BMA4723 VEHICLE DYNAMICS

Ch5 Steering System and Steer Performance

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Chapter Description

- Aims
  - Explain the steering system and its components.
  - Explain the equation of motion at the steering wheel and at the front wheel.
- Expected Outcomes
  - Students are able to determine the mechanism of the steering system.
  - Students are able to derive the equation of motion at the steering wheel and at the wheel.
- 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

5.1 Steering System Model

5.2 Equation of Motion of the Steering System

Steering System Model

- The purpose of the steering system is to turn the wheel and guide the vehicle to the desired path.
- The steering system consist of three major sub-system:

  i) steering linkage

  ii) steering gear

  iii) steering column

Steering System Model

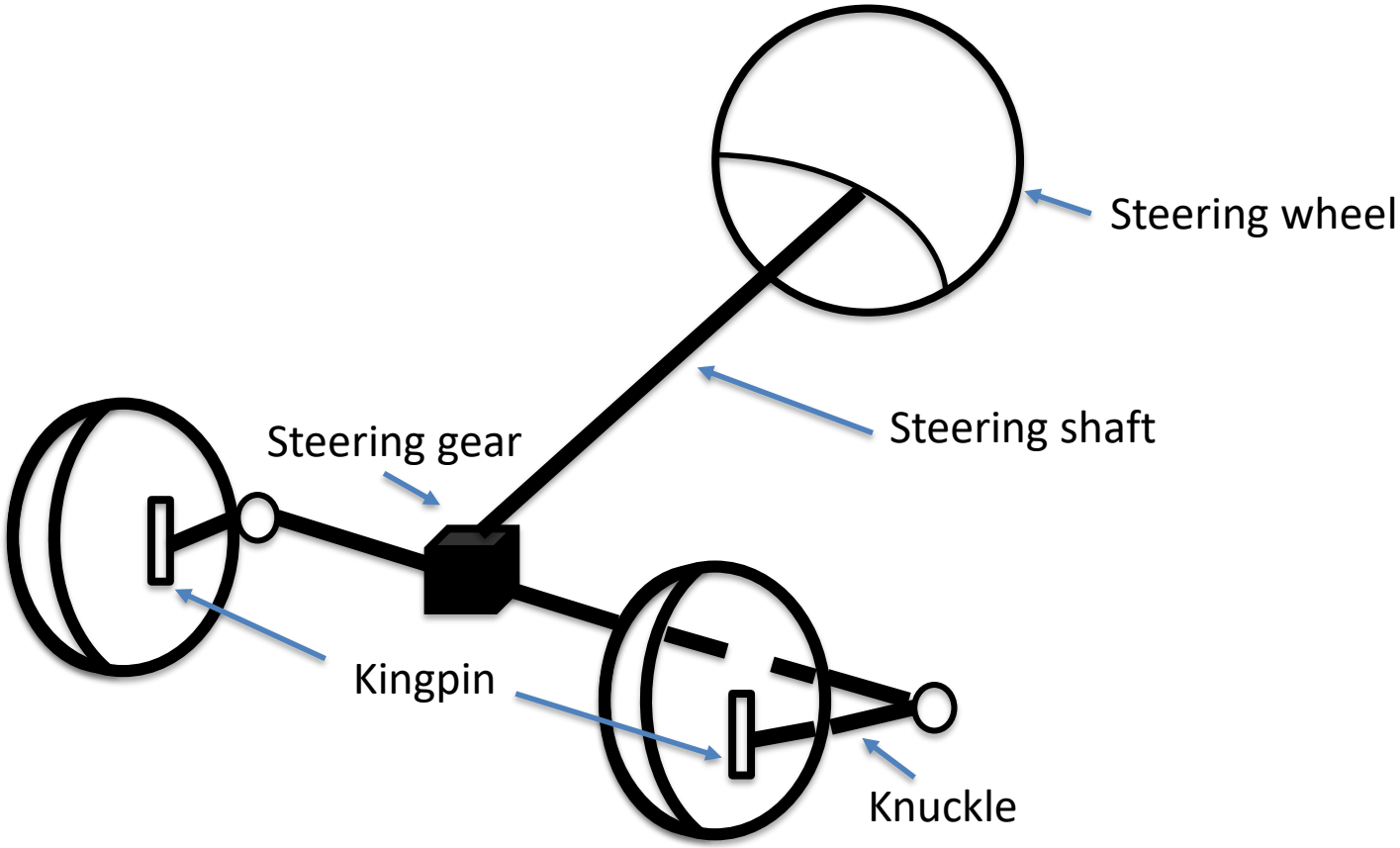


Figure 1 Steering system of the vehicle

Steering System Model

- From Fig.1, when the driver turn the steering wheel, the steering shaft will rotate either to the clockwise or counter clockwise.
- Then, the steering gear transfer this motion to the knuckle arm.
- This motion will allows the front wheel rotation around the kingpin.

Equation of Motion of the Steering System

- In the analysis of the steering system performance, it is easy if we convert all the steering system motion to the rotation motion around the kingpin.

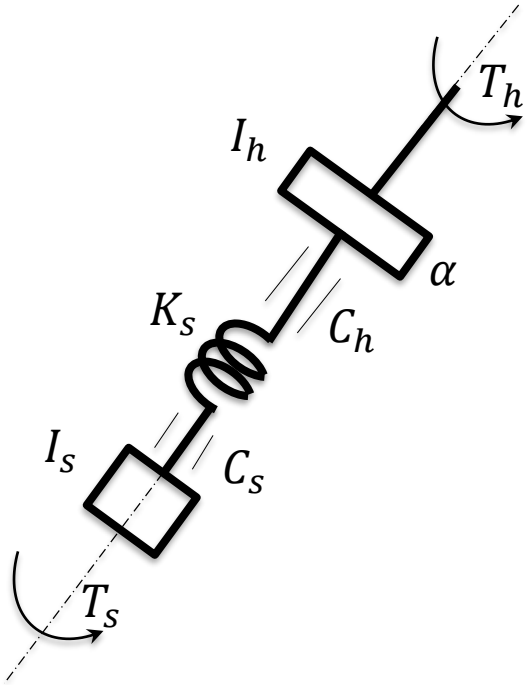


Figure 2 Steering system model

Equation of Motion of the Steering System

- From Fig.2:

I_h: Moment of inertia of the steering wheel

I_s: Moment of inertia of the front wheels

K_s: Spring constant of the steering wheel shaft and gearbox

C_h: Damping coefficient of the steering wheel shaft

C_s: Damping coefficient of the kingpin

α: Rotational steering wheel angle

δ: Actual front wheel steering angle

T_h: Torque at the steering wheel (Provided by the driver)

T_s: Torque acting at the tire

I_s and C_s are the total of the left and right wheels.

Equation of Motion of the Steering System

- T_h is the external moment provided by the driver.
- When the driver turn the steering wheel at the certain angle, the torque is generated to bring back the steering wheel to its original position.
- At this moment, the lateral force created at the front wheels and produced the moment around the kingpin.

Equation of Motion of the Steering System

- Fig.3 shows the lateral force, ${}^{y}F$ acting on the tire.
- As can be seen in Fig.3, the acting point of the lateral force is shifted slightly behind the contact plane centreline.
- At the same time. this lateral force will generate a moment, M around the vertical axis that passes through the contact plane centreline.
- This moment is called self-aligning torque.
- The distance from the contact plane centreline to the acting point of the lateral force is called the pneumatic trail, ξ_n and is defined as:

$$\xi_n = M/{}^{y}F$$

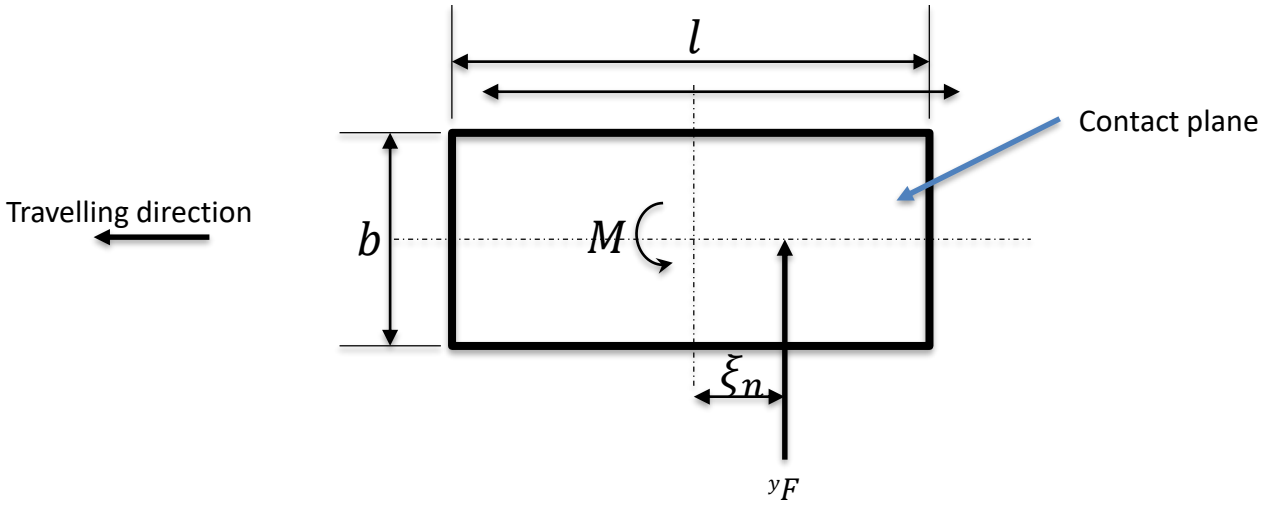


Figure 3 Lateral force and self aligning torque acting on the tire

Equation of Motion of the Steering System

- Fig.3 shows the self-aligning torque on the front wheel.

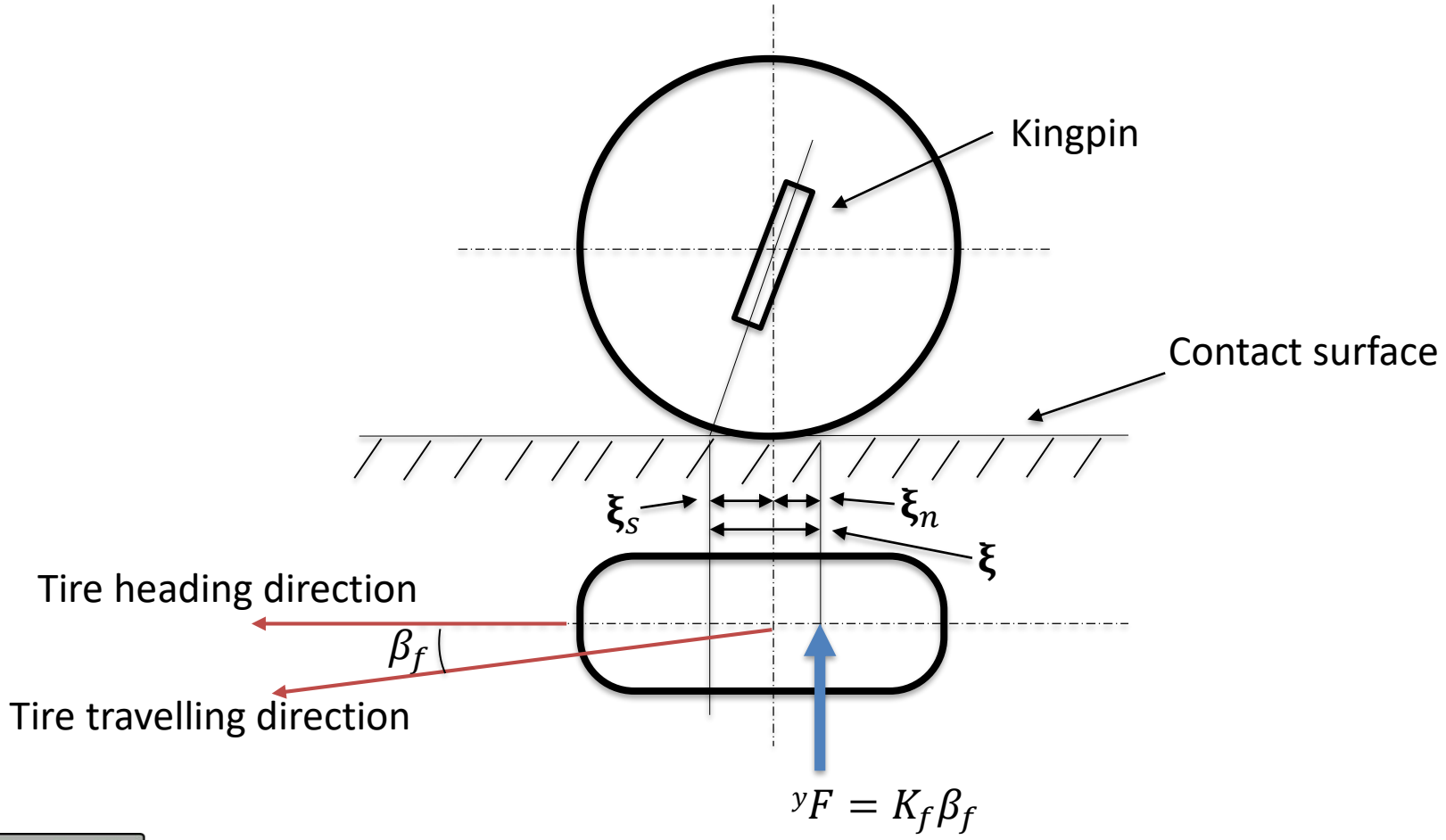


Figure 4 Self aligning torque acting on the tire

Equation of Motion of the Steering System

- From Fig.3, the moment acting at the tire around the kingpin, $T_s/2$ is:

$$\frac{T_s}{2} = (\xi_n + \xi_c)^y F = \xi K_f \beta_f \qquad \text{(Eq.1)}$$

Whereby,

$$\xi = \xi_n + \xi_c$$

ξ_n: pneumatic trail ξ_c: castor trail

- Rearranging Eq.1, the moment T_s can be written as:

$$T_s = 2\xi K_f \beta_f \qquad \text{(Eq.2)}$$

Equation of Motion of the Steering System

- In Chapter 3, we have defined the side-slip angle of the front tire is:

$$\beta_f = \beta + \frac{l_f r}{v} - \delta \qquad \text{(Eq.3)}$$

- Substitute Eq.3 into Eq.2 gives:

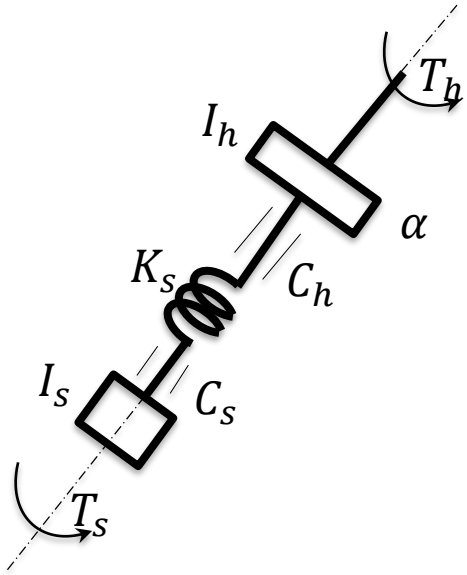
$$T_s = 2\xi K_f \left(\beta + \frac{l_f r}{v} - \delta\right) \qquad \text{(Eq.4)}$$

- From Eq.4, $2\xi K_f$ is called the restoring moment coefficient of the steering system.

Equation of Motion of the Steering System

- From Fig.2, the steering system equation of motion at the steering wheel transferred around the kingpin can be expressed as:

$$I_h\left(\frac{d^2\alpha}{dt^2}\right) + C_h\frac{d\alpha}{dt} + K_s(\alpha - \delta) = T_h \qquad \text{(Eq.5)}$$



- And the equation of motion at the front wheel can be expressed as:

$$I_h\left(\frac{d^2\delta}{dt^2}\right) + C_s\frac{d\delta}{dt} - K_s(\alpha - \delta) = T_s$$

$$I_h\left(\frac{d^2\delta}{dt^2}\right) + C_s\frac{d\delta}{dt} - K_s(\alpha - \delta) = 2\xi K_f\left(\beta + \frac{l_f r}{v} - \delta\right) \qquad \text{(Eq.6)}$$

Conclusion of The Chapter 5

- Conclusion #1
  - Steering wheel angle can effect the motion of the vehicle
- Conclusion #2
  - The lateral force will generate the moment around the centreline of the tire.

Vehicle Dynamics

Chapter 5

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