Model-Based Powertrain Design for Fuel Cell Electric Vehicles

HEV 2017 – Hybrid and Electric Vehicles
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Agenda

- Introduction
- Definition of boundary conditions
- Simulation results
- Conclusion
Introduction

Model-Based Powertrain Design for Fuel Cell Electric Vehicles
Investigation goals and approach

**Basis:**
- Fuel cell vehicle simulation model
  - Modular vehicle layout
  - Fuel cell stack and system
  - Operation strategy: ECMS – power split to minimize \( \text{H}_2 \) consumption

**Task:**
- Varying fuel cell system and battery size

**Key assessment:**
- \( \text{H}_2 \) consumption
- Range
- Performance
Definition of boundary conditions

Model-Based Powertrain Design for Fuel Cell Electric Vehicles
Selected fuel cell and battery size

5 feasible variants

Fuel cell* system size

H2 tank: 5kg
H2 tank: 2.5kg

Performance!

Battery size

A: HEV
B: PHEV
C: REX - 10kWh
D: REX - 18kWh
E: REX - 27kWh

30kW (Range Extender)

110kW (Full size fuel cell)

Costs!

*Fuel cell system located in vehicle front-end
Vehicle weight

Big differences in vehicle weight
Driving cycles

WLTC, class 3
- Cycle for homologation
- Top speed: 131.42km/h
- Max Acceleration: 1.75m/s²

Berlin cycle
- Real driving cycle
- Top speed: 126.01km/h
- Max Acceleration: 2.58m/s²

BAB 130
- Performance cycle
- Top speed: 130.62km/h
- Max Acceleration: > 1g
Simulation results

Model-Based Powertrain Design for Fuel Cell Electric Vehicles
Efficiency comparison fuel cell stack and fuel cell system

Efficiency advantages for enlarged fuel cells at medium loads
Operating parameters and operation strategy important for system efficiency
ECMS based power split example
in WLTC for Variant A: HEV

→ Optimum power split for a minimal H₂ consumption due to IAV´s ECMS
ECMS based efficiency comparison example in BAB cycle for variant A: HEV and B: PHEV

- HEV: More energy converted in higher operating points
- PHEV operates in points with higher efficiency
Energy consumption results

Small differences in $\text{H}_2$ consumption as IAV’s ECMS provides optimum results

REX variant C with the 10kWh battery delivers good results in WLTC and BC despite high fuel cell load due to lowest weight

All REX variants are not able to provide equal SOC in BAB cycle
## Range results

### Overall comparison:
- **PHEV** with best range
- **But**: REX with 10kWh battery with best results in city and homologation cycles
- **REX variants D and E** are limited due to small H₂ tank

### Range [km]

<table>
<thead>
<tr>
<th>Category</th>
<th>A: HEV</th>
<th>B: PHEV</th>
<th>C: REX - 10kWh</th>
<th>D: REX - 18kWh</th>
<th>E: REX - 27kWh</th>
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</tbody>
</table>

- **Range combined**
- **Pure battery range**
- **Additional hydrogen range (performance loss)**

* HEV with H₂ range only (no external recharging)
Required cooling results

Average propulsion power and cooling power for the sections with maximum acceleration in BAB

→ REX variants have big advantages in maximum cooling sections
Performance results

Comparison of powertrain performance in acceleration section of BAB Cycle*

* Reminder: Optimization on best H\textsubscript{2} consumption

→ Best performance with biggest battery

→ Full size fuel cell can not generate the power as fast as batteries

→ Full size fuel cells compensate the lack at beginning in later stage

→ REX variants C and D loose momentum in the later stage due to lower power
Conclusion

Model-Based Powertrain Design for Fuel Cell Electric Vehicles
Assessment of range and hydrogen consumption (bubble size) including performance ranking

→ REX variant with 27kWh battery provides the best performance with midlevel range
→ PHEV variant is a good compromise between range and performance
→ REX variant with 10kWh provides best range with some disadvantages in performance, but could be a good solution for city and mid performance usage (e.g. countries with highway limits)
Outlook

Optimization targets
• $H_2$ consumption
• Range
• Performance Index

Constraints
• Costs
• Package

Multi objective optimization

Inputs
• Vehicle layout
• Fuel cell layout
• Derating
• (Degradation)
• Operation scenarios/cycles
• Limiting conditions
• Additional parasitic losses

Results
• Fuel cell system size
• Battery size
• Operation strategy
Thank you

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