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(cfd modeling of the interaction between a smoke plume and a sprinkler spray)

(Abstract)

This thesis illustrates a detailed sensitivity analysis for the penetration capabilities of an Early Suppression Fast Response (ESFR) sprinkler spray over a smoke plume. The study was done by the Computational Fluid Dynamics (CFD) code namely Fire Dynamics Simulator (FDS) and the sensitivity analysis was based on the sprinkler flow rate, spray angle, droplet size, spray momentum, ceiling height, target area and the hot air plume momentum.

A hot air plume is assumed to represent a real heptane pool fire. Three different convective heat release rates (500 kW, 1000 kW and 1500 kW) were analyzed. Two hot air models (namely model A and model B) were investigated in this research. Where model A was proposed by O Mégret et al. and model B was developed in this research based on empirical correlations. The early hot air simulations showed the need to add synthetic turbulence at the boundary conditions. This was done by using the Synthetic Eddy Model (SEM). This synthetic turbulence helped the hot air plumes to act like real fire plumes by increasing the dissipation along the height. When comparing the velocity and temperature profiles along the heights of the pool fire simulations and the hot air plume simulations, the results were found to be promising, especially for model B in the region above the flame height.

The interaction between hot air plumes and water spray simulations were done under two different ceiling heights (6.0 and 3.0 m), where, three different heat release rates (500 kW, 1000 kW and 1500 kW) and six different water flow rates (1.9, 3.16, 4.42, 6.26, 7.58 and 9.48 l/s) were analyzed. The results are showing that, the drop size and the spray angles are the most effective parameters on the penetration capabilities. It was also indicated that (despite some exceptions) for a given sprinkler there is an optimal water flow rate corresponding to the highest penetration ratio within a practical range of fire sizes and water flow rates. In this research it was found to be 6.26 l/s for the 6.0 m ceiling case and 4.42 l/s for the 3.0 m ceiling case.