Engineering Tripos Part IIA, 3C8: Machine Design, 2022-23

Module Leader

Prof. DJ Cole [1]

Lecturers

Prof. DJ Cole, Prof. MPF Sutcliffe and Dr RL Roebuck [2]

Lab Leader

Prof. DJ Cole [1]

Timing and Structure

Michaelmas term.16 lectures.

Aims

The aims of the course are to:

- Analyse the contact stresses and kinematical behaviour of solid contacts and to understand the design of rolling element bearings and other machine elements.
- Understand the design of involute gears and appreciate the stress limits and practical problems of gears.
- To analyse the behaviour of multiple gear drives and planetary gears.
- Understand how components are combined to make up a mechanical power transmission system, including power matching to achieve a desired operating point.
- Apply the principles of power matching to hybrid drives.
- Introduce methods for specifying the type and arrangement of rolling element bearings to meet a specified duty.

Objectives

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

- Calculate the strength limitations of solid contacts.
- Analyse the kinematical behaviour of contacts, especially in rotating machinery.
- Understand and analyse the performance of friction drives.
- Be familiar with the geometry and kinematics of involute gear wheels and racks.
- Understand the criterion for tooth bending failure and be able to derive the Hertz pressure at tooth contacts.
- Use power and torque calculations to analyse epicyclic gears and multiple gear drives.
- Understand how power transmission components are used as part of a system, including hybrid drives.
- Determine the operating point and calculate the optimum speed ratio for specified conditions.
- Select a rolling element bearing for a specific duty.

Content

Mechanics of contacts (5L) Dr Richard Roebuck

- Hertzian point contacts
- Stresses and stiffness
- Hertzian line contacts
- Applications in bearings and CVTs
- Traction drives and CVTs

Gears (6L) Prof. Michael Sutcliffe

- Geometry and kinematics
- Failure, root bending and contact fatigue
- Design and applications
- Multiple drives and planetary gears
- Design calculations for planetary gears

Power matching (3L) Prof. David Cole

- Introduction and applications: automotive transmission, bicycle transmission
- Sources and loads; devices and their characteristics
- Power matching using a simple gear ratio
- Hybrid drives

Rolling element bearings (2L) Prof. David Cole

- Bearing types; life equation
- Shaft and bearing arrangements

Examples papers

Examples Paper 1 - Mechanics of contacts (issued at lecture 1)

Examples Paper 2 - Gears (issued at lecture 6)

Examples Paper 3 - Power matching, rolling element bearings (issued at lecture 12)

Coursework

Power output characteristic of a cyclist

In this experiment the power output charateristic of a cyclist will be determined by holding the heart rate (a proxy for power input) constant and determining the dependence of crank torque and crank power on crank speed.

Learning objectives:

- to calibrate and operate instrumentation to measure human power output
- to propose and test an hypothesis using measured data with large inherent uncertainty
- to understand the power output characteristic of a cyclist

Practical information:

- Sessions will take place in the Baker Building, South Wing Mechanics Laboratory, during weeks 2 to 8 (Fridays and Wednesdays, 11am-1pm)
- This activity does involve preliminary work, approximately 40 minutes: read the lab sheet carefully and watch the demonstration video before the session.
- Book a timeslot online via the moodle site.
- The practical needs to be done in pairs, with at least one member of the pair being comfortable riding the stationary bicycle. It is not possible to perform the experiment individually.
- The lab report must be written individually. All data processing, analysis and interpretation performed after the lab session must be done independently and not in collaboration with each other or anyone else.

Full Technical Report:

Students will have the option to submit a Full Technical Report. The FTR should be a complete, detailed, formal report of the experiment, suitable for publication in an engineering journal. It should include all of the information necessary for the reader to understand the aim, objectives, apparatus, method, results, analysis, discussion and conclusions. In addition the FTR should describe in precise engineering terms the operating principles of three different commercially-available devices for measuring cyclist power output, and comment upon likely sources and magnitudes of error.

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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