Leader
Dr K A Seffen

Reader in Structural Mechanics
Dr K A Seffen

Lab Leader
Dr K A Seffen

Timing and Structure
Michaelmas term. 14 lectures + coursework. Assessment: 100% coursework

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

- understand the kinematical properties of curved surfaces;
- understand the load-carrying mechanisms for plates and shell structures;
- formulate the governing equations of deformation for small displacement behaviour;
- identify the benefits and limitations associated with closed-form solutions;
- appreciate the difference between stretching and bending effects in shells;
- appreciate the effects of geometrical non-linearity;
- be aware of the current state-of-the art in advanced shells;
- understand the nature of stability, instability and multistability in shells, and their practical exploitation.

Syllabus
This module introduces the mechanics of plates and shells: thin-walled elastic surfaces that are important components of many structures and engineering devices. Key kinematical concepts are introduced for describing the initial and deformed shape of surface, either to make the description more succinct, or to reveal essential/invariant properties: these include the familiar Mohr’s circle, surfaces of revolution, and the Gaussian curvature. The relationship between internal strains and external shape is revealed for conventional smooth elastic shells. The manufacture of traditional engineering shells is reviewed, and their constitutive response is formulated: more “advanced” shell materials are introduced, including smart materials. The imperatives of equilibrium, compatibility and Hooke’s law are presented for deriving the final governing equations of deformation for circular and rectangular plates undergoing small displacements—a fraction of the thickness of shell. The distinction between bending and stretching responses of the shell is tackled through the membrane hypothesis and extended, first, to axisymmetrical pipe problems, and then to panel buckling under end-wise compression, which introduces geometrically non-linear behaviour. This is extended in cases of more compliant shells where displacements are expected to be much larger—of the order of the thickness, requiring more elaborate analysis techniques for tractable solutions: two approaches are presented, including an introduction of inextensibility theory. Finally, the behaviour and analysis of multistable shells are introduced: these show dramatic shape-changing properties, which may be exploited in novel “morphing” structures.
Geometry and kinematics of surfaces (4L)

- Properties of curves and surfaces: curvature and twist.
- Mohr’s circle of curvature and twist.
- Kinematics of surfaces of revolution and circular plates.
- Gaussian curvature: extrinsic and intrinsic viewpoints, principal radii of curvature.
- Inextensibility of creased sheets: simple surface strain, Gauss’ Theorema Egregium.
- Mixed/hierarchical kinematics: corrugated and compliant shells.

Materials (2L)

- Traditional engineering materials: metals, composites and natural materials, methods of manufacture, applications.
- Constitutive laws: bending and stretching generalised Hooke’s laws, thermal effects.
- Bending and stretching strain energy densities.
- Advanced engineering materials: review of smart/actuating materials, applications.
- Natural shells: growth and bio-mimicry, constitutive laws.

Loading of shells: small displacement theories (3L)

- Bending of circular and rectangular plates: imperatives of equilibrium, Hooke’s Law, and compatibility.
- Surfaces of revolution: membrane hypothesis and bending-stretching interaction in pipes.
- Two-surface idealisation and panel buckling.

Loading of shells: large displacement theories (3L)

- Non-linear methods: solutions by inspection and substitution; the lenticular plate.
- Inextensibility Theory.

Unloaded shells: multistability (2L)

- Applications.
- Analytical modelling: effects of material constitution, pre-stress, actuation and shape.

Coursework

Students will first answer a short examples paper, mid-Term, in order to refresh key ideas and principles; they will then answer one research question from a choice of two questions relating to the syllabus at the end of Term. Their solution will require a mixture of theoretical, practical and possibly numerical approaches, and will be presented in report format (max. 10 pages A4), to be submitted at the start of Lent Term.

Booklists

Please see the [Booklist for Group D Courses][2] for references for this module.

Assessment

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

UK-SPEC

The [UK Standard for Professional Engineering Competence (UK-SPEC)][4] describes the requirements that have to be met in order to become a Chartered Engineer, and gives examples of ways of doing this.

UK-SPEC is published by the Engineering Council on behalf of the UK engineering profession. The standard has been developed, and is regularly updated, by panels representing professional engineering institutions, employers and engineering educators. Of particular relevance here is the ‘Accreditation of Higher Education Programmes’.
The Output Standards Matrices [6] indicate where each of the Output Criteria as specified in the AHEP 3rd edition document is addressed within the Engineering and Manufacturing Engineering Triposes.

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