TRAIN MOVEMENT AND ENERGY CONSUMPTION

Types of Railway Services – There are three types of passenger services which traction system has to cater for – namely Urban, Sub-urban and Main line services.

1. **Urban or city service** – In this type of service there are frequent stops, the distance between stops being nearly 1 km or less. Thus in order to achieve moderately high schedule speed between the stations it is essential to have high acceleration and retardation.
2. **Sub-urban service** – In this type of service the distance between stops averages from 3 to 5 km over a distance of 25 to 30 km from the city terminus. In this case also, high rates of acceleration and retardation are necessary.
3. **Main line service** – In this type of service the distance between stations is long. The stops are infrequent and hence the operating speed is high and periods corresponding to acceleration and retardation are relatively less important.

The characteristics of each type of service are given in table 1 given below:

S.No.	Parameter of Comparison	Urban Service	Sub – urban Service	Main line Service
1	Acceleration	1.5 to 4 kmphps	1.5 to 4 kmphps	0.6 to 0.8 kmphps
2	Retardation	3 to 4 kmphps	3 to 4 kmphps	1.5 kmphps
3	Maximum Speed	120 kmph	120 kmph	160 kmph
4	Distance between stations	1 km	2.5 to 3.5 km	More than 10 km
5	Special Remark	Free running period is absent and coasting period is small	Free running period is absent and coasting period is long	Long free running and coasting periods. Acceleration and braking periods are comparatively small

Speed Time Curves for Train Movement - The movement of trains and their energy consumption can be conveniently studied by means of speed-time and speed-distance curves. The speed time curve is the curve showing instantaneous speed of train in kmph along ordinate and time in seconds along abscissa. The area in between the curve and abscissa gives the distance travelled during given time interval. The slope of the curve at any point gives the value of acceleration or retardation. The fig. 1 shows a typical speed time curve for electric trains operating on passenger services. It mainly consists of (i) constant acceleration period, (ii) acceleration on speed curve, (iii) free running period, (iv) coasting period and (v) braking period

(i) **Constant Acceleration Period (0 to t_1)** – During this period the traction motors accelerate from rest, the current taken by the motors and the tractive effort are practically constant. It is also known as notching up period and it is represented by portion OL of the speed time curve.

(ii) **Acceleration on Speed Curve (t_1 to t_2)** – After the starting operation of the motors is over, the train still continues to accelerate along the curve LM. During this period, the motor current and torque decrease as train speed increases. Hence, acceleration gradually decreases till torque developed by the motors exactly balances that due to resistance to the train motion. The shape of LM portion of the speed time curve depends primarily on the torque speed characteristics of the traction motors.

(iii) **Free Running Period (t_2 to t_3)** – At the end of speed curve running i.e. at t_2 the train attains the maximum speed. During this period the train runs at constant speed attained at t_2 and constant power is drawn. This period is represented by the portion MN of the speed time curve.

(iv) **Coasting Period (t_3 to t_4)** – At the end of free running period (i.e. at t3) the power supply is cut off and the train is allowed to run under its own momentum. The speed of the train starts decreasing due to the resistance offered to the motion of the train. The rate of decrease of speed during coasting period is known as coasting retardation (which practically remains constant). Coasting is desirable because it utilizes some of the kinetic energy of the train which would otherwise, be wasted during braking. This helps in reducing the energy consumption of the train. The coasting period is represented by the portion NP of the speed time curve.

(v) **Braking Period (t_4 to t_5)** – During this period brakes are applied and the train is brought to a stop. This is represented by the portion PO of the speed time curve.

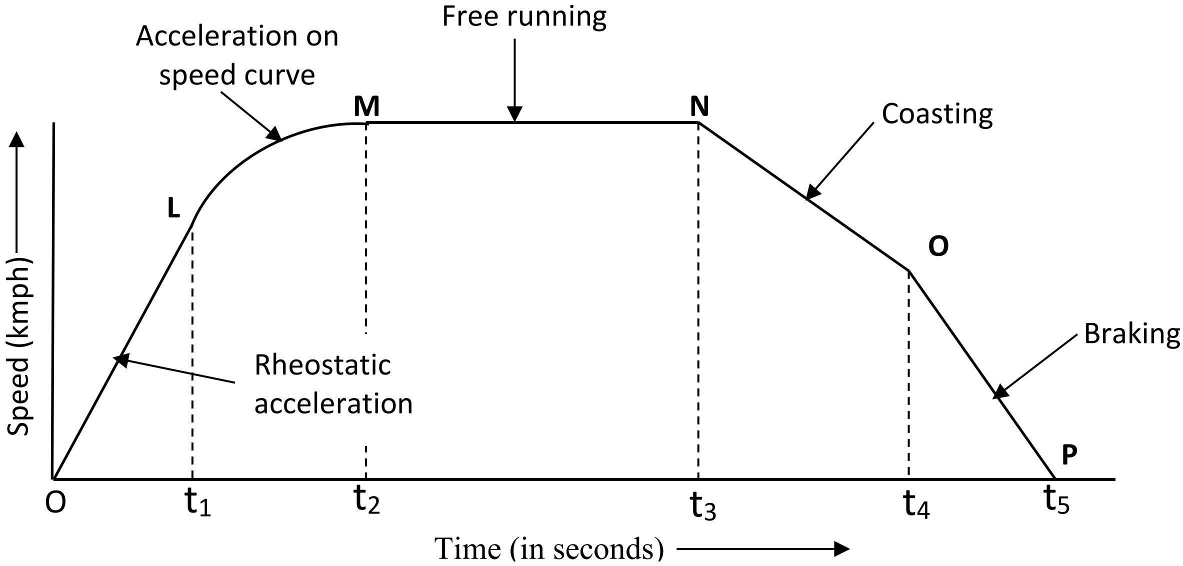


Fig. 1 Actual Speed Time Curve of Train

Simplified Speed Time Curve - The actual speed time makes calculations quite difficult as some part of it is non – linear. Therefore in order to make calculations simpler with least error the speed time curve is modified by keeping both the acceleration and retardation as well as distance between stations the same for both actual and modified speed time curves. The speed time curves are modified in two ways – (a) Trapezoidal speed time curve and (b) Quadilateral speed time curve as shown in fig. 2 In the case of simplified trapezoidal speed time curve OA'B'C speed curve running and coasting periods are replaced by constant speed period. On the other hand, in case of simplified quadrilateral speed time curve OA"B"C , speed curve running and coasting periods are extended. The trapezoidal speed time curve gives closer approximation of the conditions of main line service where long distances are involved and quadrilateral speed time curve is suitable for urban and sub-urban services.

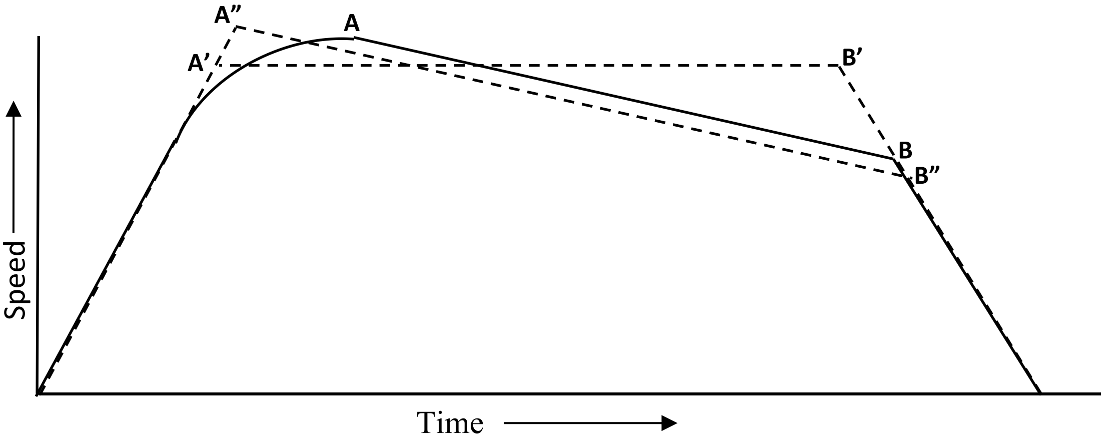


Fig.2 Simplified Speed Time Curve

Trapezoidal Speed Time Curve - The fig.3 shows a simplified trapezoidal speed time curve with speed in kmph and time in seconds. If V_m is the maximum speed attained, α is acceleration in kmphps and β is retardation in kmphps; D is the total distance travelled in km then

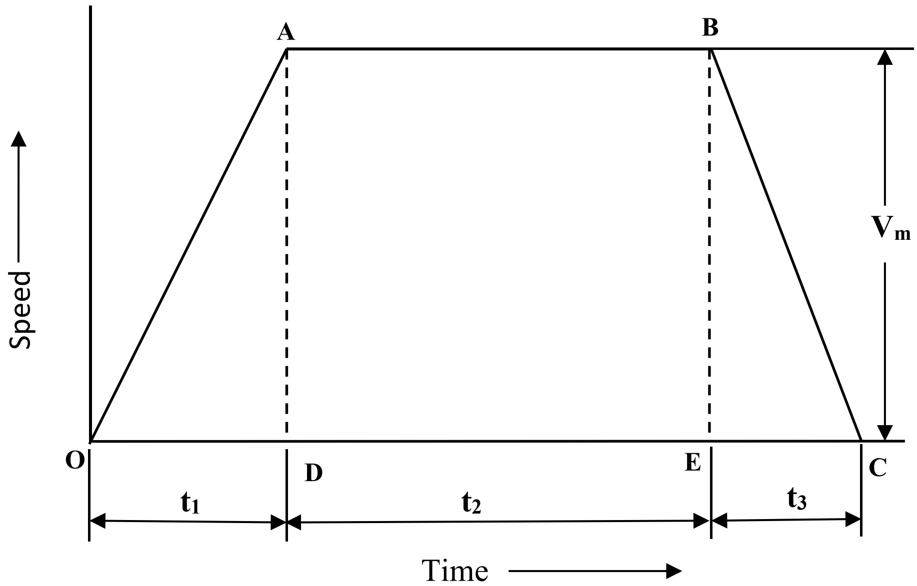


Fig.3 Simplified Trapezoidal Speed Time Curve

Time of acceleration $t_1 = \dfrac{V_m}{\alpha}$ seconds

Time of retardation $t_2 = \dfrac{V_m}{\beta}$ seconds

If T is the total time of travel then $T = t_1 + t_2 + t_3$

Total distance of travel D = area OABC = area OAD + area ABED + area BEC

$$D = \left(\frac{1}{2} \times AD \times OD\right) + \left(AD \times AB\right) + \left(\frac{1}{2} \times BE \times EC\right)$$

$$D = \left(\frac{1}{2} \times V_m \times \frac{t_1}{3600}\right) + \left(V_m \times \frac{t_2}{3600}\right) + \left(\frac{1}{2} \times V_m \times \frac{t_3}{3600}\right) = \frac{V_m}{7200}\left[t_1 + 2t_2 + t_3\right]$$

$$D = \frac{V_m}{7200}\left[t_1 + 2(T - t_1 - t_3) + t_3\right] = \frac{V_m}{7200}\left[2T - t_1 - t_3\right] = \frac{V_m}{7200}\left[2T - \frac{V_m}{\alpha} - \frac{V_m}{\beta}\right]$$

$$or\ D = \frac{V_m}{7200}\left[2T - V_m\left(\frac{1}{\alpha} + \frac{1}{\beta}\right)\right]$$

If $K = \dfrac{\alpha + \beta}{2\alpha\beta}$ then $D = \dfrac{V_m}{7200}\left[2T - 2V_m K\right] = \dfrac{V_m}{3600}\left[T - V_m K\right]$

$$or\ KV_m^2 - V_m T + 3600D = 0 \qquad or \qquad V_m = \frac{T \pm \sqrt{T^2 - 14400KD}}{2K}$$

The positive sign gives a very high value of V_m which is not possible in practice. Hence negative sign is considered for calculating the value of maximum speed of train.

Hence $V_m = \dfrac{T - \sqrt{T^2 - 14400KD}}{2K}$

Quadrilateral Speed Time Curve – The fig.4 shows the simplified quadrilateral speed time curve with speed in kmph and time in seconds. If α = acceleration in kmphps, β_C = coasting retardation in kmphps, β = braking retardation in kmphps, V_1 = maximum speed at the end of acceleration in kmph, V_2 = speed at the end of coasting in kmph, T = total time of run in seconds then

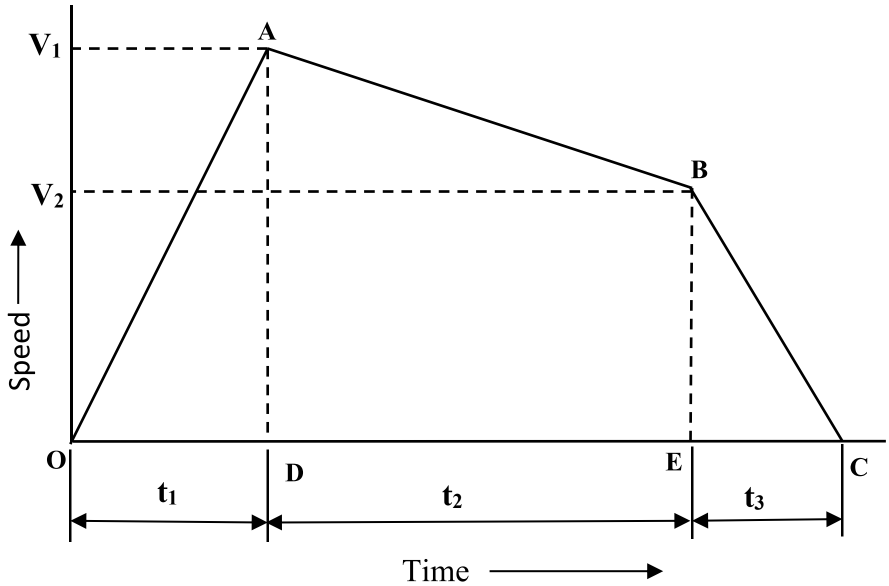


Fig.4 Simplified Quadrilateral Speed Time Curve

Time of acceleration $t_1 = \dfrac{V_1}{\alpha}$ seconds

Time of coasting retardation $t_2 = \dfrac{V_1 - V_2}{\beta_C}$ seconds

Time of braking retardation $t_3 = \dfrac{V_2}{\beta}$ seconds

Total distance of travel D = area OABC = area OAD + area ABED + area BEC

$$D = \left(\frac{1}{2} \times AD \times OD\right) + \left(\frac{1}{2}(AD + BE) \times DE\right) + \left(\frac{1}{2} \times BE \times EC\right)$$

$$D = \left(\frac{1}{2} \times V_1 \times \frac{t_1}{3600}\right) + \left(\frac{1}{2}(V_1 + V_2) \times \frac{t_2}{3600}\right) + \left(\frac{1}{2} \times V_2 \times \frac{t_3}{3600}\right)$$

$$D = \left(\frac{V_1 t_1}{7200} + \frac{V_1 t_2}{7200} + \frac{V_2 t_2}{7200} + \frac{V_2 t_3}{7200}\right) = \frac{V_1}{7200}(t_1 + t_2) + \frac{V_2}{7200}(t_2 + t_3)$$

$$or\ D = \frac{V_1}{7200}(T - t_3) + \frac{V_2}{7200}(T - t_1) \quad \text{since } T = t_1 + t_2 + t_3$$

$$or\ 7200D = V_1 T - V_1 t_3 + V_2 T - V_2 t_1 = T(V_1 + V_2) - V_1 t_3 - V_2 t_1$$

$$or\ 7200D = T(V_1 + V_2) - V_1 \times \frac{V_2}{\beta} - V_2 \times \frac{V_1}{\alpha}$$

$$7200D = T(V_1 + V_2) - V_1 V_2 \left(\frac{1}{\alpha} + \frac{1}{\beta}\right) \quad ----(1)$$

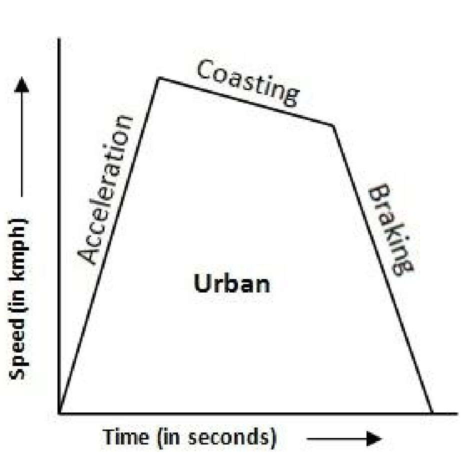
Also $V_2 = V_1 - \beta_C t_2 = V_1 - \beta_C (T - t_1 - t_3) = V_1 - \beta_C \left(T - \frac{V_1}{\alpha} - \frac{V_2}{\beta}\right)$

$$or \left(V_2 - \frac{\beta_C}{\beta} V_2\right) = V_1 - \beta_C \left(T - \frac{V_1}{\alpha}\right)$$

$$or\ V_2 = \frac{V_1 - \beta_C T + \frac{\beta_C}{\alpha} V_1}{\left(1 - \frac{\beta_C}{\beta}\right)} \quad ----(2)$$

Solving equation (1) and equation (2) we can determine the values of D, V_1, V_2 etc.

Speed Time Curves for Railway Services – The fig.5 (a) and fig.5 (b) shows the typical speed time curves for urban, suburban and main line railway services. There is no free running period both in the case of urban and suburban railway services. In case of suburban services the coasting period is longer than coasting period of urban service. Hence the simplified quadrilateral speed time curve is most suited for calculations regarding urban and suburban services. In the case of main line services, the free running period is the longest period and acceleration, coasting and retardation periods are comparatively smaller. The coasting period can be neglected in the case of main line services and hence the simplified trapezoidal speed time curve is most suited for calculations.



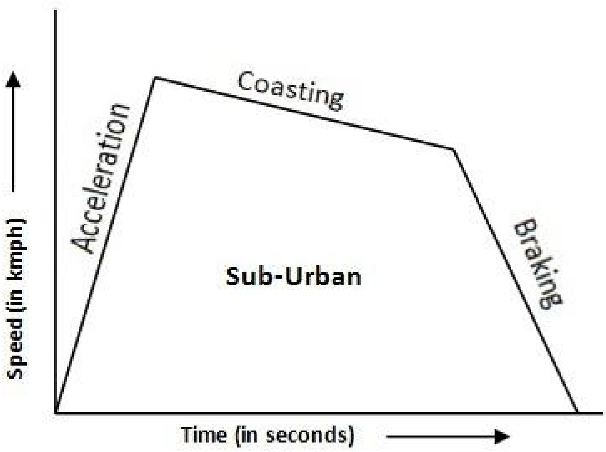


Fig.5 (a) Speed Time Curves for Urban and Sub-Urban Services

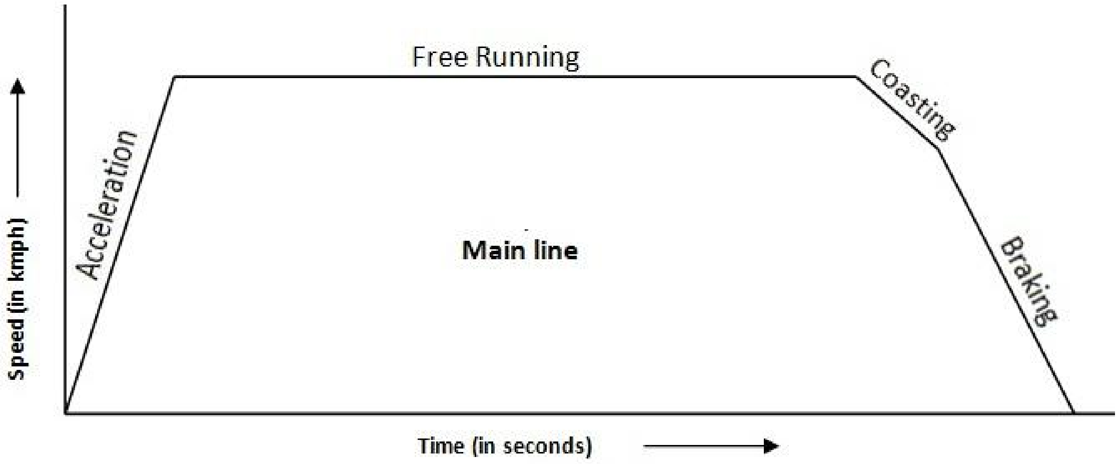


Fig.5 (b) Speed Time Curves for Main line Services

Crest Speed – It is the maximum speed (V_m) attained by the vehicle during the run.
Average Speed - It is defined as the ratio of the distance covered between two stops and the actual time of run.

$$Average\ Speed\ V_a = \frac{D}{T} \times 3600\ kmph$$

Where D = distance between the stops in km and T = actual time of run in seconds

Schedule Speed – It is defined as the ratio of the distance covered between two stops and total time of run including the time of stop.

$$Schedule\ Speed\ \ V_S = \frac{D}{(T + t_S)} \times 3600\ kmph$$

Where D = distance between the stops in km, T = actual time of run in seconds and t_S = time of stop in seconds.
The schedule speed is always smaller than average speed. The difference is large in case of urban and suburban services whereas negligibly small in case of main line service. In case of urban and suburban services the stops must be reduced to have a fairly good schedule speed.

Factors Affecting Schedule Speed – The schedule speed of a train when running on a given service (i.e. with a given distance between the stations) depends upon the following factors:

- Acceleration and braking retardation
- Maximum or crest speed
- Duration of stop

(a) **Effect of Acceleration and Braking Retardation** – For a given run and with fixed crest speed the increase in acceleration will result in decrease in actual time of run and lead to increase in schedule speed. Similarly increase in braking retardation will affect speed. The variation in acceleration and retardation will have more effect on schedule speed in case of shorter distance run in comparison to longer distance run.
(b) **Effect of Maximum Speed** – With fixed acceleration and retardation, for a constant distance run, the actual time of run will decrease and therefore schedule speed will

increase with increase in crest speed. In case of long distance run, the effect of variation in crest speed on schedule speed is considerable.

(c) **Duration of Stop** – The schedule speed for a given average speed will increase by reducing the duration of stop. The variation in duration of stop will affect the schedule speed more in case of shorter distance run in comparison to longer distance run.

Mechanism of Train Movement – The fig. 6 shows the essentials of driving mechanism in an electric vehicle. The armature of the driving motor has a pinion of diameter d’ attached to it. The tractive effort at the edge of the pinion is transferred to the driving wheel by means of a gear wheel.

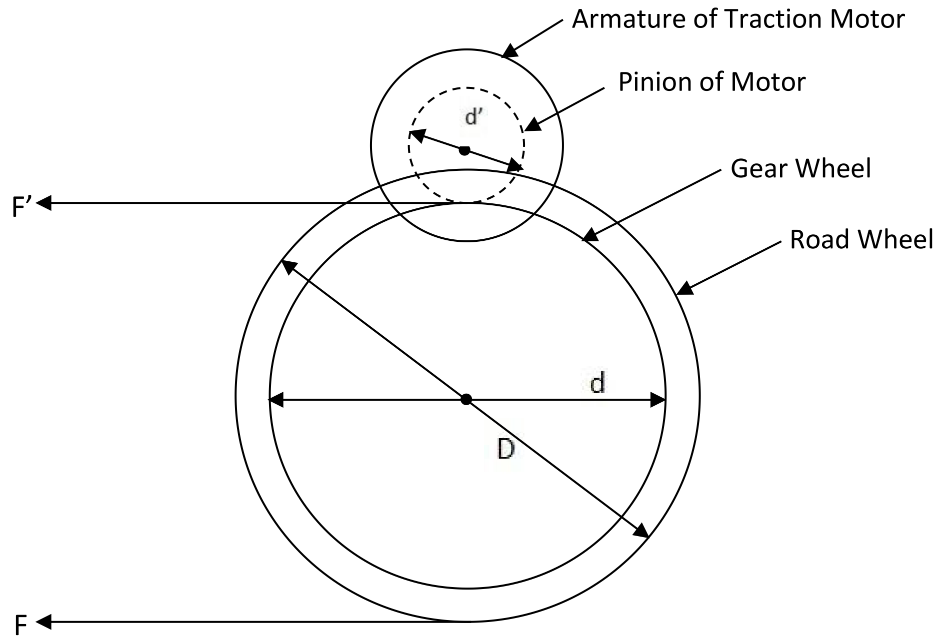


Fig.6 Essentials of driving mechanism in an electric vehicle

Let the driving motor exert a torque T in Nm, d = diameter of the gear wheel in meters, d’ = diameter of pinion of motor in meters, D = diameter of driving wheel in meters, γ = gear ratio η = efficiency of transmission.

The tractive effort at the edge of the pinion is given by the equation

$$T = F'\frac{d'}{2} \; or \; F' = \frac{2T}{d'}$$

Tractive effort transferred to the driving wheel is given by the equation

$$F = \eta F'\left(\frac{d}{D}\right) = \eta T\left(\frac{2}{D}\right)\left(\frac{d}{d'}\right) = \eta T\frac{2\gamma}{D}$$

The maximum frictional force between the driving wheel and the track = µW where µ is the coefficient of adhesion between the driving wheel and the track and W is the weight of the train on the driving axles (called adhesive weight). Slipping will not take place unless tractive effort F > µW. For motion of trains without slipping tractive effort F should be less than or at the most equal to µW but in no case greater than µW.

The magnitude of the tractive effort that is required for the movement of vehicle depends upon the weight coming over the driving wheels and the coefficient of adhesion between the driving wheel and the track. The coefficient of adhesion is defined as the ratio of tractive effort to slip the wheels and adhesive weight.

i.e. coefficient of adhesion $\mu = \dfrac{\text{tractive effort to slip the wheels}}{\text{adhesive weight}} = \dfrac{F_t}{W_a}$

The normal value of coefficient of adhesion with clean dry rails is 0.25 and with wet or greasy rails the value may be as low as 0.08. It depends upon the following factors:

- Coefficient of friction between wheels and the rail.
- Nature of motor speed – torque characteristics – a characteristic with low speed regulation is preferred.
- Series – parallel connections of motors.
- Smoothness with which the torque can be controlled.
- Speed of response of the drive.

Driving Axle code for Locomotives – The weight of a locomotive is supported on axles which are coupled to the wheels. The weight per axle is limited by the strength of the track and bridges, and usually varies between 15 and 30 tonnes. The total number of axles is calculated by the following equation:

$$\text{Number of Axles} = \frac{\text{Weight of Locomotive}}{\text{Permissible weight per Axle}}$$

The number of driving axles and coupled motors are described using a code as follows:

2 driving axles ---- Category B
3 driving axles ---- Category C
4 driving axles ---- Category BB
6 driving axles ---- Category CC

When each axle is driven by an individual motor, a subscript 'O' is used alongwith these symbols. When axles are divided into groups and each group is driven by single motor, only letters B and C are appropriately used. The number of dummy (non-driving) axles is denoted by numerals.

Tractive Effort for Propulsion of Train – The effective force necessary to propel the train at the wheels of locomotive is called the tractive effort. It is tangential to the driving wheels and measured in newtons.

Total tractive effort required to run a train on track = Tractive effort required for linear and angular acceleration + Tractive effort to overcome the effect of gravity + Tractive effort to overcome the train resistance

Or $F_t = F_a \pm F_g + F_r$

(i) **Tractive Effort for Acceleration** – The force required to accelerate the motion of the body according to the laws of dynamics is given by the expression

Force = Mass X Acceleration

Let us consider a train of weight W tonnes being accelerated at α kmphps

Mass of train m = 1000 W kg

Acceleration = α kmphps = α X $\frac{1000}{3600}\, m/s^2$ = 0.2778 α m/s^2

Tractive effort required for linear acceleration is given by

$$F_a = m\,\alpha = 1000\text{ W} \times 0.2778\,\alpha = 277.8\text{ W}\alpha\text{ N}$$

When a train is moving then the rotating parts of the train such as wheels and motors also accelerate in an angular direction and therefore the tractive effort required is equal to the arithmetic sum of tractive effort required to have angular acceleration of rotating parts and tractive effort required to have linear acceleration. Hence while calculating tractive effort for acceleration, W_e (equivalent or accelerating weight of train) is considered which is generally higher than the dead weight W by 8 to 15 percent. Hence the net tractive effort required for acceleration is given by

$$F_a = 277.8\,W_e\alpha \qquad Newtons$$

(ii) **Tractive Effort for Overcoming the Effect of Gravity** – When a train is on a slope, a force of gravity equal to the component of the dead weight along the slope acts on the train and tends to cause its motion down the gradient or slope.

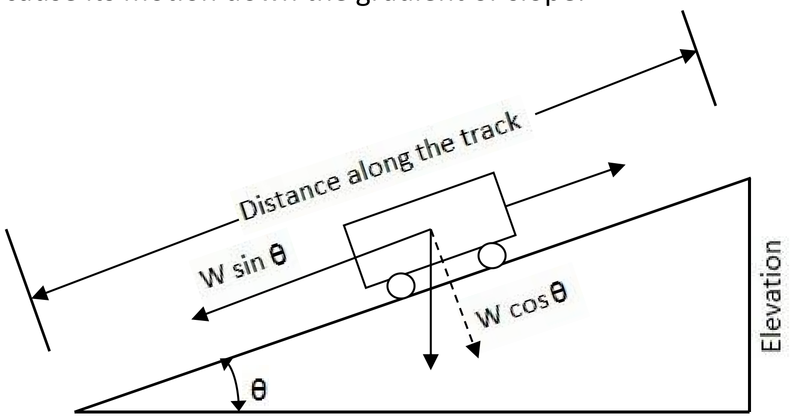


Fig.7 Gradient of Railway Track

From fig. 7 we have force due to gradient F_g = 1000W sin θ ---- (1)

In railway work gradient is expressed as rise in meters in a track distance of 100 meters and is denoted as percentage gradient (G%)

G = sin θ x 100 or sin θ = G/100. Substituting the value of sin θ in equation (1) we get

$$F_g = 1000W \times \frac{G}{100} = 10WG\ kg = 10WG \times 9.8$$

$$F_g = 98\,WG \qquad Newtons$$

When a train is going up a gradient, the tractive effort will be required to balance this force due to gradient but while going down the gradient, the force will add to the tractive effort.

(iii) **Tractive Effort for Overcoming the Train Resistance** – The train resistance consists of all the forces resisting the motion of the train when it is running at uniform speed on a straight and level track. Under these circumstances the whole of the energy output from the driving axles is used against train resistance. The train resistance consists of the following:

a) **Mechanical Resistance** – It consists of internal resistance like friction at axles, guides, buffers etc and external resistance like friction between wheels and rail, flange friction etc. The mechanical resistance is almost independent of train speed but depends upon its dead weight.

b) **Wind Resistance** – It varies directly as the square of the train speed.

The train resistance depends upon various factors, such as shape, size and condition of track etc. and is expressed in newtons per tonne of the dead weight. For a normal train the value of specific resistance has been 40 to 70 N/t. The general equation for train resistance is given as $r = k_1 + k_2V + k_3V^2$

Where k1, k2 and k3 are constants depending upon the train and the track etc., r is train resistance in N/t and V is speed in kmph. The first two terms represent the mechanical resistance and the last term represents wind resistance.

The tractive effort required to overcome the train resistance is given by

$$F_r = W \times r \qquad Newtons$$

The total tractive effort required by a train is given by the following equation

$$F_t = F_a \pm F_g + F_r = 277.8 W_e \alpha \pm 98\, WG + Wr \qquad newtons$$

+ve sign is taken for the motion up the gradient

- ve sign in taken for the motion down the gradient

Power Output From Driving Axles – The power output is given by

$$P = Rate\ of\ doing\ work = \frac{Tractive\ effort \times distance}{time} = Tractive\ effort \times velocity = F_t \times v$$

Where F_t is the tractive effort and v is the train velocity

When F_t is in newton and v is in m/s then P = F_t x v watt

When Ft is in newton and v is in kmph, then we have $P = F_t \times \left(\frac{v \times 1000}{3600}\right) watt = F_t \times \left(\frac{v}{3600}\right) kW$

If η is the efficiency of transmission gear, then power output of motors

$$P = \frac{F_t \times v}{\eta}\ watt\ ...v\ in\ m/s\ and\ P = \frac{F_t \times v}{3600\ \eta}\ kW\ ...v\ in\ kmph$$

Energy Output From Driving Axles – Energy is defined as capacity to do work is given by the product of power and time.

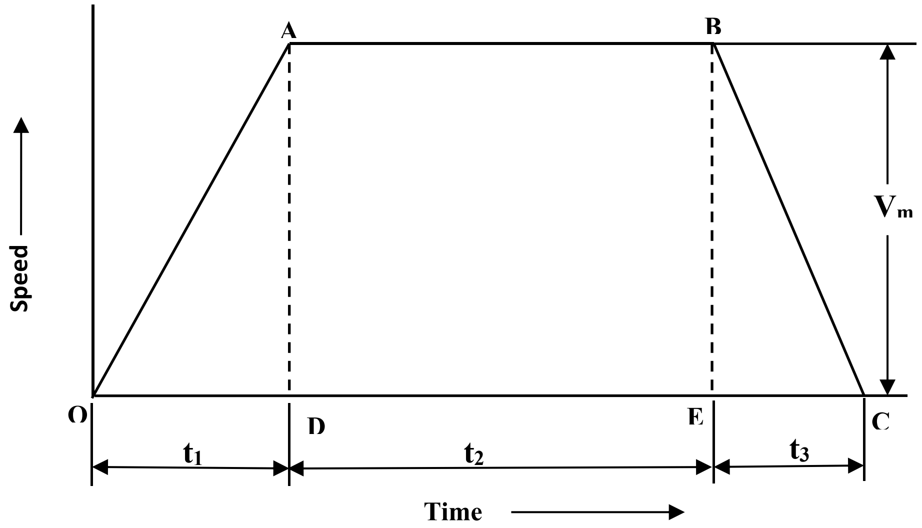


Fig.8

$$E = (F_t \times v) \times t = F_t \times (v \times t) = F_t \times D$$

where D is the distance travelled in the direction of tractive effort. The total energy output from driving axles for the run is given by

E = Energy during acceleration + Energy during free run

From fig.8 we have $E = F_t \times area\ OAD + F_t^{'} \times area\ ABED$

$$or\ E = F_t \times \frac{1}{2} V_m t_1 + F_t^{'} \times V_m t_2$$

Where F_t = the tractive effort during acceleration periods
And F_t' = 98 MG + Mr provided there is an ascending gradient

Specific Energy Consumption – The specific energy output is the energy output of the driving wheel expressed in watt-hour (Wh) per tonne-km (t-km) of the train. It can be found by first converting the energy output into Wh and then dividing it by the mass of the train in tonne and route distance in km. Hence, unit of specific energy output generally used in railway is Wh/tonne-km (Wh/t-km). The specific energy output is used for comparing the dynamical performances of trains operating to different schedules.

While calculating the specific energy output, the total energy output of driving wheels is calculated and then it is divided by the train mass in tonne and route length in km. It is assumed that there is a gradient of G throughout the run and power remains ON upto the end of free run in case of trapezoidal curve and upto the accelerating period in case of quadrilateral curve. The output of the driving axles is used for accelerating the train, overcoming the gradient and overcoming the train resistance.

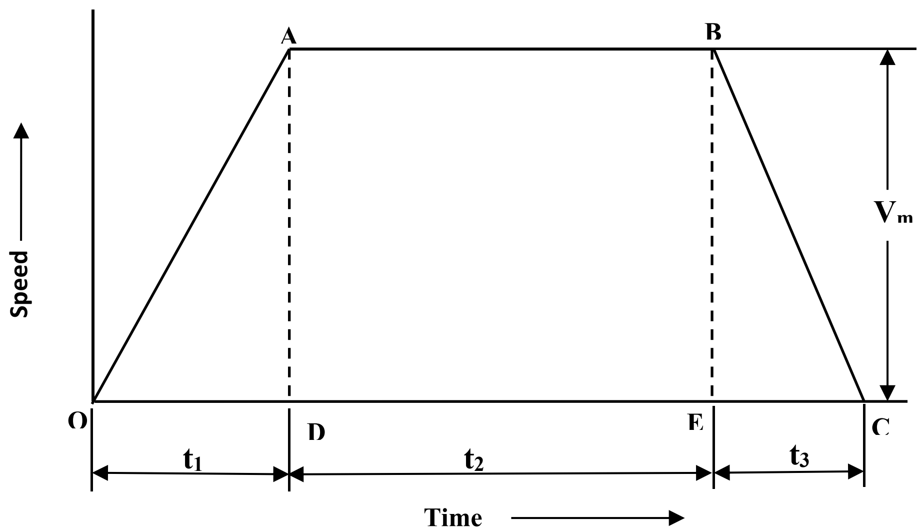


Fig.9 Trapezoidal Speed Time Curve

(i) **Energy required to accelerate the train (E_a)** – From fig.9 corresponding to the trapezoidal speed time curve we have
$E_a = F_a$ x distance OAD

$$E_a = 277.8\,\alpha\, W_e \times \frac{1}{2} V_m t_1 = 277.8\,\alpha\, W_e \times \frac{1}{2} V_m \times \frac{V_m}{\alpha}$$

$$E_a = 277.8\,\alpha\, W_e \times \frac{1}{2} \times \frac{V_m \times 1000}{3600} \times \frac{V_m}{\alpha}$$

It may be noted that since V_m is in kmph, it has been converted into m/s by multiplying it by conversion factor of (1000/3600). In case of V_m. In case of V_m/α conversion factor for V_m and α being same cancel out each other. Since 1 Wh = 3600 J therefore

$$E_a = 277.8\,\alpha\,W_e \times [\frac{1}{2} \times \frac{V_m \times 1000}{3600} \times \frac{V_m}{\alpha}] \times \frac{1}{3600}\,Wh$$

$$or\ E_a = 0.01072\,V_m^2\,W_e \quad Wh$$

(ii) **Energy required overcoming gradient (E_g)** – In this case we consider the distance travelled for the period over which the power remains ON. The energy required to overcome gradient is given by

$E_g = F_g$ x D' where D' is the total distance over which the power remains ON. Its maximum value equals the distance represented by area DABE in fig. 9 i.e. from the start to the end of free running period in case of trapezoidal curve

$$E_g = 98\,WG\left(1000\,D'\right) Joules = 98000\,WGD'\ where\ D'\ is\ in\ km$$

$$or\ E_g = 98000\,WGD' \times \frac{1}{3600} \quad Wh$$
$$= 27.25\,WGD'\ Wh$$

(iii) Energy required to overcome resistance (Er) – The energy required to overcome the train resistance is given by

$$E_r = F_r \times D' = W.r \times \left(1000D'\right) Joules$$

$$or\ E_r = \frac{W.r \times 1000D'}{3600}\,Wh$$
$$= 0.2778\,WrD'\ Wh$$

Total energy output of the driving axles is given by $E = E_a + E_g + E_r$

$$E = \left(0.01072\,V_m^2 W_e + 27.25\,WGD' + 0.2778\,WrD'\right) Wh$$

$$Specific\ Energy\ Output\ E_{spo} = \frac{E}{W \times D}\ where\ D\ is\ the\ total\ run\ length$$

$$or\ E_{spo} = \left[0.01072\frac{V_m^2}{D} \bullet \frac{W_e}{W} + 27.25\,G\frac{D'}{D} + 0.2778\,r\frac{D'}{D}\right] \quad Wh/t-km \text{ ------(1)}$$

If there is no gradient then

$$or\ E_{spo} = \left[0.01072\frac{V_m^2}{D} \bullet \frac{W_e}{W} + 0.2778\,r\frac{D'}{D}\right] \quad Wh/t-km$$

Factors Affecting Specific Energy Consumption – The factors which affect the specific energy consumption of an electric train operating on a given schedule speed are as follows:

(a) Distance between the stops
(b) Acceleration
(c) Retardation
(d) Maximum speed
(e) Nature of route

(f) Type of train equipment

The specific energy output is independent of locomotive overall efficiency. From equation (1) it can be seen that specific energy consumption depends upon the maximum speed Vm, the distance travelled by the train while power is ON, the specific resistance r , gradient G and distance between stops. Therefore greater the distance between stops lesser will be the specific energy consumption. For a given run at a given schedule speed, greater the value of acceleration and retardation , more will be the period of coasting and therefore lesser the period during which power is ON and therefore specific energy consumption will be less. Steep gradient will involve more energy consumption even if regenerative braking is used. Similarly more the train resistance, greater will be the specific energy consumption. The typical values of specific energy consumption are 50 – 75 watt-hours per tonne-km for suburban services and 20 – 30 watt-hours per tonne-km for main line service.

Dead weight – It is defined as the total weight of locomotive and train to be pulled by the locomotive

Accelerating weight – It is the dead weight of the train which is divided into two parts – (i) the weight which requires angular acceleration such as weight of wheels, axles, gears etc. and (ii) the weight which requires linear acceleration. The effective weight which is greater than dead weight is called the accelerating weight and it is taken as 5 to 10 percent more than the dead weight.

Adhesive weight – The total weight to be carried on the driving wheels is known as the adhesive weight.