ENGINEERING & THE BUILT ENVIRONMENT FACULTY

School of Chemical & Metallurgical Engineering

IIW

STUDY GUIDE FOR

Fatigue Design of Welded Joints

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. Basics of weld design.
2. Fatigue analysis.
3. Fracture Mechanics.
4. Non-destructive examination – only 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 14 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	:	www.investmech.com
Website for the course	:	http://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	:	Ms. Natasha Zimmermann, ceopa@investmech.com ; +27 82 823-6719

2.2 Lecture Rooms

Lecture rooms will be as indicated by the School for Chemical and Metallurgical Engineering.

2.3 Consulting Hours

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

2.4 Schedule

The contact session will take place as indicated by the School for Chemical and Metallurgical Engineering.

3. STUDY MATERIALS

3.1 Prescribed Material

- One of the following standards: BS 7608 or EN 1993-1-9.
- Notes.
- Reference is made in notes to websites that are part of the course.
- Reference is also made to standards that are part of the course.

3.2 Additional Study Material

- Standards on the topics.

3.3 Web pages

- As indicated in the notes.

4. LEARNING ACTIVITIES

Number of lecture hours: 40
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 and the student will be tested by an online test to be written in the student's own time over a specific period. For the purpose of the online test the student will draw a unique logon username and password from a registration code handed over during class.

5. RULES OF ASESSMENT 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: 60%
Individual Assignment: 40%
This will make up 50% of the final mark. The examination will contribute 50%.

5.2 Assignments

One individual assignment will be done after the attendance block and must be handed in on the latest on the first day of the next block. 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 by them.

5.3 Tests

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

1. You will receive a letter during the lectures.
2. The letter will contain your unique student 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
IIWDummy	A dummy test that will not count any marks	10	0%	12 Jun	19 Sept
IIWBehaviour	Behaviour of dynamically loaded structures	60	20%	12 Jun	19 Sept
IIWDesign	Design of dynamically loaded welded structures	60	40%	12 Jun	19 Sept
IIWPracticals	Practicalities on weld improvements	40	20%	12 Jun	19 Sept
IIWPressure	Design of pressure equipment	40	20%	12 Jun	19 Sept

Please note on the following for these online tests:

1. 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.

2. It is also strongly advised to have at least a 3G data connection if you choose to use mobile connection.
3. 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.
4. It is not required to have completed assignments before taking tests.
5. Available tests can be completed in any order.
6. **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.
7. 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.
8. During the test, you can move forward and backward and change answers if required.
9. You are allowed to finish the test with some questions unanswered if you are not sure of an answer.
10. Your marks will be available immediately after completion of each test.

5.4 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 introductory knowledge in the application of material properties, stress calculation, fatigue, fracture mechanics, post-weld treatement and non-destructive testing in the design and evaluation of welded joints.

6.2 Critical Learning Outcomes

Having completed this module the student will be able to:

- Design welded joints for static loads.
- Use factored resistance equations in SANS 10162-1 for the design of welded joints for static loads.
- 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 for the design of weld detail subject to variable amplitude loading.
- Explain the basis of fatigue design used in applicable standards.
- Design of welded pressure equipment.
- Explain the principle used in Elastic Plastic Fracture Mechanics.
- Solve fatigue design and damage control problems.

7. MODULE STRUCTURE

Study Theme	Study Unit
3.4 Basics of weld design – summary only • Explain the different types of stresses in welded joints. • Calculate in detail simple welded joints. • Calculate the values of cross sections for welded joints. • Calculate nominal stresses in welds. • Calculate combined stresses in welds (superposition).	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.
3.7 Behaviour of welded structures 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	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
3.8 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	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
3.12 Introduction to fracture mechanics • 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.	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.

Study Theme	Study Unit
	9. Standards.
3.9 Design of welded pressure equipment (6 hrs) Objective: Understand in detail the special requirements of design and construction of structural elements in this field of application with regard to welds Outcomes: • Explain fully the design of given structural details • Interpret appropriate standards • Calculate circumferential and longitudinal welds • Detail the advantages of different structural details	1. Construction of boilers, pressure vessels, pipelines, etc 2. Calculation (formulae) of the welds 3. High and low temperature applications 4. Details of the design (flanges, nozzles, shells, compensation plates, etc.) 5. Use of laws and design rules, standards and specifications 6. Worked examples of construction and design 7. Standards (ISO, CEN, BS, ASME, etc.)

8. MODULE CONTENT

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