Electric and Hybrid Vehicles

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1 Study of Internal Combustion Engine, Electric and Hybrid Vehicle

The pictures show an every day driving cycle, it has been measured using a GPS device with an aquisition frequency of 5 Hz. The distance of this cycle is 21.5 km

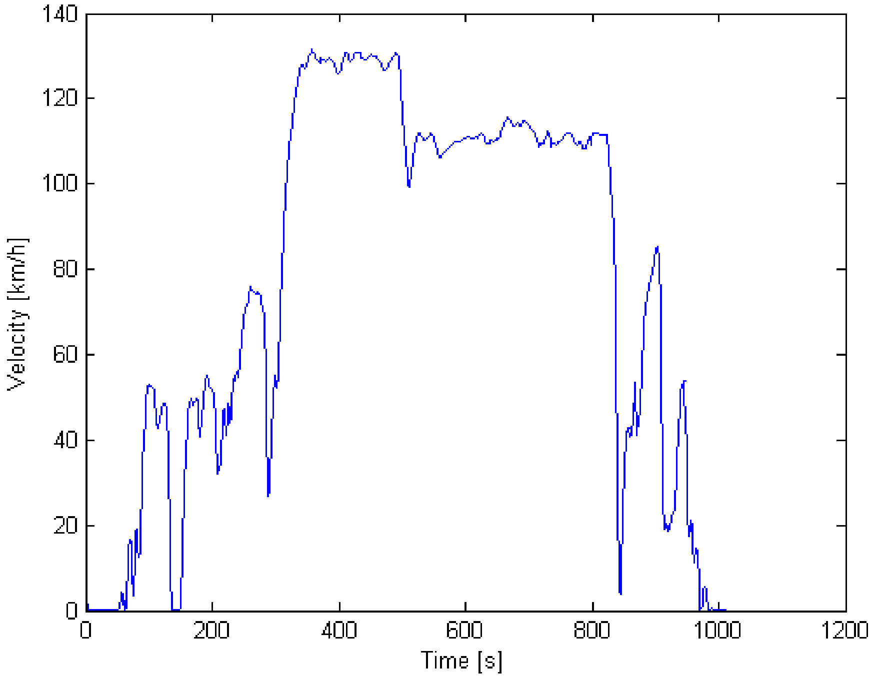

FIGURE 1 – Velocity profile

1.1 Analyse of the driving cycle

1. Name the different driving phases. (In France : town/urban < 50km h^{-1}, outside town/extra urban < 90km h^{-1}, motorway < 130km h^{-1} sometimes < 110km h^{-1}.)
2. What kind of vehicle is most adapted for this solution ?

1.2 Analyse of power and energy needs

3. What is the maximum power needed during the cycle ?

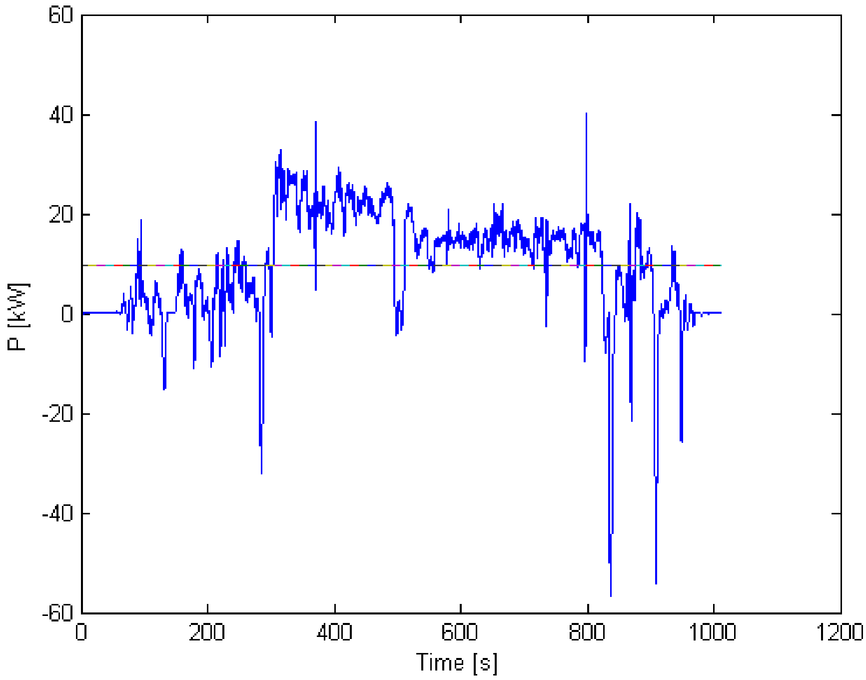

FIGURE 2 – Power profile

4. What is the mean power needed during the cycle ?
5. Calculate the ratio between the maximum and the mean power.
6. What is presented in figure 1 ?

1.3 Internal combustion engine vehicle

The accumulated positive energy is 2.95 kWh, the accumulated negative energy is -0.26 kWh.

An internal combustion engine has an average efficiency of 18% (including motor and transmission). The lower heating value of gasoline is 9.7 kWh L^{-1}.

7. How many liters of gasoline do you consume for the given driving cycle ?
8. How many liters of fuel is this compared to 100 km ?

1.4 Evaluating the energy demand of en electric driven vehicle during the cycle

Assuming that the propulsion efficiency is of 80% and the energy recovery efficiency is of 30%.

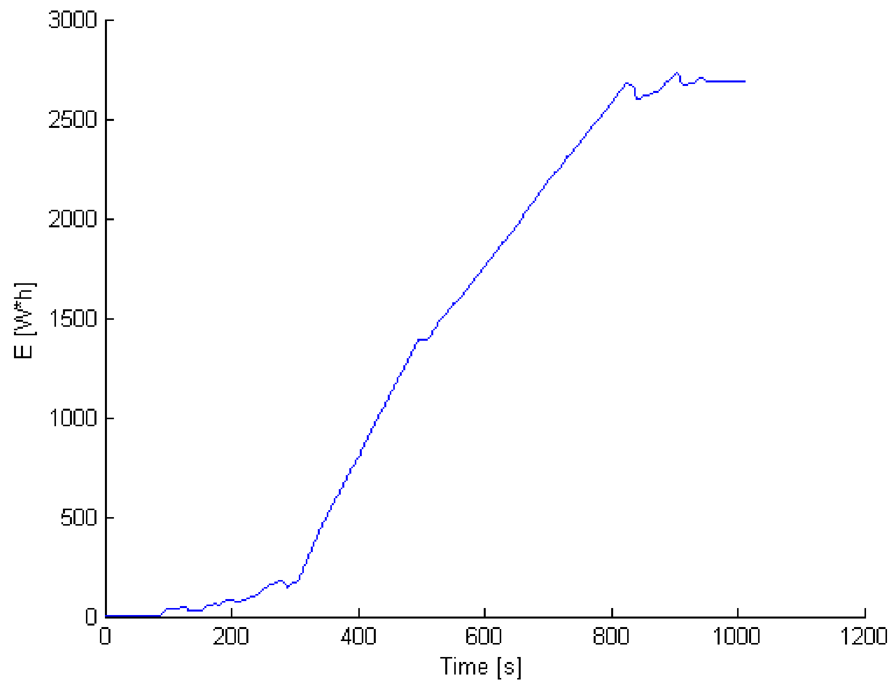

FIGURE 3 – Energy distribution

9. Calculate the positive energy that has to be supplied during the cycle.
10. Calculate the negative energy that can be recovered during the cycle.
11. What is the total energy needed during the cycle ?

1.5 Electric vehicle with batteries

The electric vehicle takes its energy from a lithium ion battery with the following characteristics :

- nominal voltage : 3.5 V
- specific energy : 170 Wh kg^{-1}
- energy density : 280 Wh L^{-1}
- specific power : 300 W kg^{-1}
- costs : 1900 EUR kW^{-1}h^{-1}

12. What is the weight and the volume of the battery if you want to have an authonomy of 100 km using the given cycle ?
13. What it the price of such a battery ?
14. Does this battery reply to the power demands ?

1.6 Hybrid car using fuel cell and secondary power source

In the hybrid system the mean power is supplied by the fuel cell. The fuel cell characteristics can be evaluated from an existig fuel cell, therefor you have to measure voltage over current and power over current. As the fuel cell will run on a constant power, we chose to use the maximum power point.

If you have a fuel cell that you can test : You have to evaluate the power density per square centi meter as well as the voltage at this maximum power point in order to do the calculations.
If you are not able to do measurements you can use the following values :
- The power density of the fuel cell is 0.5 W $c^{-2}m$.
- The current density is j = 940 mA $c^{-2}m$.
- The cell voltage can be calculated using :
  $V_c(j) = 1.031 - 2.45e^{-4}j - 0.03\ln(j) - 2.11e^{-5}\exp(8e^{-3}j)$

15. A fuel cell system consits of the fuel cell it self and its auxilliaries. It can be assumed that the auxiliaries consume 25% of the produced power. How much power has to be supplied by the fuel cell ?
16. What is the total surface of the fuel cell ?
17. The total stack voltage must not be bigger that 100 V. How many cells are ther inside the stack ?
18. What is the size of each cell ?
19. Each cell has is 0.4 cm thick. What is the volume of the stack in L ?
20. Name the main auxiliaries of a fuel cell system.
21. Assume that the auxiliaries have the same volume as the stack itself, what is the fuel cell system volume ? .