Motor Torque Calculations For Electric Vehicle

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Abstract: It is estimated that 25% of the total cars across the world will run on electricity by 2025. An important component that is an integral part of all electric vehicles is the motor. The amount of torque that the driving motor delivers is what plays a decisive role in determining the speed, acceleration and performance of an electric vehicle. The following work aims at simplifying the calculations required to decide the capacity of the motor that should be used to drive a vehicle of particular specifications.

Index Terms: Acceleration, Electric Vehicle, Grade ability, Motor, Speed, Torque, Traction

1 Introduction

Electric vehicles save fuel cost, cause less pollution and bring lucrative tax cuts. They are a much safer ride as they can't travel too fast and have less tyre wear. All electric vehicles have one thing in common and that is that all of them use Direct current electric motors to drive the wheels. However, these motors are available with a number of variations in speed, size and method of operation, the torque required from the vehicle to obtain desirable characteristics is the same. It is the torque that forms the part of the force to drive the wheels and set the vehicle in motion. in simple terms the torque may be defines the turning power of the motor. . The following paper presents one such method of calculating the torque.

2 Factors Affecting The Required Torque

When selecting drive motor for the electric vehicle, a number of factors must be taken into account to determine the maximum torque required. These factors are:

1. Rolling resistance
2. Grade resistance
3. Acceleration force

3 Calculating The Rolling Resistance

Rolling Resistance is the opposing force that the vehicle has to overcome due to the rolling motion between the wheels and the surface of motion of the vehicle. The rolling resistance depends on the co-efficient of rolling friction which varies depending upon the material of tyres and the roughness of the surface of motion. The Rolling resistance can be calculated as:

$$RR = GVW \times C_{rr} \quad (1)$$

$RR =$ Rolling Resistance
$GVW =$ Gross Vehicle Weight
$C_{rr} =$ Co-efficient of Rolling Resistance

Table 1 shows some important values of C_{rr} for normally used tyres .

TABLE 1
Values Of Co-efficient of Rolling Resistance

Contact Surface	C_{rr}
Concrete(good/fair/poor)	0.010/0.015/0.020
Asphalt(good/fair/poor)	0.012/0.017/0.022
Macadam(good/fair/poor)	0.015/0.022/0.037
Snow(2 inch/4 inch)	0.025/0.037
Dirt(smooth/sandy)	0.025/0.037
Mud(firm/medium/soft)	0.037/0.090/0.150
Grass(firm/soft)	0.055/0.075
Sand(firm/soft/dune)	0.060/0.150/0.300

4 Calculating The Grade Resistance

Grade resistance is the form of gravitational force. It is the force that tends to pull the vehicle back when it is climbing an inclined surface. The grade resistance acting on the vehicle can be calculated as:

$$GR = GVW \times \sin\theta \quad (2)$$

$GR =$ Grade Resistance
$\theta =$ Grade or inclination angle

5 Calculating The Acceleration Force

Acceleration force is the force that helps the vehicle to reach a predefined speed form rest in a specified period of time. The motor torque bears a direct relationship with the acceleration force. Better the torque, lesser the time required by the vehicle to reach a given speed. The acceleration force is a function of the mass of the vehicle. Acceleration force is calculated as:

$$FA = m \times a \quad (3)$$

$$m = GVW / g \quad (4)$$

$FA =$ Acceleration force
$m =$ mass of the vehicle
$g =$ acceleration due to gravity($9.81 m/\sec^2$)
$a =$ required acceleraion

6 Finding the Total Tractive Effort

The Total Tractive Effort is the total force required to move the vehicle with the desired characteristics and is the sum of the forces calculated in above three sections. Therefore, the Total Tractive Effort can be calculated as:

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$$TTE = RR + GR + FA \quad (5)$$

$TTE =$ Total tractive effort

7 Torque Required On The Drive Wheel

The torque that is required on the drive wheel will be the one that the drive motor requires to produce so as to obtain the desired drive characteristics. The torque is:

$$\tau = R_f \times TTE \times r_{wheel} \quad (6)$$

$\tau =$ Torque

$R_f =$ Friction factor that account for frictional losses between bearings, axles etc.

$R_{wheel} =$ radius of drive wheel

This torque can be obtained by directly mounting a motor with the torque value on the differential of the vehicle or by using a gearbox or chain drive to magnify a lesser torque to this value before it drives the wheel.

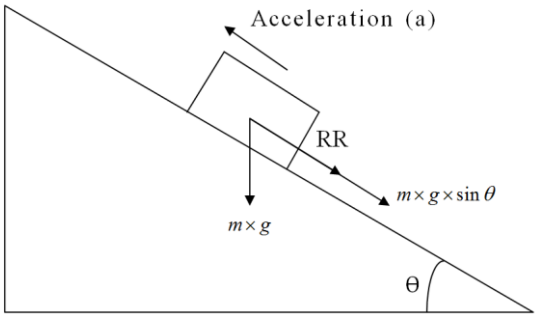

Fig 1. *Free Body Diagram of a Vehicle moving up an Inclined surface.*

8 Reality Check

When the required torque has been calculated it is necessary to check if the wheels of the vehicle are capable enough to transmit the required amount of torque for which the maximum torque that can be transmitted through the wheels need to be calculated. The maximum torque is given as:

$$\tau_{\max} = (\mu \times GVW \times f \times r_{wheel}) / 2 \quad (7)$$

$\mu =$ co-efficient of static friction

$f =$ fraction of the total weight acting on rear of the vehicle

For satisfactory performance of the vehicle

$$\tau_{\max} \geq \tau \quad (8)$$

This condition should be satisfied in all cases so that there is no slipping of the wheels.

9 Conclusion

The above results show that the motor torque for an electric vehicle can be determined if some parameters of the vehicle like required grade ability and acceleration are known. Further, if the required torque calculated is not produced by the available motor specifications then modifications can be made in vehicle parameters like Gross Vehicle Weight, Wheels size, Material of the wheels and transmission system.

References

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