

Abstract

Fire hazards might be fatal for evacuees and firefighters and might cause irrecoverable and severe damage to infrastructures. The progress in fire safety science has created opportunities to mitigate and minimize fire risks effectively. Fixed water-based fire suppression systems such as water mist systems are considered effective fire protection tools in the fire safety community. Despite recent advancements in water mist spray technology, gaps remain in our understanding of the efficacy of these systems in controlling fires under specific conditions, such as shielded fires.

Shielded fires represent realistic fire scenarios in spaces like warehouses or machinery areas, where the fire source can be partially or completely covered by nearby objects. In such situations, the effectiveness of water mist systems is questionable due to the limited ability of water mist droplets to reach the fire source. Therefore, this thesis aims to investigate the performance of water mist systems in extinguishing shielded fire scenarios experimentally and numerically.

First, a numerical model in FDS is developed to investigate the fire behavior in shielded scenarios in order to design experiments and select suitable instruments. Different shielding conditions and nozzle characteristics are analyzed numerically in Chapter 2.

Next, a comprehensive experimental campaign is conducted to perform various shielded fire tests in an enclosure with measurements of $2.4\text{ m} \times 2.4\text{ m} \times 3.1\text{ m}$ equipped with a mechanical fan. Diesel pool fires with two different HRRs are used as the fire source. A specific structure is designed to install plate obstacles with diverse sizes at different heights to provide different shielding conditions for the diesel pool fire. Several independent variables are defined, such as the size and height of the obstruction, the length of the fuel pan, the characteristics of the nozzle, and a variety of variables such as the temperature distribution, the exhaust gas concentrations, and the extinguishing time are measured for each fire test. In total,

three different water mist systems are utilized in this thesis to investigate their performances for sheltered fire applications. These systems include a multi-orifice low-pressure (LP) water mist nozzle, a multi-orifice high-pressure (HP) water mist nozzle, and a water mist nozzle with additives (F500 encapsulator agent). The characteristics of the LP and HP nozzles, including the downward velocity and the droplet size, are measured by a PDPA system, and the outputs are presented in Chapter 3. The results of each series of experiments for the LP nozzle, the HP nozzle, and the water-F500 nozzle are presented and discussed in Chapters 4, 5, and 6, respectively.

Finally, a model developed in FDS is utilized to simulate the experimental tests represented in previous chapters. The obtained data from the experiments are used to validate the numerical model, and different fire scenarios including shielded fire tests with and without water mist systems are simulated. Moreover, comparisons between experimental and numerical data are represented (Chapter 7).

The data and results represented in this thesis will serve as valuable insights for the design and advancement of water mist systems, particularly in environments where fire sources are potentially shielded by obstructions. These insights can guide the development of more efficient fire suppression strategies tailored to such challenging spaces.