HYBRID DRIVE SIMULATION OF THE CITY VEHICLE

Ing. Mruzek M., Ing. Barta D. PhD., Prof. Ing. Kukuča P. PhD., assoc. prof. Kendra M. PhD.
Faculty of Mechanical Engineering – University of Zilina, Slovakia

Abstract: *This article deals with simulation of series and parallel hybrid drivetrain with different size of main components. Simulation is based on the real world driving cycles measured in Central Europe and urban part of NEDC cycle. The real driving cycles were measured in real city traffic in the cities of Middle Europe. Simulation was created using the Matlab/Simulink software. Comparison of the hybrid vehicles is based on their range.*

Keywords: HYBRID VEHICLE, REAL DRIVING CYCLE, SIMULATION

1. Introduction

Reducing vehicle fuel consumption and emissions is on great demand nowadays. In some cities in EU is entry to the city center allowed only for vehicles complying emissions limits. One of the possibilities is to use a hybrid vehicle. Hybrid drive is the combination of two or more power sources. The most common combination is the use of internal combustion engine and electric motor. According to the architecture of the components are hybrid drives divided into series, parallel and series-parallel. This article presents a simulation of the series plug-in and parallel plug-in hybrid. Plug-in hybrid means that battery can be charged from the public electricity network. The series hybrid drivetrain is shown in Fig.1 and parallel hybrid drive train in Fig.2.

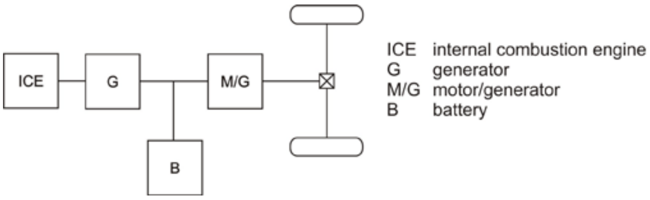

Fig. 1 *Series hybrid*

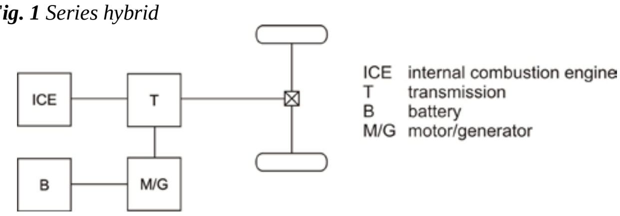

Fig. 2 *Parallel hybrid*

For the evaluation and designing hybrid vehicles are most commonly used driving cycles for determination fuel consumption and emissions. However these cycles are simplified. For example doesn't contain the grading resistance. For better evaluation we created real world driving cycles.

2. Real Driving Cycle

The measurement of real world driving cycle was made on the conventional vehicle (see Fig. 3). The vehicle has been driven how the traffic situation requires and the measured data can be used for simulation of different vehicles types. The measurements were made in the cities of Central Europe. Measured was velocity, acceleration, time, distance, grade and brake signal. The measurement of velocity, acceleration, distance and brake signal was made by using data acquisition system DAS3 with contactless measuring device based on the Doppler phenomenon and pedal force sensor. For determining grade was used GPS data logger.

Cities with higher population, larger size and more complicated transport system, with the expected use of vehicles with alternative drive systems have been deliberately chosen to measure the real driving cycles. In these cities are a higher proportion of reasons to stop or reduce speed, which is a potential source of re-use of energy.

Fig. 3 *Measurement vehicle*

At the same time the cities continue in solving of issues of environment pollution and reducing emissions from transport.

Since each of the three monitored countries has a different geographic structure it is reflected even in the elevation profiles of individual cities. Table 1 indicates the basic information of the monitored cities.

Table 1: *The basic information of the monitored cities*

City	Population	Density [inhabitants/km^2]	City area [km^2]	Elevation [m]
Žilina	85295	1066	80,03	342
Prague	1272690	2602,5	496	399
Wroclaw	632996	2161,7	292,82	105 - 155

Real driving cycle measured in Žilina you can see in Fig. 4, Prague in Fig. 5 and Wroclaw in Fig. 6

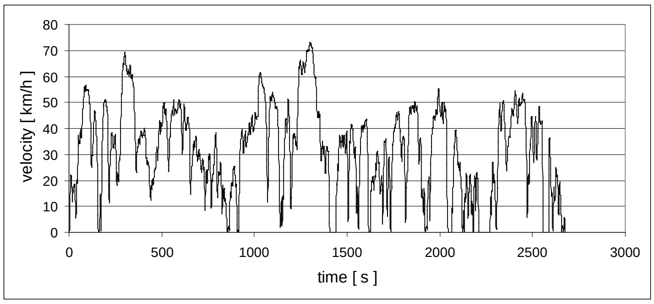

Fig. 4 *Real driving cycle of Žilina*

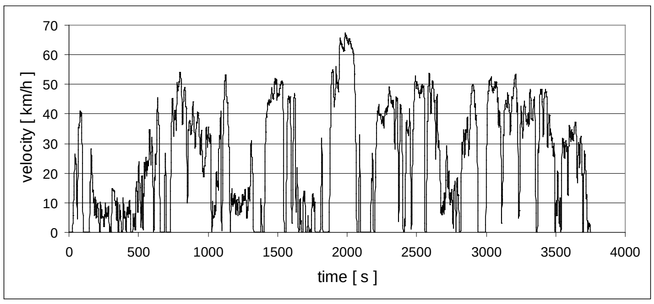

Fig. 5 *Real driving cycle of Prague*

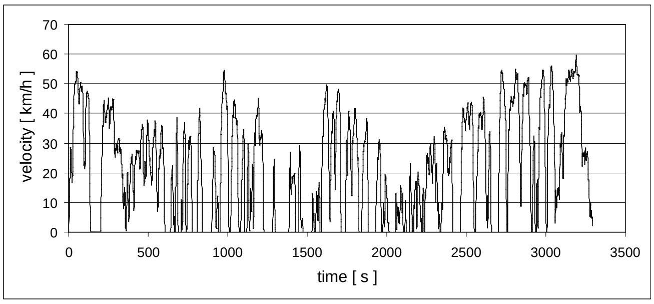

Fig. 6 *Real driving cycle Wroclaw*

In the figure 7 is shown urban part of NEDC part which is using for testing emission and fuel consumption.

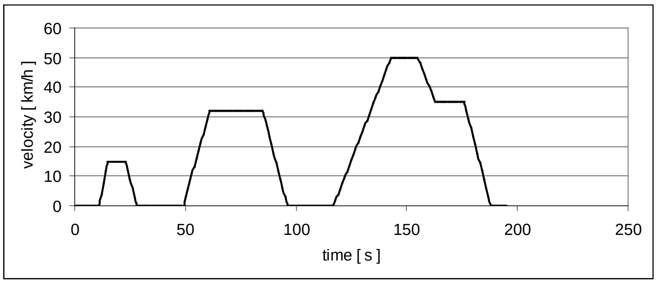

Fig. 7 *UDC cycle*

Figures 8 to 10 show the elevation profiles recorded during the measurement and compare the elevation profiles differences, which affect the possibility of energy recovery as well as increase the demands on vehicle power unit.

Fig. 8 *Žilina elevation profile*

Fig. 9 *Prague elevation profile*

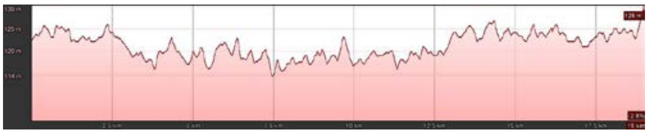

Fig. 10 *Wroclaw elevation profile*

3. Vehicle simulation

Hybrid vehicle simulation was made using the Matlab Simulink. Series and parallel hybrid drivetrain model is consists of electric motor, internal combustion engine, control system, transmission and battery subsystem. Series hybrid vehicle is shown in Fig. 11, parallel hybrid vehicle in Fig. 12.

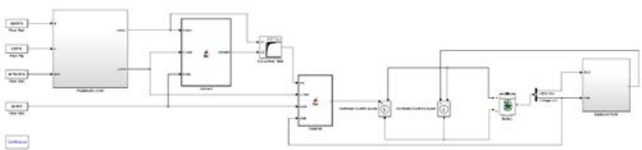

Fig. 11 *Series hybrid vehicle model*

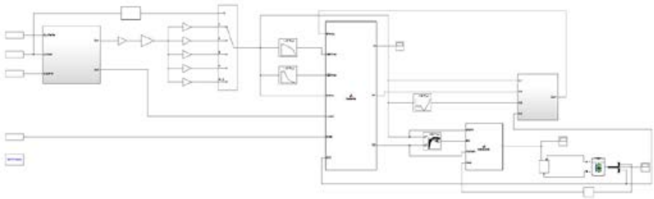

Fig. 12 *Parallel hybrid vehicle model*

The primary inputs to the simulation are the measured values of velocity, acceleration, grade and brake signal from the real driving cycle. These values enter into the subsystem for calculating demand power. The demand power is calculated by tractive effort such as rolling resistance, aerodynamic drag, grading resistance and inertia resistance. To calculate tractive effort is necessary to choose the weight of the vehicle, the coefficient of rotating parts, rolling resistance coefficient, frontal vehicle area, aerodynamic drag coefficient and air density.

Internal combustion engine is created by Lookup tables. In these lookup tables is insert performance characteristics and specific fuel consumption characteristic of engine.

Electric motor is also created by Lookup tables in which are motor efficiency characteristic (see Fig. 13) and power characteristic.

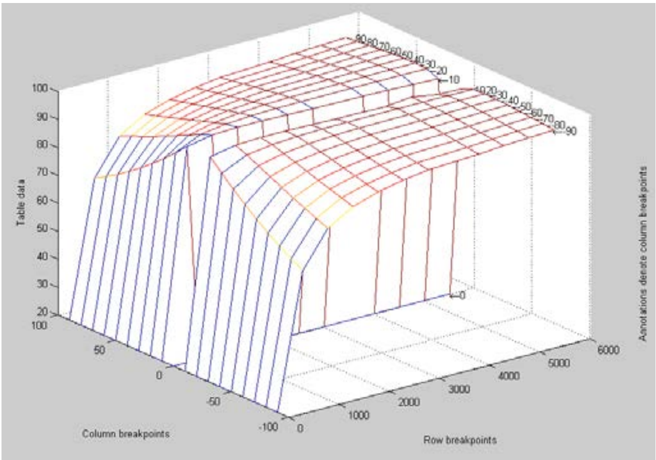

Fig. 13 *Electric motor efficiency*

For byttery simulation is choosen battery block from SimScape library. The Battery block implements a generic dynamic model parameterized to represent behavior of rechargeable batteries.

Parallel hybrid drivetrain has transmission. Gear shifting is determined by vehicle velocity.

Charging system determine demand value of current as input to battery. Maximum current value is controlled.

Control management system is defined in Matlab Function block. Control management system control the complete vehicle based on SOC (State Of Charge), demand power and other criteria's.

Main output from simulation is value of SOC and fuel consumption.

4. Simulation with various components

A key factor in hybrid vehicles is correctly dimensioned size of key components such as traction electric motor, internal combustion engine and batteries. For comparison are chosen 8 city vehicles (see Table 2) for two passengers with different main component size. Six vehicles are with serial drivetrain and two with parallel drivetrain.

Series hybrid has 15kW traction electric motor, which is same for all 6 vehicles. For comparison are choose three internal combustion engines and two battery packs. Three spark ignition engines with displacement of 120, 280 and 505 cm^3 are selected. Two 240V NiMH battery packs have capacity 34Ah and 8.5Ah.

Two parallel hybrid vehicles have combustion engine with 505cm^3 displacement, 10kW electric motor and 5 speed automatic transmission. Difference between vehicles is in different battery packs with 34Ah and 8.5Ah.

In total vehicle weight is included 75kg weight of passenger and 15kg of luggage.

***Table 2:** Vehicle comparison*

	Hybrid drivetrain	Engine [cm^3]	Engine weight [kg]	Battery pack [Ah]	Battery weight [kg]	Total weight [kg]
Vehicle1	series	505	49	34	180	669
Vehicle2	series	280	30	34	180	650
Vehicle3	series	120	13	34	180	633
Vehicle4	parallel	505	49	34	180	709
Vehicle5	series	505	49	8.5	45	534
Vehicle6	series	280	30	8.5	45	515
Vehicle7	series	120	13	8.5	45	498
Vehicle8	parallel	505	49	8.5	45	569

Control strategy series hybrid vehicles

Internal combustion engine operates in one revolution mode where is the best specific fuel consumption. The operation of combustion engine is controlled by SOC. If the SOC reaches preset bottom line combustion engine is turned on. When SOC reches preset top line where is battery fully charged engine is turned off[1].

Control strategy of parallel hybrid drive

In this strategy is effort to combustion engine is workiing in areas with best efficiency. If the SOC is higher than preset value and load of combustion engine is low, the elctric motor supply demand power. Also electric motor supply demand power in low speeds when the SOC is high. When the SOC reaches the bottom line combustion engine deliver more power then is demand and excess power is used to charging battery.

Vehicles are compared by their range. For comparison each vehicle consume one liter of petrol during the simulation. Due to the fact that it is a plug-in hybrid, it is important to compare vehicle with fully charged and discharged battery. In the Fig. 14 and Fig. 15 you can see fully charged vehicles and in the Fig. 16 and Fig. 17 discharged vehicles. It should be noted that due to the battery life can not be discharged to 100%.

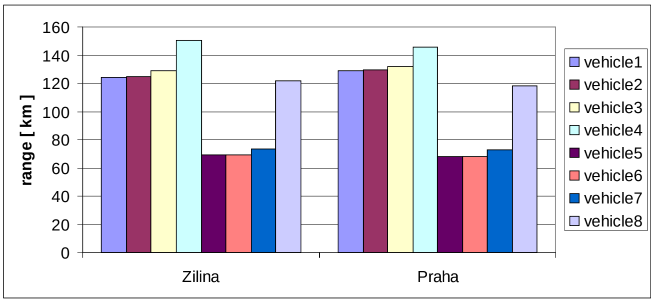

***Fig. 14** Comparison of fully charged vehicles*

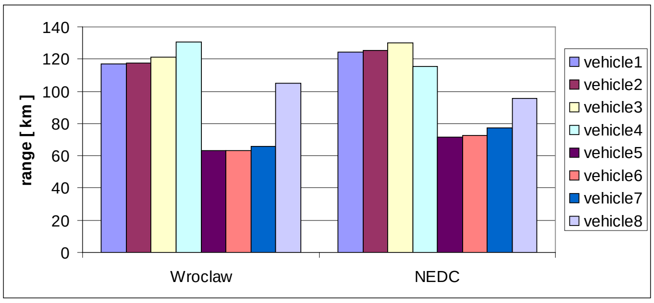

***Fig. 15** Comparison of fully charged vehicles*

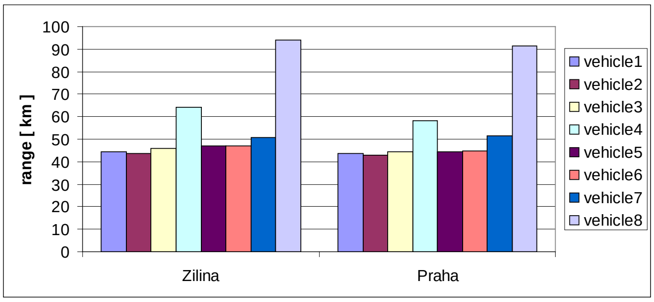

***Fig. 16** Comparison of discharged vehicles*

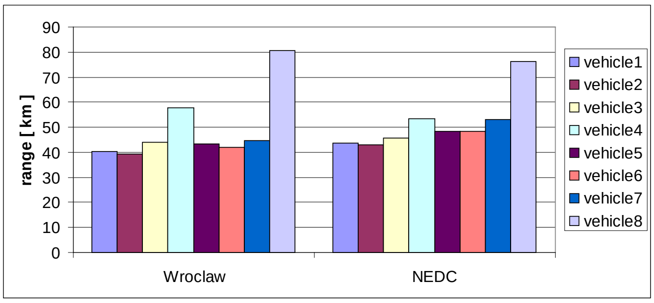

***Fig. 17** Comparison of discharged vehicles*

5. Conclusion

As you can see in the Fig. 4 and Fig. 5 the greatest range have fully charged vehicles with 34Ah battery pack. Situation is changing with the discharged battery, where the vehicle with heaviest 34Ah battery pack needs to make more power due to the increased weight of the vehicle. In comparison of hybrid drivetrains better result has parallel drivetrain. However combustion engine in serial hybrid drivetrain operate in one revolution with the best specific fuel consumption, multiple energy conversion decrease vehicle range in comparison of parallel hybrid drive train. The advantage of series hybrid is short distance driving, when the vehicle is propelled only by the electric engine therefore vehicle doesn't produce any local emissions.

References

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This paper is prepared with the support of the project EUREKA E! 6726 LOADFIX and the company OLTIS Group.