Modeling and fuel economy studies of a power steering pump and an air conditioning compressor for hybrid electric vehicles

Modeling and Fuel Economy Studies of a Power Steering Pump and an Air Conditioning Compressor for Hybrid Electric Vehicles

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1 Introduction

The hybridization and electrification of powertrains has greatly entered multiple transport sectors in the last decade. To find the optimal design of a vehicle that has more than one power convertor and one energy source is a complex optimization problem. As motivated in more detail in [1], the choice of the optimization algorithm and the definition of the problem will strongly influence the resulting power train. Beside the main components that are used for vehicles propulsion, also important energy consumptions are given by the auxiliaries present in the system. The goal of this research is to analyse the influence of the electrification of auxiliaries on fuel consumption and drive efficiency. The focus here will be on the modeling and fuel economy analysis of the power steering pump (PSP) and air conditioning compressor (ACC).

2 Modeling of auxiliaries units

In [2] it is shown that the energy utilization of auxiliaries in hybrid electric vehicles can be improved, compared to a mechanical design. In order to analyse the fuel economy impact of these auxiliaries the physical models are required. The models are built from physical principles with parameters identified from various tests, as schematically depicted in Fig. 1, resulting in so called gray-box models. In these models the parameters cannot be usually assessed from experimental data alone. Here the modeling of the PSP and the ACC (see Fig. 2) are described. The prime goal of this investigation is to enable studying the effects on the fuel economy from alternative designs of sub-systems. This design can vary in terms of the control algorithms or in terms of topology and technology selection. A validation of the total model is performed and shows that the model is capable to capture the main dynamics of auxiliaries systems quite well.

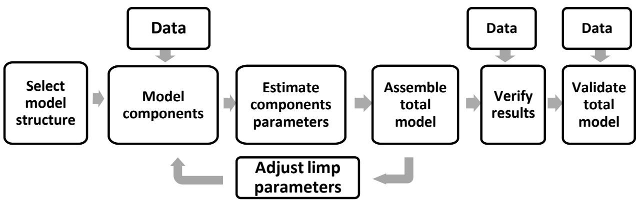

Figure 1: Sequential modeling and identification procedure

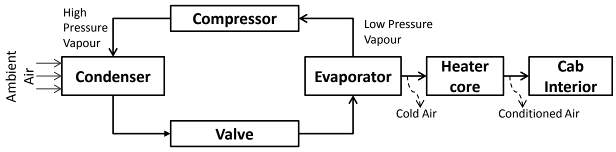

Figure 2: Block diagram of the ACC system

3 Control concepts for fuel efficiency studies

The fuel economy benefit from the electrification of the power steering pump is possible as a result of removing excess hydraulic losses, mechanical losses and a better control of the system. As a primary step, the conventional, rule-based, control design applied to the simplified model of the power steering pump is evaluated. The influence on fuel consumption of having different control parameters for the components irrespective of engine speed dependency are show in this paper. Decreases up to 50% of sub-system fuel consumption can be found for the PSP, under given conditions.

4 Results, conclusions and future work

Within this study it is shown that for both PSP and ACC systems significant improvements can be achieved by electrification. This first step, in independently controlling the auxiliary units, enables a first glance on what could be achieved with more sophisticated control strategies as optimal control. Furthermore, given the freedom brought by the electrification of these components, topologies selection studies can be made (see Fig. 3 for three examples of possible topologies).

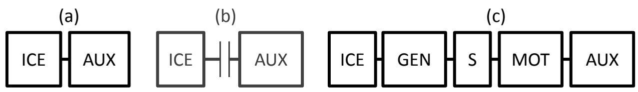

Figure 3: Topology concepts for auxiliary systems (ICE = Internal combustion engine; AUX = Auxiliary unit; S = Storage device; GEN = Generator; MOT = Motor)

References

[1] Emilia Silvas, Theo Hofman, and Maarten Steinbuch. Review of optimal design strategies for hybrid electric vehicles. *IFAC Workshop on Engine and Powertrain Control, Simulation and Modeling*, 3(1):57–74, 2012.

[2] N. Pettersson and K. H. Johansson. Modelling and control of auxiliary loads in heavy vehicles. *International Journal of Control*, 79(5):479–495, 2006.