## UNIT IV SUSPENSION TYRES AND VEHICLES HANDLING

Requirements,
Sprung mass frequency,
Wheel hop,
Wheel wobble,
Wheel shimmy,
Choice of suspension spring rate,
Calculation of effective spring rate,
Vehicle suspension in fore and aft,
Roll axis and vehicle under the action of side forces, the dynamics,
Tire dynamics,
Ride characteristics power consumed by a tire.

Over steer, under steer, steady state cornering, effect of braking, driving torques on steering, effect of camber,
Transient effects in cornering

### Functions:

- It must provide a high degree of isolation between a passenger/ goods of the vehicle from irregularities of the road surface, forces due to non balancing of the wheel.
- It has to maintain the close contact of the wheel with the road surface to get adequate adhesion for acceleration, braking and cornering.

### Requirements:

- The main requirement of the good spring system is that it should allow the wheels to have a vertical movement.
- It should resist the roll of chassis
- It must keep the tires in contact with the road with the minimum road variations
- It must provide vertical compliance so that wheels can follow the even road, isolating the chassis form the roughness in the road
- It maintain the wheel in the proper steer
    - Stiffness/Displacement bound
    - Compatibility
    - Minimum wear
    - low Maintenance
    - low Initial cost

### Sprung mass frequency,

It is the resonant condition of the sprung mass acting on the suspension spring in series with the tire spring with the interposed unsprung mass.

$$\omega = 2\pi f$$

$$f = \omega / 2\pi$$

### Wheel hop

- The vertical oscillating motion of the wheel between the road surface and the sprung mass

- Contact area of the tire is very less at the time of wheel hop.
- Wheel hop occurs
    - Road irregularities
    - Wheel out of round balsnce

**Wheel wobble**

- A self- excited oscillation of steerable wheels about their steering axes, occurring without appreciable tramp
- Horizontal vibration of front axle assembly around the longitudinal axis
- Front axle is mounted between two springs namely 1. Chassis spring 2. Tire spring when there is wheel wobble chassis spring on one side tire on the other side compresses simultaneously while other spring on the tire rebumb this condition called wheel wobble

Wheel shimmy:

- A self-excited oscillation of a pair of steerable wheel about their steering axes, accompanied by appreciable tramp.
- A violent front wheel shake caused by over corrective action

**Choice of suspension spring rate**

$$\omega_{nat} = \frac{187.8}{\sqrt{d}}$$

Where the **d** is the static deflection in inch when spring rate is linear
Let us consider the system having:

Unladen mass = m
Laden mass= m+L
Change in deflection= x

**Then**

$$S = \frac{laden\ mass - unladen\ mass}{change\ in\ deflection}$$
$$= \frac{M + L - M}{x}$$
$$= \frac{L}{x}$$

**Sprung** mass frequency,

$$\omega_{nat} = \frac{1}{2\pi}\left(\frac{\sqrt{gS}}{m}\right)$$

$$= \frac{1}{2\pi}\left(\frac{\sqrt{g\frac{L}{x}}}{m}\right)$$

To provide maximum isolation of the vehicle from irregularities the minimum possible spring rate is the best.

**Spring Rate**: The change of load of a spring per unit deflection, taken as a mean between loading and unloading at a specified load.
**Sprung Weight:** All weight which is supported by the suspension, including portions of the weight of the suspension members
**Unsprung Weight:** All weight which is not carried by the suspension system, but is supported directly by the tire or wheel and considered to move with it
**Suspension Rate(Wheel Rate): the** change of wheel load, at the center of tire contact, per unit vertical displacement of the sprung mass relative to the wheel at a specified load

**Tire Rate**:(static) the static rate measured by the change of wheel load per unit vertical displcement of the wheel load per unit vertical displacement of the wheel relative to the ground at a specified load and inflation pressure

**Ride Rate:** the change of wheel load, at the centre of tire contact per unit vertical displacement of the sprung mass relative to the ground at a specified load.

**Caster angle:** the angle in side elevation between the steeing axis and the vertical. It is considered positive when the steering axis is inclined rearward and negative when the steering axis is inclined forward

**Jounce**: the condition of the suspension which causes spring compression

**Rebound:**

- An expansion of a suspension spring after it has been compressed as a result of jounce.
- the relative displacement of the sprung and unsprung masses in a suspension system in which the distance between the masses increases from that at static condition.

**Camber angle:** the inclination of the wheel plane to the vertical. It is considered positive when the wheel leans outward at the top and negative when it leands inward.

## CALCULATION OF EFFECTIVE SPRING RATE

- Let W be the load acting on the tire and L be the load acting on the spring.
- Due to some disturbance on the wheel due to road irregularities there will be some displacement in wheel and spring.
- The corresponding values assume to be dx and dy respectively.

Spring rate = (Effective spring rate) X (Installation ratio)$^2$

Installation ratio = dx/dy
Effective spring rate = dW/dx
Actual spring rate = dL/dx

$$\frac{dL}{dy} = \frac{dW}{dx} + \left(\frac{dx}{dy}\right)^2$$

We know that W.dx=Ldy

$$W = L\frac{dy}{dx}$$

Differentiating the above, we get

$$\frac{dW}{dx} = \frac{d}{dx}\left(L\frac{dy}{dx}\right)$$

$$= \frac{dL}{dy}\frac{dy}{dx} + L\frac{d^2y}{dx^2}$$

Multiplying and dividing by dy in first term

$$= \frac{dL}{dy}\frac{dy}{dx}\frac{dy}{dx} + L\frac{d^2y}{dx^2}$$

$$= \frac{dL}{dy}\left(\frac{dy}{dx}\right)^2 + L\frac{d^2y}{dx^2}$$

Neglecting the second order terms

$$\frac{dW}{dx} = \frac{dL}{dy}\left(\frac{dy}{dx}\right)^2$$

Now as per the law if conservation of energy, the work done by the movement of wheels must be equal to the potential energy stored in the spring

W.dx=L.dy

The ratio between the small displacements at the wheel corresponding small displacement of spring is called as installation ratio. Installation ratio is assumed to be a constant value

**Vehicle suspension in fore and aft,**

**Roll axis and vehicle under the action of side forces, the dynamics,**

To describe the characteristics of a tire and the forces and moments acting on it, it is necessary to define an axis system that serves as a reference for the definition of various parameters. One of the commonly used axis systems recommended by the Society of Automotive Engineers is shown

- The origin of the axis system is the center of tire contact.
- The X axis is the intersection of the wheel plane and the ground plane with a positive direction forward.
- The Z axis is perpendicular to the ground plane with a positive direction downward.
- The Y axis is in the ground plane, and its direction is chosen to make the axis system orthogonal and right hand
- There are three forces and three moments acting on the tire from the ground.

- Tractive force (or longitudinal force) *F,* is the component in the X direction of the resultant force exerted on the tire by the road.
- Lateral force *F,* is the component in the Y direction, and normal force *F,* is the component in the Z direction. Overturning moment ***M,*** is the moment about the X axis exerted on the tire by the road.
- Rolling resistance moment ***My*** is the moment about the Y axis, and aligning torque ***M,*** is the moment about the Z axis

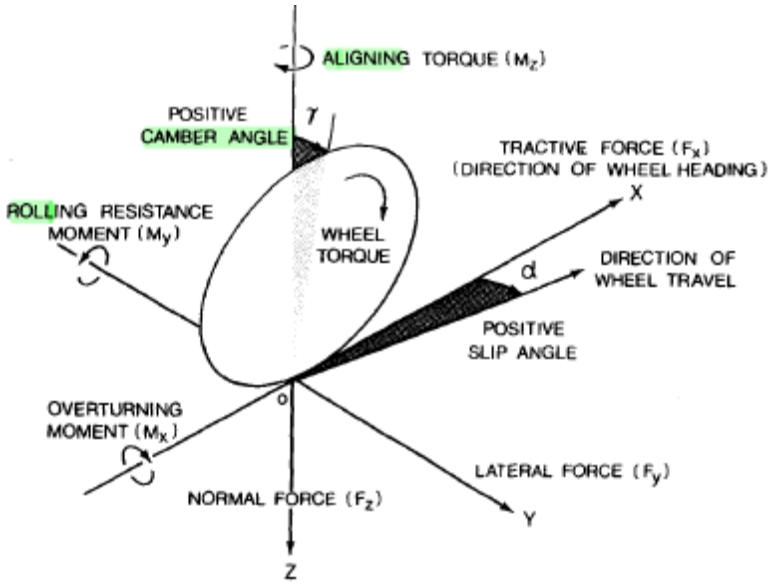


**Fig. 1.2** Tire axis system.

- The longitudinal shift of the center of normal pressure is determined by the ratio of the rolling resistance moment to the normal load.
- The lateral shift of the center of normal pressure is defined by the ratio of the overturning moment to the normal load.
- The integration of longitudinal shear stresses over the entire contact patch represents the tractive or braking force.
- A driving torque about the axis of rotation of the tire produces a force for accelerating the vehicle, and a braking torque produces a force for decelerating the vehicle.
- Slip angle *a* is the angle formed between the direction of wheel travel and the line of intersection of the wheel plane with the road surface.
- Camber angle *y* is the angle formed between the *XZ* plane and the wheel plane. The lateral force at the tire-ground contact patch is a function of both the slip angle and the camber angle.