Fundamentals of Steering Systems

ME5670

Lecture 3


http://www.me.utexas.edu/~longoria/VSDC/clog.html
http://www.slideshare.net/NirbhayAgarwal/four-wheel-steering-system

Class timing
Monday: 14:30 Hrs – 16:00 Hrs
Thursday: 16:30 Hrs – 17:30 Hrs

Date: 12/01/2015
Steering System

- To control the angular motion of the wheels and thus the direction of vehicle motion
- To provide the direction stability of the vehicle
- There are different types of steering systems
  - Front wheel steering system
  - Rare wheel steering system
  - Four wheel steering system
- Four wheel steering system is arranged so that the front wheels roll without any lateral slip
- In this system, the front wheels are supported on front axle so that they can swing to the left or right for steering.
- Such movement is produced by gearing and linkage between the steering wheel and steering knuckle
- There are two types of steer modes: rear steer mode for slow speeds and crab mode for high speeds.
- To control the direction stability of the vehicle using steering system, the force/moment analysis is important
Ackerman Steering Mechanism

- At any angle of steering, the center point of all the circular path traced by all the wheels will coincide at a common point.

- It is difficult to achieve with simple linkages. However, it is applicable for low speed.
Turning Radius

• Turning circle of a car is the diameter of the circle described by the outside wheels when turning on full lock.

• A typical turning radius of a car is 35.5 feet.
Steering Axle Inclination, Caster, and Camber Angles

- The angle between the vertical line and center of the king pin or steering axle, when viewed from the front of the wheel is known as *steering axle inclination or king pin inclination* (0-5 degrees for trucks and 10-15 degrees on passenger cars).

- **Caster:** The angle between the vertical line and kingpin center line in the plane of the wheel (when viewed from the side) is called *caster angle*.

- **Camber:** The angle between the center line of the wheel and the vertical line when viewed from the front
  
  *Positive Camber:* Upper portion is tilted outward.
  *Negative Camber:* Upper portion is tilted inward
 Toe-In and Toe-Out

- **Toe-in:** The front wheels are usually turned in slightly in front so that the distance between front ends is slightly less than the back ends when viewed from the top. *The difference between these distances is called toe-in*.

- The difference in angle between the two front wheels and the car frame during turns. The toe-out is secured by providing the proper relationship between the steering knuckle arms, tie rods and pitman arm.
Vehicle Dynamics and Steering

- **Under steer**: When the slip angle of front wheels is greater than the slip angle of rear wheels.
- **Over steer**: When the slip angle of front wheels is lesser than the slip angle of rear wheels.
- **Neutral steer or counter steering**: When the slip angle of front wheels is equal to the slip angle of rear wheels.
Steering Gear Boxes

Steering Knuckle Arm
Tie Rods
Pitman Arm
Steering Gear
Steering Wheel

Kingpin (Wheel Pivot Point)
Typical Steering Systems

Rack-and pinion linkage:

Steering gearbox:

Differential steer:

Truck steering system:

Trapezoidal tie-rod arrangement:

Right turn:

Left turn:
Ideal Steering Geometry

- Tie rod end connect with the relay linkage end at the ideal centre.
- Relay linkage is connected to the pivot of the wheel.
- If the linkage joint is either inboard or outboard of this point, the steering geometry error will cause a steer action as the wheels moves into jounce or rebound.
Steering Geometry Error

Error due to toe change

Error due to understeer

Such phenomena leads to understeer/oversteer condition.
Tire Force/Moment Convention

SAE Tire Axis

Three forces and three moments at the tire-surface interface w.r.t. O

Different angles are selected to minimize the front type wear rather than handling.
Lateral or Cornering Force on Wheels/Tires

- A slip angle, $\alpha$, defines the difference between the wheel plane and the direction of motion, which may arise due to induced motion or because of an applied side force, $F_s$.

- A cornering force, $F_{ya}$, is induced in the lateral direction between the tire and ground, and it is found to be applied along an axis off the wheel axis. This force can be treated as the frictional force.

- The couple $T_a$ acting on the wheel tends to turn it so its plane coincides with the direction of motion.

- Steering and suspension systems must constrain the wheel if it is to stay, say, in the plane $OA$. 
More on Tire Cornering Forces

• The slip angle, $\alpha$, is shown here as the angle between the direction of heading and direction of travel of the wheel (OA).

• The lateral force, $F_{y\alpha}$, (camber angle of the wheel is zero) is generated at a tire-surface interface, and may not be collinear with the applied force at the wheel centre. The distance between these two applied forces is called the pneumatic trail.

• The self-aligning torque is given by the product of the cornering force and the pneumatic trail

• The induced self-aligning torque helps a steered wheel return to its original position after a turn.

“...side slip is due to the lateral elasticity of the tire.”
Cornering Force Data for Pneumatic Tires

“linear region”

Maximum cornering forces:
- passenger car tires: 18 degrees
- racing car tires: 6 degrees

(Wong)

Variables that impact cornering force:
- Normal load
- Inflation pressure
- Lateral load transfer
- Size

In general, tractive (or braking) effort will reduce the cornering force that can be generated at a given slip angle. This can be important in acceleration or braking in a turn, or in maintaining stability subject to disturbances.
Cornering Stiffness and Coefficients

- The cornering stiffness will depend on tire properties such as:
  - tire size and type (e.g., radial, bias-ply, etc.),
  - number of plies,
  - cord angles,
  - wheel width, and
  - tread.

- Dependence on load is taken into account through the cornering coefficient, where $F_z$ is the vertical load.

$$CC_\alpha = \frac{C_\alpha}{F_z}$$
Example of Yaw Instability

Yaw instability can occur when front and rear wheels do not lock up at the same time.

- Rear tires lock and **ability to resist lateral force decreases**.
- A perturbation about the yaw center of the front axle will be developed
- Yaw motion progresses with increased acceleration, with a decrease as it completes 180 degree turn.

Lock-up of front tires causes loss of directional control, but not directional instability. This is because a self-correcting inertial moment about the yaw center of the rear axle is induced whenever lateral movement of the front tires occurs.