TO: The Engineering Faculty

FROM: The Faculty of the School of Materials Engineering

RE: New graduate course – MSE 51800 Failure Analysis

The Faculty of the School of Materials Engineering has approved the following new graduate course in April 2021 (see attached document for course description). This action is now submitted to the Engineering Faculty with a recommendation for approval.

FROM:

MSE 597FA Failure Analysis, Sem. 1, 2, SS, Class 3, Cr. 3. Prerequisites: MSE 335, MSE 382 or graduate standing

Temporary course number. Course was taught Fall 17, Fall 19, and Fall 21. Enrollment was 25, 24, and 30 respectively.

TO:

MSE 51800 Failure Analysis Sem. 1, 2, SS, Class 3, Cr. 3. Prerequisites: MSE 335, MSE 382 or graduate standing

Introduction to failure analysis and prevention. Concepts of materials failure, root cause analysis, manufacturing aspects of failure, techniques for identifying failure, fracture, corrosion, wear, and case studies. Also includes business and entrepreneurship aspects.

Reason: This course has been taught successfully as a temporary course and it is now being submitted for a permanent course number. It is expected that in the future the course may also be delivered via distance education using a lecture capture mode in the future.

David Bahr
Head of MSE

Proposal for New Graduate Level Course for Academic Review
MSE 51800 – Failure Analysis

Note: The detailed course proposal is intended for academic review by the appropriate area committee of the Graduate Council. It supplements the Form 40G that is intended for administrative review of the Graduate School and Registrar.

TO: Purdue University Graduate Council

FROM: Faculty Member: David Bahr
Department: School of Materials Engineering
Campus: West Lafayette

DATE: March 17, 2021

SUBJECT: Proposal for New Graduate Course

MSE 51800 Failure Analysis
SEM 1 or 2, Lecture 3, cr. 3

1. Course Description

This course provides an introduction at the graduate level to failure analysis and prevention in materials engineering. The course covers the concepts of materials failure, root cause analysis, manufacturing aspects and the typical ways that they lead to failure, techniques for identifying and characterizing failure, fracture, corrosion, and wear. The course uses analytical descriptions, historical documentation, and case studies to provide context for the process of failure analysis. Business and entrepreneurship aspects of materials failure analysis are also introduced. The course covers all classes of materials (metals, ceramics, polymers, and electronic materials) and failure mechanisms ranging from mechanical loading to failures caused by electrical and thermal conditions.

2. Justification for the Course

2.1 Justification of the need for the course

The course is designed to meet the needs of students within the School of Materials Engineering (MSE), and potentially other engineering or technology majors studying mechanics of materials, characterization of materials, and forensics. The course fits within the courses related to both materials characterization techniques and mechanisms of deformation and fracture. MSE 51800 will complement topics covered in MSE 382, 510, 555 and 556. Currently no course on Purdue's campus provides a microstructural and characterization focus relating the mechanisms of failure with the resulting morphology of the material that provide documentation of the failure processes.

2.2 Justification that course will be taught at a graduate level

MSE 51800 will be taught at the graduate level. The course builds on undergraduate topics (MSE 250, 382), advances beyond an undergraduate laboratory course (MSE 335), and complements material in MSE 445, 510, 531, 555 and 556. Students taking this course require the existing undergraduate knowledge in these courses to be able to apply those techniques to failure in a wide range of materials systems. The cannon for the course is covered in the ASM International Handbook (Volume 11) on Failure Analysis, and supplemented by journal articles from the peer reviewed source Journal of Failure Analysis and Prevention.

2.3 Justification for online delivery

MSE 51800 may be of interest to students pursuing the Masters of Science in Engineering with a Materials emphasis. Informal surveys of alumni from the MSE undergraduate and graduate programs have noted that 15-20% of materials engineering graduates perform some type of failure analysis in their jobs. The likelihood that graduated engineers pursuing an online MS degree would be interested in taking the course are significant.

3. Learning Outcomes and Methods of Assessment

3.1 Learning Outcomes

1. All Students

A. Become familiar with and be able to identify the categories of failure.
B. Recognize types of failure based on microstructural and post-mortem characterization
C. Relate failure to stressors driving failure (mechanical, thermal, electrical, etc.)
D. Communicate results of a failure analysis clearly to professional audiences

2. Most Students

A. Estimate stressors driving failure in relationship to materials properties, service conditions, and design constraints.
B. Use or select appropriate characterization tools for failure analysis.
C. Select appropriate inspection criteria to prevent failure.
D. Recommend improvements in design, service or inspection to prevent failure.

3.2 Assessment Methods

Assessment is achieved in three methods: Exams (one in-class exam and a final exam), small homework projects, and 2-3 practical failure analysis projects based on in-field failures of real engineering parts. The exams require intensive problem solving and the utilization of concepts covered in class to interpret scenarios and provide explanations of likely mechanisms that are responsible for failure. The homeworks are short problems sets designed to highlight a particular topic (such as types of surface characterization and mechanisms related to processes-based defects). The projects are shared-data projects based on failure examples from industrial partners and consumer applications that require the class to select analysis methods, process data, draw conclusions based on failure morphology, and provide recommendations for future prevention. All of these methods require education beyond the 200-400 level undergraduate MSE curriculum.

3.3 Final Grading Criteria

Grading is based on a fixed scale, and advanced undergraduates should be able to succeed in a manner similar to first- and second-year graduate students as long as they've had the required background course material.

Grading: Midterm exam 20%
Final exam 30%
Homework 10%
Projects 40%

Grading Scale: 85% - A; 70% - B; 60% - C; 50% - D. May be scaled downward depending on class performance on projects which are drawn from industry and consumer sources.

3.4 Methods of Instruction

Lecture – Lectures will be used to help the students to achieve the learning outcomes. These include hands-on analyses of basic principles of concepts covered during lectures and sharing data collected by the instructor based on class-selected techniques.

3.5 Prerequisite(s)

Graduate Standing OR MSE 382 and MSE 335

4. Course Instructor

David Bahr, Professor MSE, member of the Graduate Faculty:

Prof. Bahr has experience and training in materials reliability, deformation, and fracture of engineering materials. He has served as a failure analysis consultant to industry and as an expert witness in failure cases, and performed failure analysis for industrial partners during externally funded research.

5. Course Outline:

1. Introduction to microstructural history in materials
2. Overview of mechanical behavior
3. Principles and Approaches in Failure Analysis Work
4. Characterization techniques for failure parts
5. Inspection and non-destructive testing
6. Codes and standards
7. Types of manufacturing processes and ties to failure
8. Failure in specific equipment – application systems
9. Typical historical case studies
10. Classic dramatic failures
11. Career considerations and business aspects of failure
12. Class-based case studies on failed parts

6. Reading List

- ASM Handbook Volume 11: Failure Analysis and Prevention Editors: Brett A. Miller, Roch J. Shipley, Ronald J. Parrington, and Daniel P. Dennies | Hardcover | 856 pages | ISBN: 978-1-62708-293-8 (2021)

This handbook is available in the Purdue library as an electronic resource for no cost to students. Selected chapters will be assigned as reading.

- ASM Digital Database for Failure Analysis: https://dl.asminternational.org/failure-analysis. Contains 100's of case studies of failed parts with explanations and processes. Purdue libraries provides access to all Purdue students.

- Selected reading from the Journal of Failure Analysis and Prevention. JFAP is a publication of ASM International and the Failure Analysis Society, Print ISSN 1547-7029. The journal is available electronically to all Purdue students for no cost through the library.

7. Course Syllabus

MSE 597 FA: Failure Analysis Fall 2019 CNR 16603

Professor: D.F. Bahr dfbahr@purdue.edu; 494-4100
Assistant: None
Location ARMS 1021, MWF 9:30-10:20
Credits 3 – Three 50 minute lectures per week
Office hours By appointment with Prof. Bahr. TBD if fixed times are needed. Email is quickest way to get contacts
Prerequisite class: MSE 382 or equivalent, MSE 335
Prerequisite topics: Basic statics, mechanics, deformation mechanics, materials characterization
Post-requisites: N/A
Required Text: Online resources, ASM Handbook Vol 11, ASM Materials Analysis Database. These are available through the library at Purdue to enrolled students for free. All resources links will be posted on the course blackboard site.

Introduction to failure analysis and prevention. Concepts of materials failure, root cause analysis, manufacturing aspects of failure, techniques for identifying failure, fracture, corrosion, wear, and case studies. Also includes business and entrepreneurship aspects.

Relation of Course to Program Outcomes
This course will enable students to demonstrate an ability to
Apply knowledge of mathematics, science, and engineering to problems in materials engineering.
Identify, formulate, and solve engineering problems, particularly in the context of materials selection and design.
Exhibit effective oral and written communication skills.
Use the techniques, skills, and experimental, computational and data analysis tools necessary for materials engineering practice.

Goals
1. All Students
A. Become familiar with and be able to identify the categories of failure.
B. Recognize types of failure based on microstructural and post-mortem characterization
C. Relate failure to stressors driving failure (mechanical, thermal, electrical, etc.)
D. Communicate results of a failure analysis clearly to professional audiences

2. Most Students
A. Estimate stressors driving failure in relationship to materials properties, service conditions, and design constraints.
B. Use or select appropriate characterization tools for failure analysis.
C. Select appropriate inspection criteria to prevent failure.
D. Recommend improvements in design, service or inspection to prevent failure.

Assignments: Homework will be relatively short, and are primarily for you to learn, they will be posted on blackboard. We will have several (2-4) larger projects during the semester where you cover a case study in failure analysis and provide either a written report or a class presentation of

the results, likely as teams (depending a bit on class size). Again, these will be posted on blackboard.

Grading: Midterm exam 20%
Final exam 30%
Homework 10%
Projects 40%

Grading Scale: 85% - A; 70% - B; 60% - C; 50% - D. May be scaled downward depending on class performance.

Office Hours: Contact via email for appointments.

Students with Disabilities: Purdue University responds to the needs of the students with disabilities as outlined in both the Rehabilitation Act of 1973 and the Americans with Disabilities Act of 1990 through the provision of auxiliary aids and services that allow a student with a disability to fully access and participate in the programs, services, and activities at Purdue University. Purdue University strives to make learning experiences as accessible as possible. If you anticipate or experience physical or academic barriers based on disability, you are welcome to let me know so that we can discuss options. You are also encouraged to contact the Disability Resource Center at: **drc@purdue.edu** or by phone: 765-494-1247. It is the student's responsibility to notify the Disability Resource Center (http://www.purdue.edu/drc) of an impairment/condition that may require accommodations and/or classroom modifications.

Academic Integrity: Purdue prohibits "dishonesty in connection with any University activity. Cheating, plagiarism, or knowingly furnishing false information to the University are examples of dishonesty." Furthermore, the University Senate has stipulated that "the commitment of acts of cheating, lying, and deceit in any of their diverse forms (such as the use of substitutes for taking examinations, the use of illegal cribs, plagiarism, and copying during examinations) is dishonest and must not be tolerated. Moreover, knowingly to aid and abet, directly or indirectly, other parties in committing dishonest acts is in itself dishonest."
In other words, do your own work, never plagiarize, and don't even think of cheating on an exam. Students found to engage in acts of academic dishonesty are subject to sanctions. For a first offense the student will receive a failing grade for the assignment or exam in question. Depending on the severity of the offense the instructor may refer the case to the Office of the Dean of Students for further action. A second offense will result in a failing grade for MSE 382 and definite referral to the Office of the Dean of Students.

Safety and Emergencies: In the event of a major campus emergency, course requirements, deadlines and grading percentages are subject to changes that may be necessitated by a revised semester calendar or other circumstances beyond the instructor's control. Information in this case will be posted on blackboard and sent to your @purdue.edu address. Information is available at https://www.purdue.edu/emergency_preparedness/flipchart/index.html

Copyrighted materials: Among the materials that may be protected by copyright law are the lectures, notes, and other material presented in class or as part of the course. Always assume the materials presented by an instructor are protected by copyright unless the instructor has stated

otherwise. Students enrolled in, and authorized visitors to, Purdue University courses are permitted to take notes, which they may use for individual/group study or for other non-commercial purposes reasonably arising from enrollment in the course or the University generally. Notes taken in class are, however, generally considered to be "derivative works" of the instructor's presentations and materials, and they are thus subject to the instructor's copyright in such presentations and materials. No individual is permitted to sell or otherwise barter notes, either to other students or to any commercial concern, for a course without the express written permission of the course instructor.

Attendance: Classroom attendance is expected for all students. University sponsored events and activities or other legitimate reasons for missing class should be communicated to the instructor in advance when possible, and accommodations will be made to allow work to be made up. Illness should be documented per university procedures.

There will be a few class periods where the lecture is provided via video on blackboard, this will be announced in class ahead of time. We will also have a few times where class is replaced through on-line video or webcast.

Nondiscrimination: Purdue University is committed to maintaining a community which recognizes and values the inherent worth and dignity of every person; fosters tolerance, sensitivity, understanding, and mutual respect among its members; and encourages each individual to strive to reach his or her own potential. In pursuit of its goal of academic excellence, the University seeks to develop and nurture diversity. The University believes that diversity among its many members strengthens the institution, stimulates creativity, promotes the exchange of ideas, and enriches campus life. Purdue's nondiscrimination policy can be found at http://www.purdue.edu/purdue/ea_eou_statement.html.

MSE 597 FA: Failure Analysis
Weekly Schedule Fall 2019

When	What	Notes
Week 1 8/19	Introduction and microstructures	
2 8/27	Overview of mechanical behavior	Online HW assignment for 8/29
3 9/2	Principles and Approaches in Failure Analysis Work	
4 9/9	Approaches continued	
5 9/16	Characterization techniques	Online HW assignment for 9/19
6 9/23	Characterization continued	
7 9/30	Inspection and NDT	
8 10/7	Codes and standards	Oct. break 10/7
9 10/14	Types of manufacturing processes and ties to failure	Midterm exam 10/14 most likely
10 10/21	Equipment – application specific systems 1	

11 10/28	Equipment specific 2	
12 11/4	Case studies	
13 11/11	Some classic dramatic failures	Online assignment 11/14
14 11/18	Career considerations	
15 11/25	Class case studies	Thanksgiving 11/28
16 12/1	Class case studies	
Final exam		