Assignment - 2

Q.1. Drive the Equation of motion and maximum tractive effort for a car inclined at angle θ. Also give the expression of maximum gradeability for a 4 wheel drive.

Ans:-

Dynamic Equation

In the longitudinal direction, the major external forces acting on a two-axle vehicle include:

1. The rolling resistance of the front and rear tires (F_{rf} and F_{rr}), which are represented by rolling resistance moment, T_{rf} and T_{rr}
2. The aerodynamic drag (F_w)
3. Grade climbing resistance (F_g)
4. Acceleration resistance (F_a)

The dynamic equation of vehicle motion along the longitudinal direction is given by:

$$M\frac{dV}{dt} = (F_{tf} + F_{tr}) - (F_{rf} + F_{rr} + F_w + F_g + F_a) \quad \text{— (1)}$$

The first term on the right side is the total tractive effort and the second term is the total tractive resistance. To determine the maximum tractive effort, that the tire ground contact can support, the normal loads on the front and rear axles have to be determined. By summing the moments of all the forces about point R, the normal load on the front axle W_f can be determined as:

$$W_f = \frac{MgL_b\cos(\alpha) - \left(T_{rf} + T_{rr} + F_w h_w + Mgh_g\sin(\alpha) + Mh_g\frac{dV}{dt}\right)}{L} \quad \text{— (2)}$$

Similarly, the normal load acting on the rear axle can be expressed as

$$W_r = \frac{MgL_a\cos(\alpha) - \left(T_{rf} + T_{rr} + F_w h_w + Mgh_g\sin(\alpha) + Mh_g\frac{dV}{dt}\right)}{L} \quad \text{— (3)}$$

In case of passenger cars, the height of the centre of application of aerodynamic resistance (h_w) is assumed to be near the height of centre of gravity of the vehicle (h_g). The equation 16 and 17 can be simplified as:

$$W_f = \frac{L_b}{L} Mg\cos(\alpha) - \frac{h_g}{L}\left(F_w + F_g + Mgf_r\frac{r_{dyn}}{h_g}\cos(\alpha) + M\frac{dV}{dt}\right) \quad — ④$$

and

$$W_r = \frac{L_a}{L} Mg\cos(\alpha) - \frac{h_g}{L}\left(F_w + F_g + Mg f_r\frac{r_{dyn}}{h_g}\cos(\alpha) + M\frac{dV}{dt}\right) \quad — ⑤$$

Using eq^n ①, ④ and ⑤ can be rewritten as:

$$W_f = \frac{L_b}{L} Mg\cos(\alpha) - \frac{h_g}{L}\left(F_t - F_r\left(1 - \frac{r_{dyn}}{h_g}\right)\right) \quad — ⑥$$

$$W_r = \frac{L_a}{L} Mg\cos(\alpha) + \frac{h_g}{L}\left(F_t - F_r\left(1 - \frac{r_{dyn}}{h_g}\right)\right) \quad — ⑦$$

The first term on the right-hand side of equation 6 and equation 7 is the static load on the front and the rear axles when the vehicles is at rest on level ground. The second term is the dynamic component of the normal load.

For the front wheel drive vehicle

$$F_{tmax} = \mu W_f = \mu\left[\frac{L_b}{L} Mg\cos(\alpha) - \frac{h_g}{L}\left(F_{tmax} - F_r\left(1 - \frac{r_{dyn}}{h_g}\right)\right)\right]$$

$$F_{tmax} = \frac{\mu Mg\cos(\alpha)\left[L_b + f_r(h_g - r_{dyn})\right]/L}{1 + \mu h_g/L} \quad — ⑧$$

For the rear-wheel-drive vehicle,

$$F_{tmax} = \mu W_r = \frac{\mu Mg\cos(\alpha)\left[L_a - f_r(h_g - r_{dyn})\right]/L}{1 - \mu h_g/L} \quad — ⑨$$

Gradeability

Gradeability is defined as the grade angle that the vehicle can negotiate at a certain constant speed. For heavy commercial vehicles the gradeability is usually defined as the maximum grade angle that the vehicle can overcome in the whole speed range.

when the vehicle is driving on a road with relatively small grade and constant speed, the tractive effort and resistance equilibrium can be expressed as

$$\frac{i_g i_o \eta_t T_p}{r_{dyn}} = M g f_r + \frac{1}{2} \rho A_f C_d V^2 + M g i$$

Hence,
$$i = \frac{i_g i_o \eta_t T_p / r_{dyn} - M g f_r - \frac{1}{2} \rho A_f C_d V^2}{M g} = d - f_r$$

where,
$$d = \frac{i_g i_o \eta_t T_p / r_{dyn} - \frac{1}{2} \rho A_f C_d V^2}{M g}$$

The factor d is called the performance factor. when the vehicle drives on a road with a large grade, the gradeability of the vehicle can be calculated as

$$\sin(\alpha) = \frac{d - f_r^2 \sqrt{1 - d - f_r^2}}{1 - f_r^2}$$

Q.2. Consider a car with the following specifications that is parked on a level road. Find the load on the front and rear axles.
$m = 1765$ kg, $l = 2.84$ m, $a_1 = 1.22$ m, $a_2 = 1.62$ m.

Ans:

Given:

mass of car $= m = 1765$ kg

wheelbase $= l = 2.84$ m

$a_1 = 1.22$ m

and $a_2 = 1.62$ m

The load on front axles

~~F_{z}~~ =

$$W_{fs} = W \cdot \frac{a_2}{l} = mg \frac{a_2}{l}$$

and load on Rear axles $= W_{rs} = W \cdot \frac{a_1}{l} = mg \frac{a_1}{l}$

where $g = 9.81$ m/s

$\therefore$ Load of front axles = $mg \frac{a_2}{l}$

$$W_{fs} = \frac{1765 \times 9.81 \times 1.62}{2.84}$$

$\therefore$ Load of front axles = 9876.67 N

= 9.88 kN

And Load of Rear axles = $mg \frac{a_1}{l}$

$$W_{rs} = \frac{1765 \times 9.81 \times 1.22}{2.84}$$

$\therefore$ Load of Rear axles = 7437.98 N

= 7.44 kN

Q.3. What are the different parts of tires? Differentiate between types of tires on the basis of their construction.

Ans: A tire is an advanced engineering product made of rubber and a series of synthetic materials cooked together. fibre, textile, and steel cords are some of the components that go into the tire's inner liner, body plies, bead bundle, belts, sidewalls, and tread.

The main components of a tire are explained below:

Bead or bead bundle is a loop of high strength steel cable coated with rubber. It gives the tire the strength steel it needs to stay seated on the wheel rim and to transfer the tire forces to the rim.

Inner layers are made up of different fabrics, called plies. The most common ply fabric is polyester cord. The top layers are also called cap plies. Cap plies are polyesteric fabric that help hold everything in place.

Cap plies are not found on all tires; they are mostly used on tires with higher speed ratings to help all the components stay in place at high speeds.

Belts or belt buffers are one or more rubber-coated layers of steel or other high strength cords tied to bead bundles. The cords in a radial tire, run perpendicular to the tread.

The sidewall provides lateral stability for the tire that comes in contact with the road. Tread designs vary widely depending on the specific purpose of the tire. The tread is made from a mixture of different kinds of natural and synthetic rubbers. The outer perimeter of a tire is also called the crown.

The tread groove is a space or area between two tread rows or blocks. The tread groove gives the tire traction and is especially useful during rain or snow.

Tires are divided in two classes: radial and non-radial, depending on the angle between carcass metallic cords and the tire-planes. Each type of tire construction has its own set of characteristics that are key to its performance.

The Radial Tire is constructed with reinforcing steel cables belts that are assembled in parallel and run side to side, from one bead to another bead at an angle of 90° to the circumferential centerline of the tire. This makes the tire more flexible radially, which reduces rolling resistance and improves cornering capability.

The Non-Radial Tires are also called bias-ply and cross-ply tires. The plies are layered diagonal from one bead to the other bead at about a 30° angle, although any other angles may also be applied. One ply is set on a bias in one direction as succeeding plies are set alternately in opposing direction as they cross each other.