

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

Citation for published version (APA):

Silvas, E., Turan, O., Hofman, T., & Steinbuch, M. (2013). Modeling and fuel economy studies of a power steering pump and an air conditioning compressor for hybrid electric vehicles. In *Proceedings of the 32st Benelux Meeting on Systems and Control, March 26-28, 2013, Houffalize, Belgium* (pp. 27-27)

Document status and date:

Published: 01/01/2013

Document Version:

Accepted manuscript including changes made at the peer-review stage

Please check the document version of this publication:

- A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
- The final author version and the galley proof are versions of the publication after peer review.
- The final published version features the final layout of the paper including the volume, issue and page numbers.

[Link to publication](#)

General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal.

If the publication is distributed under the terms of Article 25fa of the Dutch Copyright Act, indicated by the "Taverne" license above, please follow below link for the End User Agreement:

www.tue.nl/taverne

Take down policy

If you believe that this document breaches copyright please contact us at:

openaccess@tue.nl

providing details and we will investigate your claim.

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

Emilia Silvas, Omer Turan, Theo Hofman, Maarten Steinbuch

Department of Mechanical Engineering, Technische Universiteit Eindhoven, P.O. Box 513, 5600 MB Eindhoven, The Netherlands

Email: e.silvas@tue.nl

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 converter 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

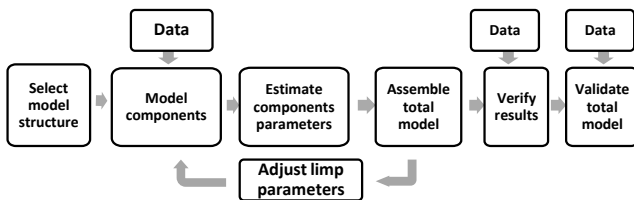


Figure 1: Sequential modeling and identification procedure

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.

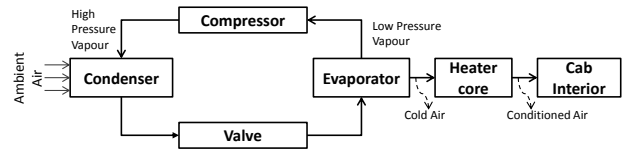


Figure 2: Block diagram of the ACC system

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 shown 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.