BMA4723 VEHICLE DYNAMICS

Ch2 Fundamentals of Vehicle Dynamics

by
Mohamad Heerwan Bin Peeie
Faculty of Mechanical Engineering
mheerwan@ump.edu.my

Chapter Description

- Aims
  - Explain the Newton's Second Law in translational and rotational motions
  - Explain the dynamic axle loads at level ground, grades, static and acceleration.

- Expected Outcomes
  - Students are able to differentiate translational and rotational motions
  - Students are able to sketch the free body diagram of the vehicle.
  - Students are able to derive the equation of loads in different condition (static, accelerating, level ground and grades)

- References
  - M.Abe, Vehicle Handling Dynamics Theory and Application, Second Edition, Published by Elsevier Ltd, 2015
  - Thomas D.Gillespie, Fundamental of Vehicle Dynamics, Published by Society of Automotive Engineers

Outlines

- 2.1 Newton's Second Law
- 2.2 Dynamic Axle Loads
    - 2.2.1 Static Loads on Level Ground
    - 2.2.2 Low-speed Acceleration on Level Ground
    - 2.2.2 Low-speed Acceleration on Grades
- 2.3 Vehicle Equations of Motion

2.1 Newton's Second Law

- The dynamics analyses begin with the Newton's Second Law.
- This law consists of two motion:

i. **Translational systems** – the total external forces acting on a vehicle, F is equal to the mass, m and acceleration, a.

$$\sum F_x = ma_x$$
$$\sum F_y = ma_y$$

ii. **Rotational system** – the sum of the torques acting on a vehicle, T is equal to the rotational moment of inertia, I and the rotational acceleration, a.

$$\sum T_x = I_{xx}a_x$$

2.2 Dynamic Axle Loads

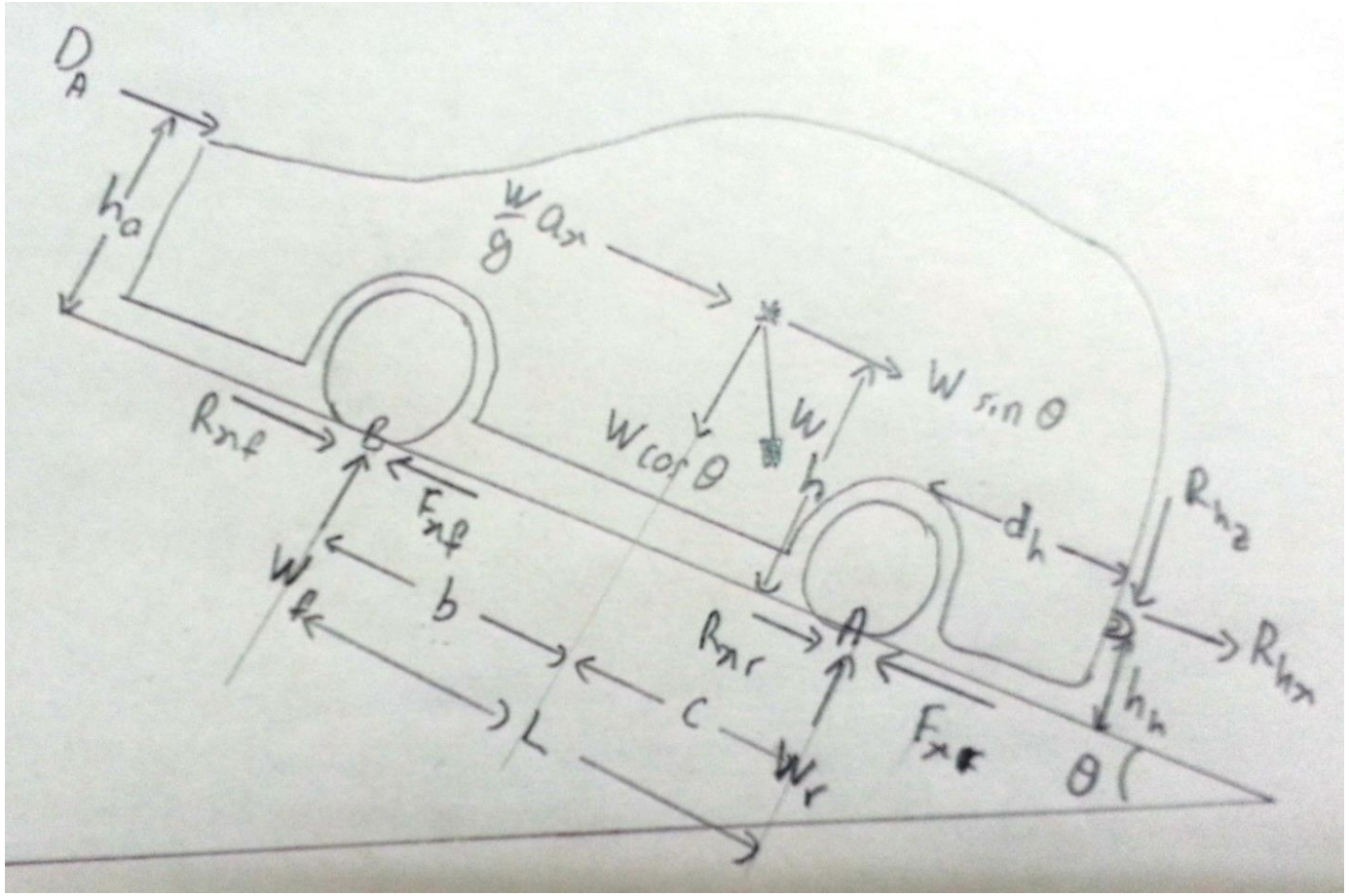

Figure 1 Forces acting on a vehicle

2.2 Dynamic Axle Loads

From Fig.1:

- W : the weight of the vehicle acting at the center of gravity .
  W = ma (mass times acceleration)
- W_f, W_r: the dynamic weights at the front and rear tires.
- F_{xf}, F_{xr}: Traction forces at the front and rear tires
- R_{xf}, R_{xr}: Rolling resistance at the front and rear tires
- D_A: Aerodynamic force acting on the vehicle
- h : Height from the ground to the center of gravity of the vehicle
- h_h: Height from the ground to the hitch point when the vehicle is towing a trailer
- R_{hz}, R_{hx}: Vertical and longitudinal forces acting at the hitch point when the vehicle is towing a trailer

2.2 Dynamic Axle Loads

- If we considered a clockwise about point A is positive. Then:

$$W_f L + D_A h_a + \frac{W}{g} a_x h + R_{hx} h_h + R_{hz} d_h + W\ h\ sin\theta - \mathrm{W\ c\ cos\ \theta} = 0$$

(Eq 1)

- By using Eq.1, the load at the front and rear tires are, W_f and W_r:

$$W_f = \frac{\mathrm{W\ cos\ \theta} - W\ h\ sin\theta - D_A h_a - \frac{W}{g} a_x h - R_{hx} h_h - R_{hz} d_h}{L}$$

(Eq 2)

$$W_r = \frac{\mathrm{W\ b\ cos\ \theta} + W\ h\ sin\theta + D_A h_a + \frac{W}{g} a_x h + R_{hx} h_h + R_{hz} d_h}{L}$$

(Eq 3)

2.2.1 Static Loads on Level Ground

- When a vehicle in a static condition on level ground, the drag force and acceleration can be neglected.
- Then, the static load at the front and rear tires W_{fs} and W_{rs} are:
- $W_{fs} = W\frac{c}{L}$ (Eq 4)
- $W_{rs} = W\frac{b}{L}$ (Eq5)

2.2.2 Low-speed Acceleration on Level Ground

- During low-speed acceleration on level ground, the vehicle will have acceleration, a_x.
- In this condition, only the drag force D_A can be neglected.
- The loads on the front and rear tires W_f and W_r are:

$$W_f = W\left(\frac{c}{L} - \frac{a_x}{g}\frac{h}{L}\right) = W_{fs} - W\frac{a_x}{g}\frac{h}{L} \quad \text{(Eq6)}$$

$$W_r = W\left(\frac{b}{L} + \frac{a_x}{g}\frac{h}{L}\right) = W_{rs} + W\frac{a_x}{g}\frac{h}{L} \quad \text{(Eq7)}$$

- From Eq.6 and Eq.7, during acceleration, the load is transferred from the front axle to the rear axle
- In contradict, during braking, the load is transferred from the rear axle to the front axle.

2.2.2 Low-speed Acceleration on Level Ground

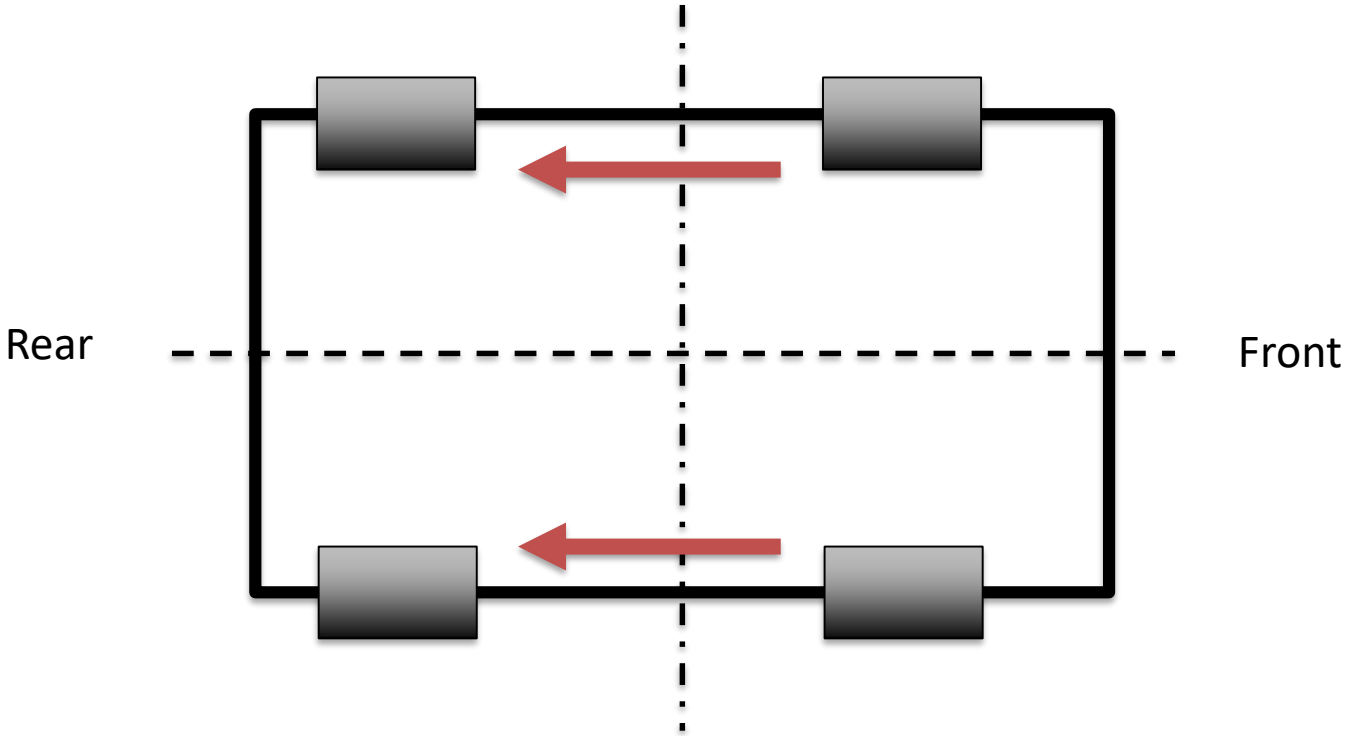

Figure 2 During acceleration, weight is transferred from the front tires to the rear tires.

2.2.2 Low-speed Acceleration on Level Ground

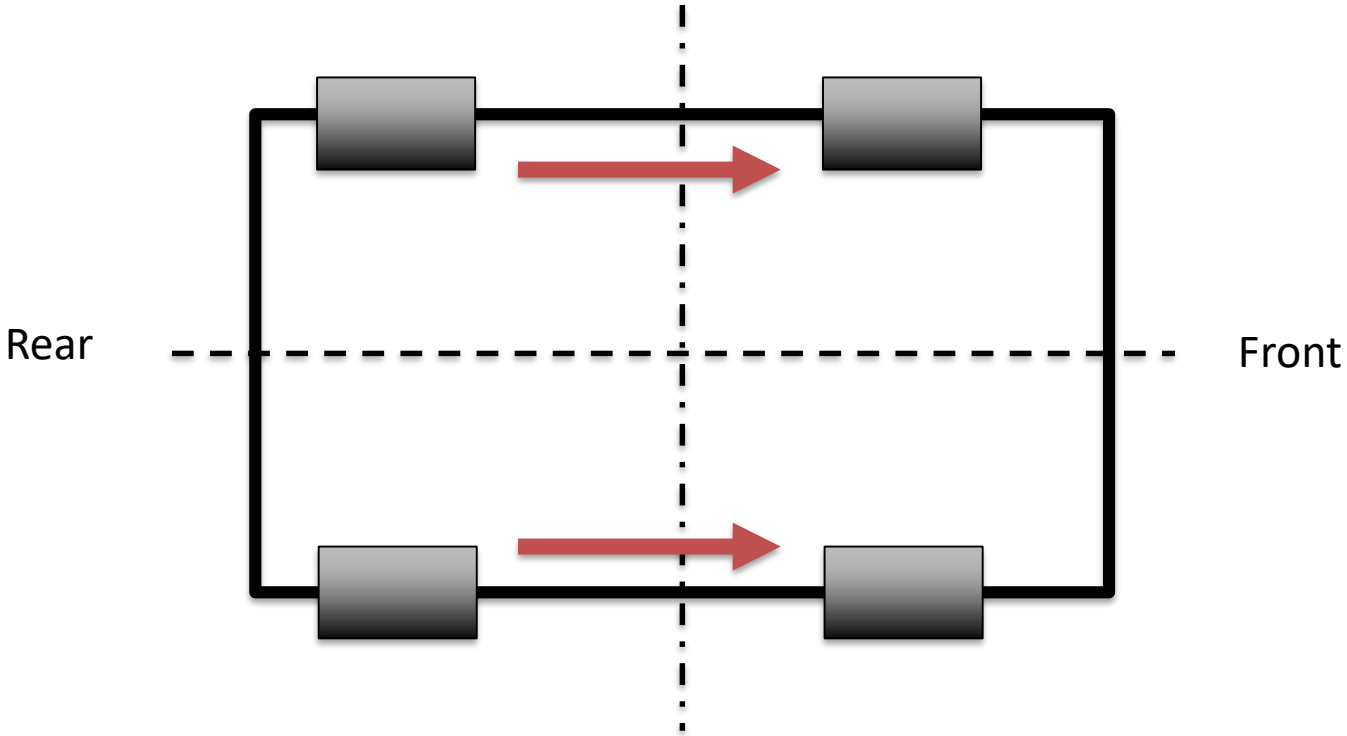

Figure 3 During braking, weight is transferred from the rear tires to the front tires.

2.2.3 Low-speed Acceleration on Grades

- Grade is defined as the “rise” over the “run”.
- The ratio is the tangent of the grade angle, θ.

➢ The load at the front tire:

$$W_f = W\left(\frac{c}{L} - \frac{h}{L}\theta\right) = W_{fs} - W\frac{h}{L}\theta \qquad \text{(Eq8)}$$

➢ The load at the rear tire:

$$W_{rs} = W\left(\frac{b}{L} + \frac{h}{L}\right) = W_{rs} + W\frac{h}{L}\theta \qquad \text{(Eq9)}$$

- From Eq.6 and Eq.7, during acceleration on grades, the positive grade causes load to be transferred from the front to the rear axle.
- And if the grades are negative, the load is transferred from the rear to the front axle.

Conclusion of The Chapter 2

- Conclusion #1
  - Newton's Second Law is used to determine the dynamics of the vehicle.
  - From the Newton's Second Law, the translational and rotational motions can be determined.

- Conclusion #2
  - From the dynamics load, the weight will be transferred either to the front or rear axles based on the motions of the vehicle (accelerating, braking, level ground, grades).

Vehicle Dynamics

Chapter 2

Dr Mohamad Heerwan Bin Peeie