Unit 4: Mechanical Principles

Unit code: F/601/1450

QCF level: 5

Credit value: 15

Aim

This unit aims to develop learners' understanding of an extended range of mechanical principles that underpin the design and operation of mechanical engineering systems.

Unit abstract

This unit will develop learners' understanding of complex loading systems and will provide an introduction to the concept of volumetric strain and the relationship between elastic constants. The expressions derived for linear and volumetric strain then form a basis for determining dimensional changes in loaded cylinders.

The unit will build upon learners' existing knowledge of the relationship between the distribution of shear force and bending moment in loaded beams, to include the relationship between bending moment, slope and deflection.

Learners will analyse the use of mechanical power transmission systems, both individually and in the combinations that are used in practical situations. Learners' knowledge of rotating system elements is further extended through an investigation of the dynamic characteristics of the slider-crank and four-bar linkage. The balancing of rotating systems is also investigated, together with the determination of flywheel mass and size to give sufficiently smooth operating conditions.

Learning outcomes

On successful completion of this unit a learner will:

1 Be able to determine the behavioural characteristics of materials subjected to complex loading systems

2 Be able to determine the behavioural characteristics of loaded beams and cylinders

3 Be able to determine the dynamic parameters of power transmission system elements

4 Be able to determine the dynamic parameters of rotating systems.

Unit content

1 **Be able to determine the behavioural characteristics of materials subjected to complex loading systems**

Relationship: definition of Poisson's Ratio; typical values of Poisson's Ratio for common engineering materials

Two- and three-dimensional loading: expressions for strain in the x, y and z-directions; calculation of changes in dimensions

Volumetric strain: expression for volumetric strain; calculation of volume change

Elastic constants: definition of Bulk Modulus; relationship between Modulus of Elasticity; Shear Modulus; Bulk Modulus and Poisson's Ratio for an elastic material

2 **Be able to determine the behavioural characteristics of loaded beams and cylinders**

Relationships: slope $i = \frac{1}{E1}\int Mdx$

deflection $y = \frac{1}{E\,1}\iint Mdxdx$

Loaded beams: slope and deflection for loaded beams eg cantilever beams carrying a concentrated load at the free end or a uniformly distributed load over the entire length, simply supported beams carrying a central concentrated load or a uniformly distributed load over the entire length

Stresses in thin-walled pressure vessels: circumferential hoop stress and longitudinal stress in cylindrical and spherical pressure vessels subjected to internal and external pressure eg compressed-air receivers, boiler steam drums, submarine hulls, condenser casings; factor of safety; joint efficiency

Stresses in thick-walled cylinders: circumferential hoop stress, longitudinal stress and radial stress in thick-walled cylinders subjected to pressure eg hydraulic cylinders, extrusion dies, gun barrels; Lame's theory; use of boundary conditions and distribution of stress in the cylinder walls

3 **Be able to determine the dynamic parameters of power transmission system elements**

Belt drives: flat and v-section belts; limiting coefficient friction; limiting slack and tight side tensions; initial tension requirements; maximum power transmitted

Friction clutches: flat single and multi-plate clutches; conical clutches; coefficient of friction; spring force requirements; maximum power transmitted by constant wear and constant pressure theories; validity of theories

Gear trains: simple, compound and epicycle gear trains; velocity ratios; torque, speed and power relationships; efficiency; fixing torques

4 **Be able to determine the dynamic parameters of rotating systems**

Plane mechanisms: slider crank and four bar linkage mechanisms; production of vector diagrams and determination of kinetic characteristics

Balancing: single plane and multi-plane rotating mass systems; Dalby's method for determination of out-of-balance forces and couples and the required balancing masses

Flywheels: angular momentum; kinetic energy; coefficient of fluctuation of speed; coefficient of fluctuation of energy; calculation of flywheel mass/dimensions to give required operating conditions

Effects of coupling: conservation of angular momentum; common final velocity and energy loss due to coupling of two freely rotating systems

Learning outcomes and assessment criteria

Learning outcomes On successful completion of this unit a learner will:	Assessment criteria for pass The learner can:
LO1 Be able to determine the behavioural characteristics of materials subjected to complex loading systems	1.1 apply the relationship between longitudinal and transverse strain to determine the dimensional effects of uniaxial loading on a given material 1.2 determine the effects of two-dimensional and three-dimensional loading on the dimensions of a given material 1.3 determine volumetric strain and change in volume due to three-dimensional loading 1.4 apply the relationship between elastic constants
LO2 Be able to determine the behavioural characteristics of loaded beams and cylinders	2.1 apply the relationship between bending moment, slope and deflection to determine the variation of slope and deflection along a simply supported beam 2.2 determine the principal stresses that occur in a thin-walled cylindrical pressure vessel 2.3 determine the distribution of the stresses that occur in a pressurised thick-walled cylinder
LO3 Be able to determine the dynamic parameters of power transmission system elements	3.1 determine the dynamic parameters of a belt drive 3.2 determine the dynamic parameters of a friction clutch 3.3 determine the holding torque and power transmitted through compound and epicyclic gear trains
LO4 Be able to determine the dynamic parameters of rotating systems	4.1 determine the parameters of a slider-crank and a four-bar linkage mechanism 4.2 determine the balancing masses required to obtain dynamic equilibrium in a rotating system 4.3 determine the energy storage requirements of a flywheel 4.4 determine the dynamic effects of coupling two freely rotating systems.

Guidance

Links

This unit can be linked with *Unit 1: Analytical Methods for Engineers*, *Unit 2: Engineering Science*, *Unit 35: Further Analytical Methods for Engineers* and *Unit 60: Dynamics of Machines*.

Essential requirements

Sufficient laboratory/test equipment will need to be available to support a range of practical investigations.

Employer engagement and vocational contexts

Liaison with employers would prove of benefit to centres, especially if they are able to offer help with the provision of suitable mechanical systems/equipment that can be used to demonstrate applications of the principles.