4. Diagonal BD

In ΔAFD, $\tan\frac{\alpha}{2} = \frac{DF}{AF} \Rightarrow DF = AF \cdot \tan\alpha/2$

$$DF = \frac{AC}{2}\tan\alpha/2$$

$$\frac{BD}{2} = \frac{G}{2}\cdot \operatorname{cosec}\alpha/2 \cdot \tan\alpha/2$$

$$\boxed{BD = G\sec\alpha/2} \longrightarrow (4)$$

Q.7.b ES1997. Design a diamond crossing b/w two B.G tracks crossing each at an angle of 1 in 10.

$$N = 10 = \cot\alpha \Rightarrow \alpha = \cot^{-1}(10) = 5^\circ 42' 38.14''$$

$$\text{Length} = G\operatorname{cosec}\alpha = 1.676\operatorname{cosec}\alpha = 16.84\ m.$$

$$BH = \text{Distance}, DE = G\cot\alpha = 16.759\ m.$$

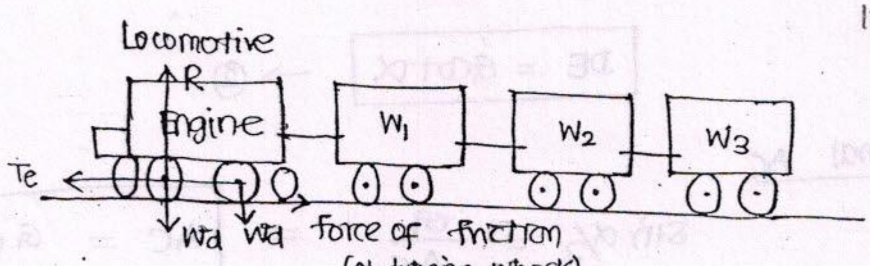
$$\text{Diagonal } AC = G\operatorname{cosec}\alpha/2 = \frac{1.676}{\sin\alpha/2} = 33.65\ m.$$

$$\text{Diagonal } BD = G\sec\alpha/2 = \frac{G}{\cos\alpha/2} = 1.678\ m.$$

#. TRACTION AND TRACTIVE EFFORT :

Weight of train = wt of locomotive + wt. of all wagons.

$W_T = W_L + W_W$



(Hauling capacity)

$F = \mu R = \mu . W_d$

For the movement of a train three forces are important to understand.

1. Total resistance: Total resistance offered by the train and due to other reasons that restrict the movement of train.

2. Tractive effect of locomotive: The force applied by the engine on the driving wheels to overcome the resistances for movement of the train.

$T_e >$ Total resistance (for the train to move)

3. Hauling capacity:

This is the force of friction developed at driving wheels. This force of friction should be sufficient (not less than the tractive effort).

Hauling capacity (H.C) $= \mu . R = \mu . W_d$.

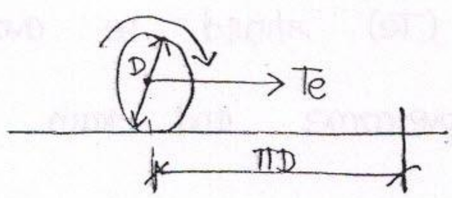
W_d = total weight on the driving wheels.

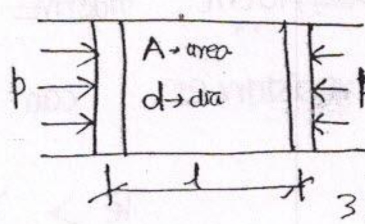
If sufficient force of friction is not available, the train will not move even tractive effort is more than the total resistances.

#. sufficient weight must be there on driving wheels.

10.02.2014

#. Tractive effort of locomotive:





let us take example of a steam engine. Tractive force effort is generated in the cylinder on piston and converted to the driving wheels as 'Te' force.

#. Power generated on piston:

$n \rightarrow$ no. of cylinders

$$= \text{Force} \times \text{distance} = p \times \pi/4 \, d^2 \times 2l \times n$$

Workdone on wheel:

$$= \text{Tractive force} \times \text{Distance} = Te \times \pi D$$

Equating,

$$p \times \pi/4 \times d^2 \times 2l \times n = Te \times \pi \times D$$

$$\boxed{Te = \frac{n \cdot p \times l \times d^2}{2D}}$$

#. Diameter of driving wheel is selected such that sufficient speed of train can be obtained with sufficient value of tractive effort obtained.

If dia is more, speed $\Rightarrow$ more ; Te $\Rightarrow$ less

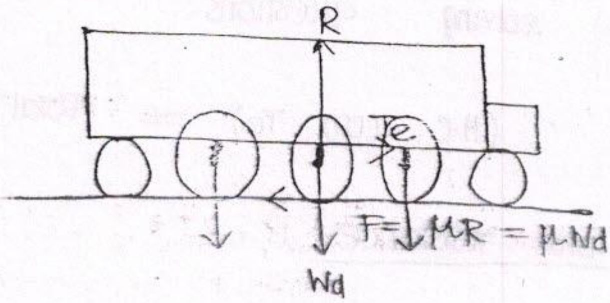
If dia is less, speed $\Rightarrow$ less ; Te $\Rightarrow$ more.

$$\text{Speed} \propto D \quad ; \quad Te \propto \frac{1}{D}$$

#. Sufficient tractive effort (Te) should be available, so that all resistances can be overcome and train can move.

$$Te > \text{Total resistances}.$$

2. Hauling capacity (H.C):



→ Hauling capacity is max. frictional force that can be obtained at the surface of rail between rail & wheel.

if w_d = weight on one pair of driving wheel (one axle).

n = no. of axles.

W_d = Total weight on driving wheel = $n \cdot w_d$.

Hauling capacity:

$$\boxed{H \cdot C = \mu \cdot R = \mu \cdot n \, w_d} \longrightarrow (1)$$

Value of μ:

$\mu = 0.10$ to 0.30

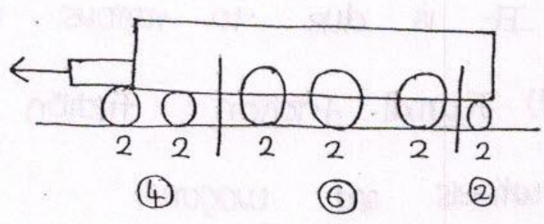
When speed is less, $\mu = 0.30$

When speed is more, $\mu = 0.10$

For calculation purpose, $\mu = 0.20$ (avg. value) (or) $\frac{1}{6} = 0.167$.

#. Designation of a locomotive:

4-6-2 locomotive



A locomotive is designated as $x_1 - x_2 - x_3$. say like 4-6-2.

④ - ⑥ - ②

④ → front wheels
⑥ → driving wheels
② → back wheels.

No. of pair of driving wheels $= \frac{x_2}{2}$.

4-6-2 will have 3 pairs of driving wheels.

For solving questions:

(H.C (or) Te) = Total resistance.

3. Total resistances:

(i) Train resistance.

(ii) Resistance due to track profile → gradient, → curve

(iii) Resistance due to starting and acceleration.

(iv) Resistance due to wind.

A. Train Resistance (R_T):

It is due to various reasons.

1. Resistance independent of speed:

(Also called rolling resistance)

$$R_{T_1} = 0.0016\ w \rightarrow (1)$$

w = weight of train (in tonnes)

R_{T_1} = resistance in tonnes.

It is due to various reasons.

(i) Journal friction: friction between internal parts of engines, wheels and wagons.

(ii) Friction between rail and wheel.

(iii) Due to any other irregularity in track.

2. Resistance dependent on speed

$$R_{T_2} = 0.00008\ w.V \rightarrow (2)$$

w = weight of train in tonnes.

V = speed in kmph.

(Total weight of train includes weight of locomotives and weight of wagons) $w = w_L + w_w$

3. <u>Atmospheric resistance</u> :

(When speed of wind is not considered)

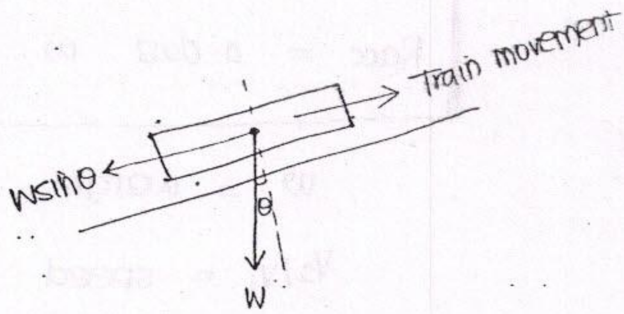
$$R_{T_3} = 0.0000006\, w \cdot V^2 \longrightarrow (3)$$

Total train resistance : $R_T = R_{T_1} + R_{T_2} + R_{T_3}$

** $$R_T = 0.0016\, w + 0.00008\, w \cdot V + 0.0000006\, w \cdot V^2$$

B. <u>Resistance due to track profile</u> :

a) <u>Due to gradient</u> :



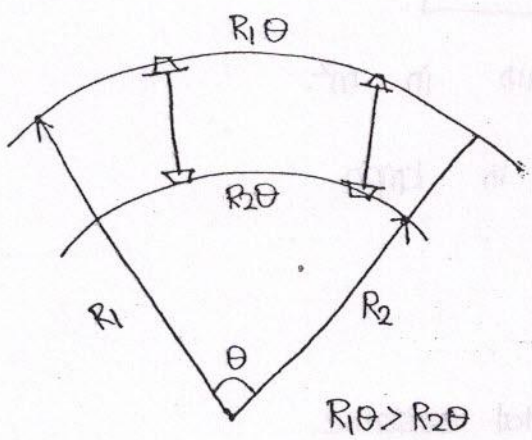
For small values of θ,

$\sin\theta = \tan\theta$

$$R_g = w \tan\theta \longrightarrow (a)$$

$R_g = W\sin\theta = w\tan\theta$.

b) <u>Due to curve</u> :



$R_1\theta > R_2\theta$

When a train is moving on a curved track, due to difference of length travelled on the two rails, some resistance will be there due to skid/slip of wheels over rail surface.

The wheel flange may also be touching to rail.

** $R_c = 0.0004\ W\ D$ ---- for BG

$= 0.0003\ W\ D$ ---- for M.G

$= 0.0002\ W.D$ ---- for N.G

C. Due to starting and acceleration :

a) Due to starting :

for locomotive , $R_s = 0.15\ W_L$

for wagons , $R_s = 0.005\ W_W$

b) Due to acceleration :

$$R_{acc} = 0.028 \cdot W \cdot \left(\frac{V_2 - V_1}{t}\right)$$

W = weight in tonnes.

V_2 / V_1 = speed in Kmph ; t = time in sec.

D. Wind resistance :

$$R_W = 0.000017 \times A \times V_W^2$$

A = exposed area of train in m^2.

V_W = velocity of wind in kmph.

#. For solving questions :

(Te (or) H.c) = Total resistance.

(minimum value)

* If train is moving at a speed of V kmph.

$$T_e / H.C = R_T = R_{T_1} + R_{T_2} + R_{T_3}$$

$$= 0.0016 w + 0.00008\, w.V + 0.0000006\, w\, V^2$$

+ (any other resistance as per case).

ES2013. 7. c) Calculate the max. permissible load that a BG steam locomotive can pull with three pair of driving wheels with axle load of 22t each, on a straight level track at a speed of 80 Kmph. (ii) Also calculate the reduction in speed if the train has to run on a rising gradient of 1 in 200. (iii) what would be further reduction in speed if the train has to run on a 4° curve on the rising gradient. Take $\mu = 0.20$.

If w = total weight of train that can be pulled.

1. Hauling capacity:

No. of pairs of driving wheels, $n = 3$.

W_d = load on each pair = 22t

$$H.C = \mu . n . W_d = 0.2 \times 3 \times 22 = 13.2\ t.$$

1. When train is moving on a straight level track:

$H_c = R_T$ — straight → no curve; level → no gradient.

$$H.C = 0.0016 w + 0.00008.V.w + 0.0000006.w.V^2$$

$$13.2 = w\,(0.0016 + 0.00008 \times 80 + 0.0000006 \times 80^2)$$

$$= w \times 0.01184 \Rightarrow w = 1114.86\,t \simeq 1115\,t \text{ (say)}.$$

2. When there is a gradient of 1 in 200:

$H.C = 0.0016\,w + 0.00008\,w.V + 0.0000006\,w.V^2 + w.\tan\theta$

$13.2 = 1.784 + 0.0892V + 6.69\times10^{-4}V^2 + 5.575$ $\quad \tan\theta = \frac{1}{200}$

$6.69\times10^{-4}V^2 + 0.0892V - 5.841 = 0$

$V = 48.117$ kmph.

3. When there is curve + gradient :

$H.C = 0.0016\,w + 0.00008.w.V + 0.0000006.w.V^2 + w.\tan\theta + 0.0004.w.D^\circ$ $\quad D^\circ = 4^\circ$

$13.2 = 1.784 + 0.0892V + 6.69\times10^{-4}V^2 + 5.575 + 1.784$

$6.69\times10^{-4}V^2 + 0.0892V - 4.057 = 0$

$V = 35.84$ kmph.

ES2010, 6.e) A locomotive on BG track with 4 pairs of driving wheels carrying 20t load on each is required to haul at a speed of 80 kmph. The train is made to run on a curvature on a levelled track with curvature 2°. calculate max. load that can be pulled. consider $\mu = 1/6 = (0.167)$.

n = no. of pairs = 4. Load on one pair = 20t

$H.C = \mu.n.W_d = 0.167\times4\times20 = 13.36$ t $\quad V = 80$ kmph

$H.C = 0.0016\,w + 0.00008.w.V + 0.0000006.w.V^2 + 0.0004.w.D^\circ$

$13.36 = (0.0016 + 6.4\times10^{-3} + 3.84\times10^{-3} + 8\times10^{-4})\,w$

$= 0.01264\,w \Rightarrow w = 1056.9$ t

ES.1995.8c) A train having 20 wagons weighing 18t each is to run at a speed of 50 kmph. The tractive effort of a 2-8-2 locomotive with 22.5 tonnes load on each driving axle is 15t. The weight of locomotive is 120 t. Rolling resistance of wagons and locomotives are 2.5 kg/ton and 3.5 kg/t respectively. The resistance which depends on speed is 2.65t. Find out the steepest gradient for these conditions.

Total no. of driving wheel = 8. ⇒ no. of pairs = 4.

Hauling capacity. $H.C = \mu . n . W_d = \mu \times 4 \times 22.5 = 0.2 \times 4 \times 22.5$

$= 18t$.

max. tractive effort, $T_e = 15t$

solve by considering, $H.C = T_e = 15t$.

| loc. | 20 wagons |

Total weight of train = 120 + 360

$W = 480\ t$

wt. of locomotive = 120 t (Given)

1 wagon = 18t

20 wagon = 360 t.

speed of train = 50 kmph.

With gradient:

Resistance that does not depend on speed is called rolling resistance. (R_{T_1}).

$H.C = R_{T_1} + R_{T_2} + R_{T_3} + W.\tan\theta$.

here R_{T_1} = rolling resistance $= 360 \times 2.5 + 120 \times 3.5$

$= 1320\ kg = 1.32\ t$

R_{T_2} = resistance depend on speed = 2.65t (directly given).

$R_{T_3} = 0.0000006 W V^2 = 0.0000006 \times 480 \times 50^2 = 0.72 t$.

(15) ← $H.C = 1.32 + 2.65 + 0.72 + 480 \times \tan\theta$

$\tan\theta = 0.0214$ ⇒ 1 in 46.56 (gradient).