METU EE 7566 - Spring 2019

Homework 1: Vehicle Dynamics and Electrified Vehicle Powertrains

Due: 23:59, 7th of April 2019

1. (5 pt.) In a parallel hybrid vehicle, there is a need for mechanical couplers to couple the output of internal combustion engine and electric machine. Name the two main types of coupling devices and give one example for each of them.
2. (5 pt.) Draw the topology of a series hybrid electric vehicle. Name at least two advantages and two disadvantages. What is the most common application of a series hybrid vehicle train?
3. (5 pt.) Which components are required for an electrical continuous variable transmission (eVT)? What is the motivation of using an eVT?
4. You are asked to redesign a midsize internal combustion engine vehicle (characteristics of the car is given at the end) as a battery electric vehicle with following requirements:
    - Max vehicle speed 150 km/h and acceleration capability at maximum speed 0.05g
    - 0-100 km/h acceleration time in 7.5 sec
    - 350 km for WLTP drive cycle

    a. (5 pt.) If the maximum speed of the vehicle is limited by the maximum speed of the electric motor, calculate the maximum speed of the electric machine.

    b. (5 pt.) Draw the characteristic line of electric machine in forward motoring mode. Show and give the values of the maximum speed, maximum torque and base speed.

    c. (5 pt.) Plot the reference (driving cycle - WLPT) and actual speed of the vehicle. Please give the value of your proportional constant that you used to control vehicle speed. What is the effect of the proportional controller on speed output and fuel economy? Do cars have different variable controller values? If yes, what is its application?

    d. (5 pt.) Plot the operating points of the electric machine for the given driving cycle (Points on torque speed characteristics).

    e. (10 pt.) Calculate the consumption and economy of this BEV car in kWh/km and TL/km, assume a constant efficiency of 98% for the charger and 0.5 TL/kWh of electricity price.

    f. (10 pt.) What is percentage of regenerative braking energy that is recuperated brake energy over tractive energy for cruising and acceleration? Comment on importance of regenerative braking. In which driving pattern it is more crucial, city or highway driving?

    g. (10 pt.) Fill the table with your previous results. Repeat the calculations for the following cases:
    - 350 km range + acceleration at maximum speed 0.05g and power requirement of accessories is equal to 0 W.
    - 500 km range + acceleration at maximum speed 0.05g and power requirement of accessories is equal to 750 W.
    - 500 km range + acceleration at maximum speed 0.05g and power requirement of accessories is equal to 0 W.

5. Your company wants to design a range extender version of the electric vehicle in question 4 with a total range of 500 km (Powertrain components you designed in question 4 for 350 km range are kept the same). Select an ICE power output and capacity of the fuel tank. Assume a constant efficiency of 35% for the ICE. (**The power of ICE** needs to be equal to electric machine power in a series HEV but **in a range extender it has to be the average power consumption**, please also consider that you also need to add a generator)
   a. (10 pt.) Calculate the mixed fuel consumption and fuel economy of this car in WLTP in kWh and TL/km, assume a constant efficiency of 98% for the charger and 0.5 TL/kWh of electricity and 6.25 TL/l of gasoline (take gasoline energy density as 9700 Wh per liter)
   b. (10 pt.) Fill the table following table by changing variables as explained in question 4.
6. Compare all of electric vehicles designed so far.
   a. (5 pt.) Which of the electric cars with 500 km range would you favor? Why?
   b. (5 pt.) Comment on effect of electric machine power on the consumption and car performance.
   c. (5 pt.) Calculate the charging durations of the battery in question 5 with Level 1 & 2 charging.

Level	Charger Location	V/amps	Electricity Delivered (kW)
1	On board	120/15	1.8
2	On board	240/80	19.2
3	Off board	480/max 200	max 90

Please submit the code with your homework.

Good Luck!

		Capacity of battery In kWh	Electric machine power in kW	Electric machine torque in Nm	Mass of drivetrain in kg (incl. battery)	Cost of drivetrain in $	Fuel consumption in kWh	Fuel economy In TL/km	Total Regen. energy in %
BEV with 350 km range	0.05g & 750 W								
	0.05 g & 0 W								
BEV with 500 km range	0.05g & 750 W								
	0.05 g & 0 W								
BEV REX with 350+150 km range	0.05g & 750 W								
	0.05 g & 0 W								

Vehicle and component characteristics:

Mass of body without powertrain	1000 kg
Increase in mass due to acceleration of rotating masses	1.05
Gravitational acceleration	9.8 m/s^2
Frontal area	2.57 m^2
Aerodynamic drag coefficient	0.26
Density of air	1.25 kg/m^3
Friction coefficient of tires	0.006
Radius of wheels	0.3 m
Gear ratio (electric motor to wheels	9.0478
Accessories consumption (fixed)	750 W
Adhesive coefficient of tires to ground surface	0.9
Front wheel drive with equally distributed load on wheels	0.5 (Acceleration)
Load distribution during braking, W_{front}/W_{total}	0.65 (Braking)
Specific cost of electric machine + inverter	$30/kWh
Specific mass of electric machine + inverter	1.1 kW/kg
Specific volume of electric machine + inverter	2.6 kW/l
Battery pack specific cost, P_{batt}/E_{batt}: power-to-energy ratio	**$(200 + 13 x P_{batt}/E_{batt})/kWh**
Battery pack specific mass	**(200 - 3 x P_{batt}/E_{batt}) Wh/kg +120 kg**
Specific cost of internal combustion engine	$50/kW
Specific mass of internal combustion engine	0.55 kW/kg
Charger mass and cost (fixed)	10 kg and $300
Fuel tank mass and cost (fixed)	5 kg and $150

Assume following constant efficiency values for the energy converters.

Efficiency of electric machine + inverter	*92%*
Efficiency of gearbox + differential	*97%*
Efficiency of battery pack	*95%*