Multiscale approach applied to fires in tunnels

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Tunnel fire simulations are a constant topic in the literature, where through CFD (computational fluid dynamics) simulations the distribution of the temperatures and other properties in a fire can be calculated, giving information capable of improving the performance of tunnel ventilation and emergency management systems, among others. But tunnels are domains difficult to simulate, due to their length, consuming high amounts of calculation time and resources. Still this disadvantage can be mitigated by using multiscale models.

Multiscale modelling are a kind of CFD simulation where the simulation is divided into two submodels, one to simulate in 3D and other in 1D. The 3D model simulates the more complex part of the domain, the zone close to the fire, and the 1D model simulates the distant areas, where the flow is almost homogeneous. The objective of using these two models together is to save calculation time, as 1D simulations take only a small fraction of the time consumed by 3D modelling, obtaining accurate results, as the 3D manages the more complex areas.

This work continues the development of a multiscale model that uses FDS as its 3D algorithm and Whitesmoke to calculate the properties distribution in the 1D part of the domain. The model exploits the best capabilities of each one of the two submodels and connects and compile them together in Fortran language.

The main goals of this thesis are to improve the multiscale model that has been in development in Politecnico di Torino in the last years. This improvement include: changes to the compilation to guarantee shorter calculation times, modifications to the boundaries to respect the conservation laws in the boundaries, changes to the exchange of data among the models to minimize perturbations due to their interaction and verification of the pressure

calculating capabilities of the simulations.

The results of this work are divided among four chapters:

Chapter 3, shows the capabilities of the multiscale to reduce the calculation time needed to complete tunnel fire simulations. The tests in the chapter use a small theoretical tunnel as test case and simulate a small fire (2 MW). The tests results exhibit a simulation time reduction that is proportional to the percentage of the domain simulated into the 1D.

Chapter 4, Examines FDS tunnel fire simulations and compares them to Fluent and FDS heat source simulations finding that the pressure presented some inconsistencies. An equivalent model was developed to calculate an accurate pressure field using the other properties provided by the FDS. The pressure results of this model where compared with the other reference simulations proving that the properties obtained from FDS were correct, but there was some source of error accumulating in the pressure.

Chapter 5, shows testing regarding the pressure model of the FDS. Reporting that changes in the pressure solver of the FDS were capable of giving better results to the simulations. Simulations modelling the Dartford tunnel were capable of demonstrating that using UGLMAT was capable of guaranteeing better pressure results across the tunnel

Chapter 6 includes multiscale simulations compared to a tunnel fire test in a 2600 meters long tunnel and FDS simulations in the Dartford tunnel.

In the first tunnel, the simulations show trends similar for all the measurements and maintain a low error for anemometer measurements and thermocouples 30 and 130 m away from the fire, demonstrating that the multiscale model is capable of reproducing a real life fire test.

In Dartford, the multiscale is compared to FDS simulations. The trends along the tunnel and in 5 sections of the tunnel are analyzed, showing the same behavior and values as the FDS curves, with low error in some regions of the tunnel, and pressure curves that were more steady than the ones observed in FDS. This tests confirm the capability of the multiscale model of simulating long tunnels without introducing important sources of error.