

LOCATION: SWANSEA

LLEOLIAD: ABERTAWE

LEVEL 5

LEFEL 5

EXAMINATION PERIOD
MAY 2018

CYFNOD ARHOLIADAU
MAI 2018

MODULE CODE: M5X00402
Motorcycle Dynamics

TIME: 2 HOURS

ANSWER 3 OUT OF 4 QUESTIONS

Equipment or materials required – Calculator

Question 1

A motorcycle with suspension can be represented as several simple masses m attached to springs of stiffness k with viscous dampers with damping coefficients c . The displacement, x , representing the front and rear suspension displacements allows us to use the equation $ma + cv + kx = 0$ to represent the dynamics of the masses making up the system.

- a) Derive a set of equations that can be used to solve the case of a simple motorcycle suspension in pitch and bounce.
(5 marks)
- b) Write the above equations in matrix form including damping in the model.
(5 marks)
- c) If a sprung mass of 100kg is supported by a spring of stiffness $18,000 \text{ Nm}^{-1}$ with a damping constant of 1200 Ns m^{-1} , determine the general solution for the system and state what damping regime the system is in?
(5 marks)
- d) Find the position of the mass at any time t if it starts from the equilibrium position and is given a push to start it with an initial velocity of 2 ms^{-1}
(5 marks)

The general solutions to 2nd order differential equations are given by:

$$\begin{aligned}y &= Ae^{m_1x} + Be^{m_2x} \\y &= (A + Bx)e^{mx} \\&\text{and} \\y &= e^{\alpha x} [A \cos(\beta x) + B \sin(\beta x)]\end{aligned}$$

Question 2

Shown below is the Yamaha MOTOROiD Electric Motorcycle presented at the 45th Tokyo Motor Show (2017).



It has a mass of 213Kg and is driven by a Rear Wheel Hub Motor giving a rear un-sprung mass of 68Kg. It has a traditional rear shock setup with a link ratio of 3.7 and an overall wheelbase of 1,760mm. The front suspension is a variation on a 'fork' design and has a rake angle of 30° with a trail value of 112mm and the front un-sprung mass is 11.6Kg. With a 60Kg rider the weight distribution is front biased at 57:43.

- a. Using your knowledge of suspension design, specify suitable front and rear spring rates and suitable damping values for the motorcycle's intended application.
(15 marks)
- b. The MOTOROiD is also self-drive & self-balancing, using its own battery pack as a counter-weight to maintain balance at zero/low speeds. Most self-balancing motorcycle concepts use a gyroscope to maintain balance. Describe how a gyroscope can be used to balance a motorcycle at low speed and what gyroscopic effects (if any) you expect the MOTOROiD to take advantage of at higher speeds.

(5 marks)

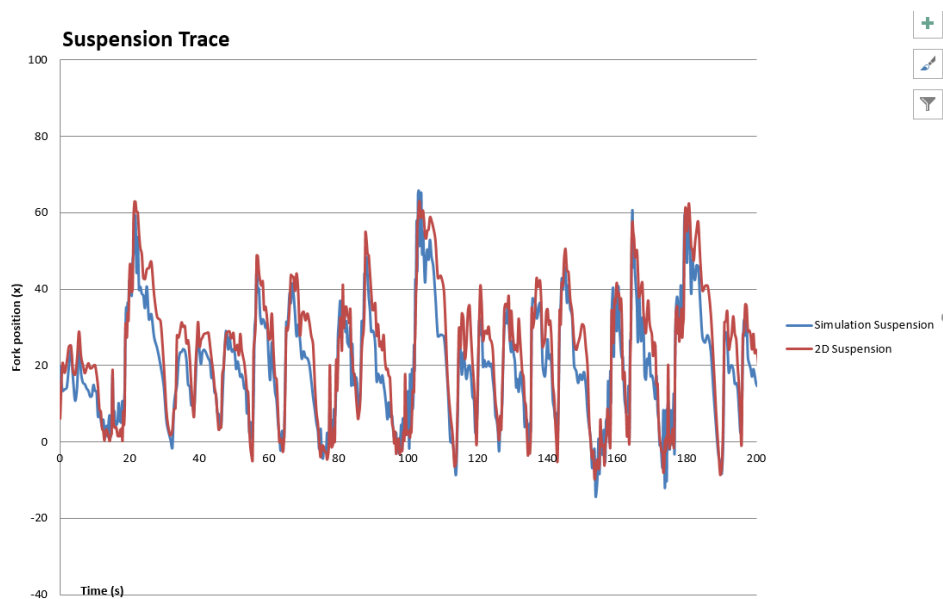
Question 3

The wheel loads of a motorcycle are normally represented by N_f and N_r , representing the combination of static and dynamic loads acting on the motorcycle.

- a) From first principles, derive equations for both N_f and N_r .

(8 marks)

Shown below is a comparison between a 'simulated suspension trace, using wheel velocity as a start point' and 'measured suspension data' for a MotoGP bike.



- b) Explain how N_f and N_r can be used to determine the simulated suspension trace for the motorcycle. (4 marks)
- c) Using the above method with the velocity from a 'LapSim' software, comment on differences you would expect to see in the suspension trace when compared to the result from using a real bikes velocity trace? (3 marks)
- d) The differential of the suspension position trace gives valuable data often used by suspension technicians in conjunction with a suspension dynamometer data to help them optimise the bike setup. Explain in detail how these two sources of data are used together to aid bike setup. (5 marks)

Question 4

The concept of an 'Ideal Lean Angle' allows us to look at the cornering characteristics of a motorcycle in a simple but effective way.

- a) Derive the equation for the 'Ideal Lean Angle'

(4 marks)

The formula implies that 'mass' is not a variable of significance in the lean angle that a bike takes during a corner. This implies that for a given velocity and radius, a BMW R1200 GS and a Honda RS125 would be at the same lean angle.

- b) Discuss if you believe this to be correct?

(3 marks)

The variation in a motorcycle's tyre thickness can also be taken into account in regard to how much it would change the ideal lean angle of the bike.

- c) Derive an expression that relates the 'change in lean angle due to tyre thickness' and the 'ideal lean angle'.

(5 marks)

Modern MotoGP bikes can achieve lean angles of up to 64° during steady state cornering. At these lean angles, the riders are leant as far off the side of the bike as possible.

- d) Discuss how you think the aerodynamics of a motorcycle and rider would effect it mid-corner and how you could potentially take advantage of aerodynamic aids to assist the motorcycle's cornering ability (You are free to ignore all FIM regulations and to consider 'active' devices)

(4 marks)

The handling characteristics of the modern MotoGP bike have changed greatly in the last 3 years to the extent that they are now very different in characteristic to the support classes and WSB.

- e) How has the geometry, dynamics and aerodynamics of the MotoGP bike changed and how is it effecting the riding style and rider requirements?

(4 marks)