# Assignment – 01 (HEV)

Name:- Antu Roy

ROLL No:- M23OG35EE

Qun (01) :-

An Electric vehicle has to be designed with 1200 Kg of net weight for the following assumptions, Drag coefficient $C_d = 0.44$, rolling resistance is 1.3% of frictional load force, frontier area $= 2m^2$, battery is rated with 50 units of energy, Density of air $\rho = 1.2\ kg/m^3$. The driving profile details are, A vehicle has reached 0.2 Km within 15 secs and average speed is 50 Km/h. Neglect the transient responses. Estimate the following,

a) The aerodynamic drag force, rolling resistance force, Gradient force and acceleration force.

b) And also, calculate the maximum assumed mileage of EV for 15 Km/h head and tail wind velocity.

c) What is the H.P rating of the motor with power train efficiency of 88%.

d) How much greater is the power requirement for climbing in 10 degree slope compared to a flat road?

**Solution:** Given: $m = 1200 kg$, $C_d = 0.44$, $\mu = 0.013$, $A = 2m^2$

$\rho = 1.2\ kg/m^3$

$E = 50\ kWh$,

$V$ (vehicle speed) $= 50\ km/h = 13.88\ m/s$.

a) Drag force $(F_D) = 0.5 \times \rho \times C_d \times A \times (V \pm V_{air})^2$

$= 0.5 \times 1.2 \times 0.44 \times 2 (13.08)^2$

$= 101.72\ N$

Rolling resistance force $(F_R) = mg\mu = 1200 \times 9.81 \times 0.013$

$= 153.036\ N$

$\because h = ut + \frac{1}{2}at^2 \Rightarrow 200m = 0 + \frac{1}{2} \cdot \cancel{a} \times 15^2$

$\Rightarrow a = 1.77\ m/s^2$

$\therefore$ Acceleration force $(f_a)$ = $ma$ = $1200 \times 1.77$
$= 2124$ N

Gradient force $(F_g)$ = $mg \sin\theta$
$= 1250 \times 9.81 \times \sin 10°$
$= 2044.18$ N

b) $V_{air} = 15$ km/h $= 4.167$ m/s

Headwind: $F_D = 0.5 \times \rho \times C_d \times A \times (V + V_{air})^2$
$= 172$ N

$\therefore F_T = F_D + F_R = 172 + 153.036 = 325.036$ N

Power $= F_T \times v = 325.036 \times 13.88 = 4.5$ kW

$\therefore$ Range (mileage) $= \dfrac{E_b \times V}{P} = \dfrac{50 \text{ kWh} \times 50 \text{ km/h}}{4.5 \text{ kW}}$

$= 555.5$ km

Tail wind :

$F_D = 0.5 \times 1.2 \times 0.44 \times 2 \times (13.88 - 4.167)^2$
$= 49.81$ N

$F_T = F_D + F_R = 49.81 + 153.036 = 202.846$ N

$P_T = F_T \times V = 202.846 \times 13.88 = 2.8$ kW

$\therefore$ Range (s) $= \dfrac{E_b \times V}{P_T} = \dfrac{50 \text{ kWh} \times 50 \text{ km/h}}{2.8 \text{ kW}}$

$= 892.85$ km

c) HP rating :- $F_T = F_D + F_R + F_G$
$= 101.72 + 153.036 + 2044.18$
$= 2298.936$ N

$P = F_T \times V = 2298.936 \text{ N} \times 13.88 \text{ m/s} = 31.9$ kW

$\therefore$ Mechanical Output power : $= \frac{P}{\eta} = \frac{31.9}{0.88} = 36.25$ KW

In HP :
$$HP = \frac{36.25}{0.746} = 48.59 \text{ Hp}$$

d) $F_a = 2044.18N$

$P = 2044.18 \times 13.88 = 28.37$ KW

$\therefore$ 28.37 KW Greater power is required for climbing in 10 degree slope compared to a flat road.

Qn (02) An electric drive features a 24 KWh battery pack and has a range of 170 Km at a constant speed of 88 Km/h. What is the new range when travelling at 88 Km/h if the heating, ventilation, and air conditioning draw a constant power of 6 KW?

Solution; Given : $E_b = 24$ KWh

Range $= 170$ Km at a constant speed of 88 Km/h

$$\text{Time} = \frac{\text{distance}}{\text{Speed}} = \frac{170}{88} = 1.9318 \text{ hr}$$

$$\text{Power} = \frac{\text{Energy}}{\text{time}} = \frac{24 \text{ KWh}}{1.9318 \text{ hr}} = 12.42 \text{ KW}$$

Additional Power (due to heating, ventilation & air conditioning) :-
$= 6$ KW

$\therefore$ Total power $= 12.42 + 6 = 18.42$ KW

$$\text{time } (t) = \frac{\text{Energy}}{\text{Power}} = \frac{24 \text{ KWh}}{18.42 \text{KW}} = 1.3 \text{ hr}$$

$\therefore$ New Range $=$ Speed $\times$ time $= 88$ Km/h $\times$ 1.3 hr

$= 114.4$ Km Ans

Qn (03) An electric vehicle has the following attributes: mass $m = 500 kg$, wheel radius $r = 0.3 m$, gear ratio from motor to drive axle $n_g = 10$, and a nominal gear efficiency $\eta_g = 95\%$. The vehicle is required to accelerate linearly from 0 to 36 Km/h in 5 s on a flat road surface under calm wind conditions. Neglecting load forces, calculate the electromagnetic torque from the electric motor to achieve this acceleration torque.

Solution: Given: $m = 500 kg$, $r = 0.3 m$

gear ratio $(n_g) = 10$, gear efficiency $(\eta_g) = 95\%$

$\because$ Vehicle is accelerating from 0 to 36 Km/h in 5 s

As we know
$$t_2 - t_1 = \frac{m V_g}{\eta_g \cdot n_g \cdot T_{rated}}$$

$$\Rightarrow 5 \text{ sec} = \frac{500 \times 36 \times 5/18 \times 0.3}{10 \times 0.95 \times T_{rated}}$$

Acceleration torque $\Rightarrow T_{rated} = 31.57 \text{ N.m}$ Ans

Qn (04) The vehicle of Problem 3 is required to decelerate linearly from 36 to 0 Km/h in 5 s on a flat road surface under calm wind conditions. Neglecting load forces, instantaneously at 18 Km/h Calculate the regenerative torque to the electric motor to achieve this braking.

Solution: Given: $m = 500 Kg$, $r = 0.3m$, $\eta_g = 93\%$, $n_g = 10$

36 Km/h $\rightarrow$ 0 Km/h in 5 sec,

Regenerating torque = ?

$$\because t_2 - t_1 = \frac{m V r}{n_g \times T_{rated}} \times \eta_g$$ { In case of deacceleration.

$$\Rightarrow -5 = \frac{500 \times 10 \times 0.3}{10 \times T} \times \eta_g$$

$\Rightarrow T = -28.5$ N-m

$\therefore$ Regenerating torque $= \underline{28.5 \text{ N-m}}$ Ans

Ans 05 : After some engine and transmission performance upgrades, the same vehicle is taken to a test track to find out the new vehicle top speed. The upgrades have increased engine torque to 450 N-m and engine horsepower to 300 kW and an overall power train efficiency of 88%. After the upgrading, the minimum gear ratio of the transmission is 0.9 and the differential gear ratio is 3.21. Calculate the maximum speed of the vehicle.

Solution: Given: Engine torque = 450 N-m

Engine power = 300 kW

Min gear ratio = 0.9

Differential gear ratio = 3.21 , $\eta = 88\%$

$\because P = \omega \cdot T \Rightarrow \omega_{rated} = \frac{P}{T} = \frac{300 \times 10^3}{450}$

$= 667$ rad/s

$\because$

$$V_{rated} \text{ (speed)} = \frac{r \cdot \omega_{rated}}{\eta \cdot N_g}$$

$$\Rightarrow V = \frac{0.3 \times 667}{0.9 \times 3.21 \times 0.88}$$

$$\Rightarrow \underline{V = 78.70 \text{ m/s}}$$

Ans 06 An electric car is climbing at 80 Km/h up a 5° incline against a 10 Km/h head wind. The vehicle has the following attributes; mass $m = 1400$ Kg, drag coefficient $C_d = 0.19$, vehicle cross section $A = 2.4 \text{ m}^2$, coefficient of rolling resistance $C_R = 0.0044$, wheel radius $r = 0.3$ m, gear ratio from rotor to drive axle $\eta_g = 11$, and a nominal gear efficiency $\eta_g = 95\%$. Assume a density of air $\rho_{air} = 1.2 \text{ Kg-m}^{-3}$.

i) Calculate the rotor output torque and speed.

ii) How much greater is the power requirement for climbing the 5° slope compared to a flat road?

Solution: Given: $V = 80\ Km/h = 22.22\ m/s$

$V_{air}$ (headwind) $= 10 km/h = 2.77 m/s$

$\theta = 5°$, $m = 1400 Kg$, $C_d = 0.19$, $A = 2.4 m^2$,

$C_r(\mu) = 0.0044$, $r = 0.3m$, gear ratio $(N_g) = 11$;

$\eta_g = 95\%$.

$$\because F_D = 0.5 * \rho * C_d * A * (V + V_{air})^2$$

$$= 0.5 * 1.2 * 0.19 * 2.4\ (22.22 + 2.77)^2$$

$$= 170.88\ N$$

$$F_R = mg\mu = 1400 * 9.81 * 0.0044 = 60.43\ N$$

$$F_g = mg.\sin\theta = 1400 * 9.81 * \sin(5°) = 1196.96\ N$$

$$\text{Total force}(F_T) = F_D + F_R + F_g$$

$$= 1428.25\ N$$

Radius $= 0.3m$

$$\text{Torque} = \frac{T_{rotor}}{\eta * N_g} = \frac{428.495}{0.95 * 11} = 41\ N\text{-}m$$

Output torque $= 41$ N-m

Velocity of wheel $(\omega) = V/r$ $\{\because V = \omega r$

$$= \frac{22.22\ m/s}{0.3} = 74.07\ rad/s$$

$$\therefore \omega_{rotor} = 74.07 * 11 = 814.73\ rad/s$$

$$\text{speed in rpm } (N_{rpm}) = \frac{60}{2\pi} * \omega_{rotor}$$

$$= 7780\ rpm$$