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INFLUENCE OF USING A HYBRID ELECTRIC POWERTRAIN COMBINED WITH AN ICE VARIABLE DISPLACEMENT IN AUTOMOTIVE ARCHITECTURE

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Abstract: *Using internal combustion engines in driving auto vehicles depends on natural resources such petrol and gas, which have a significant environmental impact. Facing EURO5 and EURO6 demands it is need to improve fuel consumption and decrease harmful emissions. The most automotive manufacturers had developed new propulsions systems, as hybrid powertrains, to ensure the new regulations demands to reduce climate change by improving fuel economy. Using both an internal combustion engine and electric motor many research can be done to develop and optimize a hybrid electric vehicle.*
This paper aims to create different architectures for hybrid electric vehicles and to simulate their behavior during NEDC, using AMESim software, trying to find out the advantages and the disadvantages of a HEV.
Keywords: *HEV, automotive, powertrain, CO_2 emissions, fuel consumption*

1. INTRODUCTION

Automotive original equipment manufacturers (A-OEMs) in Europe are now facing the challenge of reducing CO_2 emission from cars apart from the Euro norms. Aiming to reduce harmfull emissions A-OEMs are developing new systems such as hybridization, using all-electric powertrains, engine downsizing and many new technlogies. Some of A-OEMs has combined these systems and has obtained great results regarding fuel economy and less emission. Hybrid electric vehicles (HEV) have gained momentum and have proved to be the most efficient method to reduce tailpipe CO_2 emissions when the engine benefits of a variable displacement.

A hybrid propulsion system contains two or more power sources: the conventional internal combustion engine and one or more mechanical sources capable to develop mechanical torque at the driving wheels. While braking or decelerating the hybrid system is able to recover a part of the kinetic energy. The usual second drive system is an electric one, but it can easily be of any kind of nature, as pneumatical, hydraulical or mechanical. The energy is stored in the fuel reservoir and electrical batteries, also in super-capacitors, kinetic (flywheels) or hydraulic accumulators (Oprean, 2003).

In this paper it have been developed the usual hybrid electrical system containing two power sources, the ICE and the electric motor. Depending on the connection architecture between the engine and the electric motors there are two different basic configurations:

a)-series transmission systems;

b)-parallel transmission systems with:

- one axle driven;
- both axles driven (i.e.: through-the-road=TTR).(Croitorescu et al., 2009, a)(Kawata 2004)

The variable displacement of the internal combustion engines is given by cylinder deactivation. Cylinder deactivation is part of a tool kit that the auto industry is using to improve fuel economy and reduce to CO_2 emissions. This technology helps the engine to seamlessly operate on a reduced number of cylinders under light conditions. Using cylinder deactivation develops a way to reduce the number of active cylinders under light load conditions or when the electric motor ensures most of the work. Cylinder deactivation saves fuel by deactivating cylinders when they are not needed. (Neguresc u et al., 2001)

Disconnecting cylinders, in other words deactivating some of them at partial load, leads to savings of fuel consumption by 10 to 15%. This technology was been introduced a few years ago in large engines (V12 and V8) and has been applied more recently in a V6 engine having a displacement of 3.5 liters. In the future, its application could be extended to 4-cylinder in-line engines, representative of the great majority of European applications, provided that a way can be found to relieve the problems of vibration and roughness resulting from the deactivation.

2. MODEL AND SIMULATION PARAMETERS

The HEV with variable displacement of the ICE was simulated using the AMESim software tool. Developing the model for simulation consists in linking submodels from various software libraries. The submodels are shown as icons. After linking the icons (which represent each component of the vehicle) in sketch mode and choosing the proper submodel in submodel mode, the parameters will be set. Each icon covers a fragment of C code, written using the specific equations for the system. (Croitorescu et al., 2009, b)

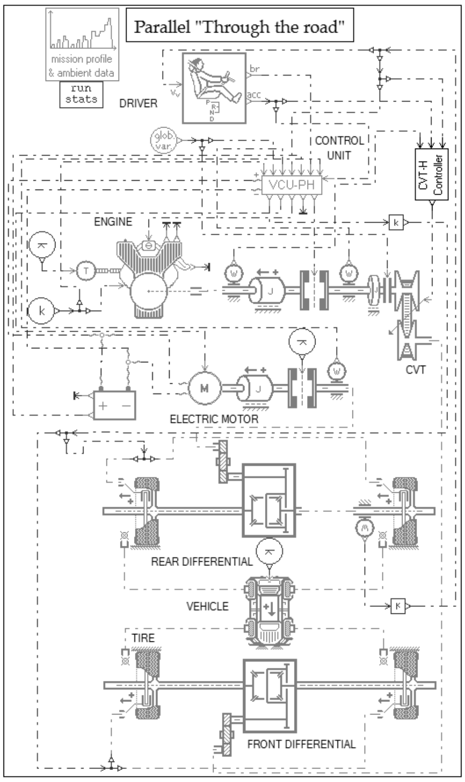

Fig.1. Model of the HEV equipped with a variable displacement ICE

Parallel `through the road` hybrid (TTR) uses the internal combustion engine with variable displacement and the electric motor placed on different axles (Croitorescu et al., 2008). For the front wheel drive the transverse powertrain arrangement remains unchanged. In addition, the rear axle is driven by an electric motor (fig.1).

The parameters used in the simulation are shown in Table 1.

Submodel	Parameter	Value / Unit
Engine	Type	ICE-Spark Ignition
	Displacement	3456 cm^3, 576cm^3/cylinder
	Maximum power	218 kW / 6400 rev/min
	Maximum torque	368 Nm / 4400 rev/min
	Low threshold for engine temperature	20 ^{0}C
	High threshold for engine temperature	80 ^{0}C
	Hot engine idle speed	700 rev/min
	Cold engine idle speed	1100 rev/min
	Hot idle consumption	500 g/h
Electric motor	Type	M&G
	Maximum power	25,4 kW
	Maximum torque	275 Nm
	Efficiency	0.85
	Maximum rotary velocity	9147 rev/min
Battery	Voltage	288 V
	SOC	0.9
	Cells in series per battery bank	8
	Battery banks in series	30
Transmission type	Continuously Variable Transmission with sequential shift mode	
Vehicle	Kerb weight	1865 kg
	Wheel Inertia (4 wheels)	2,5 kgm^2
	Wheels	215/45R18 99V
	Maximum brake torque	1000 Nm
	Drag coefficient	0,27
	Frontal area	2,14 m^2

Tab.1. The most important parameters used in simulation

3. SIMULATION AND RESULTS

The simulation mode must follow the mission profile defined using tables and it will use the New European Driving Cycle (NEDC). The NEDC consists in the fact that the engine starts at 0 (zero) seconds and the emission sampling begins at the same time. The duration of the cycle is 1180 seconds.

The ECU analyses the driver command (acceleration and braking) in order to minimize the battery consumption, the fuel consumption and CO_2 emissions. During the braking, the electric motor behaves as a generator to charge the battery. Depending on vehicle speed, the electric motor or/and the ICE is used to realize the displacement of the vehicle. Depending on the load given by the driver and the battery`s state of charge the ICE can sustain the electric motor with partial or full torque and power with or without cylinder deactivation. If the optimum power of the ICE is higher than the requested one, when it is working, the difference could be used to charge the battery (LMS Imagine Suite – Tutorials). Three of the cylinders were deactivated when the load value was 30% of the maximum engine load.

Deactivating three of the cylinders won`t harm the behavior of the HEV. The electric motor will provide more torque when three of the cylinders are being deactivated, at the final of the cycle, when the ICE starts.

Evaluating the engine torque in both cases with three cylinders deactivated and, respectively, without deactivated cylinders, shows that the mission of the electric motor to achieve the propulsion meets the requirements of fuel economy and less harmful emissions. The electric motor ensures the displacement of the vehicle during all the NEDC assisted only by 3 from 6 of the ICE`s cylinders

Deactivating some of the cylinders tries to realize fuel economy. The hybrid system does not suffer from these changes, keeping the required properties. Evaluating ECU behavior and considering the regenerating function of the batteries no changes occurred.

It is essential to know the evolution of the fuel consumption depending on the engine load when the cylinders were deactivated. Taking values from 10% to 90% of the maximum engine load (EL in tab.2.) for the moment when the cylinders were deactivated will result the values for the fuel consumption. Following the example above, during last year, there were studied the next cases: hybrid combined with cylinder deactivation (HEVCD), hybrid combined with usual ICE, without deactivation (HEVNCD), ICE with cylinder deactivation (NORCD) and ICE without cylinder deactivation (NORNCD).

	HEVCD		HEVNCD		NORCD	NORNCD
EL	TFC[g]	SOC[%]	TFC [g]	SOC[%]	TFC[g]	TFC [g]
0,1	327,89	88,604	328,13	88,604	688,20	691,62
0,2	311,64	88,604			651,41	
0,3	287,21	88,604			615,76	
0,4	273,84	88,600			576,36	
0,5	263,58	88,600			554,88	
0,6	255,79	88,601			541,15	
0,7	251,24	88,602			535,87	
0,8	248,04	88,603			532,47	
0,9	248,04	88,603			532,61	

Tab.2. Comparing studied cases (TFC=total fuel consumption, SOC=state of charge)

4. CONCLUSION

The model presented in this paper provides an efficient tool for the simulation of a parallel hybrid vehicle associated with cylinder deactivation. It can be used for issues as the development, validation and optimization of the energy strategy, taking into account fuel consumption and pollutant emissions. This model can also be used as an initial application in order to build a more advanced model and to take into account more issues.

For a hybrid electric vehicle, the electric motor and the battery are the core of economically functioning. Associating the cylinders deactivation less fuel consumption and CO_2 emissions will be obtained.

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