MIE 1303: ENGINEERING FRACTURE MECHANICS

(Failure Analysis, Diagnostics and Prevention)

Instructor Professor S. A. Meguid

Students undertaking this subject must possess a solid grasp of solid mechanics
The course content may be changed from year to year without prior notice

CHAPTER 1: FUNDAMENTALS OF ELASTIC AND PLASTIC BEHAVIOURS OF SOLIDS

(Assumed Known by the Students)

The stress Tensor, Equations of Equilibrium, Strain Displacement Relations, Compatibility of Strain, The Stain Tensor, The Stress and Strain Invariants, Constitutive Laws for Elastic Solids, Two-Dimensional Problems, Airy's Stress Function, Stress Concentration, Complex Stress Functions, Complex Potentials of Muskhelishvili, Displacement and Stress in Terms of Complex Potentials, An Overview of Plasticity Theory, Stress and Strain Deviator Tensors, Criteria for Yielding, Subsequent Yield Surface, Hardening Rules, Plastic Stress Strain Relations.

CHAPTER 2: MODES OF FAILURE

Failure and Fracture, Plastic Collapse, Ductile Failure, Brittle Fracture, Plastic Instability, Buckling and bifurcation, Fatigue Failure (Crack Initiation, Crack Propagation: Stages I & II and Crack Arrest), Creep and Creep Rupture and Corrosion. Emphases will be Given to Brittle Fracture and Fatigue.

CHAPTER 3: BRITTLE FRACTURE

Ductile Fracture, Brittle Fracture, Case History: Liberty Ships, Griffith Thermodynamic Energy Balance, The Griffith Crack, Irwin-Orowan Postulate, Design Against Brittle Fracture.

CHAPTER 4: LINEAR ELASTIC FRACTURE MECHANICS (LEFM)

Modes of Crack-Tip Deformation, Elastic Stress Field Equations: Westergaard Stress Function, Opening Mode Analysis, Sliding Mode Analysis, Tearing Mode Analysis, Superposition of Stress Intensity Factors, Effect of Finite Size of Component, Mixed Mode Problem, Determination of Stress Intensity Factors, Analytical Methods, Numerical Methods, Experimental Methods

CHAPTER 5: CRACK-TIP PLASTICITY

Plastic Zone Size Due to Irwin, Plastic Zone Size Due to Dugdale, Plastic Zone Size Using Classical Yield Criteria, Plastic Zone Shape and Size, Effect of Material Thickness Upon the Plastic Zone Size and Shape, Plane Strain and Plane Stress Fracture Toughness, Measurement of Plane Strain Toughness.

CHAPTER 6: ELASTO-PLASTIC FRACURE MECHANICS

The J-Integral, Path Independence of the J-Integral, The J-Integral: A Fracture Criterion, or a Characterising Parameter, Experimental Determination of the J-Integral, The Crack Opening Displacement, Crack Opening Displacement (COD), Experimental Determination of COD

CHAPTER 7: FATIGUE CRACK GROWTH

Constant Amplitude Loading, Fatigue Life Prediction, Fatigue Crack Growth Data, Crack-Tip Plasticity and Closure Effects, Variable Amplitude Loading, Crack Retardation: Over-Load, Prediction of Crack Growth in the Presence of Residual Stresses, The Short Crack Problem, Effective Stress Intensity Factors and Elber Model, Design Against Fatigue.

CHAPTER 8: FAILURE ANALYSIS, DIAGNOSTICS AND PREVENTION

A number of case studies will be covered to show the use of Fracture Mechanics as a powerful design tool in Failure Analysis, Diagnostics and Prevention. These will be integrated in the above chapters.

Example Case Studies

(i) Failure of aeroengine discs
(ii) Defence hole systems
(iii) Mechanically induced residual stresses
(iv) Liberty ships
(v) Space shuttle “Challenger”

FRACTURE MECHANICS PROJECTS

In support of the above syllabus, students will be assigned failure analysis projects.