FACULTY OF ENGINEERING, BUILT ENVIRONMENT AND INFORMATION TECHNOLOGY

Department of Mechanical and Aeronautical Engineering

STUDY GUIDE FOR

MSV 780 Fatigue

Compiled by:

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ORGANISATIONAL COMPONENT

1. GENERAL PREMISE AND EDUCATIONAL APPROACH

This module will focus on background theory and the application of the following specialist fields:

1. Fatigue of materials using stress- and strain-based approaches.
2. Basics of weld fatigue design.
3. Application to machine components, structures and pressure vessels.
4. Fracture Mechanics – only an overview.

It is important to attend classes in order to attain theoretical knowledge and insight of the subject material. The module will comprise a total of 18 (3 days) lecture hours.
The website contains downloads of notes, slides, the assignment as well as detail of the online tests.

2. LECTURERS, VENUES AND CONSULTING HOURS

2.1 Lecturer

This module will be presented by Dr. Michiel Heyns Pr.Eng. Contact details are:

Company	:	Investmech (Pty) Ltd
Website	:	investmech.com/FatigueBlog
Address	:	8 Topaz Avenue, Lyttelton Manor X3, Centurion, 0157
GPS coordinates	:	25°50'28" S, 028°12'46" E
Telephone	:	+27 12 664-7604
Facsimile	:	+27 86 535-1379
Cellular	:	+27 82 445-0510
Skype	:	drmichielheyns
E-Mail	:	mheyns@investmech.com
Assistant	:	ceopa@investmech.com; +27 82 823-6719

2.2 Course website

You can find handout downloads, memoranda, etc. from the website:

http://investmech.com/FatigueBlog/

2.3 Lecture Rooms

Lectures will be as indicated by the Department of Material Science and Metallurgical Engineering, University of Pretoria.

2.4 Consulting Hours

The lecturer is available by appointment. Skype or Teamviewer video conferencing and telephone conferencing can also be scheduled where required.

2.5 Schedule

As arranged by the Department of Mechanical and Aeronautical Engineering, University of Pretoria.

3. STUDY MATERIALS

3.1 Prescribed Material

- Dowling, N.E. 2013. *Mechanical Behavior of Materials: Engineering Methods for Deformation, Fracture and Fatigue*. 4th Edition. Pearson, Boston
- One of the following standards: BS 7608 or EN 1993-1-9.
- Notes.
- Reference is made in notes to websites that is part of the course.
- Reference is also made to standards that is part of the course.

3.2 Additional Study Material

- Standards on the topics.

4. LEARNING ACTIVITIES

Number of lecture hours: 20
The student should spend about 10 hours to prepare the individual assignment.
The student should spend about 10 hours to prepare for the online tests.
In this assignment, only a selection of answers will be marked by the lecturer and the student will be tested by online tests to be completed in the student's own time over a specific period.
For the purpose of the online test the student will receive a unique registration number from which each student can select his/her own unique logon username and password. More detail is available on the website.

5. RULES OF ASESSMENT AND PASS REQUIREMENTS

A total semester mark of at least 50% is required.

5.1 Calculation of Final Mark

Although there is an emphasis on discussion and class interaction, there must be some form of evaluation in order to obtain a pass mark for the course. The total points will be calculated as follows:
Online tests: 40%
Individual Assignment: 30%
Written test: 30%
This will make up 50% of the final mark. The examination will contribute 50%.

5.2 Assignments

One individual assignment will be done.
Submission date: **Within two weeks after the last lecture**.
Further details will be provided in the class.
Please note that assignments must be submitted in Acrobat Reader format or MS Word formats by e-mail to mheyns@investmech.com and ceopa@investmech.com. Copies to the school should also be submitted as specified.

5.3 Online tests

There will be online tests in this module. The detail will be handled and discussed during the first and last lecture. Detail is also available on the website. The following process will be followed:

1. You will receive a letter during the lectures.
2. The letter will contain your unique student registration code that you will use to register for the online testing.
3. Follow the process and register. Please remember your new login name and password because that is what you will use for future logins.
4. Logon on the website www.classmarker.com and do the dummy test.
5. The other tests will only be available as shown below.

The tests were made available for completion as shown in Table 1. It is your responsibility to write the test during a suitable time over the availability period. The online tests are open book and can be answered from the notes given to you. Note, the duration of the tests require that you are prepared before taking a test.

Table 1: Online test schedule

Test name	Topic	Duration [min]	Weight	Available from	Available to
Dummy	A dummy test that will not count any marks	10	0%	15 Feb	1 week after last lecture
Behaviour	Behaviour of dynamically loaded structures	60	30%	15 Feb	1 week after the first lecture
Design	Design of dynamically loaded welded structures	60	30%	15 Feb	1 week after the second lecture
Practicals	Practicalities on weld improvements,	40	20%	15 Feb	1 week after the third lecture
Pressure	Pressure equipment	40	20%	15 Feb	1 week after the third lecture

Please note on the following for these online tests:

1. The available to date, is until 24:00 on the specific date. The Classmarker website may show availability to one day later, but, that is simply because it is until 12 a.m. on that day.
2. Tests can be completed from any device with Internet connection. That includes iPhone, iPads, Android tablets, etc. Because images are used in some questions, you are strongly advised to take tests on a notebook or desktop computer or a device with large screen to show images and allow you to see more than one document at the same time.
3. It is also strongly advised to have at least a 3G data connection if you choose to use mobile connection.
4. You will need a calculator for calculations during the online tests. You can also use Excel or the scientific calculator on your computer for this purpose.
5. It is not required to have completed assignments before taking tests.
6. Available tests can be completed in any order.
7. **You must complete a test once you have started with it.** That is, you will have only one attempt to complete the test. Therefore, make sure that you have sufficient bandwidth to complete a test.
8. The time for each test, with remaining time will be clearly indicated on your screen. When reaching the end of the time for each test, the online test software will automatically submit your test.
9. During the test you can move forward and backwards and change answer if required.
10. You are allowed to finish the test with some questions unanswered if you are not sure of an answer.
11. Your marks will be available immediately after completion of each test.

5.4 Written test and exam

Parameter	Written test	Exam
Duration	1 hour	3 hours
Date	Second lecture day	See department schedule
Type	Closed-book with the formula sheet	Closed-book with the formula sheet

5.5 Class Participation

Full time attendance is required during the attendance block. This course will focus on insight and will be evaluated as such in the assignments. It is important to share your knowledge with the rest of the class.

STUDY COMPONENT

6. MODULE OBJECTIVES, ARTICULATION AND LEARNING OUTCOMES

6.1 General Objective

To obtain knowledge in the application of stress-based and strain-based fatigue.

6.2 Critical Learning Outcomes

Having completed this module the student will be able to:

- Design materials for static loads.
- Use factored resistance equations in SANS 10162-1 for the design of welded joints for static loads.
- Apply stress-life and strain-life principles to solve problems.
- Identify the weld detail class.
- Select the suitable S_r-N fatigue curve for probabilistic design of weld detail.
- Design welded joints for variable amplitude loads.
- Use EN 1993-1-9 or BS 7608 for the design of weld detail subject to variable amplitude loading.
- Explain the basis of fatigue design used in applicable standards.

- Explain the principle used in Elastic Plastic Fracture Mechanics.
- Solve fatigue design and damage control problems.

7. MODULE STRUCTURE

Study Theme	Study Unit
Basics of stress distribution – summary only • Explain stress distributions due to forces and moments • Explain the different types of stresses joints. • Calculate in detail simple welded joints. • Calculate the values of cross sections. • Calculate nominal stresses. • Calculate combined stresses (superposition). **File: Investmech (Force moment and stress distributions) P R0.0.pptx**	1. Types of stresses in welded joints a. Nominal stress b. Shear stress c. Bending stress d. Hot spot stress e. Notch stress 2. Stresses in butt welds. 3. Stresses in fillet welds. 4. Calculation of section properties of welded joints. 5. Determination of reference values of stresses due to multi-axial stressing. 6. Determination of design resistance of arc-welded and resistance welded joints. 7. Worked examples of calculation of nominal stresses in welded joints.
Behaviour of materials under dynamic loading • Draw and use and S-N diagram. • Describe methods of counting load cycles. • Calculate the stress ratio. • Detail the influence of notches and weld defects. • Explain the methods for improving fatigue performance. **File: Investmech (Behaviour of welded structures under variable amplitude loading) TN R0.0.docx**	1. Types of cyclic loading. 2. Statistical stress analysis on real structures. 3. S-N diagram. 4. Stress collective. 5. Fatigue strength (low cycle, and others). 6. Effect of mean stress. 7. Effect of stress range. 8. Stress distribution. 9. Influence of Notches. 10. Influence of weld defects. 11. Fatigue improvement tecniques: a. Peening (shot, hammering, needle, high-frequency) b. TIG dressing. c. Burr grinding. d. Stress relieving. 12. Standards. 13. Palmgren-Miner rule. 14. Classification of weld joints. 15. Stress-life 16. Strain-life 17. Very high cycle fatigue (VHCF)
Design of dynamically loaded welded structures • Design welded joints in accordance with given details. • Detail the influence of notch effects on the classification of welded joints. • Interpret appropriate standards. • Compare details in different standards and classify them. **File: Investmech (Design of dynamic loaded welded structures) TN R0.0.docx**	1. Range of application: a. Bridges b. Cranes c. Machines d. Ships and offshore constructions e. Chimneys f. Towers and masts g. Vehicles (cars, trucks, railway vehicles) 2. Acceptance criteria. 3. Use of standards and specifications. 4. Worked examples.
Design of welded pressure equipment Understand in detail the special requirements of design and construction of structural elements in this field of application with regards to the welds. • Explain fully the design of given structural weld details. • Interpret appropriate standards. • Calculate circumferential and longitudinal welds. • Detail the advantages of different structural	1. Construction of boilers, pressure vessels, pipelines, etc. 2. Calculation of the welds 3. High and low temperature applications 4. Details of design (flanges, nozzles, shells, compensating plates, etc.) 5. Use of laws and design rules, standard and specificaions 6. Worked examples of construction and design 7. Standards (ISO, CEN, BS, ASME, etc)

Study Theme	Study Unit
details. **File: Investmech (Design of welded pressure equipment) TN R0.0.docx** For the purpose of the weld fatigue lectures, focus will be on fatigue only. Other sections are handled by other lecturers.	For the purpose of the weld fatigue lectures, focus will be on fatigue only. Other sections are handled by other lecturers. Standards will be briefly discussed in class.
Design of aluminium alloys and structures Understand in detail the behavior of welded aluminium structures with respect to strength, stresses and design. • Explain fully the occurrence of softening in the heat affected zone. • Design aluminium profiles for a given use. • Explain fully how to solve the most common imperfections on aluminium welds. • Detail the causes and development of stresses and strains in an aluminium weld. • Detail the strength of different alloys. • Deduce correct selection of alloys for given applications. **File: Investmech (Design of aluminium alloys structures) TR R0.0.docx** For the purpose of the weld fatigue lectures, focus will be on fatigue only. Other sections are handled by other lecturers.	1. Comparison of design between steel and aluminium structures 2. Lightweight structures 3. Standard alloys for practical use and relevant stresses and strains 4. Effects of heat affected zone softening 5. Special design principles regarding profiles 6. Significance of defects. 7. Range of application: a. Vehicles b. Rolling stock c. Ships d. Aircraft e. Vessels f. Space 8. Dimensioning according to different standards and specifications 9. Worked examples For the purpose of the weld fatigue lectures, focus will be on fatigue only. Other sections are handled by other lecturers.
Introduction to fracture mechanics – only if there is time • Explain the principles of linear-elastic and elastic-plastic fracture mechanics. • Describe the influence factors for linear-elastic and elastic-plastic fracture mechanics. • Describe the use of fracture mechanics for dynamically loaded structures. • Describe fracture mechanics testing methods. **File: Investmech (Introduction to Fracture Mechanics) TR R0.0.docx**	1. Viewpoint of fracture mechanics. 2. Application of fracture mechanics. 3. Linear elastic fracture mechanics. 4. Fundamentals of elastic-plastic fracture mechanics. 5. Critical flaw size, K_{IC}-value. 6. Fracture mechanics testing: a. CTOD 7. Sub-critical crack growth. 8. Fatigue testing. 9. Standards.

8. MODULE CONTENT

As is available on the module website and for which notes have been distributed.