Fatigue and Fracture of Metals
ME 472/672
Spring 2021

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Office Hours: TBD

Textbook: Metal Fatigue in Engineering, 2nd Edition, R.I. Stephens, A. Fatemi, R.R. Stephens, and H.O. Fuchs, John Wiley, 2001

Lecture: MWF: 11 – 11:50 am, AGHILL CTR 330, or online via Blackboard (Zoom)

Prereq: ME 442 (Machine Design I) or graduate standing.

Course Description:

This course will provide an overview of the causes and effects of fatigue failure in metals, and present in-depth coverage of common analytical methods for fatigue design and fatigue life prediction. The differing mechanisms and analytical techniques for fatigue crack initiation, crack propagation, and fracture will be highlighted. Emphasis will be given to techniques used in industry to design against fatigue failure, including testing, analysis, and validation methods.

Course Outcomes:

1. Students will understand the mechanisms responsible for fatigue crack initiation and propagation in metals.
2. Students will be able to apply the stress-life approach for fatigue design and analysis.
3. Students will be able to apply the strain-life approach for fatigue design and analysis.
4. Students will understand the fundamentals of linear elastic fracture mechanics and its application to the analysis of fatigue crack propagation in metals.
5. Students will be able to account for the effects of notches and residual stresses in metal fatigue.
6. Students will be able to analyze the effects of variable amplitude loading.
7. Students will understand and be able to apply the different methods for analyzing multiaxial loadings in fatigue.
8. Students will understand the effects of the environment on the fatigue behavior of metals.
9. Students will understand the various techniques used to generate fatigue test data, perform field testing, validate models, and fatigue software capabilities.

Grading Procedures:

	Undergraduate	Graduate
Homework Assignments*	25%	20%
Midterm Exams	50%	45%
Final Exam	25%	20%
Special Project**		15%

* Homework assignments may include problems from the textbook, as well as small projects involving computer applications and the analysis of test data.

** Graduate students are required to complete a special project on an advanced topic. Examples may include a research paper on a subject not covered in the course, the development of a computer algorithm for analyzing variable amplitude loading or multiaxial stresses, or the application of iterative design methods for a component based on fatigue testing and analysis. The specific topic will be mutually agreed upon by the instructor and students(s).

General Course Expectations:

No late homework or reports accepted without special permission from the instructor.

The academic community is operated on the basis of honesty, integrity, and fair play. *NDSU Policy 335: Code of Academic Responsibility and Conduct* applies to cases in which cheating, plagiarism, or other academic misconduct have occurred in an instructional context. Students found guilty of academic misconduct are subject to penalties, up to and possibly including suspension and/or expulsion. Informational resources about academic honesty can be found at www.ndsu.edu/academichonesty.

Any students with disabilities or other special needs, who need special accommodations for this course, are invited to share those concerns with the instructor and contact the Disability Services Office as soon as possible.

Veterans and student service members with special circumstances or who are activated are encouraged to notify the instructor in advance.

Course Policies Related to COVID-19

Communication

- The class will be conducted both online and face-to-face, observing the NDSU guidance regarding COVID-19. Notification of any schedule or assignment changes will be communicated through the NDSU Blackboard announcements page and email.
- Your NDSU email address is the official route for information.
- I will use Zoom (via Blackboard) for online course delivery. Virtual participation in this course requires both video and audio capabilities.
- You can use *IT Help Desk* for technology concerns.
    - Help Desk: Email: ndsu.helpdesk@ndsu.edu
    - Call: 701-231-8685 (option 1)

Health and Safety Expectations

Please refer to https://www.ndsu.edu/police_safety/covid_19_preparedness_and_response/ for information on COVID-19 and NDSU's response.

NDSU requires face coverings, physical distancing, and sanitation.

- NDSU requires students to wear face coverings in classrooms. Wearing face coverings helps reduce the risk to others in case you are infected but do not have symptoms.
- You must properly wear a face covering (covering both the mouth and nose) for the entirety of the class.
- If you fail to properly wear a face covering, you will not be admitted to the classroom. However, you may choose to participate in the class remotely. The following will be used as needed: referral to Dean of Students Office or administrative removal from class.
- Students who cannot wear a face covering due to a medical condition or disability may seek accommodation through *Disability Services* (701-231-8463; https://www.ndsu.edu/disabilityservices/).
- Disinfecting supplies are provided for you to disinfect your learning space. You may also use your own disinfecting supplies.
- Students should observe social distancing guidelines whenever possible. Students should avoid congregating around instructional space entrances before or after class. Students should exit the instructional space immediately after the end of class to ensure social distancing and allow for the persons attending the next scheduled class to enter the classroom.
- In accordance with NDSU Policy 601, failure to comply with instructions, including this syllabus, may be handled according to the Code of Student Conduct resolution process and may result in disciplinary sanctions.

Attendance Expectations

NDSU Policy 333 Class Attendance Policy should be observed.

- Students are expected to attend every class and remain in class for the duration of the session when it is safe to do so in accordance with NDSU guidance regarding COVID-19.
- While late homework is generally not accepted, please note that I will be flexible regarding deadlines for students who are experiencing illness or other challenges related to COVID-19. Please contact me as early as possible if you think you may not be able to complete an assignment or participate in the course due to illness.
- Due to COVID-19, I do not have a strict attendance policy. Do not come to class if you are sick. You can view the lectures remotely and ask questions through the online platform. You are responsible for viewing all lectures, either synchronously or asynchronously.
- Lectures will be saved on the course Blackboard. If you are unable to attend class at the regularly scheduled time due to illness, contact me for alternate arrangements, including assignments as well as accommodations and extensions as needed.
- Please protect your health and the health of others by staying home and participate in class remotely if you are sick. For information on COVID-19, symptoms, testing, and steps to stay healthy see https://www.ndsu.edu/studenthealthservice/covid_19/ .
- Do not come to class if you have been exposed to individuals who tested positive for COVID-19 and/or you have been notified to self-quarantine due to exposure.

Tentative Course Outline (subject to change)

Topic	***Reading***	***Class Periods***
Introduction, causes and effects of fatigue failure, historical overview	Chapter 1	1
Overview of fatigue design methods, criteria, testing	Chapter 2	1
Mechanisms and characteristics of fatigue crack initiation/nucleation and propagation	Chapter 3	2
Review of stress-life (S-N) approach: fatigue strength, endurance limit, mean stress effects	Chapter 4	3
Cyclic deformation of metals, elastic-plastic behavior	Sections 5.1 – 5.3	3
Strain-life (ε-N) approach to fatigue: low-cycle fatigue, testing, mean stress models	Sections 5.4 – 5.7	4
Fundamentals of LEFM: stress intensity factors, crack tip plasticity, fracture toughness	Sections 6.1 – 6.3	3
Fatigue crack propagation: Paris law, crack closure, mean stress effects, elastic-plastic fracture mechanics	Sections 6.4 – 6.9	4
Notch effects (S-N approach): stress concentrations, stress gradients, notch sensitivity, mean stresses	Sections 7.1 – 7.2	3
Notch effects (ε-N and crack growth): localized plasticity, Neuber's & Glinka's rules, crack growth from notches	Sections 7.3 – 7.5	3
Residual stresses: causes and effects on fatigue resistance, relaxation, measurement, stress intensity factors	Chapter 8	3
Variable loading: cumulative damage, load interactions, cycle-counting methods, life estimations	Chapter 9	4
Multiaxial fatigue: effective stress models, critical plane approaches, non-proportional loading, crack growth	Chapter 10	3
Fatigue of weldments: crack initiation and growth, life estimation models, design considerations	Chapter 12	1
Fatigue testing and analysis: data acquisition, statistical analysis, reliability, software	Chapter 13	1
Three-Four Midterm Exams (Topics and dates TBD)		**3-4**
Final Exam	**Thursday, May 13, 8 – 10 am**	