*epsilon newsletter, issue 1/2016*

**2016-05-03**

Dear Sir or Madam,

The complete epsilon drivetrain including its cooling system and the system of Heat Ventilation and Air-Conditioning (HVAC) as illustrated in Fig. 1 has been investigated on the powertrain test rig at VIRTUAL VEHICLE Research Centre (ViF). Several tests have been performed to analyse both the drive system and the HVAC system in order to verify their functionality, performance and efficiency.

| Components \ Concepts | | | *V1_LGBoG*<br>Bosch<br>GKN<br>Kreisel |
|---|---|---|---|
| E-Motor | Type | | Bosch SMG 180 1.3 |
| | max. power | kW | 80 |
| | max. torque | Nm | 200 |
| Transmission | type | | GKN Driveline |
| | ratio | - | 1 : 9.59 |
| | max. torque | Nm | 200 |
| AC-DC - Converter | type | | Bosch InvCon 2.3 |
| DC-DC - Inverter | type | | - |
| Power Distribution | type | | Battery included |
| Charger | type | | Brusa NLG 513 |
| HV Battery | type | | Kreisel 102s15p |
| | Energy content | kWh | 15.9 |
| | discharge | kW | 55 / 82 (15s) |

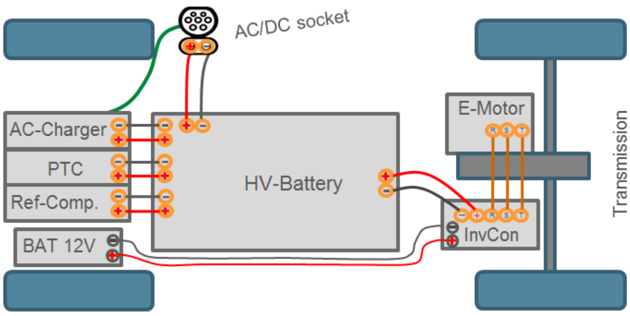


Fig. 1: Drivetrain and cooling components

The results of the test rig correlate very well with those of a preceding driving performance simulation. With the applied battery system a driving range of more than 150 km could be achieved. This means an energy consumption of less than 80 Wh/km. The 80 kW motor can accelerate the vehicle to a speed of 100 km/h within 9 s which can be considered as outstanding for such a small and efficient car.

After a general functionality test in all driving modes (P-R-N-D), the driving performance of the complete drivetrain has been tested. The motor was operated in quasi-stationary points of its map, further tests on the battery (capacity, charging, discharging) have been performed and finally the behaviour of the drivetrain in different driving cycles (NEDC, FTP 75, LA92 and WLPT class 3, see exemplarily Fig. 2) has been tested.

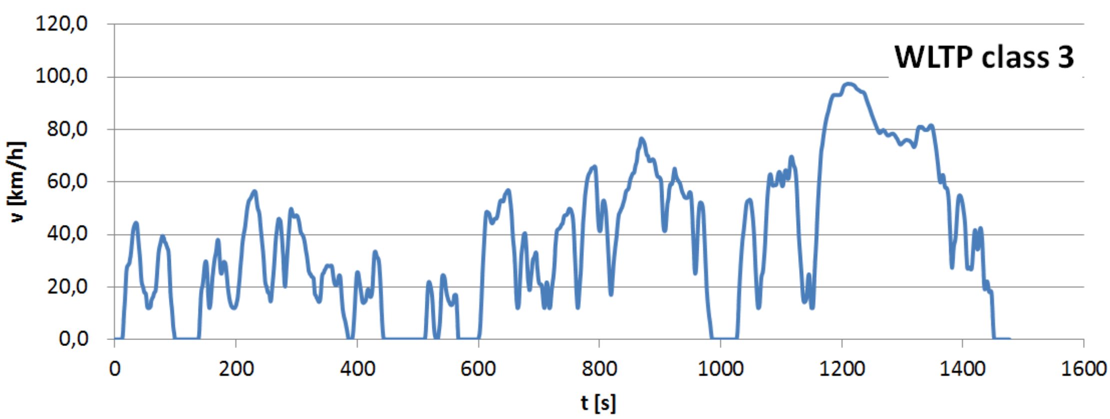


Fig. 2: WLTP class 3 driving cycle

Fig. 3 shows the complete drivetrain and HVAC system on the test rig. The components are arranged in the same way as they will be placed in the prototype vehicle. In the right bottom corner the hose of the air blower can be seen (1). This blower is coupled with the driving simulation and represents the airstream for the driving cycle tests. In (2) the components of the cooling system (HVAC-box, condenser, PTC, refrigerant compressor etc.) are located. The HV battery is located in the middle of the vehicle (3). The electric motor and the inverter are positioned at the rear axle (4). In the picture, the drive unit is enveloped in noise insulation to analyse the acoustic behaviour.

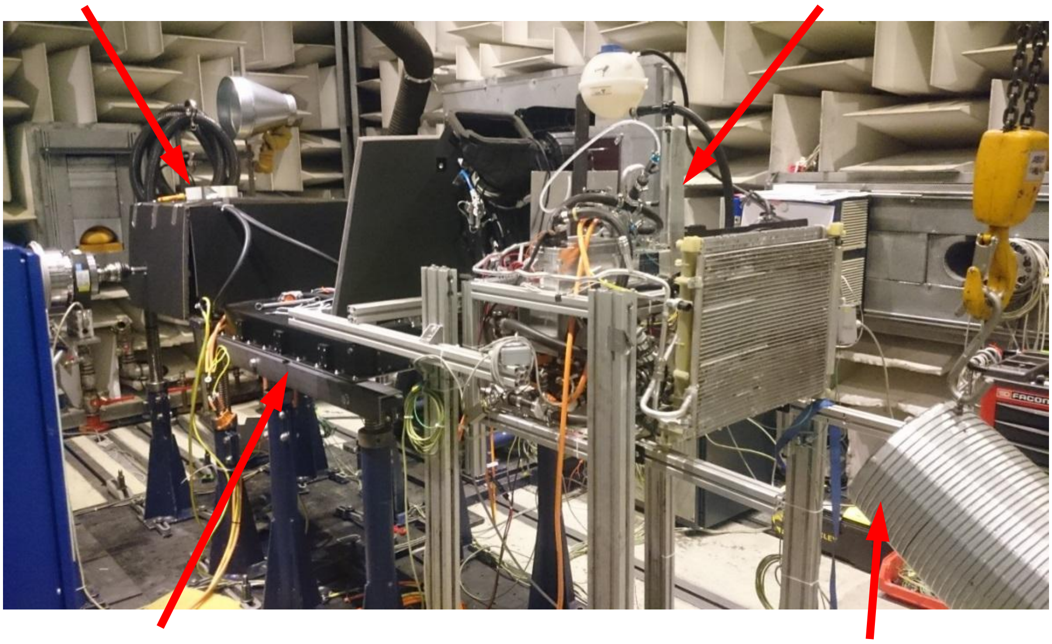


Fig. 3: Drivetrain and HVAC system on the test rig

The tests also determined a driving range of 156 km at a state-of-charge (SOC) swing of 75 % (90 % SOC → 15 % SOC) for the more challenging WLTP driving cycle. This result has been obtained considering a vehicle mass of 675 kg (including a 75 kg driver).

The complete cooling system has been tested in driving mode with and without cabin heating. During the testing phase special attention has been paid to the thermal controller's behaviour and to all relevant temperature profiles of the system during different load cases. The heat input into the cooling system by the electric machine and the inverter/converter (InvCon) has been analysed. The system architecture including some measuring points as it was implemented on the test rig is shown in Fig. 4.

The test results of the thermal behaviour show that all relevant temperatures during one WLTP cycle with the PTC (positive temperature coefficient) heater at full throttle stay below their allowable maximum value. Furthermore, it can be seen that the temperature of the air leaving the HVAC box (the blow-out temperature) reaches a steady state of 50 °C towards the end of the cycle which represents a sound target value for heating purposes of the cabin.

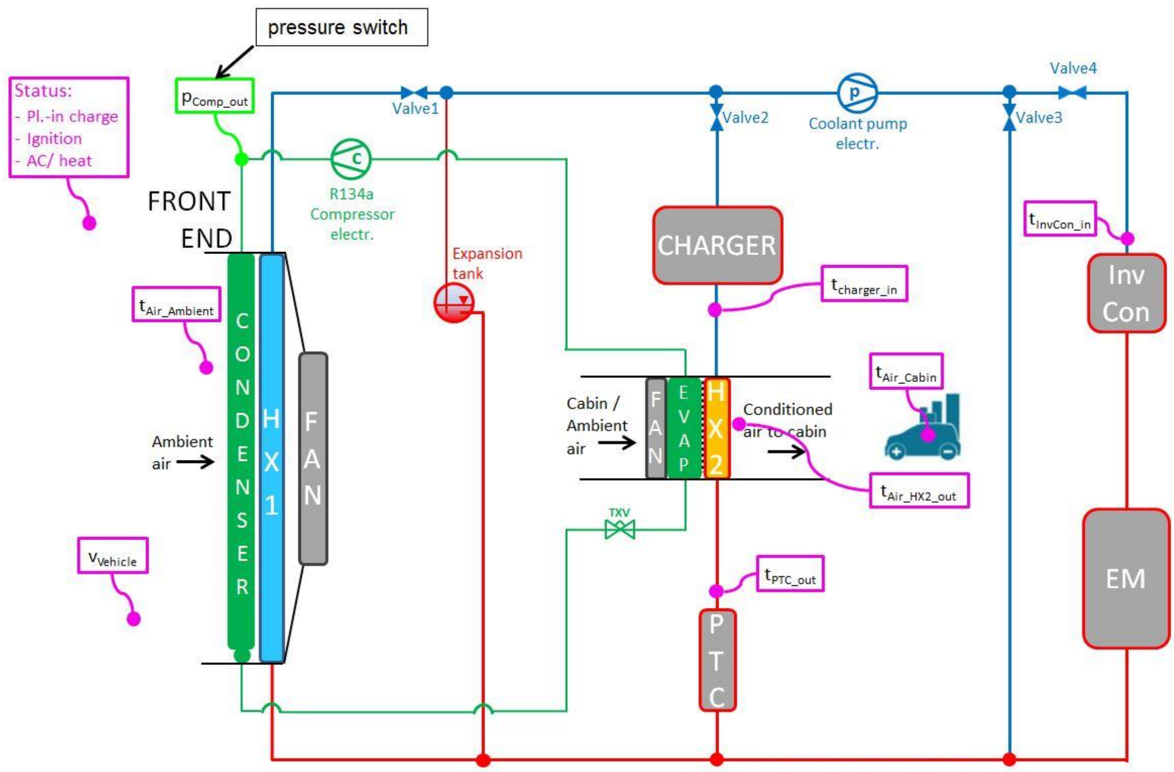


Fig. 4: System architecture of the cooling and HVAC system

Furthermore, test results have shown that the stator and rotor temperatures of the electric machine (EM) do not rise as high and quickly as suggested. Due to this, situations can arise during heating mode where the stator temperature happens to be lower than the coolant temperature. In this case the PTC does not only heat up the air leaving the HVAC box but also the EM. Clearly this reduces the efficiency of the system, but owing to the chosen system architecture this cannot be completely avoided since a minimal coolant flow rate through the InvCon and EM must be guaranteed.

However by installing a fourth solenoid valve (see Fig. 4) that can switch between two preset positions (fully open and a defined partial closure) to facilitate a minimal and maximal flow rate, the heat dissipation within the EM can be reduced to a minimum. Whenever the system is in PTC mode, the TC then checks for temperature levels of the coolant and the EM in order to decide when to fully open or to partly close the solenoid valve.

The components of the drivetrain including all cooling components for the full running vehicle are ready for their implementation in the Body-In-Black.

For more information please refer to our website www.epsilon-project.eu

On behalf of the epsilon consortium, best regards
Ralf Matheis

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epsilon aims to conceptualise and prototype the electric urban small vehicle of 2020-2025. It will focus on the development of an innovative electric vehicle concept specifically designed for the typical transport tasks in urban areas. The project is coordinated by fka Forschungsgesellschaft Kraftfahrwesen mbH Aachen. Furthermore, the consortium consists of Kompetenzzentrum - Das Virtuelle Fahrzeug, Centro Ricerche Fiat SCPA, Autoliv Development AB, HPL Prototypes LTD, Vehicle Safety Insitute of Technical University Graz, Fraunhofer Institute LBF, LEC 2 Limited and Institut für Kraftfahrzeuge (ika) of RWTH Aachen University.

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