Influences of different heating concepts for the energy demand of an airfield luggage tug

4. VDI-Fachkonferenz

Thermomanagement für elektromotorisch angetriebene PKW

24. November 2015
Dipl.-Ing. Michael Schmitt
Agenda

1. **Motivation**

2. **Approach of heating concepts**
   1. Total vehicle simulation model in Dymola
   2. Design and validation of thermal cabin model
   3. Driving cycle
   4. Power and energy demand
   5. Simulation results of different heating concepts

3. **Summary and Conclusion**
Motivation
The aim in this project is to design a FC luggage tug based on a powertrain of the BEV.

Status quo: Battery Electric Vehicle (BEV)
- Dead weight: 4 t
- 50 kWh lead-acid battery
- $P_{EM,peak} = 30$ kW
- $v_{max} = 30$ km/h
- $P_{PTC,peak} = 1.5$ kW

Aim: Fuel Cell powered luggage tug (FCV)
- 8 kWh li-ion battery
- 20 kW fuel cell
- 3 kg hydrogen
- Same power train as BEV
- *Usage of the waste heat from the FC*
Approach: Total vehicle simulation model
Simulations models of the DLR-AlternativeVehicles (blue) and the thermal cabin model (red)
Approach: Design and validation of thermal cabin model

Thermal cabin as used in simulation (flatplan) and for imagine in 3D-design
Approach: Design and validation of thermal cabin model
Measuring of heating-up power, air temperature and air mass flow with the cabin mockup

Measurement concept:
- According to DIN 1946
- Additional requirements

Sensor integration:
- Air temperature
- Air mass flow rate
- Power PTC heater
Approach: Design and validation of thermal cabin model
Comparison of the simulation results and the measured temperatures in the cabin

- 2 K Variation of real and simulated temperatures cause of the temperature stratification
- Inlet of heated air in head space outlet to air heater in footwell
Approach: Driving cycle
Define of a real life driving cycle for a luggage tug of measured speed profiles

Raw data:
• Project eFleet, electric apron vehicles at the airport Stuttgart
• Measuring of energy consumption of different apron vehicles

Define speed cycle for luggage tug:
• Distance: 3.2 km
• Duration: 1300 sec
• \( v_{\text{mean}} = 18 \text{ km/h} \)
• \( v_{\text{max}} = 29.5 \text{ km/h} \)
Approach: Power and energy demand
Energy demand for one driving cycle and for the 8h shift operation

Simulation results for one cycle:
- $E_{\text{tract}} \sim 1.1 \text{ kWh}$
- $E_{\text{spec.,tract}} \sim 34.4 \text{ kWh}/100\text{km}$
- $P_{\text{mean,tract}} \sim 3 \text{ kW}$
- Max Charge: $\sim 5.5 \text{ C}$

Calculated energy for 8h shift operation:
- $E_{\text{tract}} \sim 23.3 \text{ kWh}$
- $E_{\text{waste heat}} \sim 25 \text{ kWh}$
Approach: Simulation results of different heating concepts

Functional design and the simulated results for the heating power and cabin temperature

(1) PTC

(2) HEX
Approach: Simulation results of different heating concepts

Functional design and the simulated results for the heating power and cabin temperature

(3) PTC + HEX

(4) PTC + HEX + 60l-Storage
Approach: Simulation results of different heating concepts
Power of PTC, of HEX and the cabin temperature for all different heating strategies

Power source for the cabin heating

**PTC**

![PTC Power graph]

**HEX**

![HEX Power graph]

Regulated/adjusting temperature in cabin

![Temperature graph]
Approach: Simulation results of different heating concepts
Resulting energy demand of all four heating concepts for one shift operation (8h)

Lowest energy consumption:
- HEX

Controllability:
- PTC

Cabin temperature:
- PTC+HEX+60l

<table>
<thead>
<tr>
<th></th>
<th>PTC</th>
<th>HEX</th>
<th>PTC+HEX</th>
<th>PTC+HEX+60l</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P_{PTC,\text{mean}}$</td>
<td>1.5 kW</td>
<td>--</td>
<td>1.1 kW</td>
<td>0.6 kW</td>
</tr>
<tr>
<td>$P_{HEX,\text{mean}}$</td>
<td>--</td>
<td>0.75 kW</td>
<td>0.8 kW</td>
<td>1.35 kW</td>
</tr>
<tr>
<td>$E_{PTC}$</td>
<td>12 kWh</td>
<td>--</td>
<td>8.8 kWh</td>
<td>4.8 kW</td>
</tr>
<tr>
<td>$E_{HWT}$</td>
<td>--</td>
<td>6 kWh</td>
<td>6.4 kWh</td>
<td>10.8 kWh</td>
</tr>
<tr>
<td>$T_{\text{cab,mean}}$</td>
<td>11 °C</td>
<td>1 °C</td>
<td>18 °C</td>
<td>19 °C</td>
</tr>
</tbody>
</table>
Summary and Conclusion

Summary:
- Virtual luggage tug created using „Alternative Vehicles“ library in Modelica
- Cabin model validated
- Thermal management system designed and calculated in 4 cases
- Energy demand for shift working derived

Conclusion:
- Usage of fuel cell waste heat lead to:
  - lower energy demand for electric heating
    → less hydrogen consumption
  - higher average cabin temperature using a 60 liter enthalpy storage system