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Thermal and fluid simulation of the environment under the dashboard, compared with measurement data

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Thermal and fluid simulation of the environment under the dashboard, compared with measurement data

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Abstract. The development of vehicles during the last decade is related to the evolution of electronic systems added in order to increase the safety and the number of services available on board, such as advanced driver-assistance systems (ADAS). Cars already have a complex computer network, with electronic control units (ECUs) connected to each other and receiving information from many sensors. The ECUs transfer an important heat power to the environment, while proper operating conditions need to be provided to ensure their reliability at high and low temperature, vibration and humidity. In a car cabin, electronic devices are usually placed in the compartment under the dashboard, an enclosed space designed for functional purposes. In the early stages of the vehicle design it has become necessary to analyse the environment under dashboard, by the use of Computational Fluid Dynamics (CFD) simulations and measurements. This paper presents the cooling of heat sinks by natural convection, a thermal and fluid simulation of the environment under the dashboard compared with test data.

1. Introduction

The thermal management of the vehicle car cabin is mainly focused on the thermal comfort of passengers [1]. The air flow and temperature distribution were studied in the passenger compartment under thermal load, such as the solar heat transfer to the cabin of a parked car [2] and cooling of the cabin under solar radiation [3]. Another concern of thermal management of the car cabin is the environment of the electronic devices that provide safety functions and services available on board, such as the navigation and multimedia systems with electronic visual display.

The current study is focused on the under-dashboard compartment, where most of the electronic devices are located, a zone where there are different factors that can influence the thermal environment of the ECUs. The environment under the dashboard is a confined space, inside the vehicle car cabin, delimited by the panels placed in the lower region of the passengers' feet, the engine bay and the dashboard. The allocated volume of this region is designed mainly for functional purpose, considering other constraints than the ones usually taken into account for the car cabin comfort and ergonomics. Temperature and flow fields were studied for aircraft confined compartments that contain thermally dissipating equipment, such as the natural convection inside the crown compartment of a commercial aircraft [4].

The parts positioned in the under-dashboard compartment are from the following assemblies: structural, comfort, steering, electrical and electronic. The structural assembly includes the crossbar and supports for other parts; the comfort assembly includes the heating, ventilation and air

conditioning unit (HVAC), the ventilation and defrosting ducts; the electrical and electronic include the wiring, the multimedia system (ECU and display), the cluster and the air conditioning/heater control panel.

The potential heat sources in the under-dashboard compartment are the ECUs and the heater, which is inside the HVAC unit, and its pipes. Depending on the external conditions, the region above the exhaust pipe, called the tunnel, can also generate some heat. Usually, the multimedia system is placed in the central upper region of the dashboard, adjacent with the other heat sources like the HVAC unit and the tunnel. The electronic systems are the sources of heat that have thermal constraints for proper operating conditions, therefore their environment requires a controlled temperature.

The cooling of electronic components is performed by the use of heat sinks can be passive or active and it has been widely studied [5]. The passive heat sink relies on an increased surface area in order to transfer the heat, while the active heat sink, such as a fan, requires a power supply. Depending on the type of the heat sink the cooling with air can be achieved by a free convection, in the case of passive heat sinks or by forced convection, in the case of active heat sinks. The current study is focused on an electronic device with a passive heat sink.

2. Measurement Test
A measurement test was performed on a vehicle, in the wind tunnel at an ambient temperature for a warm climate and the engine load at a cruising speed, considering common operating conditions for the multimedia system. The current stage of the test was performed for a duration that would allow stabilized conditions, with data acquisition of 23 thermocouples placed in the under-dashboard compartment at designated locations.

3. Numerical simulation

3.1. Case setup
The geometry of the case includes most of the parts under the dashboard: multimedia system, fuse box, wiring; HVAC unit, heater pipes, AC control panel; crossbar, supports. A general view of the model is presented in Figure 1.
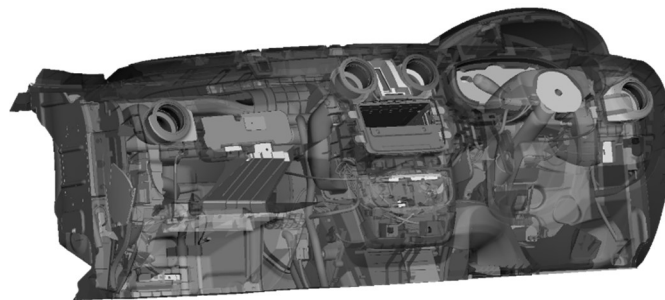
**Figure 1.** General view of the under-dashboard compartment.

The surface meshing of these parts is quite complex, considering the tight volume and the surface shapes. The geometrical details were simplified for most of the parts and fine mesh was applied on specific areas of the considered sources, such as the multimedia system. It is different than the common vehicle car cabin simulations where there are mainly large surfaces bounding a bigger volume. The under-dashboard computational volume was delimited by the cabin on the lateral sides and toward the engine bay, and by the lower region of the passengers' feet and the dashboard on the other sides. The simulation was performed with ANSYS Fluent-3D Release 15.0.

The current configuration has only passive heat sinks for the multimedia ECU, the natural convection being generated by the temperature difference between the heat sources and the ambient air. The heat sources considered in this simulation are: the multimedia system (casing and heat sink),

the lower part of the HVAC including the heater and its pipes. All the other surfaces are considered as adiabatic walls. Pressure outlet boundary condition was used for the flow of air through the open zones.
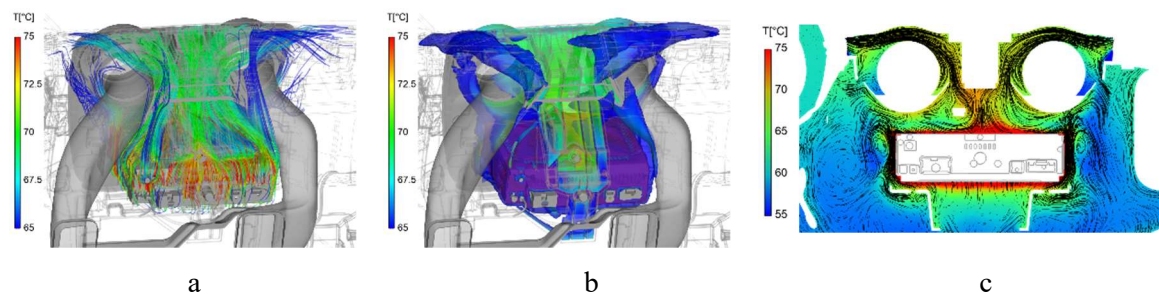
3.2. Simulation results
A general view of the flow under the dashboard, represented by temperature pathlines, is presented in Figure 2.
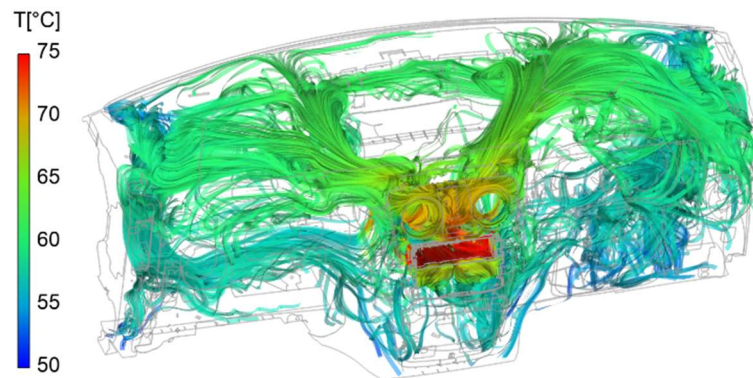
**Figure 2.** General view of the flow - temperature pathlines.

Samples of temperature results in the multimedia region are presented in Figure 3: downstream pathlines from casing and heat sink are represented in Figure 3a, volume with temperature above 65°C in Figure 3b and temperature contours in Figure 3c.

a   b   c

Figure 3. Multimedia region - temperature results.

4. Comparison between simulation results and test data
The comparison between the simulation results and test data is represented in Figure 4. Considering the 23 probes, the absolute error is approximately 5%, with an average temperature difference of 1.6 °C. Two probes have a temperature difference above the considered threshold of 3°C, with a maximum error of 15.5%.
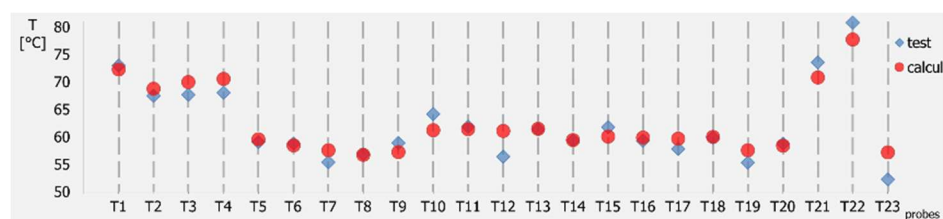
Figure 4. Comparison between simulation results and test data.

For a thorough analysis, the under-dashboard compartment was segregated into 6 regions of interest (see Table 1).

Table 1. Average temperature difference on regions.

Region	Number of probes	$\bar{\Delta}$ [°C]	$\bar{\varepsilon}$ [%]
Multimedia	6	1.3	4
Lower central - below multimedia	3	1.3	4
Upper central - under dashboard	4	2	6.4
Cross member level	5	0.9	2.8
Fuse box	2	1.3	4.1
Recycling region and heater pipes	3	3.6	11.3

5. Conclusions

The simulation results are compared with the test data, showing a good assessment in the zones of interest. The temperature values were analyzed on 23 probes and an absolute error of 5% was obtained.

The automobile manufacturer has to guarantee that the electronic systems are able to work in a wide temperature range, therefore this type of simulation was performed to ensure the performance and reliability of the electronic systems placed under the dashboard. This type of simulation provides a flexible method to identify the factors that influence the cooling of the electronic parts, by analyzing how redirecting the flow of air can improve the cooling performance.

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