Numerical Modelling of Water Spray Impingement Cooling

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Abstract

Numerical simulations of water spray surface cooling have been carried out with the Fire Dynamics Simulator (FDS 6.7.7), which is a Computational Fluid Dynamics (CFD) code developed by the National Institute of Standards and Technology (NIST, US). The validation work is based on an experimental configuration examined at the LEMTA laboratory at the University of Lorraine in France. It consists of a 1 m × 1 m plate, made of 2-mm thick steel, positioned horizontally and heated centrally from below by a radiant panel. During the heating phase, the steel surface temperature reached a steady value of about 600°C at the center. The radiant panel is then switched off and a 20° conical jet nozzle positioned at 0.5 m above the steel plate is activated, delivering a flow rate of 4.6 L/min with a volume-median droplet diameter of about 188 μm. The steel plate reached the (initial) ambient temperature at its center after about 4 seconds. Several numerical simulations have been carried out, with a particular focus on the convective heat transfer coefficient, h_w, between the water droplets and the steel plate.

The most important finding from the simulations is that the default value of h_w = 300 W/(m^2·K) in FDS 6.7.7 significantly underestimated the cooling rate and yielded a cooling period of about 90 seconds. Increasing the value of h_w up to 20,000 W/(m^2·K) improved the agreement with the experiment. As a consequence, and after a close collaboration with the NIST, the default settings in FDS have recently been changed to an empirical correlation (which was already implemented in FDS).

The validation work carried out in this master thesis has been recently incorporated in the validation suite of FDS 6.9.0 under the name 'LEMTA Spray Cooling Experiments'. This outcome has fostered a more intensive collaboration on the topic between LEMTA, UGent and NIST.

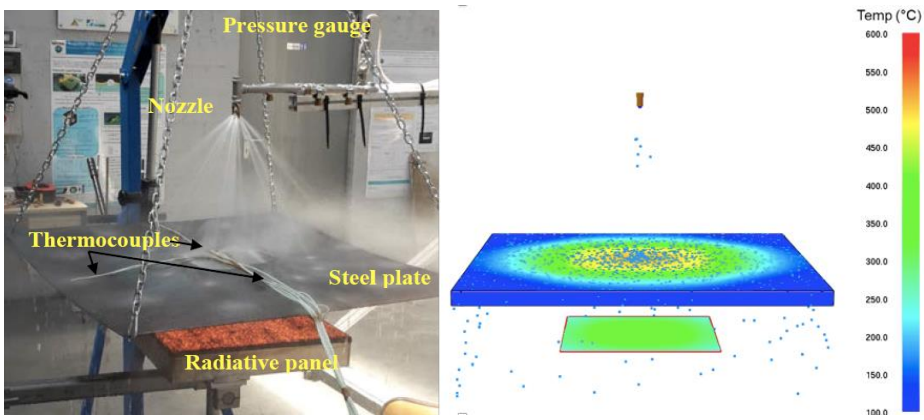

Figure 1 – Photo of the experimental set-up (left) and a snapshot of one CFD simulation (right).