Predictive Simulations of Liquid Pool Fires in Confined and Mechanically-Ventilated Enclosures

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Abstract

Predictive Computational Fluid Dynamics (CFD) simulations have been carried out for a liquid pool fire in a confined and mechanically-ventilated compartment [1] using Fire Dynamics Simulator (FDS 6.7.5) [2]. The objective is to assess the current simulation capabilities and identify key modelling aspects related to liquid evaporation and which require further developments.

The fire scenario considered in this work has been examined experimentally in [3]. The fire source is an 18 cm-diameter n-heptane pool fire with an initial fuel depth of 4.3 cm. The burner is positioned in the center of a 1.50 x 1.25 x 1.00 m^3 compartment where the outlet of the ventilation is mechanically extracted while the inlet air flow is free. The air renewal rate (ARR) of the ventilation (in the specific test of interest) was 8 h^{-1}, leading to an under-ventilated fire.

Before considering the enclosure, numerical simulations have been carried out in open atmosphere conditions. More particularly, an in-depth analysis has been undertaken on the empirical correlations used to estimate the Sherwood number and the subsequent mass transfer number, which is directly proportional to the evaporation rate. The analysis shows that the natural convection approach [4] leads to better predictions than the forced convection approach. More specifically, the former resulted in a slower and closer prediction of the fire growth rate (and time to reach the peak heat release rate) in addition to a fuel surface temperature which is closer to the boiling point.

In the enclosure fire simulations, besides the influence of the Sherwood number correlations, the importance of the fuel auto-ignition temperature (AIT) has been examined. The latter is set to -273 ℃ by default in FDS [2], in order to avoid the need to model an ignition source. This approach has been compared to the more 'realistic' approach where the actual AIT of the fuel (heptane) is prescribed, which is 215 ℃ [5]. In this case, the fire was ignited by an 8 x 8 cm^2 steel heating plate with a surface temperature of 1000 ℃. The required heating time was 4 seconds in order to have a sustained burning in the simulations. Note that in the experiments, the fire was ignited by a propane burner.

It has been found that setting the actual AIT is crucial for predicting the fire extinction in the enclosure, where the extinction is only predicted when the AIT was sufficiently high. Furthermore, the forced convection approach predicted a spurious spike for the burning rate at the beginning of the fire and as well as spurious oscillations before extinction. On the contrary, the natural convection approach predicted a closer fire growth and no spurious oscillations before extinction.

KEYWORDS: Pool fires; liquid evaporation modeling; enclosure fires; CFD; FDS

References

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