Final Exam in the course ”Hybrid Electric Drives” at LTH

Questions to NN

Means of assistance:	Calculator	
Grades:	20-30 p:	3
	31-40 p:	4
	41-50 p:	5

1 Energy consumption

a. What is the peak energy efficiency of a modern combustion engine, gasoline and diesel? (2p)

Gasoline: 35%

Diesel: 45 %

b. What is roughly the average efficiency for a car using a gasoline engine in city traffic and a truck using a diesel engine in highway traffic? (3p)

Car in City Traffic: 20%

Truck on Highway: 35%

c. How high is the tractive power from the combustion engine and the power flow from the combustion engine to the 12 V load for a car in city traffic? (2p)

Ptractive 5 kW, P12V = 1 kW/0.5= 2 kW

d. What is roughly the efficiency of a DC/DC converter from 300 V to 12 V? (3p)

95%

2 Hybridisation, potential

a. What are typical values of the energy savings potential (in [%]) with electric hybridisation in a car in city traffic and a heavy duty truck in highway traffic? (2p)

Car in City Traffic: 20…40 %

HD Truck on highway: 5%

b. A hybrid vehicle is usually said to have at least two advantages; I) The ability to adjust the operating point of the ICE and II) the ability to regenerate braking energy. Assume a parallel hybrid car with 80 kW ICE and 20 kW EM. In what type of driving is the regenerative capability most useful, highway driving or city driving? Motivate your answer! (3p)

City due to low power and dynamic speed!

c. What is roughly the energy efficiency of an electric vehicle, “electric wall plug-to-wheel”? Compare to your answer on question 1b) above. (2p)

ChxBatxBatxPexEM = 95x95x95x97x95 = 0.79

d. Compare a Series Hybrid and a Parallel Hybrid version for the same vehicle in terms of system cost, regeneration capability and packaging. (3p)

Series: TM + GEN + ICE = 1.0 + 0.4 + 0.4 = 1.8 Cost, 1x regen, better pack

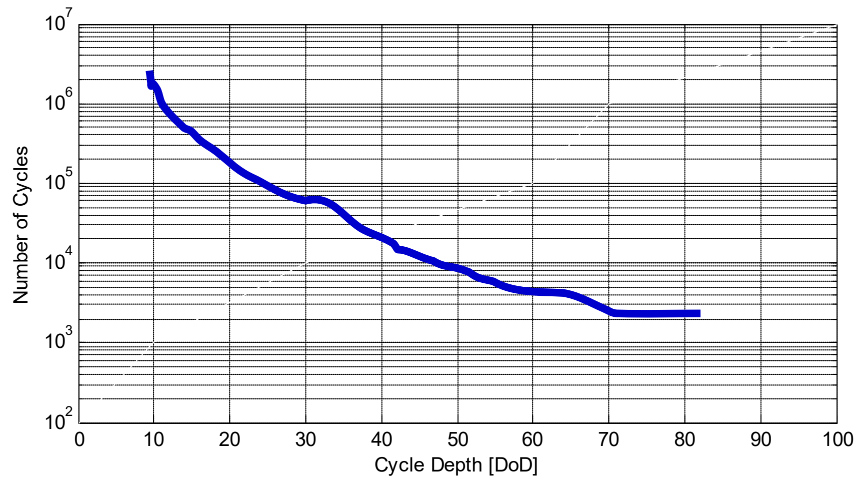
Par: TM+ICE = 0.2+0.8 = 1.0, 0.2x regen, mech pack

3 Hybridisation components

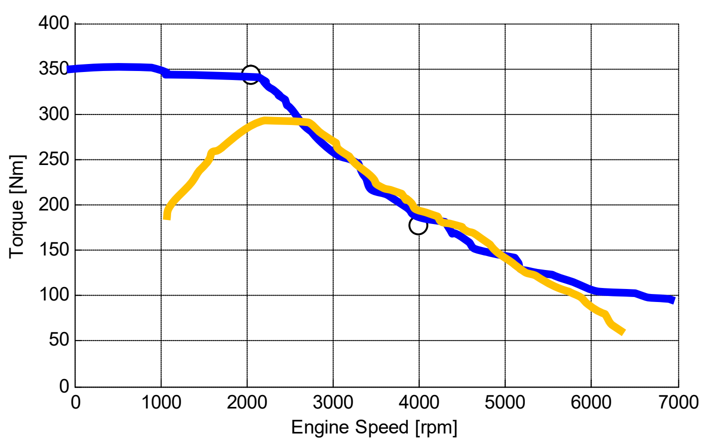
a. What is the energy and power density of a modern traction battery, expressed in [kWh/kg] and [kW/kg]? (2p)

0.1 [kWh/kg] and 1 [kW/kg]

b. How is the battery lifetime affected by cycle depth and average terminal power? (3p)



c. Draw the Torque/Speed diagram of a 73 kW electric traction machine with max speed 7000 rpm and a field weakening ratio of 1:3.5. (2p)



Base Speed = 73 kW/2000 rpm = 350 Nm.

d. Draw, in the same diagram as in c), the torque/speed diagram of a combustion engine with the same peak power as the electric machine in c). (2p)

e. What is roughly the battery weight and maximum battery power for a battery that can take a car 40 km? (1p)

0.2 [kWh/km] x 40 km = 8 kWh. 70% DoD = 8/0.7 = 11 kWh. 11/0.1 = 110 kg.

4 Charging

a. Norway, Germany, England and now Sweden are discussing ending sales of new combustion driven vehicles by 2030, if not earlier. All vehicles of Sweden consume about 80 TWh of fossil energy. Discuss the realism in this knowing that the annual electricity generation in Sweden is about 140 TWh. (3p)

Answer: Assuming 25 % average efficiency of the combustion driven vehicles and 75 % of the electric, 80/3=27 TWh of electric energy would be needed. That is only 19% of the total electric energy generation and that is reasonable to provide given that the change from fossil to electric will take at least a decade.

b. An electric distribution truck drives 150 km a day, making 10 delivery stops and one lunch break a day. The average energy consumption is 20 kWh/10 km. The lunch break is 45 minutes. Assume a 44 kW charging power available at any stop, discuss the realism of this concept. (4p)

*Answer: The energy necessary to supply at the delivery stops is (150*2-44*0.75)/10 = 26.7 kWh per stop. With 44 kW charging power, each stop would take 26.7/44=0.61 h = 36 minutes. That is probably not realistic, and a higher charging power is needed.*

c. A so called Electric Road System (ERS) is used to supply a flow of vehicles between A and B. The total distance between A and B is 300 km. The maximum ERS power per vehicle is limited to 240 kW. Roughly how large part of the distance between A and B must be equipped with the ERS system for a car with a 20 kWh battery on board that can be used to 60 % DoD? (3p)

Answer: 0.6x20=12 kWh battery range. Assume that a car use 2 kWh/km. The battery range is thus 60 km. The tractive power of a car at highway speed is about 20 kW. Assume that it uses the max charging power (240 kW) when at ERS. Then only 20/240 = 8.3% of the distance need to be covered with ERS, corresponding to 25 km. These 25 km has to be split in pieces of 5.5 km ERS followed by 60 km without ERS.

5 Auxiliaries and EMC

The electric subsystems systems of a conventional vehicle consume in average around 600 W electric power.

a. What is a normal efficiency of electric power generation, from mechanical power on the ICE shaft, in the 1.5 kW generator of a conventional vehicle and in e.g. a 10 kW FAS of a hybrid vehicle? Discuss what ICE shaft power is needed to generate the 600 W electric power with a conventional vehicle generator and relate this to the tractive power. (3p)

Answer: The conventional generator has about 50 % efficiency, the FAS can be expected to be above 90 %. The conventional vehicle thus needs 1.2 kW shaft power to generate 600 W electric power. 1.2 kW is in the range of the tractive power when driving as mall conventional vehicle in city traffic, i.e. the low generator efficiency affects the fuel consumption a lot.

b. What is the main reason to use an "APU" (=Auxiliary Power Unit) in a heavy vehicle? (3p)

Answer: When the driver is resting, the power needed onboard for his or her comfort is only a few kW at the most, but the ICE of the heavy vehicle is a few hundreds of kW. The effiency is thus to low and a smaller converter from prime energy is better.

c. Discuss conversion efficiency aspects of controlling e.g. an electric motor voltage with PWM from a higher DC link voltage. (2p)

Answer: A power electronic converter for voltage control via PWM usually have bad efficiency when the converted voltage proportions are high, e.g. from 400 V to 4 V, Thus these proportions should be kept as low as possible, like in the Toyota Prius where a variable DC link voltage is used to have as low DC link voltage as possible when the output voltage needed is low.

d. Why is it that the traction battery voltage is "floating" relative to the chassis of a hybrid vehicle, i.e. that it has no galvanic contact with the chassie? (2p)

Answer: Because of safety and EMC