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Course Description and Objectives

The course aims to prepare students for their future in academic or industrial career where "products" are of concern. Such products may be very novel or quite standard. From another perspective they are typically a combined multi-disciplinary effort of different engineers. The course perceives each product as a "material" with certain measurable/adjustable properties engineered geometrically at macro-scale (mm, m) and at micro-scale (μm, nm). These geometries and micro-structures are in constant conflict with operation conditions and time. Such struggle continues until a "failure" occurs by leaving one certain and fundamental question "Why did it happen?". This course uses forensic case studies for theoretical teaching and laboratory practice sessions to answer this question. From a top (product) to bottom(material) perspective, the objective is to identify the "suspect" with instructed methods of evidence gathering, data interpretation/gathering and diagnostics. From top to bottom perspective, the objective is effective material development pathways for specific applications where above mentioned "suspects" are key factors to eliminate. The first approach is exemplified in the course while the second approach is expected by students to perform as technical report which will be the main tool of assessment.

Course combines relative chapters and case studies from following sources and uses lecture slides as the main source.

Peter Rhys Lewis, Ken Reynolds, Colin Egg, Forensic Materials Engineering, Case Studies, CRC Press, 2004,

Peter Rhys Lewis, Forensic Polymer Engineering, Woodhead Publishing, 2016.

George D. Quinn, Fractographic analysis of ceramics and Glasses, National Institute of Standards and Technology (NIST), 2016

Micheal D. Hayes, Dale B. Edwards, Anan R. Shah , Fractography in Failure Analysis of Polymers, Plastics Design Library, 2015

Micheal F. Ashby, Material Selection in Material Design,

Wiiliam D. Callister, Introduction to Material Science and Engineering, Wiley, 2017

Course Grading:

Students are expected to write a technical report whose evaluation scheme is portrayed in **table 2.**

Technical Report: 40%

Midterm Evaluation: 30%

Lab Reports: 20%

Final Presentation: 10%

Table 1: Weekly Syllabus:

Topic	Week	Focus	Fundamental Questions
Introduction to failure analysis	1	Methodology	What is failure analysis?
Product Defects	2	Manufacturing Microstructural	What may be classified as a product defect? (macro-scale)
Materials and Failure (Strength of Materials)	3	Properties and design	What about inherent defects in the material building blocks? (microstructures)
Materials and Failure (Fracture Mechanics)	4	Fundamentals of Brittle Fracture Ductile Fracture	How serious is a defect on your engineering design?
Time Dependent Failure	5	Fatigue	What happens to these defective micro-structures over time?
Chemical and Environmental Failure	6	Corrosion Environmental Stress Cracking	How important is the surface science?
Tools and Instruments of Failure Analysis	7	Characterization methods	How can you use material science for failure analysis?
Fracture Surfaces and Material Science	8	Ceramics	How to interpret property/failure relationship in ceramics?
Fracture Surfaces and Material Science	9	Metals	How to interpret property/failure relationship in metals?
Fracture Surfaces and Material Science	10	Polymers	How to interpret property/failure relationship in polymers?
Fracture Surfaces and Material Science	11	Composites	How to interpret property/failure relationship in composites?
Mechanical Testing Laboratory	12		
Optical Microscopy Laboratory	13		How to gather evidence from failed sample/products?
Technical Report Evaluation	14		

Table 2. Technical Report Progress and Evaluation Framework

Course Topic	Week	Assignment	Task
Introduction to failure analysis	1	Abstract submissions.	**H1**: Students will submit a short abstract on the definition of a simple product that will be investigated. 4-5 keywords for each participant will be decided after an active discussion with course supervisor.
Product Defects	2		
Materials and Failure (Strength of Materials)	3	Target and Limits	**H2:** Material Datasheet-manufacturing type collection and evaluation
Materials and Failure (Fracture Mechanics)	4		
Time Dependent Failure	5	Fatigue	**H3:** A discussion essay describing advantages and disadvantages of the types of manufacturing for suggested product to operate under defined conditions.
Chemical and Environmental Failure	6	Corrosion Environmental Stress Cracking	
Tools and Instruments of Failure Analysis	7	Characterization methods	Midterm Evaluation
Fracture Surfaces and Material Science (Ceramics)	8	Image and Data Library	**H4-5**: Students are expected to collect failure analysis examples and fracture surface images from literature based on the investigation of novel materials that may be suited to the stated problem. These images will be collated as an image and data libraries to be submitted.
Fracture Surfaces and Material Science (Metals)	9		
Fracture Surfaces and Material Science (Polymers)	10		
Fracture Surfaces and Material Science (Composites)	11		
Mechanical Testing Laboratory	12	Image Processing	Lab Reports: Grain Size determination and failure observations based on very basic image processing
Optical Microscopy Laboratory	13		
Technical Report Evaluation	14		Attendants will submit a short technical report stating the key factors related with manufacturing, material selection and design of related product. Different failure modes observed for the potential material candidate will be included from the image library to discuss material/failure relation.