The Open University of Sri Lanka
Faculty of Engineering Technology

029

Study Programme	:	Bachelor of Technology Honours in Engineering
Name of the Examination	:	Final Examination
Course Code and Title		**DMX5210 Vehicle Dynamics and Design of Automotive Components**
Academic Year	:	2021/22
Date	:	February 22, 2023
Time	:	09:30 hrs. – 12:30 hrs.
Duration	:	3 hours

General instructions

1) Read all instructions carefully before answering the questions
2) This question paper consists of 07 questions. All questions carry equal marks.
3) Answers any 06 questions only.

Question 01.

Fig Q1 shows the turning moment diagram of a single cylinder engine running at a speed of 2400 rpm. The turning moment diagram repeats at 2π radians. Areas above and below the mean turning moment line are given in mm^2. If the fluctuation of speed of the engine is 0.02. Determine the moment of inertia of the flywheel.

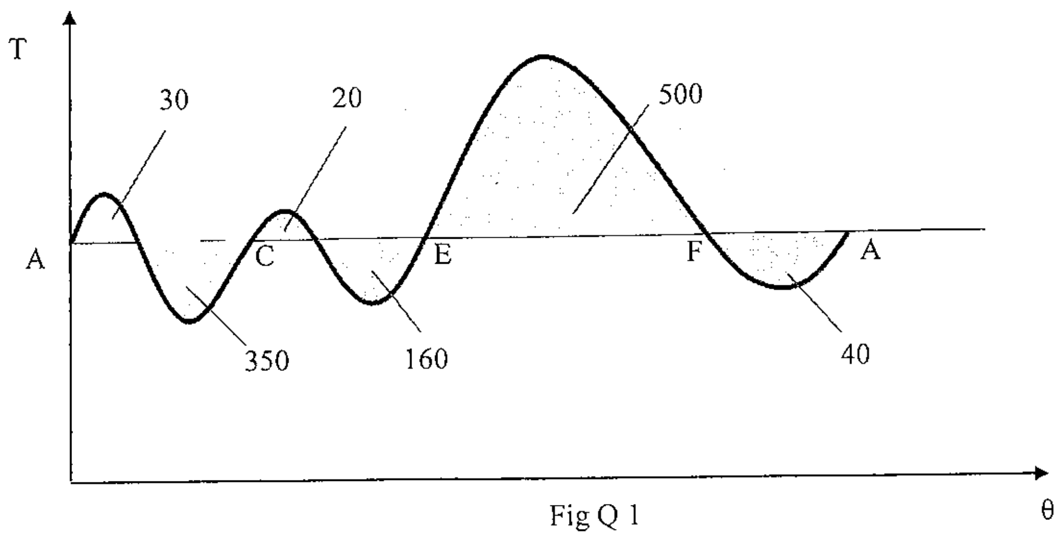

Fig Q 1

Scale Vertical axis (Turning moment): 1mm = 5 Nm

Horizontal axis (Crank angle) : 1mm = (π/90) rad

Question 02.

(a). Starting from fundamentals show that the inertia force (FI) produced by the reciprocating parts of a crank mechanism is given by

$$F_i = mr\omega^2 \left[cos\theta + \left(\frac{r}{L}\right) cos2\theta\right]$$

Where,

m- Mass of reciprocating parts
r - Crank Radius
L - Length of the connecting rod
ω - Angular speed of the crank shaft
θ - Angular displacement of the crank shaft from the outer dead centre

The following data are available for a vertical single-cylinder engine and it's crank mechanism

Length of the connecting rod	- 855 mm
Stroke Length	- 360 mm
Cylinder Bore Diameter	- 175 mm
The effective mass of reciprocating parts	- 150 kg
Speed of the engine	- 300 rpm
Maximum gas pressure on the piston	- 1.2 MPa

Considering the crankshaft has turned through an angle of 45°from the top dead center position

By using the data given above, determine the

(b).Inertia force acting on the piston

(c).Gas pressure acting on the piston

(d).Effective turning moment on the crankshaft

Question 03.

(a).Name two of each advantages and disadvantages of Disc Brakes over Drum Brakes

(b).What are the main components of a Drum brake system and describe their technically relevant functions.

(c).In a disc braking system, the distance between the centre of pressure of the pad and the centre of rotation of the disc is 0.12 m and the coefficient between rubbing surfaces is 0 35, determine the clamping force required to produce a braking torque of 84 Nm.

(Hint -braking torque T_B is given by, $T_B = 2 \mu N R$,) *Question 04.*

(a). Briefly explain the crumple zones in a modern automobile

(b). Discuss the three types of crumple zones and it's function during a crash

(c). Briefly explain the Stiff cage structural concept in modern automobile

Question 05.

(a). Show that maximum torque (T) transmitted through a clutch having n number of plates of contacting surfaces under **uniform pressure** conditions is given by,

$$T = \frac{2}{3}\mu n P \left[\frac{r_1^3 - r_2^3}{r_1^2 - r_2^2}\right]$$

Where μ – Coefficient of friction between the plate surfaces
P – Axial force
r_1 – Outer radius of the plate
r_2 – Inner radius of the plate

(b). A single plate clutch (both sides effective) is required to transmit 60 kW at 2400 rev/min. The outer diameter of the clutch plate is 3 times larger compared to the diameter of the inner diameter. The coefficient of friction is 0.3. Assume **uniform pressure**, determine the inner diameter of the clutch plate if the axial pressure is limited to 0.06 N/mm^2.

Question 06.

An engine of a motor car with a total mass of 1500 kg was tested on an engine dynamometer and typical data obtained are given in Fig Q2 .The testing revealed that the rolling resistance (Rf) and aerodynamic drag resistance (Ra) are given by

$$R_f = (155 + 0.35V)\ N \quad \text{and} \quad R_a = (0.11\ V^2)\ N$$

Where V is the speed of the vehicle in km/h. The road wheel diameter is 0.8 m. The vehicle was tested in the top gear and the maximum speed reached was 145 km/h.

Determine

(a). Overall gear ratio

(b). Overall transmission efficiency

(c). Acceleration at the maximum torque condition

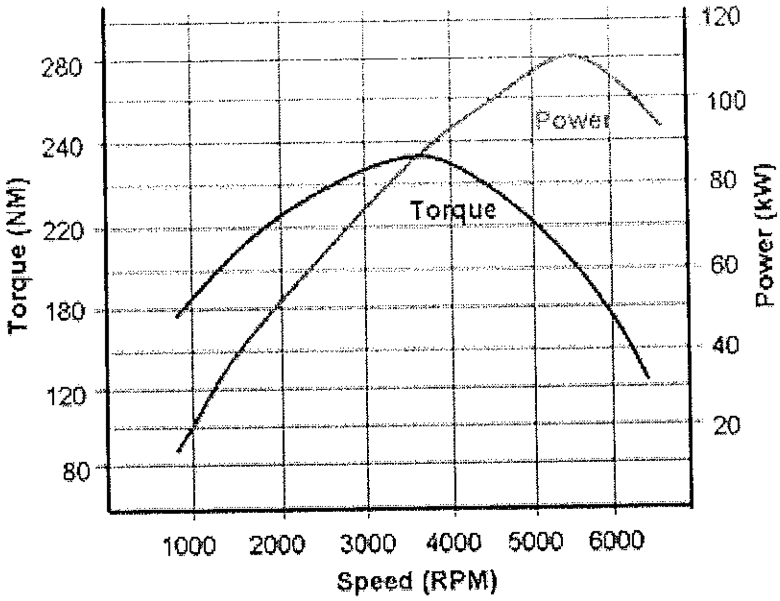

Figure 2

Question 07.

(a). Describe the boundary layer of a moving fluid by drawing it's velocity gradient.

(b) Discuss the following two vehicle body improvements used in high-speed vehicles to increase the aerodynamic downward force. Draw sketches where necessary.

(1). Using an inverted wing (a spoiler)

(2). Positive rake

(c).With the aid of a sketch of **tire threads**, describe the following technical issues,

(1). Camber wear

(2). Excessive Toe in, Toe out

(3). Over inflation and Under inflation of the tire

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VEHICLE DYNAMICS AND DESIGN OF AUTOMOTIVE COMPONENTS

Data Sheet

1. *Wear Tooth Load for gears*

$W_w = D_p \cdot b \cdot Q \cdot K$

where

W_w = Maximum or limiting load for wear in newtons.

D_p = Pitch circle diameter of the pinion in mm,

b = Face width of the pinion in mm,

Q = Ratio factor

$$= \frac{2 \times V.R}{V.R + 1} = \frac{2T_G}{T_G + T_P}, \text{ for external gears}$$

$$= \frac{2 \times V.R}{V.R - 1} = \frac{2T_G}{T_G + T_P}, \text{ for internal gears.}$$

V.R. = Velocity ratio = T_G / T_P,

K = Load-stress factor (also known as material combination factor) in N/mm^2.

2. **The thickness of a cylinder wall**

The thickness of a cylinder wall (t) is usually obtained by using a thin cylindrical formula, i.e.

$$t = \frac{p \times D}{2\sigma_c} + C$$

where

p = Maximum pressure inside the cylinder in N/mm^2,

D = Inside diameter of the cylinder or cylinder bore in mm,

σ_c = Permissible circumferential or hoop stress for the cylinder material in MPa or N/mm^2.

C = Allowance for re-boring.

The allowance for re-boring (C) depending upon the cylinder bore (D) for I. C. engines is given in the following table:

D (mm)	75	100	150	200	250	300	350	400	450	500
C (mm)	1.5	2.4	4.0	6.3	8.0	9.5	11.0	12.5	12.5	12.5

3. *Design of Cylinder Head*

The cylinder head may be approximately taken as a flat circular plate whose thickness (t_h) may be determined from the following relation:

$$t_h = D\sqrt{\frac{C.p}{\sigma_c}}$$

where

D - Cylinder bore in mm,
p - Maximum pressure inside the cylinder in N/mm²,
σ_c - Allowable circumferential stress in MPa or N/mm². It may be taken as 30 to 50 MPa,
C - Constant whose value is taken as 0.1.

4. *Design of the Piston Crown*

The thickness of the piston head for strength

The thickness of the piston head (t_H), according to Grashoff's formula is given by

$$t_H = \sqrt{\frac{3p.D^2}{16\sigma_t}} \text{(in mm)}$$

Where,

p = Maximum gas pressure or explosion pressure in N/mm²,
D = Cylinder bore or outside diameter of the piston in mm, and
σ_t = Permissible tensile stress for the material of the piston in MPa or N/mm²

Design of piston head for heat transfer

On the basis of second consideration of heat transfer

$$t_H = \frac{\dot{H}}{12.56k(T_C - T_E)} \text{(in mm)}$$

5. **Design Against fatigue**

Gerber method

$$\frac{1}{F.S} = \left(\frac{\sigma_m}{\sigma_u}\right)^2 F.S. + \frac{\sigma_v \times K_f}{\sigma_e}$$

The Goodman criteria

$$\frac{1}{F.S} = \frac{\sigma_m}{\sigma_u} + \frac{\sigma_v \times K_f}{\sigma_e}$$

The Soderberg criteria

$$\frac{1}{F.S.} = \frac{\sigma_m}{\sigma_y} + \frac{\sigma_v \times K_f}{\sigma_e}$$

where F.S. = Factor of safety,
σ_m = Mean stress,
σ_u = Ultimate stress,
σ_v = Variable stress,
σ_e = Endurance limit for reversed loading,
K_f' = Fatigue stress concentration faction