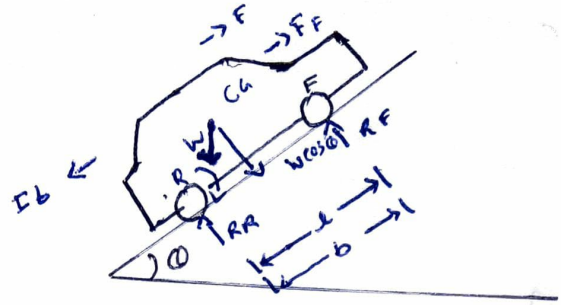
1. Derive the eqn of motion & max. tractive effort for a car inclined at angle θ. Also give the expression of max. gradeability for a 4 wheel drive.

Ans.



W = Weight of the car

CG = Centre of gravity

b = Wheel base

F = maximum forward acceleration

F_F = max. tractive effort

R & F = Rear & Front wheel

R_R & R_F = Total normal reaction at front & rear wheel

h = height from CG to Road surface

IF = Inertia force $= mF - W\sin\theta$

$mb - mg\sin\theta$

$\frac{W}{g} \cdot b - W\sin\theta$ — (1)

$\Sigma V = 0$ — (2)

$\Sigma H = 0$ — (3)

Using (2)

$W\cos\theta = R_F + R_R$ — (4)

Using ⑤

$$F_F = \frac{w}{g} f + w \sin\theta$$

$$\mu R_F = \frac{w}{g} f + w \sin\theta$$

$$R_F = \frac{w}{g}\frac{f}{\mu} + \frac{w}{\mu}\sin\theta \quad - ⑤$$

$$= \frac{w}{\mu}\left(\frac{f}{g} + \sin\theta\right)$$

Taking moment about R

$$R_F \times b + \left(\frac{w}{g} f + \sin\theta\right) h = w \cos\theta \times l$$

$$\left(\frac{w}{g}\frac{f}{\mu} + \frac{w}{\mu}\sin\theta\right) b + \left(\frac{w}{g} f + w \sin\theta\right) \times h = w \cos\theta \times l$$

$$\left(\frac{f}{g\mu} + \frac{\sin\theta}{\mu}\right) b + \left(\frac{f}{g} + \sin\theta\right) h = \cos\theta\, l$$

$$\frac{b}{\mu}\left(\frac{f}{g} + \sin\theta\right) + \left(\frac{f}{g} + \sin\theta\right) h = \cos\theta\, l$$

$$\left(\frac{f}{g} + \sin\theta\right)\left(\frac{b}{\mu} + h\right) = \cos\theta\, l$$

$$\left(\frac{f}{g} + \sin\theta\right) = \frac{\cos\theta\, l}{\frac{b}{\mu} + h} \quad - ⑥$$

$$\frac{f}{g} = \left(\frac{\cos\theta\, l}{\left(\frac{b}{\mu} + h\right)}\right) - \sin\theta$$

$$F = g\left[\left(\frac{\cos\theta\, l}{\left(\frac{b}{\mu} + h\right)}\right) - \sin\theta\right] \quad - ⑦$$

Now,

$$R_F = \frac{W}{u} \times \frac{\cos\theta\, l}{\left(\frac{b}{u}+h\right)} \quad - (8)$$

$$= \frac{W\cos\theta\, l}{b+uh}$$

$$R_R = W\cos\theta - R_F$$

$$= W\cos\theta - \frac{W}{u}\frac{\cos\theta\, l}{\left(\frac{b}{u}+h\right)}$$

$$= W\cos\theta\left[1 - \frac{l}{b+uh}\right]$$

$$= W\cos\theta\left[\frac{b+uh-l}{b+uh}\right]$$

$$F_F = uR_F = u \times \left(\frac{W\cos\theta\, l}{b+uh}\right)$$

For Four wheel Drive

$$F = R_F + R_F = uR_R + uR_F$$

$$\Sigma V = 0$$

$$W = R_F + R_R$$

$$\Sigma H = 0$$

$$\left(\frac{W}{g}\right)F = uR_R + uR_F$$

$$= u(R_R + R_F) = uW$$

$$\frac{F}{g} = u$$

$$\Sigma V = 0$$

$$W = R_R + R_F$$

$$\Sigma H = 0$$

$$\left(\frac{W}{g}\right) F = \mu R_R + \mu R_F$$

Assuming slip to occur at front wheels

F_{rest} $R_F < R_R$ then

$$\Sigma M_R = 0$$

$$2 \mu R_F = \left(\frac{W}{g}\right) F$$

$$R_F b + \left(\frac{W}{g}\right) F_h = W_a$$

Exp. for max. gradeability for a 4 wheel drive

$$P = 100 \left[\frac{F_Z}{9.81 \cdot G_Z} - f_R \right]$$

P = Gradeability in %

G_Z = overall combined mass in kg

f_R = coef. of rolling resistance

F_Z = Tractive force in N

2. Consider a car with the following specifications that is parked on a level road. Find the load on the front & rear axles. $m = 1765$ kg, $L = 2.84$ m

$a_1 = 1.22$ m, $a_2 = 1.62$ m

Ans

Load on Front axle

$$F_{Zf} = mg\left(\frac{a_2}{L}\right)$$

$$= 1765 \times 9.8 \times \frac{1.62}{2.84} = 9866.59 \text{ N}$$

Load on Rear axle

$$F_{ZR} = mg\left(\frac{a_1}{L}\right)$$

$$= 1765 \times 9.8 \times \left(\frac{1.22}{2.84}\right) = 7430.41 \text{ N}$$

3. What are the different parts of tires? Differentiate b/w types of tires based on construction.

Ans. 1) Bead : It holds the tire to the rim

It consist of high tensile steel wire strands.

2) Bead filler : Protect the tire from steel bead.

3) Inner liner : It is a soft rubber compound
Protect air from leaking

4) Body ply : -> soft rubber compound with reinforcement
-> it may be Neylon, kevlar, carbon fiber etc.
-> Give structural strength to tire

5) Side wall : It is the side or external portion of tire

6) Tread : The top contacting portion of tire
-> It contacts the road surface

7) Shoulder : In b/w side wall & tread the portion is called shoulder
-> It is a thinner portion

8) Shoulder inserts : These are inserted to provide strength for shoulder

9) Steel Belt : Used for reinforcement of tread.

Depending on construction the types

1) Bias P/g

2) Radial P/g

Bias P/g

In this type of tires that feature a bias p/g placements, have the plies in their internal structure placed diagonally. This pattern angled at 30-40 degrees to the centre line.

→ Criss cross pattern

Radial Ply

Radial tires feature structures where the plies are added at 90° angles from one bead to the other.

Bias Tires	Radial Tires
1) Thicker sidewalls	1) minimal sidewall
2) Nylon Belts	2) Steel Belts
3) Standard duty	3) Severe / Extreme duty
4) Less expensive	4) more expensive
5) Low life expectancy	5) Long life expectancy