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Numerical computation of the transient temperature of the electronic equipment enclosed in a passenger car

During the development process of a Mercedes-Benz passenger car, different departments intervene to decide the integration of the electronic equipment in the car. The department in charge of an electronic component verifies that the envisaged location meets the several requirements towards performance, electronics' architecture in the whole car, design and production. For design and packaging reasons, the electronic equipement often has to be relocated in small enclosures, where the component is susceptible of overheating. In order to ensure the thermal protection of electronics in the car and find active or passive ways of cooling, numerical methods to compute its temperature are investigated in the thermal management team of Daimler. Use cases are defined to check the electronics' temperature under critical conditions. Depending on the location and the features of the electronic component in the car, different use cases must be regarded. Typically, the electronic equipment is running under environmental and operating conditions which are varying with time. Therefore, it is important to consider the transient evolution of the electronics' temperature running under these critical conditions. The aims of this paper are to discuss the physical parameters of the electronics' temperature in the car under critical conditions and describe simulation strategies to compute the transient thermal evolution of electronics.

The investigation focuses on three electronic devices in usual packages, representing the most of physical configurations that can be found in the car:

- The additionnal battery under the trunk;
- The sound amplifier in a compartment under the passenger's feet.

To prevent the sound amplifier from overheating, an inner fan turns on depending on a sensor temperature. When the fan is not running, the electronics' temperature relies mainly on conductive and free convective heat transfers. When the fan turns on, the heat transport by forced convection in the electronic device and further in the enclosure must be considered. In case of the battery under the trunk, the flow is fully free convective. To compute the three heat transfer modes (convection, conduction and radiation), different numerical methods are investigated. The thermal source from inner chips must be taken into account in the energy balance. For the free and forced convection, a CFD code provides the heat flow rate necessary for the energy balance. Conduction and radiation can be accurately calculated by the thermal analysis software Radtherm. Another way to compute the conductive heat transfer is the FE code Permas. Several innovative 3D transient coupling strategies to compute the heat transfer mechanisms are presented in this paper. In order to reduce computing time, a quasi steady-state approach is used for the computation of convection. The accuracy of this approach is validated with different fundamental analysis in comparison with results from the literature. Moreover, the transient temperature of the electronic devices in the car provided by the coupling method are compared with experimental results showing a good agreement (see figures 1,2,3).

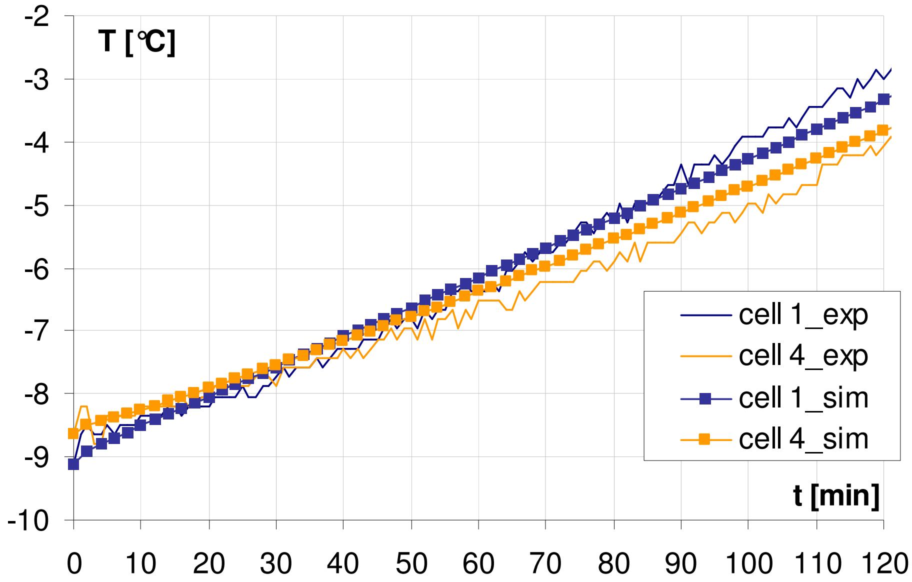

Figure 1: temperature of the battery cells in the trunk, winter case, experimental and numerical results with Radtherm

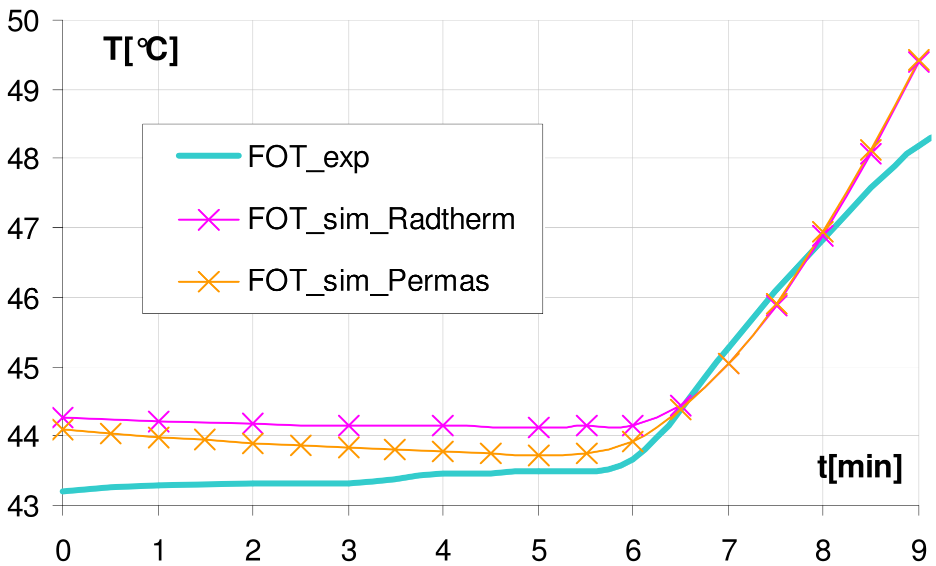

Figure 2: temperature of the Fiber Optical Transmitter (FOT) in the sound amplifier, summer case, experimental and numerical results with Permas und Radtherm

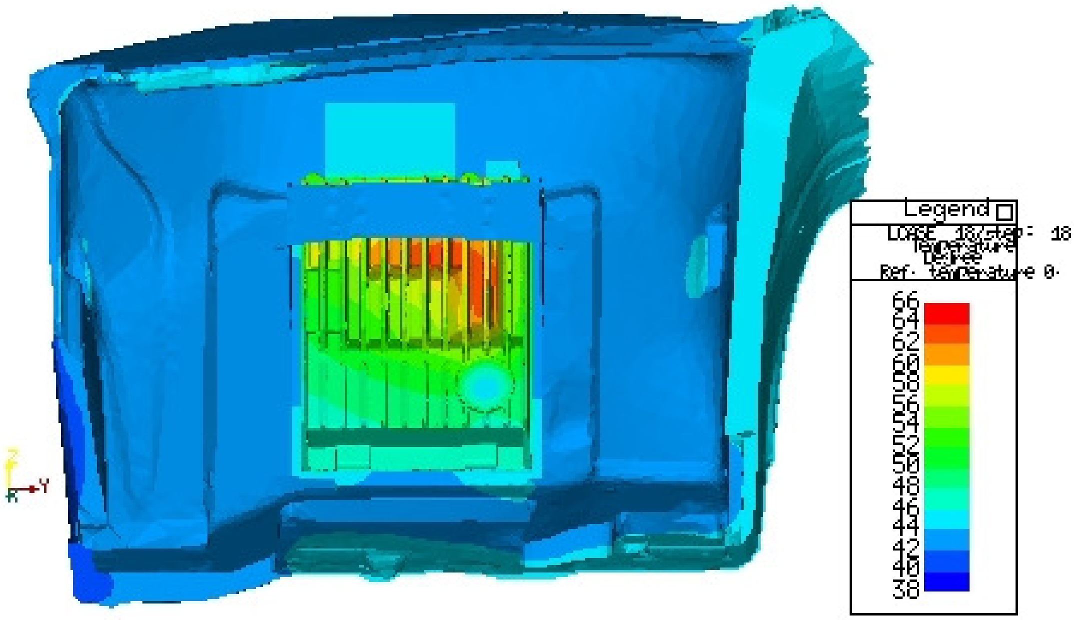

Figure3: computed temperature distribution of the sound amplifier in the feet compartment with Permas, t=9min.

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