Design and Optimization of an Electric Powertrain for Urban Commuter Vehicles with Integrated Thermal Management and Advanced Charging Solutions, Combined with EV Specifications and Component Sizing Analysis

Project synopsis submitted in partial fulfillment

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Advanced EV Engineering: Numerical Analysis, Hybrid Manufacturing, Batteries and Motor Systems

by

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CHAPTER 1

DESIGN AND OPTIMIZATION OF AN ELECTRIC POWERTRAIN FOR URBAN COMMUTER VEHICLE WITH INTEGRATED THERMAL MANAGEMENT AND ADVANCED CHARGING SOLUTION, COMBINED WITH EV SPECIFICATIONS AND COMPONENT SIZING ANALYSIS

Fig.1 ATHER RIZTA ELECTRIC SCOOTER

Objectives:

1) Design an Optimized Electric Powertrain Architecture.
2) Component Sizing and Specification Analysis.
3) Thermal Management System Integration.
4) Advanced Charging Solution Development.
5) Environmental and Economic Analysis.
6) Compliance and Safety Considerations.
7) Scalability and Modularity for Future Platforms.

PROJECT DESCRIPTION

The rapid transition towards sustainable urban transportation has intensified the demand for efficient, compact, and affordable electric vehicles (EVs) specifically tailored for daily urban commuting. This project aims to design and optimize a complete electric powertrain system for an urban commuter vehicle, integrating advanced thermal management techniques and next-generation charging solutions, while ensuring precise specification analysis and component sizing to meet real-world operational needs.

The powertrain design process begins with defining performance targets based on urban driving profiles such as stop-and-go traffic, short distances, and frequent acceleration/deceleration cycles. The project incorporates the selection and optimization of key electric vehicle components, including the electric motor, motor controller, battery pack, power electronics, and drivetrain. Each component will be sized based on rigorous vehicle dynamics calculations, energy consumption patterns, and drive cycle simulations to achieve an optimal balance between range, efficiency, and cost.

A core part of the project focuses on thermal management, as thermal inefficiencies significantly impact battery life and powertrain performance. An integrated thermal management system will be designed to ensure temperature regulation of critical components such as the battery pack and motor/inverter units under varying load and environmental conditions. Advanced thermal modelling techniques will be used to simulate heat generation and dissipation across typical urban use cases.

Furthermore, the project explores innovative charging solutions that enhance user convenience and grid interaction. This includes the development of a compact onboard charger, investigation into fast charging protocols, and consideration of smart charging technologies such as Vehicle-to-Grid (V2G) integration. The charging system will be designed to support high efficiency and minimal energy loss, with a focus on reducing charging time without compromising battery health.

Simulation tools such as MATLAB/Simulink, ANSYS, and other EV modelling platforms will be employed to validate the design under real-world scenarios. Performance parameters including energy efficiency, acceleration, thermal response, and state-of-charge behaviour will be evaluated. Trade-offs among cost, performance, weight, and reliability will be assessed to produce an optimized solution suitable for mass deployment.

In summary, this project delivers a holistic and technically advanced electric powertrain solution tailored for the future of urban mobility. The design emphasizes system-level integration, efficiency, user convenience, and sustainability, making it a scalable and practical blueprint for modern electric commuter vehicles.

CHAPTER 2

REQUIRED INPUT PARAMETERS AND CALCULATIONS

Methodology:

1. Understand the values from the vehicle spreadsheet.
2. Pick the necessary values for the calculation.
3. Consider the total mass of the vehicle.
4. Find the frontal area.
5. Calculate the wheel diameter from the Rim diameter from the vehicle specification.
6. Consider 3 cases (Acceleration, Gradeability, and Top speed).
7. Compare the cases and identify the best case which give the best value.
8. Calculate motor sizing.
9. Calculate the controller sizing.
10. Find the battery controller sizing.
11. Find the battery pack needed.
12. Find the charger sizing.

Vehicle Specifications:

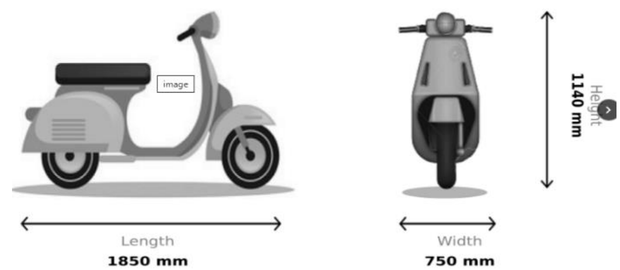
1. Max Range = 123 km
2. Top Speed = 80 km/h
3. Acceleration = 0-40 km/h in 4.7 Sec.
4. Charging Time = (0-100%) 8.3hr
5. Driving mode = Zip and Smart Eco
6. Battery information = 1 Lithium – ion battery
7. Battery warranty = 3 year / 30,000 km
8. Motor Power (continuous) = 4.3 kW, Motor Power (Peak) = 7 kW,
9. Max torque = 22 Nm
10. Water and dust resistance of floor = IP67
11. Gradeability = 15°
12. Ground clearance = 165 mm
13. Mass = 119 kg
14. Battery Capacity = 2.9 kWh

Input Parameters:

1. Mass of Scooter = 119 kg
2. Mass of Rider = 80 kg (Assume)
3. Total Mass = 199 kg
4. Overall Length = 1850 mm
5. Overall Width = 750 mm
6. Overall Height = 1140 mm

CALCULATIONS

Frontal Area (Af) = Height * Width
= 1.140 * 0.750
= 0.855 m^2
= $1m^2$



Tyre Size: 100 / 80 R 12 (Tubeless)

Width = 100mm

Aspect ratio = 80

Rim diameter = 12 inch
= 12*25.4mm
= 304.8 mm
= 0.3048 m

Tyre Height = Aspect Ratio * Tire Width / 100
= 80*100 / 100
= 80 mm

Wheel Diameter (Dw) = Rim Diameter + 2*Tyre Height
= 304.8 + 2 * 80
= 464.8 mm

Radius of Wheel (Rw) = Dw / 2
= 464.8 / 2
= 232.4 mm
= 0.232 m

Here,
Acceleration = 0 – 40 kmph in 4.7 sec
Top Speed = 80 kmph
Gradeability = 15°

FORMULAS:

1. **Aerodynamic Force (Fair) = ½*rho*Cd*Af*v^2**
(Consider, Drag coefficient (Cd)=1.5, Air density (rho)=1.225 kg/m^3)

2. **Acceleration Force (Facc) = m*a**

3. **Rolling Resistance (Frr) = μ*mg*cosα**

4. **Gradient Resistance (Fg) = mg*sin*α**

5. **Power = Force * Velocity**

6. **Torque = Force * Rw**

CASE 1: Acceleration = 0 – 40 kmph in 4.7 sec, Velocity = 40 kmph= 11.11 m/s
Gradeability = 0°
Acceleration (a) = (v-u)/t = (11.11-0)/4.7 = 2.36

Total Tractive Force (Ftrac) = Frr + Fg + Fair + Facc
= μ.mg.cosα + 0 + ½.rho.cd.Af.v^2 + m.a
= 0.02*199*9.81*cos (0)+½*1.2*1.5*1* $(11.11)^2$+199*2.36
Ftrac= 619.772 N

Torque = 619*0.232
Torque = 143 Nm

Power at Wheels:

μ mg cosα * v + 0 + ½ rho cd Af v^2 * v + ½ m.a^2*t

0.02*199*9.81*cos(0)*(11.11)+½*1.2*1.5*1*$(11.11)^2$*11.11+½*199*$(2.36)^2$*4.7

Power = 4.36 kW

Torque at Wheels = 143 Nm

Power at Wheels = 4.36 kW

CASE 2: Gradeability of 10° at 10 kmph.
Here, Facc = 0, because constant velocity of 10 kmph.

Ftract = Frr + Fg + Fair

=μ.mg.cosα + mg.sin α + ½.rho.cd.Af.v^2

= 0.02 * 199 * 9.81 * cos (15) + 199 * 9.81 * sin (15) + ½ * 1.2 * 1.5 * 1 * $(2.77)^2$

Ftract = 549 N

Torque = 549*0.232

Torque = 127 Nm

Power at Wheels:

μ.mg.cosα * v + mg.sin α*v + ½.rho.cd.Af.v^2*v

0.02*199*9.81*cos(15)*(2.77) + 199*9.81*sin(15)*(2.77) + ½*1.2*1.5*1*$(2.77)^2$*2.77

1523.17 Watt

Power = 1.52 kW

Torque at Wheels = 127 Nm

Power at Wheels = 1.52 kW

CASE 3: Top Speed = 80 kmph = 22.22 m/s, Fg = 0, Facc = 0

Ftract = Frr + Fair

$=\mu.mg.\cos\alpha + \frac{1}{2}.rho.cd.Af.v^2$

$= 0.02 * 199 * 9.81 * \cos(0) + \frac{1}{2} * 1.2 * 1.5 * 1 * (22.22)^2$

Ftract = 483 N

Torque = 483*0.232

Torque = 112 Nm

Power at Wheels:

$\mu.mg.\cos\alpha * v + \frac{1}{2}.rho.cd.Af.v^2 * v$

$0.02*199*9.81*\cos(0)*(22.22) + \frac{1}{2}*1.2*1.5*1*(22.22)^2*22.22$

9959.8 Watt

Power = 9.95 kW

To find wheel RPM

Top speed = (Π*Dw*N) / 60

22.22 = (3.14 * 0.46 * N) / 60

N = 920 rpm

Torque at Wheels = 112 Nm
Power at Wheels = 9.95 kW
Wheel RPM = 920 rpm

MOTOR SIZING CALCULATION:

Parameters consider for motor sizing,

1) Torque at wheel = 143 Nm
2) Power at wheel = 4.36 kW
3) RPM at top speed = 920 rpm
4) Gear ratio = 7.8:1

Gear ratio = Torque at wheel / Torque at motor
7.8 = 143 / T at motor
Torque at motor = 143 / 7.8
= 18.33 Nm
Power at motor = (4.36 * 1000) / 0.95 (Consider efficiency 85-95%)
= 4.58 kW
Motor RPM = Wheel Rpm * Gear ratio
= 920 * 7.8
= 7176 RPM

Torque at Wheel = 143 Nm	**Torque at Motor = 18.3 Nm**
Power at Wheel = 4.36 kW	**Power at Motor = 4.58 kW**
Speed at Wheel = 920 rpm	**Speed at Motor = 7176 rpm**

CONTROLLER CALCULATION:

Rated Motor Voltage = 51.1V (From Battery)
Continuous Power = 4300 W, Peak Power = 7000 W
P = VI
I (continuous) = P (Continuous) / V = 4300 / 51.1 = 84 A
I (peak) = P (Peak) / V = 7000 / 51.1 = 136 A

I (continuous) = P (Continuous) / V = 4300 / 51.1 = 84 A
I (peak) = P (Peak) / V = 7000 / 51.1 = 136 A

BATTERY PACK CALCULATION:

(Lithium Ion Cell)

No of cells in series = Pack Voltage / Cell Voltage (Nominal)

= 51.1 / 3.6 = 14 cells

No of cells in Parallel = Pack capacity / cell capacity
We have to satisfy motor current requirement, we are using
N parallel = I (continuous) / max discharge current = 84 / 5 = 17 cell
Total cell = N series * N parallel = 14 * 17 = 238 cells
Battery Pack should be 14S17P.

Energy of cell = 12.5 Wh = 12 * 80 % (DOD) = 10 Wh
Energy of Battery = Energy of cell * No of cells
= 12.5 * 238
= 2.97 kW

CHARGER SIZING:

E (Battery) = 2.9 kWh (Installed Capacity)
Total No. of cells = E (Battery) / E (cell) = 2900 / 12.5 = 232 cells

While, charger designing we use installed capacity and while battery sizing we fulfill motor requirement.

If we use installed capacity then,
No of cells in Parallel will be = 232 / 14 (No. of cells in series)
= 17 cells

0 to 80% = 5hours and 45 minutes = 5+(45/60) = 5.75 hrs

0 to 100% = 8 hours and 30 minutes = 8+(30/60) = 8.5 hrs

Fast charging = 1 km / min (Assume)

If the range =123 km, will take 123 min = 2 hrs

To find,
Max Voltage of Charger
Nominal Charging Current

Fast Charging Current

No. of cells in series = 14
Here we take max cell voltage = 4,2
Max Voltage of Charger = 14 * 4.2 = 58.8 V

E (battery) = 2900 Wh
E = Power * Time
Power = E (battery) / Time
Slow Charging Power = 2900 / 8.5 = 341 W
P = Vmax * I
I (pack) = Charging Power / Max voltage of charger
= 341 / 58.8 = 6 A

I (cell) = I (pack) / No. of cell parallel = 6 / 17 = 0.35 A
E battery = 2900 Wh
E = Power * Time
Power = E (battery) / Time
Fast Charging Power = 2900 / 2 = 1450 W
P = Vmax * I
I (pack) = Charging Power / Max voltage of charger
= 1450 / 58.8 = 25 A

I (cell) = I (pack) / No. of cell parallel = 25 / 17 = 1.47 A

Max Voltage of Charger = 58.8V
Nominal Charging Current = 6A
Fast Charging Current = 25A

CHAPTER 3

CONCLUSION

The scooter's design is well-balanced between **performance, efficiency, and safety**. The motor, battery, and controller are appropriately sized to handle both peak and continuous demands. With a range of 123 km, top speed of 80 km/h, and the ability to climb a 15° grade, the vehicle is suitable for **urban commuting and moderate hilly terrains**. The system is also compatible with both slow and fast charging, making it practical and user-friendly.

CHAPTER 4

REFERENCES

https://www.atherenergy.com

https://www.bikedekho.com