; mixed finite element model of flows of viscous incompressible fluids; penalty finite element model; Coupled fluid flow and hear transfer formulations; numerical examples

Lecture 10 : 11.15 to 12.45 AM
Problem solving session with examples: penalyty function method applied to a 1-D problem; penalty finite element model; Identification of element coefficients

2.00 to 4.00PM

Examination, Evaluation and Certificate distribution for Module A

Module B: Mechanics of Laminated Composite Structures

Aug 01 Monday

Lecture 11 : 9:30 to 11.00 AM
Composite Materials: An Introduction; Anisotropic Elasticity and Functionally Graded Materials

Lecture 12: 11.15 to 12:45 AM
Structural Theories of Composite Laminates and FGM Plates (CLPT , FSDT);

Tutorial 6. 2:00 to 4 PM
Problem solving session with examples: Navier solutions for laminated beams; functionally graded beams; post-computation of stresses.
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Aug 02 Tuesday

Lecture 13 : 9:30 to 11.00 AM
Structural Theories of Composite Laminates and FGM Plates (HSDT);

Lecture 14: 11.15 to 12:45 AM
Analytical Solutions of rectangular laminates for bending, vibration and buckling

Tutorial 7: 2:00 to 4.00 PM
Problem solving session with examples: Finite element models of beams; identification of stiffness coefficients; post-computation of stresses

Aug 03 Wednessday

Lecture 15 : 9:30 to 11.00 AM
Finite Element Models of Composite Laminates and FGM Structures

Lecture 16: 11.15 to 12:45 AM
Applications to bending, vibration, buckling, and transient response of laminated plate

Tutorial 8: 2:00 to 4.00 PM
Problem solving session with examples

Aug 04 Thursday

Lecture 15 : 9:30 to 11.00 AM
Applications to bending and vibration of shell structures

Lecture 16: 11.15 to 12:45 AM
Applications to buckling and transient response of shell structures

Tutorial 9: 2:00 to 4.00 PM
Problem solving session with examples

Aug 05 Friday

Lecture 19 : 9:30 to 11.00 AM
Finite Element Models of piezo Laminates

Lecture 20: 11.15 to 12:45 AM
Finite Element Models of Smart Materials

2:00 to 4.00 PM
Examination, Evaluation and Certificate distribution for Module B

The Course will have a strong emphasis on solving several numerical examples. There will also be strong emphasis on programming aspects of FEM.