Engineering Tripos Part IIA, 3C9: Fracture Mechanics of Materials & Structures, 2023-24

Module Leader

Prof N.A. Fleck [1]

Lecturers

Prof N.A. Fleck, Prof V.S. Deshpande

Lab Leader

Dr G McShane

Timing and Structure

Lent term. 16 lectures + coursework

Prerequisites

3C7 assumed

Aims

The aims of the course are to:

- Explain the physical processes underlying fracture from a single dominant crack and from a distribution of cracks.
- Describe the main concepts of fracture mechanics in terms of stress analysis, failure mechanisms and design methods.
- Discuss both linear elastic fracture mechanics (LEFM) and ductile fracture.
- Apply the methods to a wide range of engineering applications from thin film design in electronics to fatigue life assessment of nuclear pressure vessels and damage mechanics of concrete.

Objectives

As specific objectives, by the end of the course students should be able to:

- To explain the physical processes underlying fracture from a single dominant crack and from a distribution of cracks.
- Quantitative design methods are physically based and used to predict fatigue life and residual strength of damaged structures

Content

Elastic stress analysis (4L) Prof. Deshpande

- Williams solution using the Airy stress function

- LEFM and interfacial fracture
- Energy appraoch to fracture
- Practical K-calibrations and use of superposition
- Fracture of thin films and of weldments
- Prediction of fracture toughness

Small Scale Yielding (2L) Prof Deshpande

- plastic zone size and crack tip opening displacement
- R-curves: the tear resistance of metals, composites and biological tissues

Large Scale Yielding (4L) Prof Fleck

- Dugdale model for a large plastic zone from a crack tip, and transition to bulk plasticity
- Application to adhesive joints and crazing of polymers, and to pressure vessels
- Void nucleation and growth in a plastic field

Fatigue crack growth (5L) Prof Fleck

- Threshold, Paris law, variable amplitude loading for aircraft
- S-N curves for fatigue crack initiation and growth

Case study on fatigue of railway lines (1L) Prof Smith (Guest lecture)

Case studies on fatigue failure in transport applications given by the former Chief Scientific Advisor to the Ministry of Transport

REFERENCES

Fracture Mechanics: fundamentals and applications, T.L.Anderson,Taylor Francis,2005.

Coursework

Learning objectives:

(i) To develop an understanding of failure process under monotonic loading at ambient temperatures

(ii) To examine the use of stress intensity factor and strain energy release rate to describe the failure of cracked bodies.

(iii) To evaluate the use of linear elastic fracture (LEFM) and the concept of limit load in the assessment of cracked components.

Practical information:

The course work involves:

- Lab Session 1 - Tensile testing (2 hrs), location: Fatigue Laboratory, ground floor, Baker Building
- Lab Session 2 - Pipe bursting (30 mins), location: Materials Teaching Laboratory, ground floor, Inglis Building
- Feedback session (30 mins), location: Oatley 1 Meeting room, second floor, Baker Building

Please book your sessions using the following link:

http://www.eng.cam.ac.uk/teaching/apps/cuedle/index.php?context=3C9(2021) [2]

Full Technical Report:

Students have the option to submit a Full Technical Report.

Booklists

Please refer to the Booklist for Part IIA Courses for references to this module, this can be found on the associated Moodle course.

Examination Guidelines

Please refer to Form & conduct of the examinations [3].

UK-SPEC

This syllabus contributes to the following areas of the UK-SPEC [4] standard:

Toggle display of UK-SPEC areas.

GT1

Develop transferable skills that will be of value in a wide range of situations. These are exemplified by the Qualifications and Curriculum Authority Higher Level Key Skills and include problem solving, communication, and working with others, as well as the effective use of general IT facilities and information retrieval skills. They also include planning self-learning and improving performance, as the foundation for lifelong learning/CPD.

IA1

Apply appropriate quantitative science and engineering tools to the analysis of problems.

KU1

Demonstrate knowledge and understanding of essential facts, concepts, theories and principles of their engineering discipline, and its underpinning science and mathematics.

KU2

Have an appreciation of the wider multidisciplinary engineering context and its underlying principles.

E1

Ability to use fundamental knowledge to investigate new and emerging technologies.

E2

Ability to extract data pertinent to an unfamiliar problem, and apply its solution using computer based engineering tools when appropriate.

E3

Ability to apply mathematical and computer based models for solving problems in engineering, and the ability to assess the limitations of particular cases.

P1

A thorough understanding of current practice and its limitations and some appreciation of likely new developments.

US1

A comprehensive understanding of the scientific principles of own specialisation and related disciplines.

US2

A comprehensive knowledge and understanding of mathematical and computer models relevant to the engineering discipline, and an appreciation of their limitations.

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Links
[1] mailto:naf1@eng.cam.ac.uk
[2] http://www.eng.cam.ac.uk/teaching/apps/cuedle/index.php?context=3C9(2021)
[3] https://teaching23-24.eng.cam.ac.uk/content/form-conduct-examinations
[4] https://teaching23-24.eng.cam.ac.uk/content/uk-spec