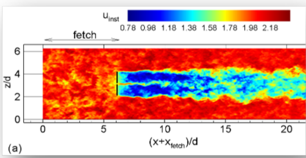
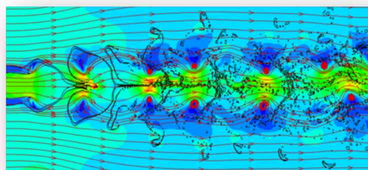
M. Tech. in Computational Mechanics (2021)

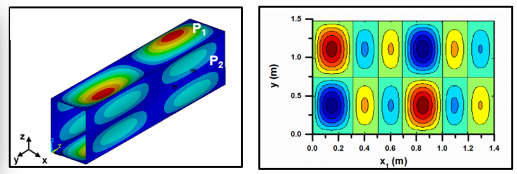
Introduction

The online M. Tech. in Computational Mechanics is a unique program offered by the Department of Mechanical and Aerospace Engineering, starting from August 2021, that will train students to solve multidisciplinary problems related to mechanical systems using computational techniques. Computational tools are ubiquitous in mechanical, aerospace and allied industries and form an integral part of the engineering design process today. Training in advanced computational techniques will greatly broaden the spectrum of opportunities available to graduates.

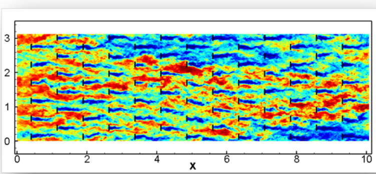


Large-eddy simulation of a multi-rotor wind turbine

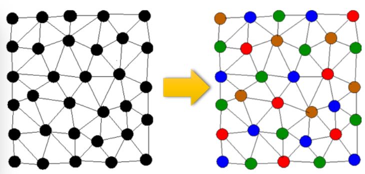

Computation of sprays and atomization

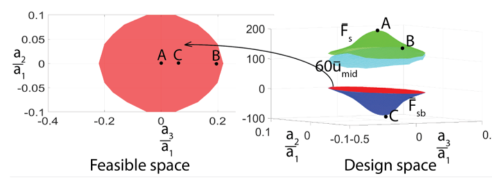


Duct and Equivalent Plate Mode Shapes



Turbine wakes simulation in large wind farms


CFD Solver Parallelization on CPU/GPU architectures



Design space and optimal profiles of bistable arches

The program combines elements of numerical methods and scientific computing with fundamental principles in solid mechanics, fluid mechanics, design and vibrations. Courses covering fundamentals of numerical analysis will be complemented with hands-on training using wide-ranging examples drawn from various domains of engineering. The program will benefit industry professionals looking to build expertise in the area looking to address technological challenges in industries in the automotive, oil and natural gas, renewable energy, defense and manufacturing sectors.

Eligibility

B. E./B. Tech. with first class (60 %) in Mechanical, Aerospace, Civil or Chemical engineering or other equivalent degrees; AND should be currently working in industry with a minimum of 2 years of industry experience after B. Tech.

Important Dates

Applications Solicited: Starting mid-June 2021

Last Date to Apply: 11 July 2021

Selection Process Completed: 30 July 2021

Classes Start: August 2021

Please check https://www.iith.ac.in/academics/post-graduate/ for applying (starting mid-June)

Duration and Structure

Option 1: M. Tech. (CM) with thesis - up to 4 years.

- Total 48 Credits (Course Credits: 24 + Thesis Credits: 24)
- Courses can be done over up to three years.
- Thesis will be done in the final year (maximum 4th year) after course work.

Option 2: Executive M. Tech. (CM) without thesis - up to 3 years.

- Total 24 Course Credits.
- Courses can be done over up to three years.

Online courses will be conducted separately from regular courses. Classes will be held in the evening and on weekends.

Students will do their project in their own industry. The project can be started only after coursework worth 24 credits is completed. During the project, each candidate will have a guide from IITH and may have another from his/her industry.

Curriculum

Semester	Course	Credit	Course Title
Semester 1/3/5 (Total 13 credits)			
Odd	ME5130	3	Finite Element Method
Odd	ME5330	3	Computational Fluid Dynamics
Odd	ME5890	2	Structural Optimization
Odd	ME5760	1.5	Applied Solid Mechanics
Odd	ME5770	1.5	Applied Fluid Mechanics
Odd	ME5900	2	Additive Manufacturing Technology
Semester 2/4/6 (Total 11 credits)			

Even	ME5780	3	Computational Dynamics and Vibrations
Even	ME5810	3	Advanced Computational Fluid Dynamics
Even	ME5790	3	Topics in Computational Mechanics
Even	ME5421	1	FEM Lab
Even	ME5441	1	CFD Lab
Semester 3/5/7 (Total 12 credits in any one semester)			
Odd	ME6005	12	Project
Semester 4/6/8 (Total 12 credits in any one semester)			
Even	ME6505	12	Project

Total: 48 Credits

Fee Details

Background of Candidate	Type of Industry/Organization	Fee Structure
Not an alumnus of IITH	Private Organization	Semester Fee of Rs. 15,000 + Rs 25,000/- per course credit + Rs. 12,500/- per thesis credit
Not an alumnus of IITH	Governmental Organization	Semester Fee of Rs. 15,000 + Rs 12,500/- per course credit + Rs. 12,500/- per thesis credit
IITH Alumnus	Private or Governmental	Semester Fee of Rs. 15,000 + Rs 12,500/- per course credit + Rs. 12,500/- per thesis credit

Course Descriptions

ME 5130 - Finite Element Methods

Theory and implementation of finite element methods for solving boundary value problems in solid mechanics. Mathematical foundations (Calculus of Variation), review of energy theorems, theory and implementation of 1D, 2D, and 3D elasticity problems. Introduction to FEM softwares.

References

1. R. D. Cook, D. S. Malkus, M. E. Plesha, R. J. Witt, “Concepts and Applications of Finite Element Analysis”, Wiley, 2001.

2. O. C. Zienkiewicz and R. L. Taylor, J. Z. Zhu, "The Finite Element Method: Its Basis and Fundamentals", Butterworth-Heinemann, 2013.
3. A. F. Bower, "Applied Mechanics of Solids", Online Resource: http://solidmechanics.org/, CRC Press, Taylor & Francis, 2010.
4. R. J. Boulbes, "Troubleshooting Finite-Element Modeling with Abaqus", Springer, 2020.

ME 5330 - Computational Fluid Dynamics

Introduction to numerical solutions of PDEs; importance of CFD; various methods; Taylor Series; Finite-difference of first, second and third derivatives; Order of accuracy; finite-differences on non-uniform grids; time-stepping; explicit and implicit time-stepping of 1D unsteady heat conduction equation; Boundary and Initial conditions; tri-diagonal solver; Explicit and Implicit schemes for 2D unsteady heat conduction equation; Gauss-Seidel method; Convergence; iterative vs direct methods; Types of PDEs, and their IC and BCs; the well-posed problem; Methods of Elliptic PDE; False-transient method; Hyperbolic PDEs; 1st order wave equation: characteristics; Methods: Lax, McCormack etc; modified equation; dissipative and dispersive errors; systems of hyperbolic equations; diagonalization; Finite-volume method; Convection-Diffusion equation; Convective schemes: Upwind, 2nd upwind, Quick, etc; Vorticity-stream function formulation: Explicit, Implicit and Semi-Implicit schemes; coupled temperature equation; segregated and coupled solution methods; SMAC method for Navier-Stokes equations.

References

1. J. D Anderson, "Computational Fluid Dynamics" McGraw-Hill International Editions, Series in Mechanical Engineering, 1995.
2. J. C. Tannehill, D. A. Anderson, R. H. Pletcher, "Computational fluid mechanics and heat transfer", Taylor and Francis, 1997.
3. T. K. Sengupta, "High accuracy computing methods", Cambridge University Press, 2013.
4. H. K. Versteeg, W. Malalasekera, "An Introduction to computational fluid dynamics", Pearson Education, 2008.

ME 5890 - Structural Optimization

Overview of size, shape and topology optimisation; constrained and unconstrained finite-variable optimization; KKT conditions; sufficiency conditions; analytical size optimization of bars and beams for stiffness, flexibility, strength, and stability criteria in the framework of variational calculus; gradient-based computational optimization of trusses, frames, and continuum structures; sensitivity analysis for parameter, shape, and topology variables; shape optimization; topology optimization; design parameterization for topology optimization of coupled structural problems involving multi-physics domains.

References

1. R. T. Haftka, Z. Gurdal, "Elements of Structural Optimization," Kluwer Academic Publishers, 1992.
2. M. P. Bendsoe, O. Sigmund, "Topology Optimization: Theory, Methods, and Applications," Springer, 2003.

ME 5760 - Applied Solid Mechanics

Introduction to basic solid mechanics, various strain measures and stress tensors, Balance laws, constitutive relations (commonly used energy density functions), special cases through simplification (incompressibility, plane stress and strain, hydrostatic loading, isotropy, linear elasticity), problems in Cartesian and other curvilinear coordinates.

References

1. A. F. Bower, "Applied Mechanics of Solids", Online Resource: http://solidmechanics.org/, CRC Press, Taylor & Francis, 2010.
2. M. Saad, "Elasticity: Theory, Applications, and Numerics", Academic Press Inc., Elsevier, 2020.
3. J. R. Barber, "Elasticity", Springer, 2010.

ME 5770 - Applied Fluid Mechanics

Tensors; Lagrangian and Eulerian frames of reference; Derivation of continuity equation and Navier-Stokes Equations; Elliptic and parabolic equations; Analytical solutions of NS equations; Boundary-layer theory; Turbulence; RANS equations; Introduction to turbulence modelling; Non-dimensionalization and non-dimensional parameters

References

1. P. Kundu, I. Cohen, D. Dowling, "Fluid Mechanics", Academic Press, 2015.
2. H. Schlichting, K. Gersten, "Boundary Layer Theory", Springer, 2016.
3. P. Davidson, "Turbulence: An introduction for Scientists and Engineers", Oxford University Press, 2015.

ME 5200 - Additive Manufacturing

Overview of Rapid Product Development: Product Development Cycle, virtual prototyping, physical prototyping, Solid Modelling: Data formats, conversion, checking, repairing and transmission. Synergic integration technologies, Part slicing and Build Orientation, Area-filling strategies, applications and limitations of RPM. Classification of RPM processes: Sheet Lamination, Material Extrusion, Photo-polymerization, Powder Bed Fusion, Binder Jetting, Direct Energy Deposition. Popular RPM processes. Selection of rapid prototyping, tooling and manufacturing systems based on product requirements. Energy sources and their interactions with feedstock.

References

1. B. Stucker, D. Rosen, I. Gibson, "Additive Manufacturing Technologies: 3D Printing, Rapid Prototyping, and Direct Digital Manufacturing", Springer-Verlag, 2015.
2. P. K. Venuvinod, W. Ma, "Rapid Prototyping, Laser-based and Other Technologies", Springer, 2004.
3. W. M. Steen, J. Mazumder, "Laser Material Processing", Springer-Verlag, 2003.

ME 5780 - Computational Dynamics and Vibrations

Governing equation and Generalized method: Newton's method, Virtual work principle, Euler-Lagrange method. Newton Raphson method, Runge kutta method, numerical tolerances and its control. Basics of linear vibration: 1 DOF linear vibration equation under free, forced and arbitrary forcing, Extension to MDOF system, Methods to solve linear equations. Basics of nonlinear vibration: 1 DOF nonlinear equation, Method to solve the equation: Perturbation methods.

References:

1. D. Greenwood, "Principle of Dynamics", Pearson, 1987.
2. L. Meirovitch, "Fundamental of Vibrations", Waveland Press Inc., 2010.
3. A. H. Nayfeh, D. T. Mook, "Nonlinear Oscillations", Wiley, 1995.
4. W. T. Thomson, "Theory of Vibrations With Applications", Pearson, 1997.

ME 5810– Advanced Computational Fluid Dynamics

Finite-volume method; pressure problem for incompressible Navier-Stokes equations; Pressure-velocity decoupling; Staggered and collocated grids; semi-explicit (SMAC) method on staggered grids; Convective schemes; Implicit SIMPLE method; higher-order accuracy implementations; Non-orthogonal grids: problems with staggered grids; collocated grid; implementation of semi-explicit and implicit schemes on rectangular collocated grids; generalization to collocated non-rectangular hexahedral grids; Boundary conditions and their implementation; adaptation of schemes to tetrahedral grids, general hybrid grids; advanced linear equations solvers; algebraic multigrid methods.

References

1. J. C. Tannehill, D. A. Anderson and R. H. Pletcher, " Computational fluid mechanics and heat transfer", Taylor and Francis, 1997.
2. J. Ferziger, M. Peric, R. Street, "Computational Methods for Fluid Dynamics", Springer, 2020.

3. H. K. Versteeg and W. Malalasekera, "An Introduction to computational fluid dynamics", Pearson Education, 2008.
4. T. K. Sengupta, "Fundamentals of Computational Fluid Dynamics", University Press, 2004.

ME 5790 – Topics in Computational Mechanics

A collection of modules (equivalent to 0.5 or 1 credit each) focusing on specialized multidisciplinary topics such as Impact Mechanics, Fluid-Structure Interaction, Parallel Computing.

ME 5421 - FEM Lab

Finite element methods for solving boundary value problems in solid mechanics. Introduction, Spatial Modelling, Geometric discretization, Element Library, Material Modelling, Loading and Boundary Conditions, Constraints, Surface/Interfaces modelling, Step and job handling and Post-processing. FEA Implementation and Visualization of 1D Problems, Truss Problem, Beam bending, Plane and axisymmetric Problems and 3D problems. Various analysis such as, Static, Transient, Harmonic, Modal, Dynamics and Multi Physics (Thermomechanical, etc).

References

1. R. D. Cook, D. S. Malkus, M. E. Plesha, R. J. Witt, "Concepts and Applications of Finite Element Analysis", Wiley, 2001.
2. O. C. Zienkiewicz and R. L. Taylor, J. Z. Zhu, "The Finite Element Method: Its Basis and Fundamentals", Butterworth-Heinemann, 2013.
3. A. F. Bower, "Applied Mechanics of Solids", Online Resource: http://solidmechanics.org/, CRC Press, Taylor & Francis, 2010.
4. R. J. Boulbes, "Troubleshooting Finite-Element Modeling with Abaqus", Springer, 2020.

ME 5441 - CFD Lab

Introduction and concepts of finite volume methods, Integral form of Navier-Stokes equations. Concepts of pressure and density-based solvers. Introduction to Ansys Workbench, basics of Design Modeler, Structured and unstructured meshing, Ansys fluent setup, solution and post processing. Laminar and turbulent viscous incompressible flow problems (2D and 3D Analysis). Compressible flow problems, Combustion modelling. Introduction to OpenFOAM solver.

References

1. Ansys Fluent documentation: Tutorial and Theory guide

2. H. K. Versteeg, W. Malalasekera, “An Introduction to computational fluid dynamics”, Pearson Education, 2008.
3. OpenFOAM Tutorial and User Guides, https://cfd.direct/openfoam/documentation/