Analysis of Electric Vehicle Drive Train

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Abstract – *From calculation 80% of the total vehicle can run on electricity upto 2030. This paper proposes a proper method for the certain calculation of the electrical vehicle transmission unit. Based on the vehicle desired performances, the electric motor power torque and output can be calculated. The liability of the mechanical parameters such as road load resistance, gear ratio, weight of the car, tractive efforts, wheel diameter, motor gearbox coupling efficiency and many more plays a very decisive role in the calculation consideration of electrical vehicle.*

Key Words: **Tractive efforts, Gear ratio, Motor gearbox coupling efficiency, Gradeability.**

1. INTRODUCTION

The Electric vehicle (EV) is very similar to the road vehicle which involves with electric propulsion. Direct current is a source which is used in all type of motors in electric vehicles to drive the wheels. In most of the cases the electric current has been supplied from the battery in the electrical vehicle [2]. However, the motors have different characteristics such as method of operation, rating, size, variation in speed and working principle. To obtain desirable characteristics the torque requirement from the vehicle is same.

2. BASIC TERMS AND FORMULAES

2.1 Transmission

The transmission refers to the transfer of the power from one part to another part. The transmission in an Electric vehicle is refers to transfer of electric power from a motor to wheels through gearbox and shaft. The main objective of the transmission is to provide the driver more than the enough torque to the wheels from the motor. The torque should be enough in such a way that the car should move faster against road load resistance.

2.2 Torque

It is the tendency of the force to move the object around an axis.

2.3 Total Tractive Efforts (TTE)

Tractive efforts is defined as the tractive force of a vehicle exerts on a surface or the amount of tractive force is parallel to the direction of motor.

2.4 Traction or Tractive Force

Tractive force is the force used for generate the variation between tangential surface and body.

Or

Tractive force is nothing but the net force present at wheels.

To calculate this type of force, use this formula:

$$Traction = \frac{(Motor\ Torque \times Gear\ Ratio \times Motor\ Efficiency)}{Radius\ of\ Wheel}$$

$$Traction = \frac{Tm \times G \times \eta t}{Rr}$$

Where,

Tm: Torque at the motor

ηt: Transmission(Motor) efficiency

G: Gear ratio

Rr: Rolling radius of wheel

2.5 Road Load Resistance

2.5.1 Rolling Resistance

Rolling resistance is the resistive force of vehicle which opposes the rolling of the wheels, which is caused due to non-elastic effects at the tire-road surface [1]; it is calculated by the formula:

$$Rr = KW\cos\theta$$

Where,

K: Coefficient of rolling resistance
W: Vehicle weight in N
θ: Inclination angle

2.5.2 Aerodynamic Resistance

It is the resistive force which opposes the motion of vehicle through the air.

$$AR = \frac{1}{2}\rho \times V^2 \times \mathrm{Cd}$$

Where,
ρ: Density of air

Cd: Drag coefficient
A: Frontal projected area
V: velocity in m/s

2.5.3 Gradient Resistance

The angle of inclination of the road surface is proportional to a weight of component which acts against the direction of motion. [1]

$$Rg = W * sin\theta$$

2.6 Acceleration

It is the rate of change of velocity of an object with respect to time. It is the ability of vehicle that how fast / quickly it reaches the maximum speed with respect to time pull force is more than road load resistance but lesser than tractive force [1].

2.7 Gradeability

The term gradeability refers when the driver should be relaxed while the vehicle moves on slop or inclination. The total pull force requires to move a vehicle in a vertical direction is generally refers to gradeability.

It is known as the grade angle that the electric vehicle can move with a constant speed.

The tractive effort requires to move a vehicle in particular direction with a given torque which must be greater than the sum of the rolling resistance. The grade percentage calculated by this formula.

$$Gradeability = \frac{Traction}{Weight}$$

Or

$$G = \frac{100 * T * R}{r - GVW} - RR$$

Where,

100 = A constant expression

T = Torque of motor

R = Total gear reduction in both axle and transmission

r = Rolling radius of loaded driving vehicle

GVW = Gross Vehicle Weight

RR = Rolling Resistance in percentage

3. POWER TRAIN CALCULATION

It provides the driving torque to wheel, it only causes the move power source should able to provide high torque at low rpm and peak power at high rpm.

For better understanding of the calculation of the electric drive train let us assume a system in which a Brushless DC motor is use which has maximum speed of 4500 rpm, torque of 38 N-M and power of 4.5 Kw. Whose torque characteristics is given below in the table and from that the graph is obtained.

3.1 Relation between Torque, Power and Speed

As we know that the basic formulation of power is

$$P = \frac{2\pi NT}{60}$$

Where,

N is the speed in RPM

T is the motor torque in N-M

P is the power in KW.

3.2 Equations for RPM at different stages of transmission

The output rpm of motor having 90% efficiency:

As motor is 90% efficient, N1 is given as

$$N_1 = \frac{90\ N}{100}$$

$$N_1 = 0.9N$$

N is Motor Speed in rpm

The output RPM of Gearbox; the output of the gearbox is given by the basic formula

$$\frac{N_1}{N_2} = \frac{D_2}{D_1}$$

$$N_2 = \frac{N_1 D_1}{D_2}$$

Where,

D_2:D_1 is gear ratio and

It is given as D_2:D_1 = 1: 12

1:12 is a gear ratio to be assumed for an electrical vehicle.

Thus,

$$N_2 = \frac{N_1}{12}$$

Also considering 0.9 as reduction ratio in gearbox

$$N_3 = N_2 * 0.9$$

3.3 Torque at Wheel and Velocity

$$Tw = \frac{60 * p}{2\pi N_3}$$

$$v = \frac{\pi d N_3}{60}$$

Where,

d is diameter of wheel =23 inches

3.4 Force

Tw = Force * Radius of Wheel

$$Tw = F * r$$

$$F = \frac{Tw}{r}$$

Where,
r is radius of wheel

3.5 Acceleration

Also,
Force at road is given as

$$F' = ma$$

Thus,
acceleration of vehicle is given as

$$a = F'/m$$

Where,
m is mass of vehicle

3.6 Traction

$$Traction = \frac{(Motor\ Torque \times Gear\ Ratio \times Motor\ Efficiency)}{Radius\ of\ Wheel}$$

$$T = \frac{Te * 12 * 0.9}{0.2921}$$

4. SPECIFICATIONS OF ELECTRIC VEHICLE COMPONENTS

4.1 BLDC Motor

Power = 4.5 Kw.

Max Speed = 4500 RPM

Max Torque = 38 Nm

4.2 Battery

Rated voltage = 48 V

Current rating = 110 Ah

5. RESULT

From above specifications and formulas of electrical vehicle we can make the result in graphical representation as shown in graph. As per the result speed is inversely proportional to torque and directly proportional to power. And the relation between speed and gradeability are also inversely proportional to each other.

Table -1: Calculation Table

Sr. No.	Speed (N)	Torque (T)	Power (P)	Velocity (Km/hr)	Traction (N)	Gradeability (%)
1	500	33	1727.9	5598.33	1220.13	44.42
2	1500	25	3927.0	12723.48	924.34	33.65
3	2500	17	4450.6	14419.94	628.55	22.88
4	3500	10	3665.2	11875.25	369.74	13.46

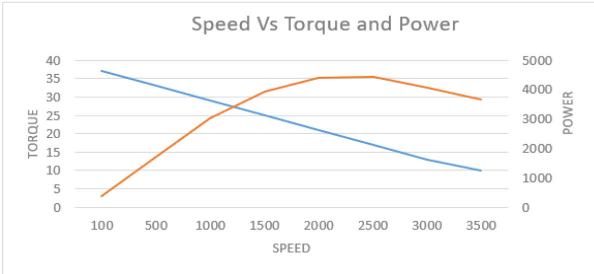

Chart -1: Speed Vs Torque and power

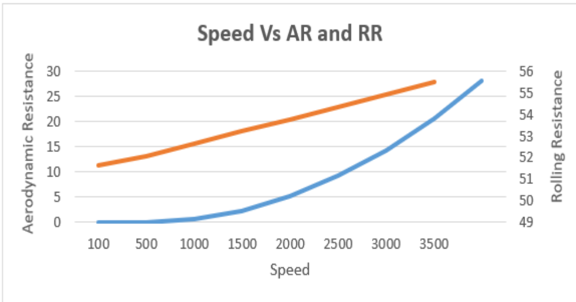

Chart -2: Speed Vs AR and RR

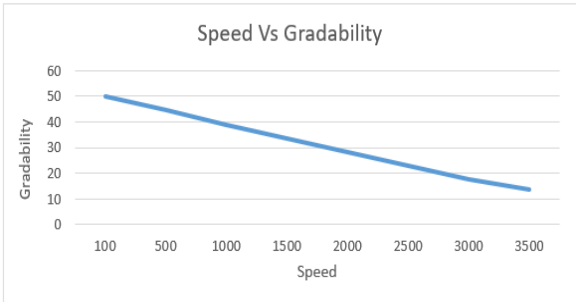

Chart -3: Speed Vs Gradeability

6. CONCLUSION

The main objective of this paper is to provide the in-detail knowledge about the Electric vehicle. The first and foremost advantage of this literature is the availability of calculation parameters along with the detail specification of each and every term of the vehicle in one segment. If some parameters of the vehicle like torque, traction, gradeability and acceleration etc. are known then we can easily calculate the transmission system calculation of electric vehicle.

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