

Climate control and HVAC simulation for occupied spaces - Implementation and validation

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Abstract

Heating, ventilation and cooling (HVAC) is one of the most prevalent application areas in CFD. For occupied spaces, like buildings, passenger vehicles and aircraft, the added complexity of human comfort becomes an important consideration when designing the general architecture and supporting climate control systems. The accurate modeling of these types of cases and the related phenomena can thus be of considerable significance. Our presentation describes the implementation of a range of ancillary physical modeling components to bring the HVAC simulation capabilities in OPENFOAM^{®1} in line with industry accepted norms. We also include passenger comfort indicators to allow more ready assessment of the system's effectiveness.

The new models and components implemented in our HVAC simulation system include (but are not limited to):

- Solar radiation using fixed-direction finite volume implementation
- Coupling of radiation and temperature boundary conditions using Newton-Raphson solver
- Multi-species with condensing/evaporating boundaries for humidity
- Passenger comfort indicators (Age of Air, Predicted Percentage of Dissatisfied, Predicted Mean Vote, Draft Risk, etc.)
- Incompressible variable density formulation; $f(p_0, T)$
- Thermal support and hybrid wall functions for incompressible turbulence, heat exchangers and other models

The resulting system is validated on a simple "heated vertical cylinder in a room" test case and finally applied to a series of representative industrial cases to measure performance and accuracy.

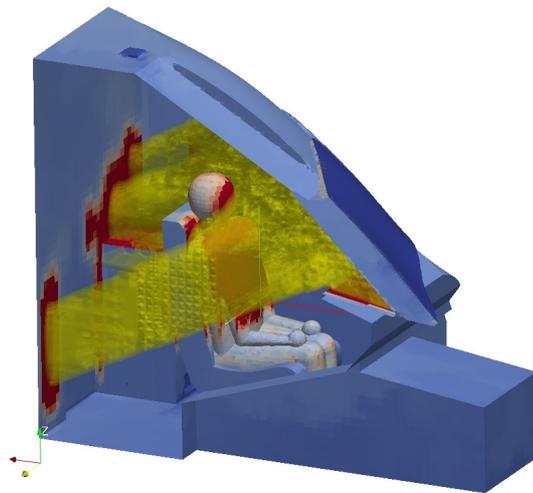


Figure 1: Iso-surfaces of solar radiation intensity and contours of wall temperature for an aircraft cockpit

The development of a HVAC-specific solution suite brings Open Source CFD another step closer to matching the more consumer oriented commercial tools in terms of ease of use and "out-of-the-box" applicability. The validation once again demonstrates OPENFOAM[®]'s flexibility and range of applicability for the modeling of complex coupled phenomena.

Key words: HVAC, Climate control, solar radiation, OPENFOAM[®]

References

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¹ OPENFOAM[®] is a registered trademark of OpenCFD Ltd., the producer of the OPENFOAM[®] software

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