



# FAILURE ANALYSIS & PREVENTION

## project 2 period

enr 3820

### OVERVIEW

The Part 2 project period is designed to provide experiential learning of failure analysis techniques through self-designed failure investigations. We will spend approximately seven weeks exploring a variety of topics in component failure. We'll focus on mechanical failures (undue stress) and environmentally influenced failures (severe environments), but you may find that your projects necessitate exploration of additional topics. The goals are simple: complete a failure analysis investigation (or two or three); write a detailed, professional quality case study report of your findings; and present your findings to and respond to questions from the class.

**Undue stress.** Stuff bends and breaks. In Part 2, you will spend some time studying factors that lead to geometrical changes (distortion) or material separation (fracture) in engineered components. You will learn about some of the microscopic mechanisms of deformation and fracture, and you will examine macroscopic and microscopic evidence of different mechanical stress-related fracture modes. By building your knowledge of crack growth, brittle and ductile fracture, mechanical fatigue, thermomechanical fatigue, friction and wear, and creep, you will be better equipped to predict possible failure modes in engineering components, and you will gain insight into methods of failure prevention.

**Severe environments.** Man and nature have created some pretty nasty service environments for our designs. Later in Part 2, we'll turn our attention to the important role that environment plays in determining the behavior and service life of materials, components, and systems. You will study the different forms of chemical, electrochemical, and radiative attack, and you will examine the deleterious effects these environmental factors have on the properties and performance of engineering polymers, metals, or ceramics. Some students may choose to focus on corrosion mechanisms in structural metallic components, while others may decide to learn more about the degradation in polymers, composites, electronic materials, biomaterials, films, or other areas.

For the project component of Part 2, you and your team will spend about seven weeks investigating components or systems that failed in a stress-related manner, or an environment-related manner. Each team may decide to tackle one larger project, or a variety of smaller projects. Once you select a failed component or system, you will organize and complete a laboratory analysis of the failure, and produce a detailed case study report.

Assignments in Part 2 will include:

- Readings: fracture mechanisms and fracture surface features, fracture-related case studies, background on corrosion and degradation in metals and polymers, environment-related case studies
- A few problems on fracture, fatigue, corrosion, and degradation
- Failure analysis project and case study report
- Presentations
- Classroom discussion (instructor- and student-facilitated)

### PROCEDURES

Although your team will determine many of the Part 2 project details, a general framework for Part 2 projects is as follows:

1. Form a team and select a failed component or system to analyze.
2. Plan your approach to the failure analysis investigation; record this plan in a written format.
3. Collect pertinent background and contextual information on the failed component or system.
4. Identify the possible causes of failure.
5. Design and implement a set of laboratory experiments to gather physical evidence to support your investigation. You may use whatever laboratory tools and experimental techniques you believe will provide the best evidence to support your analysis.
6. Locate and use reputable literature sources that provide appropriate supporting technical information for your analyses.

7. Determine probable causes of failure that are supported by your evidence, and report your conclusions.
8. Discuss preventative measures that could be used to avoid future failure of your component or system.

Your goal in this project is to identify the cause(s) of the failure and outline methods of prevention. Each team should carry their analysis as far as possible under the given constraints (time, laboratory tools, information resources, and budget). You should focus not only on answering the “what” questions, but also on the “how” and “why” questions. Don’t forget the science, and the contextual factors. For example, a simple investigation of a fractured brass component may reveal that the part failed in a brittle intergranular fracture mode (answers the “What damage is present?” question). Further investigation may reveal that the brittle intergranular fracture was due to arsenic embrittlement at the grain boundaries, and that the brass contained high arsenic content (answers the “How did the damage occur?” question). Consideration of the bronze forming, processing, handling, and environmental factors may provide the necessary context to identify the cause of the high arsenic content in the brass, and it may enable specification of preventative measures.

## DELIVERABLES

The deliverables for Part 2 are as follows:

1. Case Study Report(s). Due dates will be specified by each team. Each team should prepare detailed, professional quality, case-study style report(s) of your failure analyses, conclusions, and recommendations for failure prevention.
  - There is no page limit, but you should try to maintain clarity and succinctness in your report. Cut the fluff, and focus on the analysis and significance of your analyses.
  - Include a one-paragraph abstract that summarizes your aim, scope, results, and conclusions.
  - Include high quality figures, equations, and tables that support your analyses and conclusions.
  - Cite information sources as appropriate.
2. Presentation(s). Due dates will be specified by each team. Prepare 10-12 minute presentation(s) in which you present key evidence and analyses, and summarize your findings and recommendations. Approximately 5-10 minutes will be devoted to class discussion of your findings.

## ASSESSMENT

Your failure analysis investigations, case study reports, and presentations will be assessed according to the following criteria. Additional details on these competency assessments are provided in the Project Grading Rubric (on the web site).

- Qualitative analysis – Are your arguments clear? Are you able to use physical data and researched information to

explain technical phenomena and support your conclusions? Do you make appropriate connections among the various technical concepts and information, and between the technical and contextual information? Do you support your data analyses and conclusions with materials science theory? Do you explain discrepancies? Do you make good use of estimation (if appropriate)?

- Quantitative analysis – Are your calculated data accurate? Do you make appropriate use of published information and theory to support your data and quantitative analyses? Do your quantitative results connect to and support your qualitative discussion? Do you include quantitative analyses of loads and stresses (e.g., finite element analysis, mechanics calculations) when appropriate?
- Communication – Do you make effective use of written communication in the report, and graphical, visual, and oral communication in the presentation and discussion? Is your report well organized, well written, and appropriate for the audience? Are the arguments and goals clear, and does the report support these arguments and goals? Are the mechanics (spelling, grammar, word choice, punctuation) well executed? Do you make logical and well-supported arguments? Do you make good use of graphs and images? Are your slides and oral communication clear and professional? Is reference information and evidence carefully woven into the text?
- Diagnosis (Experimental Inquiry) – Do you identify pertinent questions in response to the defined project goals? Can you design appropriate experiments to answer the defined questions? Can you identify unexpected results and take corrective action? Are you able to verify the expert’s hypothesis, or to form and test your own hypothesis? Are the limitations of the experiment clear, and are suggestions for improvement included?

Detailed grading rubrics for project assignments are posted on the web site. You are encouraged to read these rubrics near the start of the project, and to communicate with the instructor if there are areas of uncertainty. You will use these rubrics for your competency self-assessment.

In-class teaming reflections and a brief teaming survey will be used during the project to help maintain effective teams. The results from this survey will not affect your grade, but participation in the reflection and feedback process will affect your grade. The reflections and surveys administered during the project are simply intended to spark conversations among teammates and help you recognize areas of strength and areas potentially in need of further development. Individual team member contributions and behaviors will be evaluated at the end of the project using the Comprehensive Assessment of Team Member Effectiveness (CATME) survey. The CATME self-assessment

## SELF-DIRECTION

Wow, there are so many opportunities for self-direction during the Part 2 project phase of the course. You are charged with selecting your topic of study, setting goals, selecting learning strategies, identifying and using resources, self-monitoring and controlling your processes, managing your time and effort, seeking help when needed, setting project timelines and distributing tasks among the team members, connecting your work to personal interests and motivations, finding value in what you do, internalizing the learning, managing your teaming interactions, monitoring your work environment, etc. Perhaps we should have a discussion of self-regulated learning at some point during this phase of the course. What do you think?

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