INVESTIGATION OF LIQUEFIED NATURAL GAS (LNG) DISPERSION USING COMPUTATIONAL FLUID DYNAMICS

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Key Words: *Computational Fluid Dynamics, Liquefied Natural Gas, Dispersion, Large Eddy Simulation, Reynolds-Averaged Navier–Stokes Equations.*

Liquefied Natural Gas (LNG) is currently playing an important role in the global energy markets. This is evidenced by the growing demand and increased construction of LNG facilities across Europe and United States. One of the challenging problems within the LNG industry is to protect the general public from hazards which could result from accidental spill. A spill of LNG creates a flammable gas cloud which disperses through the atmosphere constituting fire and explosion hazards. The most commonly performed risk analysis involves verifying compliance with United States federal regulations such as NFPA 95A. One method that is currently being used to establish compliance is dispersion modelling using Computational Fluid Dynamics (CFD). However, real terrain dispersion simulation is challenging due to issues related to complex turbulent phenomena development, particularly in the presence of obstacles such as buildings in the path of the dispersing cloud [1].

The present study aims to demonstrate the potential of Large-Eddy Simulation (LES) for CFD simulation of LNG dispersion. For this purpose, ANSYS CFX is used to simulate LNG dispersion based on the Coyote Series Experiments [2,3]. Turbulence in the flow field was prescribed via Smagnorinsky sub-grid scale model originally developed for atmospheric turbulence. Previous works on LNG dispersion have utilized Reynolds-averaged Navier–Stokes (RANS) equations and two-parameter turbulence models despite their shortcomings in capturing time varying concentrations. Thus, the present work represents a significant development in numerical simulation of LNG dispersion.

The simulation results are reported and compared with the experimental data. Also, results were compared with RANS simulations conducted as part of this study and with a previous work [3]. Figure 1 shows the predicted LNG volumetric concentration time history for the current LES and RANS simulations, compared against experimental data for a sensor located 140 m downwind from the spill centre and 1 m height at domain's midplane. It can be readily observed from the plots that both the LES and RANS predictions performed relatively well with respect to the experimental data. However, the RANS predictions show substantial overpredictions in the time periods from 35 to 80 seconds, and failed to capture the experimentally observed trend and peak concentrations around 90s, which is well represented by the LES predictions. Furthermore, the substantial drop in concentration at 80 seconds was better reproduced with LES predictions but not RANS. Results of the simulations demonstrate that LES can be considered as a more suitable approach to tubulence simulation for LNG dispersion. The effect of adopting different closure models for the Smagorinsky coefficent has been investigated. This include: (a) specifying the Smagnorinsky coefficient as a constant value, (b) using the traditional Smagorinsky closure model that requires the specification of a wall damping function generally referred to as the LES-WALE, and (c) using the standard closure that assumes scale-invariance (the LES dynamic model). Of all three closure models, the constant value approach with a Smagnorinsky constant of 0.1 produced results which compare more favourably with experiment. The poor performance of the LES-WALE and LES dynamic model is thought to have resulted from the models being over-dissipative and under-dissipative respectively in the near-ground región.

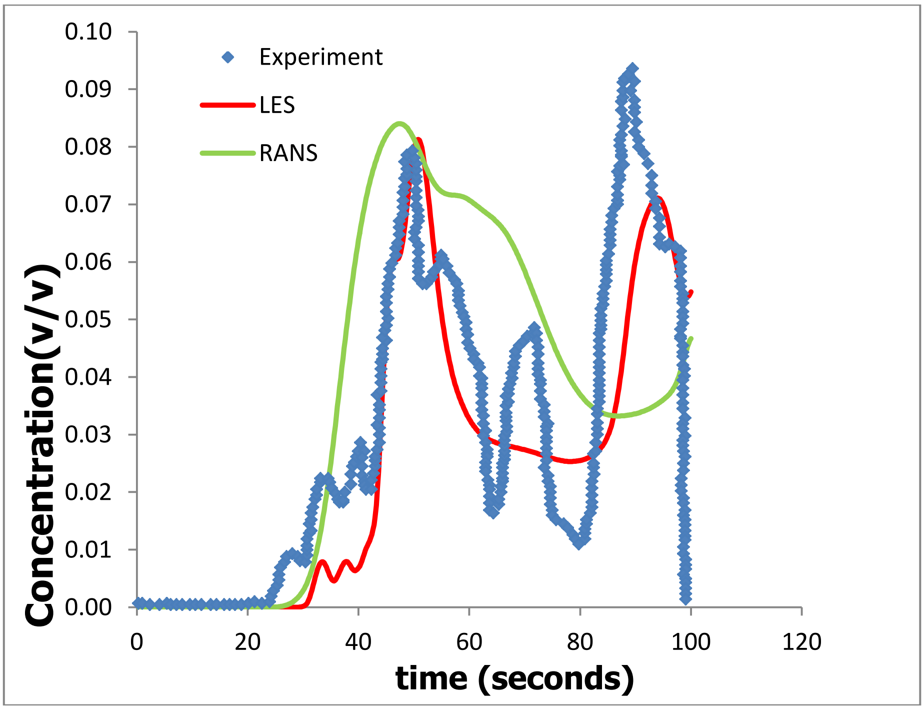

Figure 1. Comparison of Coyote 3 LNG concentration at 140 m from spill centre (1 m elevation) with current simulation using LES turbulence model and simulation using RANS

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