**BIRLA INSTITUTE OF TECHNOLOGY & SCIENCE**
**SECOND SEMESTER**
**Course Handout Part II**

**Date: 10/01/2023**

In addition to part I (General Handout for all courses appended to the time table) this portion gives further specific details regarding the courses.

**Course No** **:** DE G514
**Course Title** **:** FRACTURE MECHANICS
**Instructor-in-charge** **:** AMOL VUPPULURI
**Lab Instructor** **:** ARJOO JAIMIN

**Course Description**: Introduction, energy release rate, stress intensity factor and complex cases, anelastic deformation at the crack tip, elastic plastic analysis through J-integral, crack tip opening displacement, test methods, fatigue failure, numerical analysis, mixed mode crack initiation and growth.

**Scope and objective of the course:** Recently, the study of fracture, crack propagation in metals plays a significant role. It is crucial for design engineers to understand the various critical parameters of fracture, their evaluation method and way to restrict the crack propagation. The scope of the course is to understand various experimental and analytical method of fracture parameter determination. The basic objective of the course to strength the knowledge base and analytical abilities of students related to various concepts of fracture mechanics in order to improve the structural integrity and come up with a fail-safe design.

**Text Book:**

1. Prashant Kumar, Elements of Fracture Mechanics, Tata McGraw-Hill Publishing Company Ltd., New Delhi, 2009.

**Reference Book:**

1. T.L. Anderson, Fracture Mechanics Fundamental and Applications, CRC Press, II$^{nd}$ Edition.
2. C.T. Sun and Z.C. Jin, Fracture Mechanics, Academic Press, Elsevier Publication, I$^{st}$ Edition, 2012.

**Course Plan:**

| Lect. No. | Learning Objectives | Topics to be covered | Ref. Chap./Sec. |
|---|---|---|---|
| 1-2 | Background | Kinds of failure and history | TB-Ch.1 |
| 3-5 | Energy release rate | Dilemma of Griffith, Surface energy, Griffith's realization<br>Griffith's analysis, Mathematical formulation,<br>Thin plate vs thick plate<br>Critical energy release rate. | TB- Ch.2 |
| 6-9 | Stress intensity factor (SIF) | Linear elastic fracture mechanics (LEFM)<br>Stress and displacement fields in isotropic elastic materials, Elementary properties of complex variables | TB- Ch.3 |
| 10-13 | SIF of more complex cases | Application of the principle of superposition, Crack in a plate of finite dimensions, Edge cracks, Embedded cracks, Relation between $G_I$ | TB- Ch.4 |

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| | | and $K_I$ | |
| 14-16 | Anelastic deformation at the crack Tip | Approximate shape and size of the plastic zone, Effective crack length, Effect of plate thickness. | TB- Ch.5 |
| 17 - 20 | J-Integral | Relevance and scope, Definition of J-Integral, Path independence<br>Stress-strain relation, Further discussion on J-Integral, Engineering approach-A short cut. | TB- Ch.6 |
| 21 - 24 | Crack tip opening displacement (CTOD) | Relationship between CTOD, $K_I$ and $G_I$ for small scale yielding<br>Equivalence between CTOD and J. | TB- Ch.7 |
| 25 - 28 | Test methods | $K_{IC}$ test techniques, Test methods to determine $J_{IC,}$ Test methods to determine $G_{IC}$ and $G_{IIC}$, Determination of critical CTOD. | TB- Ch.8 |
| 29 - 33 | Fatigue failure and Environment-assisted fracture | Terminology, S-N curve, Crack initiation, Crack propagation, Effect of an overload, Crack closure, Variable amplitude fatigue load. | TB- Ch.9 |
| 34 - 36 | Finite Element Analysis of cracks in solids | Direct and Indirect method to determine fracture parameters, | TB- Ch.10 |
| 37 – 39 | Mixed mode crack initiation and growth | Fracture surface, Mixed mode crack propagation criteria, Crack growth. | TB- Ch.11 |
| 40 - 42 | Crack detection through NDT | Visual, LPI, Magnetic Methods, Radiography, Ultrasonics | TB- Ch.12 |

| **Practical No.** | **Experiment Title** |
|---|---|
| 1 | Introduction of ABAQUS software and relevant necessary skill adaptation |
| 2 | Study of energy release rate during the crack propagation in when subjected to the Mode-I loading (Experiment) |
| 3 | Computation of the stress field ahead of the crack tip (Abaqus simulation) |
| 4 | Stress and strain field computation in cracked bodies using photoelasticity |
| 5 | Plane strain fracture analysis using long pipe. |
| 6 | Effect non-linear analysis on crack propagation and outcome using simple tensile test |

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| 7 | Analysis of three point bend specimens and influence of crack length and orientation on different fracture parameters (Experiment and simulation) |
| 8 | Crack Growth in a Three-point Bend Specimen using Cohesive Connections |
| 9 | Crack Growth in a Three-point Bend Specimen using XFEM |
| 10 | Modeling Crack Propagation in a Pressure Vessel (3D analysis) with Abaqus using XFEM. |
| 11 | The determination of J-Integral for different conditions. |
| 12 | Effect of fatigue loading and environmental assisted failures on facture parameters |

Note: All simulations will be performed through ABAQUS finite element software.

**Evaluation Scheme:**

| EC No. | Evaluation Component | Duration (min) | Weightage (%) | Date, Time & Venue | Nature of Component |
|---|---|---|---|---|---|
| 1. | Mid-semester Examination | 90 | 25 | 15/03 11.30 - 1.00PM | Closed Book |
| | Project and Case studies | - | 20 | To be announced by IC | Continuous Assessment (Open Book) |
| 2 | Lab Components and class assessment | - | 20 | To be announced by IC | Continuous Assessment (Open Book) |
| 3 | Comprehensive Examination | 180 | 35 | 12/05 AN | Close Book |

- **Chamber Consultation Hours**: To be announced in the class.
- **Notices:** Notices will be displayed on CMS.
- **Make-up Policy:** Make-up will be granted only to genuine cases with prior permission from the IC. For cases related to illness, proper documentary evidence is essential. No makeup is allowed for class assessment (surprise quizzes).
- **Academic Honesty and Integrity Policy**: Academic honesty and integrity are to be maintained by all the students throughout the semester and no type of academic dishonesty is acceptable.

**Instructor-in-charge**
**(DE G514)**