Application of global sensitivity analysis to FDS simulations of large LNG fire plumes

Adrian Kelsey[*], Simon Gant[*], Kevin McNally[*], Steven Betteridge[+]

* Health and Safety Laboratory, Harpur Hill, Buxton, SK17 9JN
+ Shell Research Ltd, Shell Technology Centre Thornton, P.O. Box 1, Chester CH1 3SH

Email: adrian.kelsey@hsl.gsi.gov.uk, Tel: +44(0)1298 218000

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In 2009, a series of experiments were conducted by the Sandia National Laboratory at a large-scale test complex, in which Liquefied Natural Gas (LNG) was released onto the surface of a large pool of water and ignited. These experiments involved the largest releases of LNG ever performed. The LNG spills covered a circular area up to 81 metres in diameter. In the test with the largest LNG release rates unexpected behaviour was observed: the flames did not cover the entire area of the LNG spill, instead being confined to a smaller region, 50 metres in diameter. The flame height was also much greater than was predicted by empirical correlations and soot production rates were much lower than expected.

To study the effects of scale on LNG pool fires this paper presents a preliminary, simulation-based, sensitivity analysis of entrainment rates into the base of large LNG fire plumes. The entrainment rate into these plumes is of interest since one possible explanation for the unexpected behaviour is that the radial inflow of air into the base of the plume was so great that flames could not propagate upwind and ignite the whole of the LNG spill.

Pool fire simulations have been performed using the Fire Dynamics Simulator (FDS) software, using Large-Eddy Simulation (LES) to account for turbulence effects and a single-step combustion model. A number of input parameters to this model that could affect the entrainment rate are either uncertain or can be selected by the user. These inputs are: the burn rate, radiative fraction, grid cell size and choice of LES model. Since the objective of the study is to investigate scale effects, a fifth variable input parameter is the fire diameter.

To assess the impact of these five varying model inputs on the FDS predictions, a global sensitivity analysis has been performed. Using 200 FDS simulations a Gaussian process based emulator was constructed and checked for reliability. The sensitivity analysis was then performed using the emulator. The whole analysis, including the FDS runs and statistical analysis, took around 2 weeks of computing time using a powerful desktop computer. The influence of the five input parameters on entrainment will be presented.