Coupling strategies for multi-physics Large-Eddy Simulation: towards fire certification of composite material

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Fire certification stands as a crucial milestone in the aeronautical product development cycle. During this process, the component to be tested is exposed to a kerosene burner-induced flame for 5 to 15 minutes. The notable failure rates in fire resistance tests lead to long and costly development phases. Leveraging numerical simulation holds promise for comprehending the thermal impact of the flame and optimizing material design. These tools are essential in addressing emerging challenges, including evolving certification standards, the use of complex materials such as composites and assemblies, and the arrival of alternative fuels.

To this purpose, we present a methodology for Large-Eddy Simulation (LES) of certification fire tests, encompassing a wide range of multi-physics and multi-scale phenomena: turbulence, fuel injection and atomization, spray combustion, conduction within solid components, and conjugate heat transfers at the interface. This methodology combines a low-Mach number combustion solver, a radiative solver and a thermal solid solver, all coupled with the CWIPI library [1]. Prediction of heat transfers is validated by comparing the temperatures of a well-instrumented metal plate impacted by the flame.

First steps towards the extension of the methodology to reactive materials with a thermal decomposition solver (MoDeTheC [2]) are also presented. Thermal decomposition of exposed composite samples, outgassing at the interface, and possible ignition of decomposition products, are indeed key features in the certification process of aircraft structures. Only a limited number of studies have investigated flame–composite interactions leading to material degradation [3]. Properties such as the spatial distribution of the composite's components significantly influence heat conduction, thereby affecting the degradation kinetics at high temperatures. Coupling between previous solvers and MoDeTheC is performed and the fully-coupled methodology is validated under simplified test-bed conditions on a calorimeter cone set-up.

References

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