MEC-E5006

Vehicle Mechatronics

Title: **Project Round One**
LDoS: **Nov 30, 2018**

All-Electric Vehicle Model

Design a heavy electric vehicle powertrain and a hill holder assistant for the vehicle. The mass of the vehicle **without** batteries and motor(s) is **10500 kg**. The required level of abstraction is similar to the model in Exercise 2. Note that the first step is to get the work started early enough. Return a zip-file that contains all files related to your answer. It should have at least: a pdf that explains how you modelled the vehicle and answers the bolded subjects beneath, a Simulink model of the vehicle and Matlab scripts if you made any.

Step 1

- Pair up with your group mate and carry out **initial overall design**.
- Analyze the vehicle's **max power** need.
- Fix the **gearbox ratio(s)** and the **power of motor(s)**.
- Fix the **battery voltage**.
- Create a sketch / plan / flowchart of the **simulation model** of the vehicle.
- Submit your answers by **Nov 30**.

Answer

Table 1 presents the parameters that roughly provides the initial overall design of our vehicle. The following computations are done in order to get an idea about those parameters which cannot be directly stated but calculated pretty conveniently.

Total Mass

$$m_{\mathrm{t}} = m_{\mathrm{v}} + m_{\mathrm{pl}} + m_{\mathrm{batt}} + m_{\mathrm{m}}$$

Aerodynamic drag

$$F_{\mathrm{aero}} = \frac{1}{2} C_{\mathrm{d}} \rho A v_{\mathrm{max}}^2$$

Rolling frictional force

$$F_{\mathrm{RR}} = f_{\mathrm{RR}} m_{\mathrm{t}} g \cos\beta$$

Slope effect

$$F_{\mathrm{slope}} = m_{\mathrm{t}} g \sin\beta$$

Intertial force

$$F_{\mathrm{iner}} = m_{\mathrm{t}} a_{\mathrm{max}}$$

Tractive force

$$F_{\mathrm{trac}} = F_{\mathrm{iner}} + F_{\mathrm{aero}} + F_{\mathrm{RR}} + F_{\mathrm{slope}}$$

Table 1 – Initial Overall Design

Vehicle Data	
Vehicle mass (m_{v}) [kg]	10500
Payload (m_{pl}) [kg]	5000
Battery mass (m_{batt}) [kg]	221
Motors' masses (m_{m}) [kg]	3048
Aerodynamic drag co-efficient (C_{d})	0.36
Air density (ρ) [kg/m^3]	1.17
Vehicle frontal area (A) [m^2]	12.00
Rolling resistance co-efficient (f_{RR})	0.014
Slope (β) [deg]	0
Transmission efficient rate (η_{trans})	0.9
Dynamic tyre diameter (D_{dyn}) [mm]	686.5
Gravity acceleration (g) [m/s^2]	9.81
Gear ratio (i_{g})	5
Maximum speed (v_{max}) [m/s]	14.63
Auxiliary Load (P_{aux}) [kW]	10
Cells in series (C_{s})	192
Cells in parallel (C_{p})	25
Cell nominal voltage (V_{nom}) [V]	3.6
Cell nominal capacity (C_{nom}) [Ah]	3.2

Table 2 – Additional Design Data

Computed Vehicle Data	
Total mass (m_{t}) [kg]	18769
Aerodynamic drag (F_{aero}) [N]	541.3
Rolling frictional force (F_{RR}) [N]	2577.7
Slope effect (F_{slope}) [N]	0
Intertial force (F_{iner}) [N]	36169
Tractive force (F_{trac}) [N]	39288
Max power (P_{max}) [kW]	575.00
Max wheel torque ($T_{\mathrm{w,max}}$) [Nm]	13486 Nm
Max wheel speed ($n_{\mathrm{w,max}}$) [rpm]	407.16
Motor's maximum torque ($T_{\mathrm{m,max}}$) [Nm]	29688
Motor's maximum speed ($n_{\mathrm{m,max}}$) [rpm]	20358
Max battery power ($P_{\mathrm{batt,max}}$) [kW]	585.00
Max battery voltage ($U_{\mathrm{batt,max}}$) [V]	691.2
Max battery current ($I_{\mathrm{batt,max}}$) [A]	846.36

Max Power

$$P_{\max} = F_{\text{trac}} v_{\max}$$

Max wheel torque

$$T_{\text{w,max}} = F_{\text{trac}} \times \frac{D_{\text{dyn}}}{2}$$

Max wheel speed

$$n_{\text{w,max}} = \frac{60}{2\pi} \times \frac{v}{\frac{D_{\text{dyn}}}{2}}$$

Motor's maximum torque

$$T_{\text{m,max}} = \frac{T_{\text{w,max}}}{i_{\text{g}} \times \eta_{\text{trans}}}$$

Motor's maximum speed

$$n_{\text{m,max}} = n_{\text{w,max}} \times i_{\text{g}}$$

Max battery power

$$P_{\text{batt,max}} = P_{\max} + P_{\text{aux}}$$

Max battery voltage

$$U_{\text{batt,max}} = C_{\text{s}} \times V_{\text{nom}}$$

Max battery current

$$I_{\text{batt,max}} = \frac{P_{\text{batt,max}}}{U_{\text{batt,max}}}$$

Table 2 presents the values of those parameters which are computed from the initial design parameters. These are, however, tentative calculations based on initial design parameters. The final values may change from the ones presented over here. The .zip folder also contains the MATLAB codes for computation of calculated parameters, Simulink model which shows the rough vehicle simulation model and `.mat` file which contains the speed profile for the heavy vehicle.