FACTFILE: GCE TECHNOLOGY & DESIGN

1.45 CALCULATIONS

Calculations

Learning outcomes

Students should be able to:

- use given data and information to complete calculations for:
  - mechanical advantage and velocity ratio (see factfile 1.20: Part 1);
  - efficiency (see factfile 1.20: Part 1);
  - torque;
  - moments (see factfile 1.20: Part 1);
  - work, energy and power;
  - simple and compound velocity ratios and transmission speeds for gears, pulleys and chains and sprockets;
  - force, pressure and area associated with cylinders; and
  - air consumption of cylinders.

Course content

Torque

In rotary systems the turning force is known as torque, produced by driver shafts usually operated by a motor or other driver device. This in turn is transferred to the driven shaft that performs the output motion. Torque is measured in Newtonmetre (Nm). The formula for working out torque is:

Output Torque = Input Torque x Velocity Ratio

Torque is not restricted to gear systems but applies to all rotary systems.

An example of working out torque can be seen below:

Calculate the OT if the IT is 0.005 and the VR is 97200.

OT = IT x VR
OT = 0.005 x 97200
OT = 486

Work, Energy & Power

Work done on an object by an applied force can be described as the result of the force and the distance the object moves. If a force acts upon a point that moves a distance in the direction of the force then the work done can be calculated using the following formula:

Work Done = Force x Distance moved

Work done is measured in J. You must convert mm into metres. Another form of work done for a force which is turning can be viewed as the following:

Work Done = Tθ

T = Torque and θ **(angle turned during revs)** = 2π x revs, with your answer in Joules **(J)**

An example of this would be:

A cam is mounted on a horizontal shaft which runs on plain bearings. The cam has a torque of 1.2Nm. The amount of revs during operation = 500revs.

WD = Tθ
θ = Angle turned during 500revs is 2π x 500 = 3140
WD = 1.2 x 3140 = 3768J

Potential energy is calculated using the following calculation:

Potential Energy = mgh

m = mass, **g** = acceleration due to gravity and
h = perpendicular height

Worked example: A block is on a conveyor belt with a mass of 5kg. The conveyor is not horizontal and the block moves through a vertical height of 1m over this distance. g = 9.81m/s^2. The gain in potential energy is as follows:

PE = mgh
PE = 5 x 9.81 x 1 = 49.05J

Power is measured in watts and can be calculated using the following formulae

Power = work done / time taken for a force which is rotating

Power = Tω
ω = 2π/60 x rpm

An example can be found below:

Assuming no power loss in a mechanical system, the power from an output shaft WITH A TORQUE OF 1300Nm which rotates at 240 rev/min (rpm) will be:

P = Tω
P = T = 1300 x ω (2π/60 x 240rpm)
P = 1300 x 25.12
P = 32656W
= 32.7kW

Air Consumption of Cylinders

The volume of air used by a pneumatic cylinder is determined by the volume of the cylinder and the pressure of the air being used as a supply of energy.

Single acting cylinder (SAC)

A single acting cylinder only uses air on the outstroke. The volume of air V_o used in a single outstroke is given by:

V_o = A x L x Compression ratio

A = area of piston
L = stroke length of the cylinder
Compression ratio = (gauge pressure P + atmospheric pressure)/atmospheric pressure
If all pressures are measured in bar, atmospheric pressure = 1 so;
compression ratio = (P+1)/1 = P +1

So the volume of air used in one outstroke
= L x A x (P+1)

If the cylinder diameter is D and the stroke length is L and both are measured in centimetres then the volume of air used in one outstroke
= L x π x D^2/4 x (P+1) cm^3

If the volume is required in litres the following can be used to make the conversion.
1000cm^3 = 1 litre

Double acting cylinder (DAC)

A double acting cylinder uses air on both outstroke and instroke. The volume of air used on the outstroke would be given by the same formula as for a single acting cylinder.

The volume of air used on the instroke of a double acting cylinder Vi would be slightly less due to the reduction in area caused by the piston rod.

The following formula can be used to calculate the volume of air used in the instroke for a double acting cylinder of piston diameter D, piston rod diameter d, stroke length L operating at a gauge pressure P.

Vi = L x π x (D^2 – d^2)/4 x (P+1)

Therefore, the **total** volume of air used in one complete outstroke and instroke =

[L x π x D^2/4 x (P+1)] + [L x π x (D^2 – d^2)/4 x (P+1)]

Worked example

For a double acting cylinder calculate the difference between the positive and negative air consumption for an 80mm diameter cylinder with a 300mm stroke. The cylinder also has a piston rod diameter of 25mm and working air pressure of 5 bar. Assume atmospheric pressure = 1 bar and π = 3.14.

The difference between positive and negative air consumption is caused by the volume of air taken up by the piston rod.

Volume of air taken up by piston rod
= $(30 \times 2.5^2 \times 3.14 \times (5+1))/4$
= $883.125cm^3$

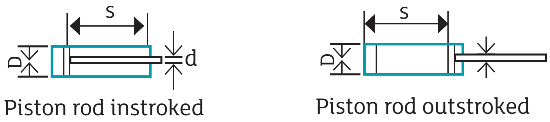
Another factor to be considered is the rate at which air is being supplied to the pneumatic cylinder by the compressor. When taking this into account the following formula is used;

Total volume of air used by cylinder per unit time = volume of cylinder x (gauge pressure + atmospheric pressure) x number of cycles per unit time produced by the compressor

Worked example

With reference to the data provided, calculate the air consumed by the cylinder as the piston rod moves through one cycle, then calculate the maximum number of complete cycles that could be made by the piston rod per minute if the compressor has a capacity to produce 285 litres per minute.

Double Acting cylinder



Diameter (D) = 100mm
Piston rod diameter (d) = 20mm
Stroke (S) = 160mm
Gauge pressure = 4 bar
Compressor capacity = 285 litres per minute
Atmospheric pressure - 1 bar
Please assume π = *3.14*

Volume = piston area x stroke x compression ratio

Volume = $S \times D^2 \times \pi/4 + S \times (D^2 - d^2) \times \pi/4$
= $16 \times 10^2 \times 3.14/4 + 16 \times (10^2 - 2^2) \times 3.14/4$
= 1256 + 1206
= $2462cm^3$

Volume of air used in one complete cycle
= $2462 \times (4+1) = 12310\ cm^3$

Volume of air/min
= piston volume x (gauge pressure + atmospheric pressure) x number of cycles/min

285 litres/min
= 2462 x (4 +1) x number of cycles/min

285000 cm^3
= 12310 x number of cycles/min

Number of cycles/min
= 285000/12310 = 23

Revision Questions

1 Calculate the output torque for the compound gear train shown, if the input torque is 180Nm.