

PRIFYSGOL CYMRU : UNIVERSITY OF WALES

DEGREE EXAMINATIONS 2006
ARHOLIADAU GRADD 2006

Swansea Institute of Higher Education
Athrofa Addysg Uwch Abertawe

Faculty of Applied Design and Engineering

NAME OF COURSE/PROGRAMME: *BEng Motorcycle Engineering*

YEAR or LEVEL (state which): *Year II*

NAME OF MODULE/UNIT: *Motorcycle Dynamics and Power Transmission*

NAME OF EXAM PAPER:
(if different to module name)

DATE OF EXAMINATION:

Tuesday 30 May 06

EXAMINATION TIMES:

Start Time:

12.00

Finish Time:

2.00

Time Allowed:

2 hrs.

INSTRUCTIONS TO CANDIDATES:

For all questions, take $\rho_{air} = 1.167 \text{ kg m}^{-3}$

An equation sheet is provided with this exam paper

Answer 3 from 4 Questions

FACULTY REF:

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1.

a.(i). A motorcycle and rider is travelling at 245 km/h. If the force resisting motion from aerodynamic drag is 1.081 kN and the drag coefficient is (C_d) is 0.57, calculate the frontal area of the motorcycle. (2 marks)

(ii) What driving force is required to maintain a rider and motorcycle of mass 240kg at a constant maximum velocity of 265 km/h if C_D is 0.65, the frontal area is 0.55m^2 and the rolling friction coefficient μ_f is 0.02. (2 marks)

(iii) What power is required at the rear wheel to achieve this maximum velocity? (1 marks)

b. Assuming the front un-sprung mass of a 180 kg motorcycle to be 16 kg and the angle of inclination of the steering head to be 21.7° .

(i) Calculate the stiffness of the reduced spring so that with a load equal to the weight of the motorcycle the fork is compressed by 60 mm. (3 marks)

(ii) From this, calculate the overall stiffness of the fork. (3 marks)

(iii) Calculate the deflection of the spring, under conditions of static equilibrium, supposing that the spring of the fork is preloaded by 18 mm. (3 marks)

c. The gyroscopic effect of engine motion can have a significant effect on the dynamics of a motorcycle. Explain the differences in handling and dynamics between a motorcycle with:

(i) A transversally mounted engine and one with a longitudinally mounted engine. (3 marks)

(ii) A motorcycle with a forward rotating crankshaft and one with a backward spinning crankshaft. Assume both have transversally mounted engines. (3 marks)

2.

a. The equations of equilibrium of a motorcycle enable us to determine the values of the reactive forces N_f and N_r , once the weight force mg , driving force S , and drag force F_D are known:

(i) Show all these forces, including standard geometry (Wheelbase, CofG height, etc) in a schematic diagram.

(3 marks)

(ii) By equating moments and forces for this system, derive equations for the dynamic loads on the front and rear wheels N_r and N_f .

(5 marks)

b. When considering the acceleration of a motorcycle of a known power, it is necessary to consider the 'reduced mass' of the motorcycle.

(i) Explain the concept of 'reduced mass'?

(2 marks)

(ii) In what situations can the reduced mass be assumed to be equal to the true mass?

(2 marks)

c. Consider a 230 kg motorcycle under acceleration to the limit of front wheel lift, with a 50% to 50% static weight distribution of the loads on the wheels, a wheelbase of 1200 mm, a centre of gravity height of 600mm, a drag area (C_dA) equal to 0.4 m^2 . The longitudinal distance of the centre of gravity from the rear axle, $b = 0.7 \text{ m}$ and the reduced mass of the motorcycle is 265 kg.

What would be the maximum acceleration if:

(i) Aerodynamic effects are ignored (Velocity = 0)

(2 marks)

(ii) The motorcycle is travelling at 100km/h

(3 marks)

(iii) The motorcycle is travelling at its maximum velocity

(3 marks)

3.

Consider the case of a rider negotiating 'Honda Curve' at Pembrey circuit on an Aprilia RS125 race bike:

Corner radius, $R_c = 185 \text{ m}$

Forward speed, $V = 140 \text{ km h}^{-1}$

The properties of the motorcycle are:

Mass, $m = 172 \text{ kg}$ (including rider)

Height of centre of gravity, $h = 0.65 \text{ m}$

Wheel radius, $R_f = R_r = 0.3 \text{ m}$

Spin inertia of front and rear wheels, $I_{wf} = I_{wr} = 0.63 \text{ kgm}^2$

a.

- (i) Calculate the yaw velocity of the motorcycle. (2 marks)
- (ii) Calculate the angular velocity of each wheel. (2 marks)
- (iii) Determine the *ideal* roll angle of the motorcycle through this turn. (3 marks)
- (iv) Calculate the gyroscopic moment generated by the motion of both wheels. (3 marks)

b. The case described above is not in equilibrium. There are two ways in which the rider will be able to achieve equilibrium.

The first method is to increase the roll angle ($\Delta\phi$).

- (i) Determine the increase in roll angle needed to achieve equilibrium. (4 marks)

The second method is to displace the mass centre toward the centre of the turn.

- (ii) Calculate by how much the mass centre must move (d) in order to achieve equilibrium. (3 marks)

(iii) What would be the effect on the effective roll angle if the motorcycle used tyres of a larger cross sectional area.

(2 marks)

- (iv) What effect does the centre of gravity height have on the effective roll angle.

(1 mark)

4.

a. Consider a motorcycle with the following properties:

250cc Transversely mounted engine, with a forward spinning crankshaft.

Total mass with rider, $m = 185 \text{ kg}$

Height of centre of gravity, $h = 0.65 \text{ m}$

Wheel radius, $R_f = R_r = 0.3 \text{ m}$

Spin inertia of the front and rear wheels, $I_{wf} = I_{wr} = 0.6 \text{ kgm}^2$

Total angular momentum of the engine, $I\omega_m = 14 \text{ kgm}^2 \text{ s}^{-1}$

The motorcycle is traversing a 200 m radius corner with a velocity of 38 ms^{-1} at a steady state ideal roll angle of 36.35° .

- (i) Calculate the gyroscopic moment due to the engine rotation. (3 marks)
- (ii) Calculate the increase in roll angle due solely to the gyroscopic effect generated by the engine. (4 marks)
- (iii) Compare the gyroscopic moment due to the engines rotation with the gyroscopic moment due solely to the wheels. (4 marks)
- (iv) Taking into account the gyroscopic contribution from the wheels, calculate the total increase in roll angle. (4 marks)

b. Now consider a motorcycle with the following properties, rolling from right to left:

Moment of axial inertia, front wheel, $I_{wf} = 0.6 \text{ kgm}^2$

Roll velocity, $\dot{\phi} = 0.5 \text{ rad s}^{-1}$

Spin velocity of wheel, $\omega = 100 \text{ rad s}^{-1}$

Rake angle, $\varepsilon = 25^\circ$

Normal trail, $a_n = 0.1 \text{ m}$

- (i) Calculate the gyroscopic moment M_g that acts on the front frame around an axis lying in the plane of the motorcycle perpendicular to the longitudinal roll axis. (3 marks)
- (ii) Calculate the gyroscopic moment around the steering axis of the motorcycle due to its roll motion from right to left. (2 marks)

Equation Data Sheet

Dynamic Loadings:

$$N_f = mg \frac{b}{p} - S \frac{h}{p} \qquad N_R = mg \frac{(p-b)}{p} + S \frac{h}{p}$$

Aerodynamic Drag

$$Force = \frac{1}{2} \rho C_D A V^2$$

Maximum Acceleration

$$\ddot{x} = \frac{mg}{m^*} \frac{b}{h} - \frac{F_D}{m^*}$$

Reduced Spring Stiffness

$$k_f = \frac{mg}{y \cos \varepsilon}$$

Overall Stiffness

$$k = k_f \cos^2 \varepsilon$$

Ideal Roll Angle

$$\varphi_i = \tan^{-1} \left(\frac{R_c \Omega^2}{g} \right)$$

Change in Roll Angle

$$\sin(\Delta \varphi) = \frac{I_w \omega \Omega \cos \varphi}{h \sqrt{(mg)^2 + (m R_c \Omega^2)^2}}$$

Gyroscopic Moment

$$M_g = I_w \omega \Omega \cos \varphi$$

$$M_g = d \sqrt{(mg)^2 + (m R_c \Omega^2)^2}$$

Gyroscopic Moment on Front Frame due to Roll Motion

$$M_{g_u} = I_{w_f} \omega_f \dot{\varphi} \cos \varepsilon$$