CHALMERS

Examination
Hybrid Vehicles and Control

TME095 HYBRID VEHICLES AND CONTROL

Friday 15 March 2013, 14.00 – 18.00, M

Aid: Pen and paper.

To pass the exam 40 % is needed (20 out of 48).
20-28.5 points correspond to grade 3
29-38.5 points correspond to grade 4
39-48 points correspond to grade 5
The result is 60 % of the final course grade.

A teacher (Sven Andersson) will be in the exam rooms around 15.00 and 17.00.

Review: 12.00 – 13.00, 23 March, 2013, and
12.00 – 13.00, 26 March, 2013
The review session will take place across the hall from my office.

Göteborg 12 Mars 2013

Sven Andersson tel Office 772 50 33
Mobile 0723 -762 362

CHALMERS UNIVERSITY OF TECHNOLOGY
Department of Applied Mechanics
Address: Hörsalsvägen 7, 412 96 Göteborg
Tel: 031 - 772 1400

Hybrid vehicles

1. If I think large brake recuperation is important, should I choose a parallel or a series hybrid? Explain! Are there any disadvantages with this hybrid powertrain?

2. The power in a combined (split) hybrid powertrain can flow in several ways. Show using a figure what power flow modes that are possible.

Subsystems

3. Describe Willans approximation for an internal combustion engine.

4. Name and give a brief description of the three types of gear boxes encountered in practical applications.

5. Make a figure showing the characteristic curve (load as a function of angular speed) of an induction AC motor. Show in the figure the breakaway torque and the synchronous frequency.

6. If efficiency is the most important parameter for the electric motor of a HEV vehicle which type would you choose? Are there any drawbacks with this choice?

7. Show in a diagram the cell voltage of a NiMH and LiIon battery respectively, and how it varies with State of Charge.

8. Consider modeling of a battery cell. Mention one good and one bad thing with electrochemical modeling. Do the same thing for empirical modeling.

Modelling

9. Show in a figure the inputs and outputs of a gear box if you do a quasistatic description. Do the same for a dynamic description.

10. Mention at least three different ways to determine the fuel consumption during a driving cycle?

11. Requirements

The requirements and the capability of a powertrain can be illustrated in a Traction force-Vehicle speed diagram. You shall analyze a vehicle with the following properties:

Total vehicle mass = 2000 kg
Front area = 2 m^2
Rolling resistance coefficient = 0.01
Aerodynamic drag coefficient = 0.3
Density of the air = 1.25 kg/m^3
Wheel radius = 0.3 m

Plot the following three operating points as different points in a F-v diagram, and explain how you reached your results, with calculations and explanations.
(Grading: For full points the force and speed values for the points shall be given, but reasonably correctly plotted points which are explained well will also give points.)

a) Acceleration of 3 m/s^2 at a take-off from standstill on a flat road

b) Driving uphill a 15% gradient in constant speed of 90 km/h

c) Driving at constant speed at the top speed of 180 km/h

12. Sizing

You shall size an electric traction motor for a series hybrid powertrain for the vehicle in the earlier task. Assume the transmission from the shaft of the electric motor to the wheels to have 100% efficiency and a gear ratio such that the electric motor shaft speed is 10 times the speed of the wheel shaft.

a) Which maximum <u>mechanical</u> peak power must the traction motor produce to meet the three operating points in the earlier task, and show which of them where the critical one for the peak power requirement?

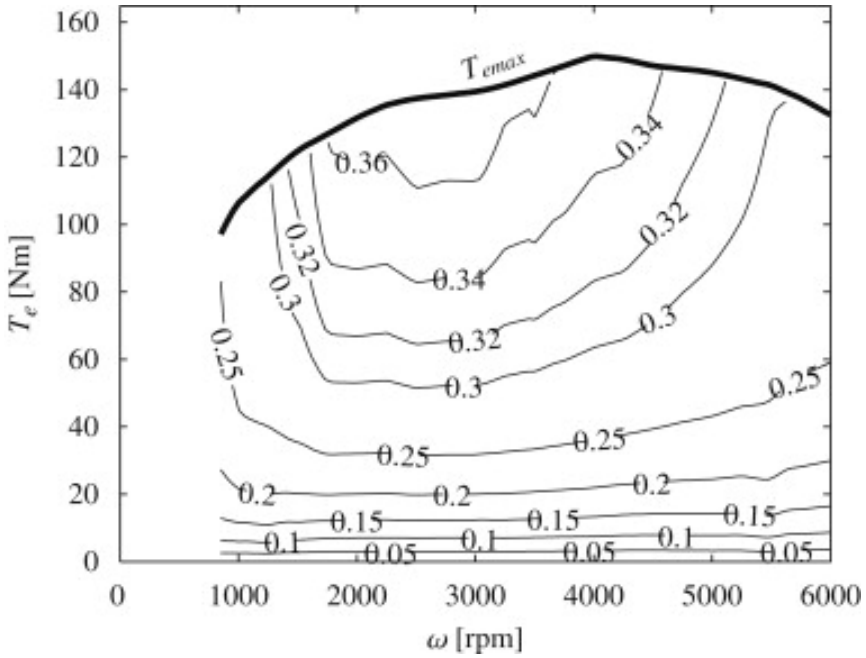
b) Which peak shaft torque must the motor be able to produce, and which of the operating points where the critical one for the peak torque requirement?

c) Translate the electric motor limits in torque, power and shaft speed into force-vehicle speed limits for the power train and plot them in the F-v diagram in the previous task. Plot them for positive vehicle speeds, and both positive and negative force.

(Grading: It is possible to get points even without exact values of torque and power, if you can clearly explain how you can find these values based on the data given in this and the earlier task, and if the limits are plotted correctly in relation to the operating points.)

13. Minimizing ICE fuel consumption

A combustion engine with the below efficiency map shall be used in a series hybrid powertrain. Assume the generator efficiency to be constantly 90 %.



a) Show which operating points the engine should use to minimize the fuel consumption when the generator shall produce 5, 10, 30 and 70 kW electric power?
Explain how you found these most efficient operating points.

b) Estimate (roughly) the minimum power under which it may be more efficient to run the ICE intermittently (On-Off-cycling) and used the battery to even out the power to the propulsion motor, rather than running the engine continuously. Assume the battery efficiency to be constantly 95% during charging and 95% during discharging.
Explain how you reached the value of the power limit you state.

14. Optimal control methods

a) Explain in words (and additional equations, if you like) the principle with which the optimal power split between combustion engine and battery is determined in a controller using ECMS. (Equivalent Cost Minimization Strategy)

b) Which parameter is critical in order for ECMS to provide optimal control.

c) Explain, by an example, why it is not possible to define if it is optimal to charge the battery (at a specific time) unless you can know in advance how the coming driving will be.

Powertrain design

(For the following questions you are expected to define the desired properties of the vehicle and then propose and explain a solution.)

15. At the Geneva Car Show this year the company Rinspeed showed a concept vehicle, the short range city bus MicroMAX, see the picture below. This vehicle should have many features, like the possibility to order the bus using your mobile phone when you want to go home from work or when the party is over. What would be a suitable powertrain for this vehicle if you only consider fuel efficiency? Your answer should be well explained!

16. A person living in a small house 50 km east (=in-land) of Gothenburg is going to buy a new car. Since he works in the centre of Gothenburg he is using the highway for these trips. However, he is also going fishing and hunting in the week-ends which means that he has to use small countryside roads of poor quality, see picture. What would be a suitable powertrain for this vehicle? Remember that there could be arguments for different solutions!