Pearson BTEC Level 4 Higher Nationals in Engineering (RQF)

Unit 8: Mechanical Principles

Unit Workbook 3

in a series of 4 for this unit

Learning Outcome 3

Mechanical Power Transmissions Systems

Contents

INTRODUCTION

Investigate elements of simple mechanical power transmission systems.

- *Simple systems:*
    - Parameters of simple and compounded geared systems.
    - Efficiency of lead screws and screw jacks.
- *Couplings and energy storage:*
    - Universal couplings and conditions for constant-velocity.
    - Importance of energy storage elements and their applications.

GUIDANCE

This document is prepared to break the unit material down into bite size chunks. You will see the learning outcomes above treated in their own sections. Therein you will encounter the following structures;

Purpose	Explains *why* you need to study the current section of material. Quite often learners are put off by material which does not initially seem to be relevant to a topic or profession. Once you understand the importance of new learning or theory you will embrace the concepts more readily.
Theory	Conveys new material to you in a straightforward fashion. To support the treatments in this section you are strongly advised to follow the given hyperlinks, which may be useful documents or applications on the web.
Example	The examples/worked examples are presented in a knowledge-building order. Make sure you follow them all through. If you are feeling confident then you might like to treat an example as a question, in which case cover it up and have a go yourself. Many of the examples given resemble assignment questions which will come your way, so follow them through diligently.
Question	Questions should not be avoided if you are determined to learn. Please do take the time to tackle each of the given questions, in the order in which they are presented. The order is important, as further knowledge and confidence is built upon previous knowledge and confidence. As an Online Learner it is important that the answers to questions are immediately available to you. Contact your Unit Tutor if you need help.
Challenge	You can really cement your new knowledge by undertaking the challenges. A challenge could be to download software and perform an exercise. An alternative challenge might involve a practical activity or other form of research.
Video	Videos on the web can be very useful supplements to your distance learning efforts. Wherever an online video(s) will help you then it will be hyperlinked at the appropriate point.

1.2 Simple Systems

1.2.1 Belt Drive Dynamics

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

Theory Revision

Consider the basic belt drive arrangement below…

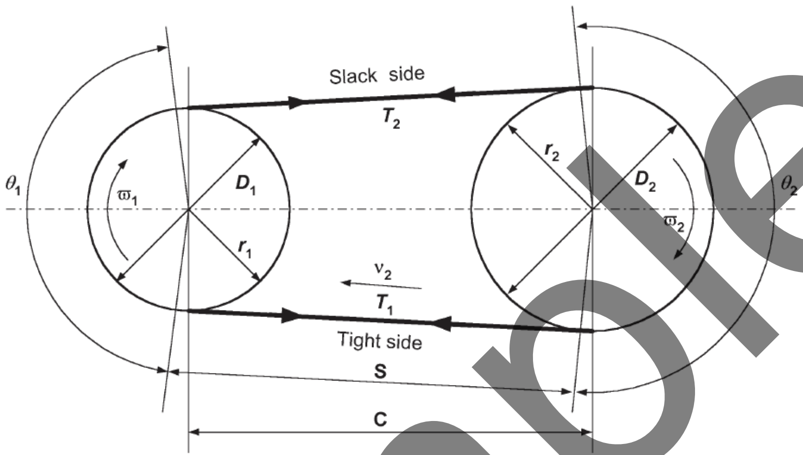

Figure 1 A basic belt drive arrangement

The belt drive arrangement in *Figure 1* has the driving side on the left and the driven side on the right. This causes the bottom of the belt to be the tight side and the top to be the slack side. Some parameters of note in this arrangement…

D_1, D_2	Respective diameters of the pulleys
r_1, r_2	Respective radii of the pulleys
ω_1, ω_2	Angular velocity of each pulley (in radians per second)
θ_1, θ_2	Lap angle (angle subtended to centre of pulley by contact length of belt with pulley surface)
T_1, T_2	Belt tensions on tight side and slack side, respectively
S	Belt length which does not touch the pulleys
C	Distance between pulley centres
v_2	Linear belt velocity

Many formulae may be derived for such a pulley system, but the most important ones are …

Belt lap angles for pulleys

$$\vartheta_1 = 180^o - 2\sin^{-1}\left\{\frac{D_2 - D_1}{2C}\right\} \qquad \text{(Eq 3)}$$

$$\vartheta_2 = 180^o + 2\sin^{-1}\left\{\frac{D_2 - D_1}{2C}\right\} \qquad \text{(Eq 4)}$$

Power transmitted by the system

$$\boldsymbol{P = T_1\left(1 - e^{-\mu\theta}\right)v} \qquad \text{(Eq 5)}$$

where: -

$v = r\omega$

μ is the coefficient of friction between the belt and the pulley

Belt pitch length

$$\boldsymbol{L = 2C + 1.57(D_2 - D_1) + \frac{(D_2 - D_1)^2}{4C}} \qquad \text{(Eq 6)}$$

Span length

$$\boldsymbol{S = \sqrt{C^2 - \left[\frac{D_2 - D_1}{2}\right]^2}} \qquad \text{(Eq 7)}$$

Worked Example 2

A flat belt drive system consists of two parallel pulleys of diameter 300 and 500 mm, which have a distance between centres of 600 mm. Given that the maximum belt tension is not to exceed 1.5 kN, the coefficient of friction between the belt and pulley is 0.3 and the larger pulley rotates at 40 rad/sec. Find;

a) the belt lap angles for the pulleys
b) the power transmitted by the system
c) the belt pitch length *L*
d) the pulley system span length between centres

ANSWERS

(a)

The belt lap angles for the pulleys are given by equations (Eq 3) and (Eq 4) …

$$\vartheta_1 = 180^o - 2\,sin^{-1}\left\{\frac{D_2 - D_1}{2C}\right\} = 180^o - 2\,sin^{-1}\left\{\frac{0.5 - 0.3}{2(0.6)}\right\} = \mathbf{160.8^o}$$

$$\vartheta_2 = 180^o + 2\,sin^{-1}\left\{\frac{D_2 - D_1}{2C}\right\} = 180^o + 2\,sin^{-1}\left\{\frac{0.5 - 0.3}{2(0.6)}\right\} = \mathbf{199.2^o}$$

(b)

The power transmitted by the system is given by equation (Eq 5) …

$$P = T_1\left(1 - e^{-\mu\theta}\right)v$$

where: -

$$v = r\omega = (0.25)(40) = 10\,m.s^{-1}$$

The angle θ_1 is expressed in degrees in part (a) but we must convert this to radians to be compatible with equation (Eq 5) …

$$160.8^o \equiv \left(160.8 \times \frac{\pi}{180}\right)\ radians = 2.81\ rads.$$

$$\therefore \quad P = T_1\left(1 - e^{-\mu\theta}\right)v = 1500\left(1 - e^{-(0.3)(2.81)}\right)(10) = \mathbf{8.54\ kW}$$

(c)

The belt pitch length is given by equation (Eq 6) …

$$L = 2C + 1.57(D_2 - D_1) + \frac{(D_2 - D_1)^2}{4C} = 2(0.6) + 1.57(0.5 - 0.3) + \frac{(0.5-0.3)^2}{4(0.6)} = \mathbf{1.53\ m}$$

(d)

Pulley system span length is given by equation (Eq 7) …

$$S = \sqrt{C^2 - \left[\frac{D_2 - D_1}{2}\right]^2} = \sqrt{0.6^2 - \left[\frac{0.5-0.3}{2}\right]^2} = \mathbf{0.59\ m}$$

Additional worked examples are available in the eBooks section on Moodle.

1.2.2 Friction Clutches

Purpose

Understand 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

Theory Revision

Consider the friction clutch shown below …

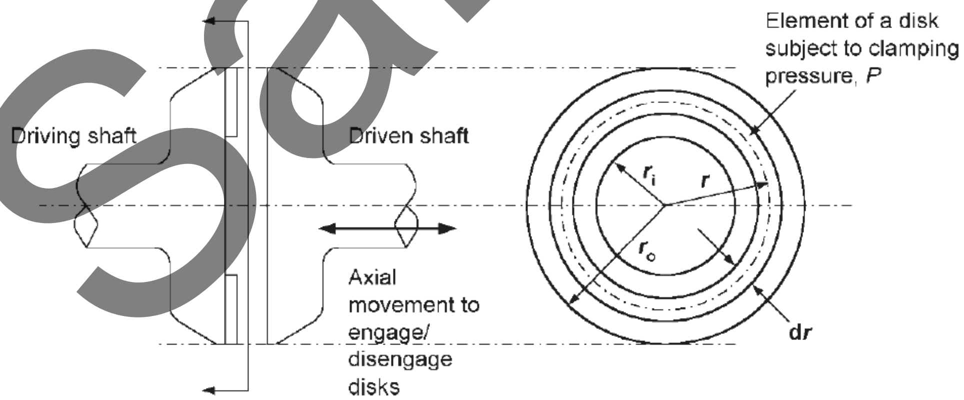

Figure 2 A basic friction clutch