Objectives

Crack growth can be simulated through moving interfaces and/or free surfaces with discontinuities, The main objective of the proposed course is to introduce various tools to understand the mechanics of fracture, which will help to develop better and efficient techniques for the design of materials. The primary objectives of the course are as follows:

- Expose the participants to the fundamental aspects of material design: Analysis of stress and strain, stress concentration, failure criterion, theories of failure, analysis of plates, closed form solutions and their limitations.
- To build confidence and capability amongst the participants on computational methods through approaches to develop constitutive equations for bulk, governing equations, strong and weak forms, overview of the finite element method (FEM), partition of unity and enrichment techniques and level sets.
- Discussions on processes and characteristics of composite materials, macro and micro-mechanical behaviour of lamina and laminate and the experimental techniques for the characterisation and testing of composite materials,
- To introduce artificial neural networks (ANN) based machine learning methods to solve partial differential equations for mechanical problems.
- Experimental techniques to predict the residual stresses and the estimation of stress intensity factor (SIF) and remaining life.

About the course

Mechanics of materials under various loading and operating conditions is an important area to be understood for efficient design of materials for various applications. Design of materials involves various topics, such as: (i) analysis of material response through load-displacement behaviour, (ii) analytical and computational techniques to simulate the material behaviour under operating conditions, (iii) influence of the defects on the material behaviour and (iv) experimental techniques to asses the actual characteristics.

Fracture simulations play a key role in devising new lighter, stronger and efficient materials for various applications. Computational fracture analysis requires developing suitable analytical models, discretisation techniques, and solution methods. Each of the above three steps poses its own difficulties, like: non-linear and non-homogeneous behaviour around the crack tip. Variety of solutions have been proposed to tackle such issues, for both academic and for practical applications, e.g. design of materials through the bottom up approach, as the material behaviour at sub-scales provide crucial information about the physical properties at higher scales, particularly with respect to material failure. On the other hand, experimental studies to asses the fracture behaviour of materials is expensive and time consuming. Therefore, the study of fracture using computational methods has deep-reaching applications throughout science and engineering.

The aim of this short course is to present the state-of-the-art and the most recent developments in computational and experimental methods for the analysis and simulation of fracture at multiple scales, such that the design of materials can be optimised.

Computational Fracture Mechanics

A Short term course under QIP scheme of AICTE

24 May 2021 - 4 June 2021

Organised by

School of Mechanical Sciences

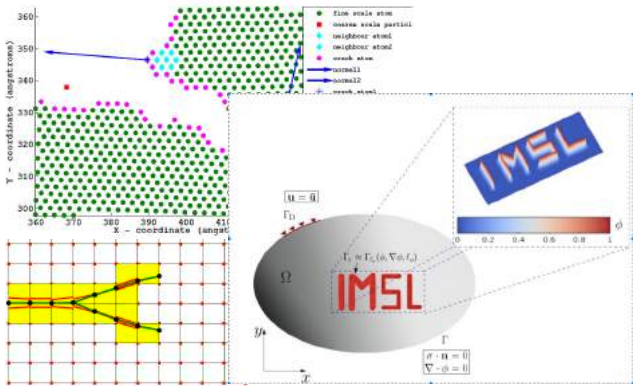
Indian Institute of Technology

Bhubaneswar

Objectives

A technique to simulate crack growth where the mesh is not required to conform to the free surface and the discontinuous quantities can be captured in the finite element interpolant with minimal smearing of the discontinuities is the extended finite element method (XFEM).

- Development of elemental and global stiffness matrices in XFEM, solution techniques, error and stability analysis, estimation of SIF and crack growth, along with the computer implementation aspects will be discussed.
- Recent computational techniques to simulate fracture, like: discrete crack and smeared/ diffused crack approaches, special singular elements, meshless methods, semi-analytical displacement formulation, phase field method for brittle fracture and cohesive zone model for fracture, where derivation of basic theory and implementation aspects will be discussed.
- The course ends with introduction to sub-scale (micro and nano) modelling aspects of fracture and recent multiscale methods to simulate fracture.



Faculty

Dr. P.R. Budarapu

Assistant Professor, School of Mechanical Sciences, IIT Bhubaneswar

Dr. Budarapu has joined the School of Mechanical Sciences at IIT Bhubaneswar as an Assistant Professor in 2017. Prior to this, he held postdoctoral research fellowship positions in the IMT School for Advanced studies Lucca, Italy and Masdar Institute of Science and Technology at Abudhabi, UAE. He received his PhD degree from Bauhaus University of Weimar, Germany. His research interests are: adaptive multiscale methods for fracture, failure mechanics of fibre reinforced and nano composites, photovoltaic solar cells, and Lithium-ion batteries.

Dr. S. Natarajan

Associate Professor, Machine Design Section, Department of Mechanical Engineering, IIT Madras, Chennai.

Dr. Natarajan joined the Machine design section in the Department of Mechanical Engineering at IIT Madras, as an assistant Professor in 2014. Prior to this, he held postdoctoral research fellowship positions in the University of New South Wales, Sydney and Indian Institute of Science, Bangalore. His research focus is on advanced computational methods for fracture, composites and functionally graded materials. He recieved Zienkiewicz best PhD prize by the Association of Computational Mechanics in Engineering, UK in 2011.

Dr. A.K. Pradhan

Associate Professor, School of Mechanical Sciences, IIT Bhubaneswar

Dr. Pradhan is currently working as an associate Professor in the School of Mechanical Sciences. He has more than 12 years of teaching experience. His research interests are: Composite Materials & Structures, Smart Materials & Structures and Natural Fibre Reinforced Composites.

Dr. V. Pandu Ranga

Associate Professor, School of Mechanical Sciences, IIT Bhubaneswar

Dr. Pandu Ranga is currently working as an associate Professor in the School of Mechanical Sciences. He did his Ph.D in Robotics and Soft Computing, at Department of Mechanical Engineering, IIT Kharagpur. His research interests are: Robotics, Manufacturing, Soft Computing. He has more than 10 years of teaching experience.

Dr. M.M. Mohapatra

Associate Professor, School of Mechanical Sciences, IIT Bhubaneswar

Dr. Mohapatra is working as associate Professor in the School of Mechanical Sciences, IIT Bhubaneswar. Prior to this, he was a faculty member at IIT Roorkee. His areas of interest are Welding Residual Stress and Distortion control, Friction Stir Welding, Thermal Spray and Laser Coating for Wear and High Temperature Applications and Metal Matrix Composites.

Dr. S. Roychowdhary

Assistant Professor, School of Mechanical Sciences, IIT Bhubaneswar

Dr. Roychowdhary joined the the School of Mechanical Sciences, IIT Bhubaneswar. s as an assistant Professor in 2019. His research interests are: Computational Solid Mechanics, Mechanics of Inflatable Structures and Nonlinear Elasticity.

Schedule

The course is planned for **60 hours** in total, with **52 lecture** hours and **13 tutorial** hours. Day wise schedule of the lecture classes and tutorials is given below.

Day 1: 24.05.2021

L1: Introduction to design of engineering materials
L2: Analysis of stress and strain
L3: Stress-strain relations for linearly elastic solids
L4: Failure criterion and preventions
T1: Case studies

Day 2: 25.05.2021

L5: Bending of straight beams, Thin-wall beams
L6: Thick and thin wall cylinders
L7: Torsion, Analysis of plates, Stress concentration
T2: Closed form solutions, their limitations and some case studies

Day 3: 26.05.2021

L8: Fundamentals of the finite element method; weak and strong forms
L9: Discretization and interpolation schemes and numerical integration
L10: Concepts of partition of unity and its relation to completeness
L11: Development of elemental and global stiffness matrices in FEM for 1D and 2D problems

Day 4: 27.05.2021

L12: Solution techniques for FEM. Time stepping algorithms, error norms and stability issues
L13: Introduction to composite materials, Processes and characteristics
L14: Macro and micro-mechanical behaviour of a lamina and laminates
T3: Applications of finite element method for various engineering problems

Day 5: 28.05.2021

L15: Working principles of Artificial neural networks
L16: Soft computing and ANN based techniques to solve partial differential equations
T4: Applications of ANN for mechanical problems
L17: Residual stresses and their effect on structures
L18: Estimation of residual stresses and their influence on life

Day 6: 31.05.2021

L19: Introduction to computational fracture mechanics - overview and difficulties with conventional FEM
L20: Discrete crack and smeared/diffused crack approaches
L21: Special singular elements for linear elastic fracture mechanics
L22: Semi-analytical displacement formulation for linear elastic fracture mechanics

Day 7: 01.06.2021

L23: An overview of linear elastic fracture mechanics (LEFM) and its limitations
L24: Introduction to the XFEM, displacement approximation, weak and strong forms
L25: Discretization and element formulation for one and two dimensional problems
L26: Development of elemental and global stiffness matrices in XFEM for 1D and 2D problems
T5. : Algorithms to estimate the crack geometry and element stiffness matrices

Day 8: 02.06.2021

L27: Solution techniques for XFEM. Time stepping algorithms, error norms and stability issues.
L28: Computational estimation of J-integral
L29: Estimation of the stress intensity factor (SIF)
L30: Computer implementation algorithms of XFEM

Date	09:00 - 09:55	10:00 - 10:55	11:15 - 12:10	12:15 - 13:10	14:30 - 15:25	15:30 - 16:25	16:40 - 17:35
Week 1 (24/05/2021 - 28/05/2021)							
24/05/2021	L1	L2	L3		L4	T1	
25/05/2021	L5		L6	L7	L7	T2	
26/05/2021	L8		L9	L10	L11		
27/05/2021	L12		L13	L14		T3	
28/05/2021	L15	L16	T4		L17		L18
Week 2 (31/05/2021 - 04/06/2021)							
31/05/2021	L19		L20	L21	L22		
1/6/2021	L23		L24	L25	L26	T5	
2/6/2021	L27		L28	L29	L30		
3/6/2021	L31		L32		T6		L33
4/6/2021	L34	L35	L36		T7		

LEGEND		PRB		AKP		MMM	
		SRC		VPR		SN	

Day 9: 03.06.2021

L31: Phase field method for brittle fracture

L32: Cohesive zone model for fracture. one and two dimensional implementation

T5: Overview and implementation aspects of the PFM and CZM

L33: Recent advances in phase field and cohesive zone models and some case studies

Day 10: 04.06.2021

L34: Introduction to micro and nano-mechanics of fracture

L35: Simulation of fracture at nano scales - molecular dynamics simulations

L36: Multiscale methods for fracture

T6: Implementation aspects of multiscale methods for fracture and case studies

Who can attend

1. Faculty members from reputed academic institutions and technical institutions.
2. Executives, engineers and researchers from manufacturing, service and government organisations including Research and Development laboratories

Registration

Registration for the first 30 participants will be at free of cost. Beyond 30 participants, a course registration fee of **₹8000 is applicable**. The registration has to be confirmed by submitting the filled in registration form to the course coordinator.

All the payments must be made in favour of **CEP, IIT Bhubaneswar, Canara Bank.**
A/C No:24282010001960, IFSC:CNRB0017282

Organising committee

Principal coordinator: Dr. Pattabhi Ramaiah Budarapu, School of Mechanical Sciences, IIT Bhubaneswar
Co-coordinator: Dr. Arun Kumar Pradhan, School of Mechanical Sciences, IIT Bhubaneswar

Contact details

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About IIT Bhubaneswar

Indian Institute of Technology Bhubaneswar (IITBBS) is a prominent institute among the eight new IITs initiated in 2008. The institute's vision is to be a highly respected institute in the world for its distinctive knowledge. Therefore, IITBBS is making strong strides to be among those which offer world class education. With an objective to create technologists and scientists of the highest calibre, the institute targets to provide its students with holistic education and opportunities to get empowered with the right academic preparation, analytical skills, creative skills and healthy mind. IITBBS offers programs like B.Tech, M.Tech, M.Sc and PhD in various disciplines. With a mission to shape ourselves into a learning community, we encourage interdisciplinary research, infuse excitement in students innovation & invention, design & creation and entrepreneurship, and strive for productive partnership between the industry and the Institute. The schools at IITBBS are equipped with state of the art equipment/facilities/laboratories and its faculty members are involved in a broad range of research areas and industrial consultancy. As a result, IITBBS is ranked 10 overall within the country by Times Higher Education in 2018.