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The Calculation of Electric Motor and Lithium Battery Capacity of IIRED E-BIKE

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Abstract : *Now days the use of fossil fuels increases continuously because of which in future there will be a stage where we are going to lost all these resources completely. Therefore there are so many organizations or companies which are preferred to used renewable energy sources. This Paper study was done with Brushless DC motor and Lithium-Polymer battery as main propulsion and energy storage for our E-Bike. In this paper we have studied various factors taken into account for designing of electric two-wheeler. This paper proposes an equation-based design for battery electric vehicles. It covers all the parts of the electric vehicle starting from the tractive force calculation, battery model, motor model, drive line model and losses associated with these models. This study is beneficial for the designing of the battery electric Two-Wheeler according to any specification. Apart from this, proper selection of rating required also contributes in using an electric motor of appropriate size, because the size of the motor depends on the rating. Thus, to meet all the needs of the traction characteristics, a proper selection of motor rating should be done based on the load.*

Keywords- *Electric motor, Electric bike, Selection of Rating of motor, Electric Vehicle, Brushless DC motor, Li-ion Battery pack.*

I. INTRODUCTION

Most of our current transportation system is neither affordable nor environmentally sustainable. So government of India is planning of development of EV sectors, so they are planning to replace 70 % of combustion vehicles by electric vehicles by the year 2035. BLDC motors are widely use because of their extraordinary characteristics and best output rate. BLDC motors have best working characteristics like high starting torque, high efficiency around 95-98%, etc. BLDC motors are preferred for high power density design as they display better characteristic with compare to other motors used.

An electric-vehicle battery is used to power the electric motors of a electric vehicle. These batteries are rechargeable batteries and they are typically lithium-ion batteries. These batteries are specifically designed for a high Ah (or Wh) capacity. The most common battery type is lithium-ion and lithium polymer, due to their high energy density by weight value. The amount of charge stored in these batteries is measured in Ah and the total energy is measured in kWh. In this Project, we are using Lithium-Ion (Li-ion) Batteries. There are many types of batteries available namely LiFePO4, Li- ion, Lead acid batteries. But we used Lithium-ion batteries because these batteries have higher efficiency than other batteries. Also for long distance travelling due to high capacity these batteries are mostly preferred. so we designed a battery pack suitable for our competition guidelines.

II. METHODOLOGY

2.1 Analyzing constraints of the competition

a. Motor Specification: - BLDC 1250 W - 2000 W
b. Battery Specification: - 1.5 kWh - 2.5 kWh
c. Model Weight: - 150 kg
d. Sled pull: - 300 kg
e. The highest slope inclination: - 40^0
f. Length of climb track: - 100 m
g. Endurance Path Length (1 lap) :- 1.5 km
h. Endurance Total race length: - 45 km

2.2 Calculating Motor & Battery Based on Constraints

2.2.1 Vehicle Mechanical Calculations & Motor Selection:-

i. Gross vehicle Weight = GVW
GVW = <u>120 kg.</u>
ii. Gross Vehicle Mass = GVM
GVM = 120/9.81 = <u>12.232 kg.</u>
iii. Radius of the tyre = r
r = <u>0.522 m.</u>
iv. Circumference of tyre = C
C = 2 π r
C = 2 * π * 0.522 = <u>3.278 m.</u>
v. Gear ratio = Rear no. of teeth : Motor Rear no. of teeth = 6 : 1
vi. Velocity = V = 50 km/hr. = 832.8 m/min = 13.88 m/sec.
vii. Acceleration: -
$v^2 = u^2 + 2as$
u = 0 m/sec
Consider, s = 50 m
a = 1.735 m/s^2
Now,
$s = ut + ½ at^2$
t^2 = 100/1.735 = 57.63 sec^2
t = 7.59 sec.
viii. Rolling Resistance Force = F_r
$F_r = Cw = C*m*a_g$
C - Coefficient of Rolling resistance of road
$C_{Concrete}$= 0.002
$C_{Asphalt}$ = 0.004
ix. For concrete,
F_r = 0.002*120*9.81 = <u>2.3544 N.</u>
x. For Asphalt,
F_r = 0.004*120*9.81 = <u>4.7088 N.</u>
xi. Aerodynamic Force = Drag Force = F_d
$F_d = C_{d12*\delta*A*V}{}^2$
C_d = Drag coefficient = 0.9
δ = Density of Medium
δ_{Air} = 1.2 kg/m^2, at NTP
v = Velocity of object in m/sec
A = Frontal area of the object = 0.75 m^2 (assumed by curved dimension)
xii. $F_d = 0.9*0.075*1.2*(13.88)^2*1$ = <u>15.61 N.</u>
xiii. Acceleration Force = F_{Acc}
F_{Acc} = GVM * acceleration
F_{Acc}= 12.232 * 1.735 = <u>21.223 N.</u>
xiv. F_t = Summation of all forces
$F_t = F_r + F_d + F_{ACC}$
xv. For concrete,
F_t = <u>39.187 N.</u>
xvi. For Asphalt,
F_t = <u>41.544 N.</u>
xvii. POWER REQ. = P_{req}
$P_{req} = F_t * {}^{V}\!/\eta m$
η_m = Efficiency of Motor
v = velocity
xviii. For concrete,
$P_{req} = \frac{39.187\ N*13.88\ m/s}{0.85}$ = 658.824 W = <u>0.66 kW.</u>
xix. For Asphalt,
$P_{req} = \frac{41.544\ N*13.88\ m/s}{0.85}$ = 691.765 W = <u>0.7 kW.</u>
xx. Wheel rpm = Ω_w
$\Omega_w = \frac{V}{c}$
Ω_w = 832.8 m/min1.256 m = 254.045 = <u>255 rpm.</u>
xxi. Required Motor rpm of system = Ω_M
Ω_M = Gear ratio * Wheel rpm (Ω_w)
Ω_M = 6 * 254.045 = 1524.27 = <u>1550 rpm.</u>
xxii. Required Torque of system = $\dot{T}$
$\dot{T}$ = r × Ft
xxiii. For concrete,
$\dot{T}$ = 0.522 × 39.187 = <u>20.456 Nm.</u>
xxiv. For Asphalt,
$\dot{T}$ = 0.522 × 41.544 = <u>21.686 Nm.</u>

i. For Torque of motor, choose motor whose RATED torque is <u>25</u> <$\dot{T}$< <u>20</u> Nm.
ii. For Power of motor, choose motor whose power rating is 1.5 kW < Motor power < 1 kW.
iii. For RPM, choose motor whose RPM is 3000 < Motor rpm

2.2.2 Battery Calculations:-

1. Cell voltage = 3.6V
2. Capacity = 2500mAh
3. Charging Voltage = 4.2V
4. Weight per cell = 45g
5. Specific Energy Density = 9.13Wh

i. Volume of cell = Vcc = $\frac{\Pi * \text{Battery cell diameter} * \text{Battery cell length}}{4}$

$= \frac{\Pi * 18 * 0.001 * 0.065}{4}$

$= 0.00092\ m^3$

ii. Battery Cell energy = Battery cell capacity * Battery cell voltage

= 2.5 * 3.6

= 9 Wh

iii. Battery cell energy density = $\frac{\text{Battery cell energy}}{\text{Battery cell mass}}$

= 9/0.045

=200 Wh/Kg

iv. Battery pack total energy =

Motor voltage *$\frac{\text{Ampere drawn}}{\text{speed (kmph)}}$ * Distance

= 48*52*45/50

= 2.246 KWh

v. No. of cells in series = 48/.6 = 13 cells

vi. Energy content of string =

Cells in series * Energy of battery cell

= 13 * 9

= 117 Wh

vii. No. of string of battery pack = $\frac{\text{Battery pack Total energy}}{\text{Energy content of each string}}$

= 19.2~20 (approx.)

viii. Battery pack capacity = 20 * 2.5 = 50 Ah

ix. Total no. of cells = 13 * 20 = 260 cells

x. Battery pack mass = 390 * 0.045 =11.7 ~ 12 Kg

xi. Peak current = crate * Battery cell capacity

= 2 * 2.5

= 5 A

xii. Battery pack peak current =

Peak current * No. of strings of battery

= 5 * 20

= 100 A

xiii. Battery pack peak power =

Battery pack peak current * Battery pack voltage

= 100 * 48

= 4800

So a battery pack of 48 v 50 Amphr should be used in this model.

III. FIGURES AND TABLES

Table 1: Parameters of Li-ion cell

Nominal voltage	3.7v
Rated charge voltage range	4.1 v (25mA)
Nominal Capacity	2500mAh , 0.2C(500mA)
Energy Density	200wh/Kg
Charge Voltage (End Current)	4.2 V + - 0.05v (25mA)
Max discharge Current	2C(5000mA) 10℃＞T≥5℃,50℃
Cell Dimension	Height: 64.85±0.25 mm Diameter: 18.35±0.15 mm
Internal Resistance	≤35 m Ω(AC Impedance, 1000 Hz)

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Table 2: - Parameters of BLDC Motor

Type	Permanent Magnet BLDC
Voltage	48 V
No load Current	A
Rated Current	40 A
Rated Speed	3000±100 RPM
Rated Torque	4.5 Nm
Max Output Torque	400% of rated value
Operating Temperature	(-20 to 80)(℃)
Protection class	IP 67
Motor weight	14 kg
Insulation class	B
Rated Power	1000 W
Output Power	1700 W
Efficiency	>85% on full load and full rmp

IV. CONCLUSION

From pre-test data and post-test data analysis, there are some conclusion that we get from the calculation of electric motor and lithium battery on Team IIRED E-BIKE: The 1000W, 48V, 3000 rpm BLDC motor has enough capacity to drive for IIRED E-BIKE to join E-BIKE CHAMPIONHIP 2021. The maximum efficiency of the BLDC motor is 85% at speed ranges 2900-3100 rpm. Lithium-ion batteries have a depth of Discharge (DOD) of 61.87%, with a discharge capacity of 1950 Wh. This means that the energy in the battery 48V 50Ah Lithium-ion battery pack is able to meet the power requirements for the endurance round. An energy consumption efficiency on the testing track, yielding of 35 km/kWh & 25 km/kWh.

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