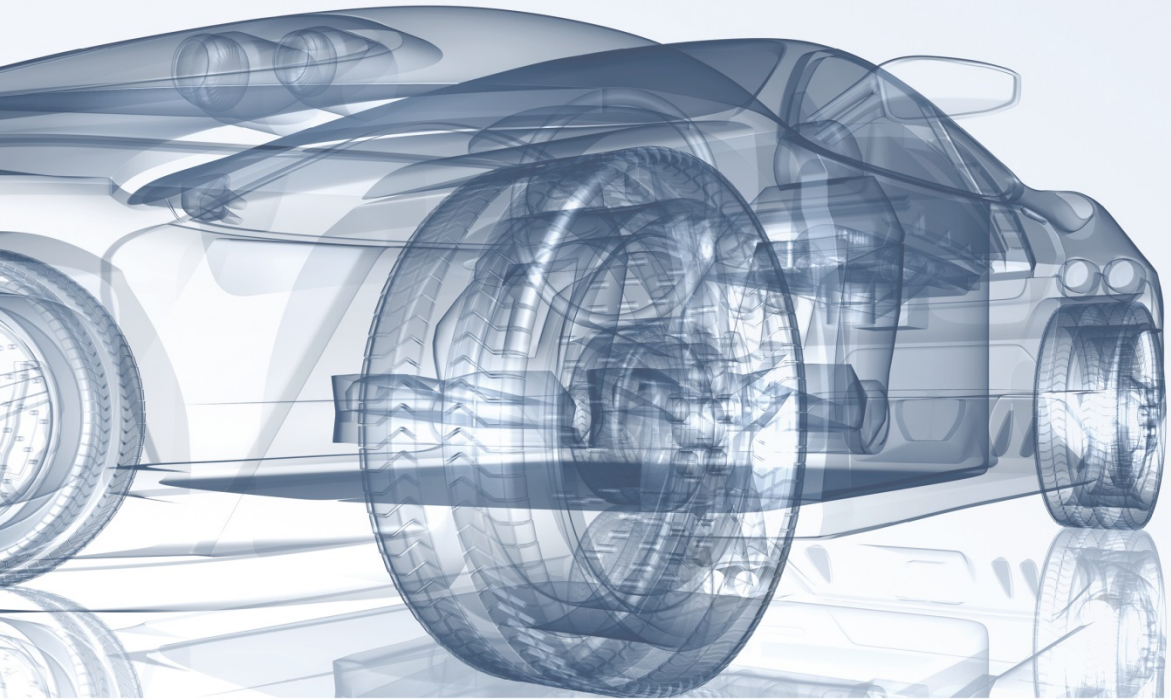
evs 30



The 30th International
Electric Vehicle
Symposium & Exhibition

October 9–11, 2017

Messe Stuttgart, Germany

www.evs30.org

Sponsored by

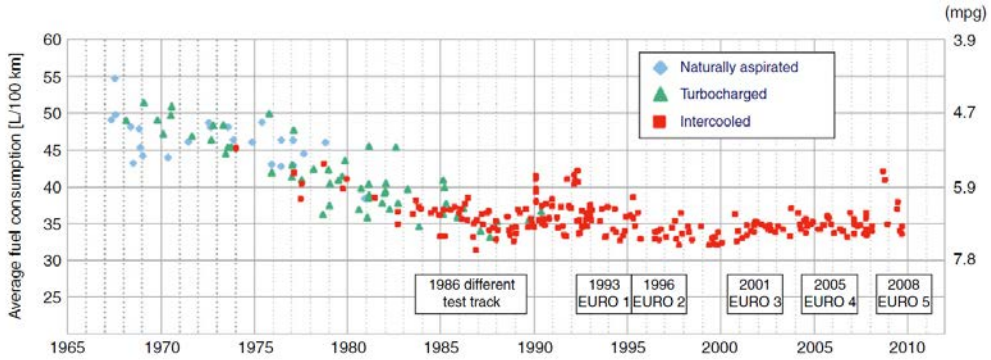
DAIMLER BOSCH Invented for life GROUPE RENAULT MAHLE EnBW PORSCHE swarco

Auxiliary Model Review for Design Analysis of Hybrid Electric Heavy-Duty Long-Haul Vehicles

ir. F.J.R. Verbruggen
dr.ir. T. Hofman
V. Anil Kumar

Introduction

- Current emission regulations:
  - Reduction of PM and NOx emissions
  - Constant fuel consumption



- Future emission regulations:
  - Reduction of CO2 emissions/ fuel consumption

[1]

→ Shift of focus of powertrain design to CO2 emission reduction

[1] ACEA. Commercial vehicles and CO2. Technical report, 2011.

Introduction

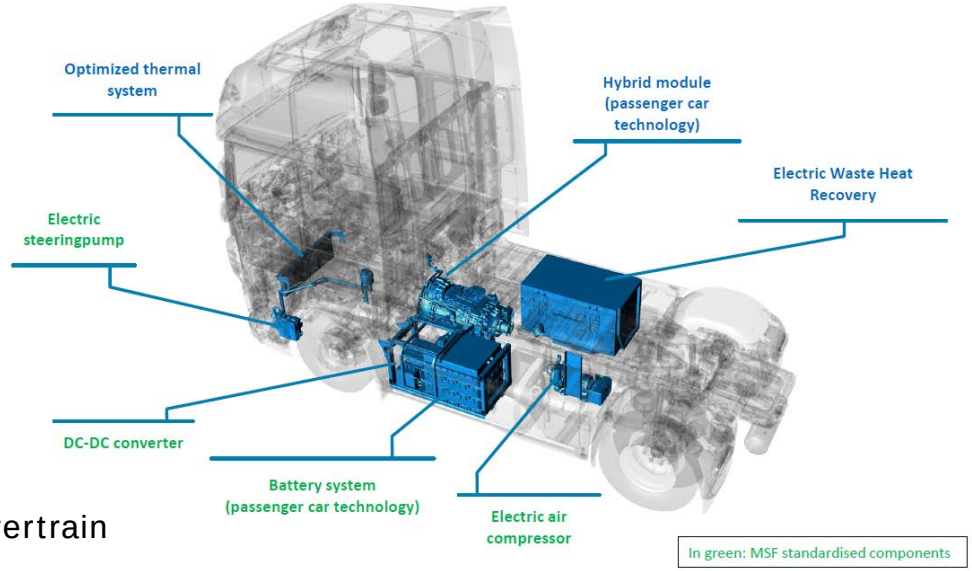
- Solutions for CO2 emission reduction:
  - Electrification of vehicle powertrain (hybridization)
    - HEV
    - PHEV
  - Electrification of auxiliary components
    - Electric Power Steering (EPS) / Electric Hydraulic Power Steering (EHPS)
    - Electric Air Compressor (EAC)
  - Waste heat recovery system
  - Etc..

Introduction

- Project ECOCHAMPS
  - Part of Horizon 2020
  - 25 project partners

- Project goal:
  - Development hybrid powertrains for passenger cars and commercial vehicles.

- Aimed project results:
  - 20% Powertrain efficiency improvement
  - 20% weight and volume reduction of Powertrain
  - Modular pre-standard format (MSF) for components of commercial vehicles



[2]

[2] http://www.ecochamps.eu

Presentation Content

- Introduction
- Powertrain design analysis
  - Design optimization
  - Integrated optimization
- Design analysis models
- Model review of:
  - Electric hydraulic power steering (EHPS)
  - Electric air compressor (EAC)
- Future research directions

Powertrain design analysis

- Powertrain design analysis:
  - Evaluate current design of powertrain
    - Fuel/ Cost/ Performance
  - Compare to optimal powertrain design

- Powertrain design optimization:
  - Optimize design of powertrain of the vehicle

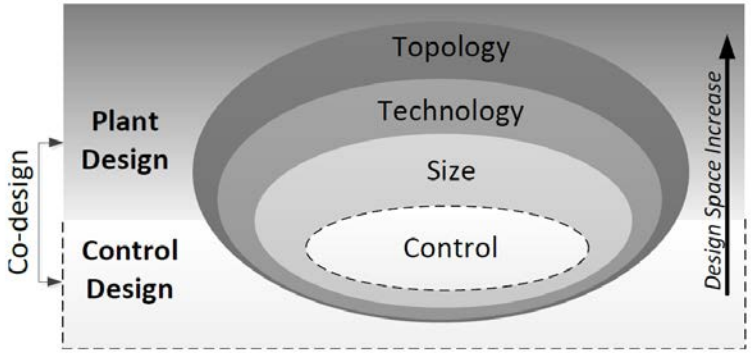
  → Gives optimal powertrain design

- Both require design analysis models:
  - Models that scale the components performance with component size

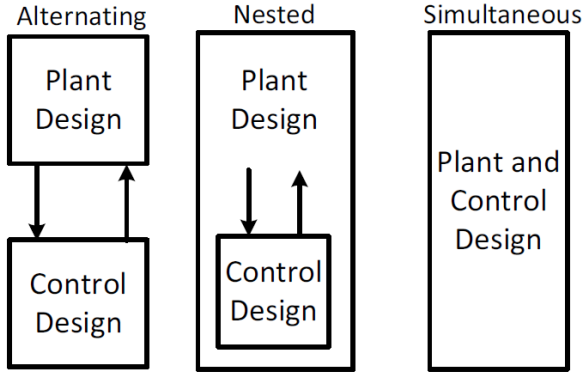
Powertrain design optimization

- Multiple levels
- Different methods to find optimum

- Current approach:
  - Based on past experience
  - Alternating
- Ideally:
  - Explore all possibilities
  - Nested or simultaneous
    - Else cannot guarantee optimal solution



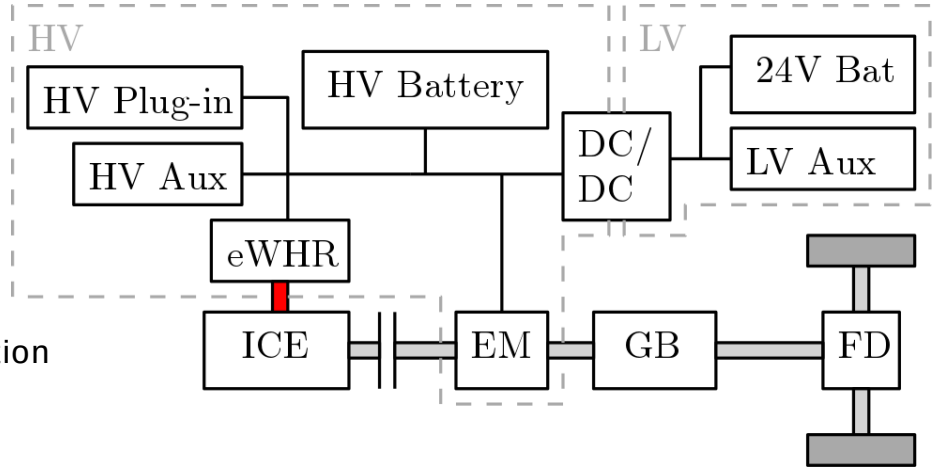
[3]



[4]

Integrated powertrain design

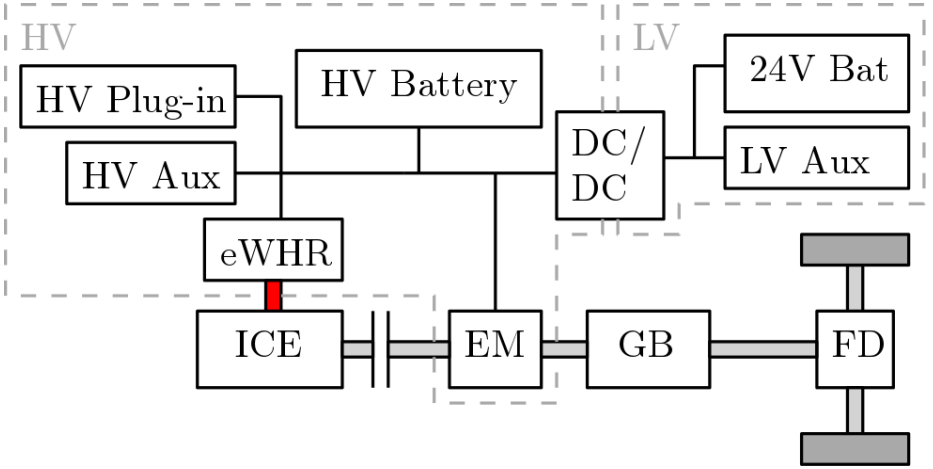
- WHR highly integrated with ICE
- Current approach:
  - One component at a time
- Ideally:
  - Integrate all components in design optimization



[5]

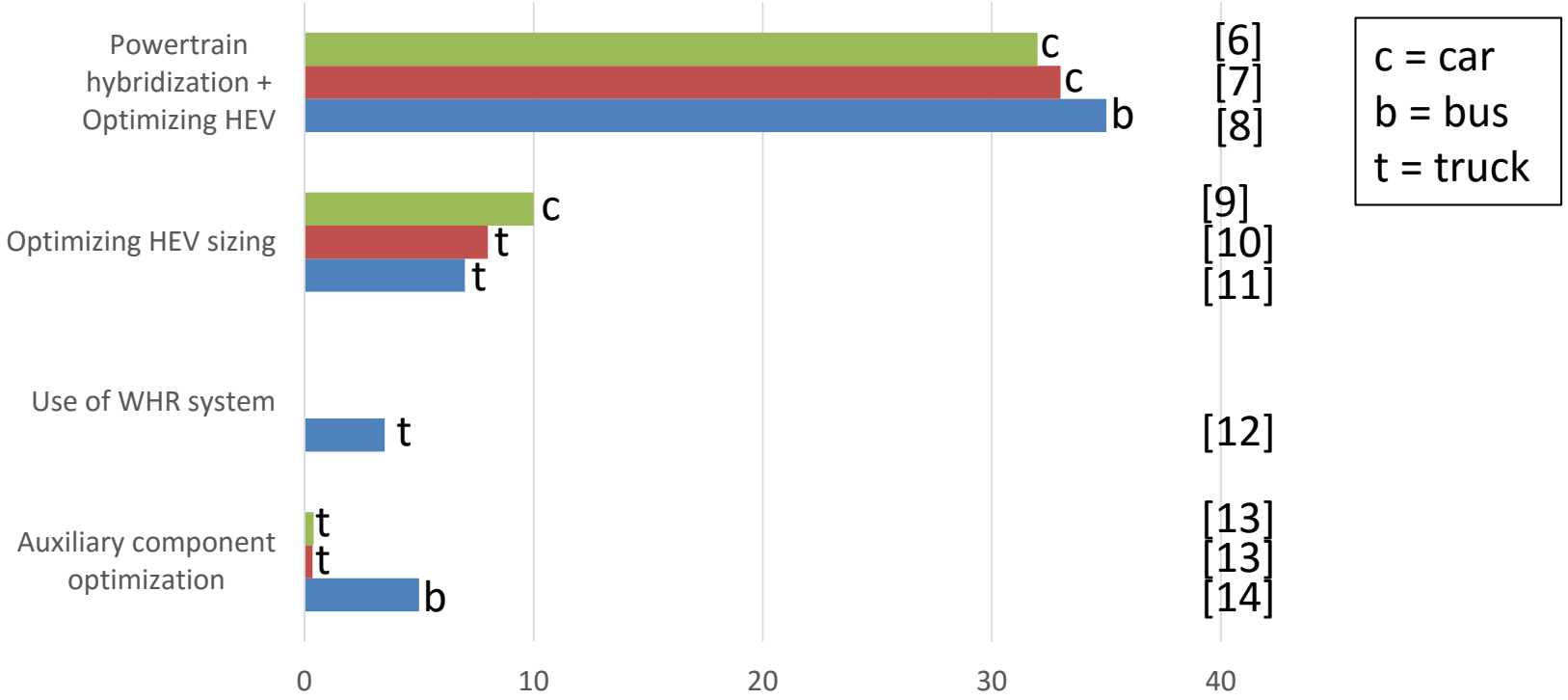
Design analysis models

- Scale the performance with component size/ sizing variable
- Currently taken into account:
  - ICE
  - EM
  - BAT
  - GB
- Next step, integrate:
  - Auxiliaries
  - WHR system
  - Air conditioning
  - Cooling system



[5]

Estimated fuel savings



For a truck 1% savings is roughly 500 L/year, 650 €/year

Model review

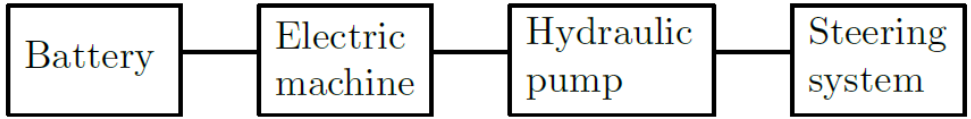
- Reviewed models for:
  - Electric hydraulic power steering
  - Electric air compressor

- Models divided in three main types:
  - Empirical
    - Based on measurement data, do not scale
  - Semi-empirical
    - Combination of both
  - Physical
    - Based on physical relations

Electric hydraulic power steering

- Currently available models
  - Either empirical (do not scale with size)
  - Or physical (too much sizing parameters)

- Models all lack:
  - Scalable models of hydraulic pump
  - Minimal number of scaling variables



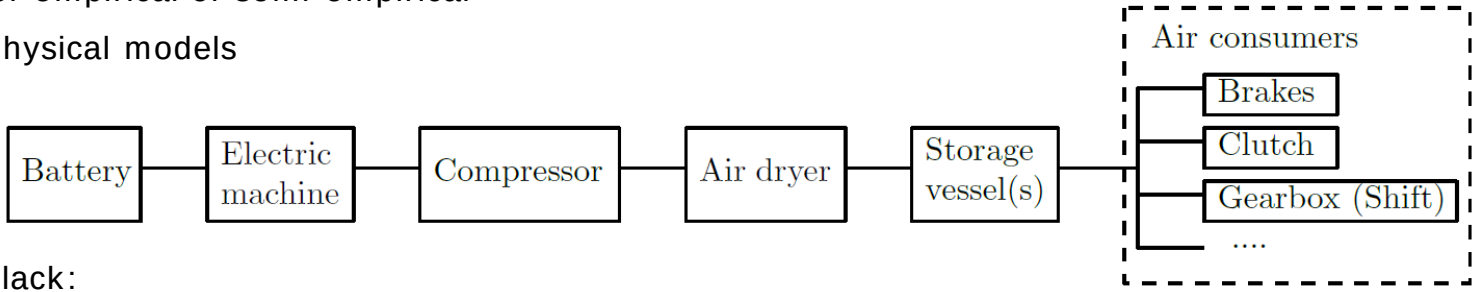
[15]

- Most research focuses on:
  - Fuel consumed by power steering

- Focus for future modeling should be:
  - Hydraulic pump

Electric air compressor

- Currently available models
  - Either empirical or semi-empirical
  - No physical models



- Models all lack:
  - Scalable air compressor models
  - Air consumer models, based on gear shifting and braking

[15]

- Focus for future modeling should be:
  - Air compressor
  - Air consumers

Future research directions

- Other Auxiliaries
  - Air conditioning
  - (Alternator)
  - DCDC converter
- Waste heat recovery (WHR)
  - Promising solution for the future
  - Interesting to investigate influence on optimal design
  - Highly integrated with the ICE
- Thermal domain
  - Cooling circuits

Questions

References

[1] ACEA. Commercial vehicles and CO2. Technical report, 2011.

[2] http://www.ecochamps.eu

[3] E. Silvas, “Integrated Optimal Design for Hybrid Electric Vehicles,” University of Technology Eindhoven, Eindhoven, The Netherlands, 2015.

[4] E. Silvas, T. Hofman, N. Murgovski, P. Etman, and M. Steinbuch, “Review of Optimization Strategies for System-Level Design in Hybrid Electric Vehicles,” *IEEE Trans. Veh. Technol.*, vol. 66, no. 1, pp. 57–70, 2016.

[5] F.J.R. Verbruggen and T.Hofman, “Design sensitivity analysis for heavy-duty hybrid electric trucks with a waste heat recovery system,“ *Vehicle Propulsion and Powertrain Conference*, Belfort, France, Dec, 2017

[6] W.Gao, C.Mi, “Hybrid Vehicle design using global optimization algorithms”, Int. J. Electric and Hybrid Vehicles, vol. 1, no. 1, 2007.

[7] E. Silvas, E. Bergshoeff, T. Hofman, and M. Steinbuch, “Comparison of Bi-level Optimization Frameworks for Sizing and Control of a Hybrid Electric Vehicle,” in *Proceedings of the IEEE Vehicle Power Propulsion Conference 2014*, pp. 1–6 , 2014

References

[8] D. Li, Y. Zou, X.Hu, and F. Sun, “Optimal sizing and control strategy design for heavy hybrid electric truck.” in *Proceedings of the IEEE Vehicle Power and Propulsion Conference 2012, pp. 1100-1106, 2012.*

[9] S. Ebbesen, P. Elbert, and L. Guzzella, “Engine Downsizing and Electric Hybridization Under Consideration of Cost and Drivability,” *Oil Gas Sci. Technol. -- Rev. IFP Energies Nouv.*, vol. 68, no. 1, pp. 109–116, 2013.

[10] E. Vinot, R. Trigui, B. Jeanneret, J. Scordia, and F. Badin, ”EVs comparison and components sizing using dynamic programming.” in *Proceedings of the IEEE Vehicle Power and Propulsion Conference 2007.* pp. 314-321, 2007.

[11] C. Desi, S.S. Williamson, “Optimal design of a parallel hybrid electric vehicle using multi-objective genetic algorithms,” in *Proceedings of the IEEE Vehicle Power and Propulsion Conference 2009,* p. 871-876, 2009

[12] E. Feru, N. Murgovski, B. de Jager, and F. Willems, “Supervisory control of a heavy-duty diesel engine with an electrified waste heat recovery system,” Control Engineering Practice, vol. 54, pp. 190–201, 2016.

References

[13] E. Silvas, O. Turan, T. Hofman, and M. Steinbuch, “Modeling for control and optimal design of a power steering pump and an air conditioning compressor used in heavy duty trucks,” in *Proceedings of the* IEEE *Vehicle Power Propulsion Conference 2013*, pp. 218–223, 2013.

[14] C. Andersson, On auxiliary systems in commercial vehicles. Ph.d. dissertation, Lund University, Lund,Sweden, 2004.

[15] F.J.R. Verbruggen, T.Hofman, and V. Anil Kumar , “Auxiliary Model Review for Design Analysis of Hybrid Electric Heavy-Duty Long-Haul Vehicles,“ *30th Electric Vehicle Symposium*, Stuttgart, Germany, Oct, 2017