Simulations of a Hydrogen Combustion at Wet Condition using OpenFOAM

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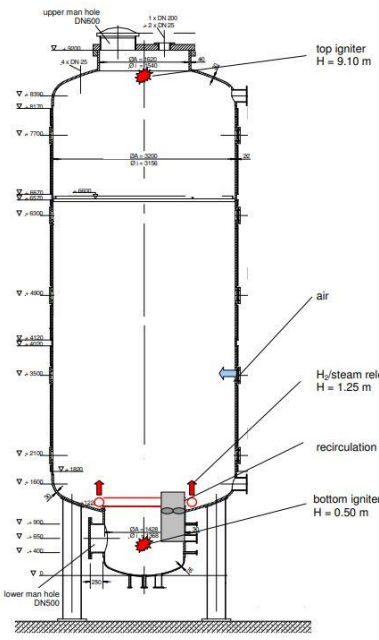
Introduction

In this study, the propagation rate and pressure of premixed hydrogen flames were calculated to ensure the safety of NPP containment from hydrogen flames with various water vapor concentrations, and is based on an experiment conducted by the OECD THAI program as a benchmark. In the situation of a NPP accident, it is difficult to predict the environment inside the containment because it varies from completely dry condition to saturated due to water vapor leakage. The THAI-HD test series was conducted to understand the behavior of a deflagrating hydrogen flame with varying amounts of water vapor. The experimental cases in which the simulation was conducted are shown in the table below

Case	HD-15	HD-22	HD-24
H_2 vol %	9.9	9.9	9.8
H_2O vol %	0	25.3	48
Equivalent ratio	0.26	0.36	0.55
Pressure	1.504 bar	1.487 bar	1.472 bar
Gas temperature	92.5 ℃	91.9 ℃	90.3 ℃

Method and CFD set-up



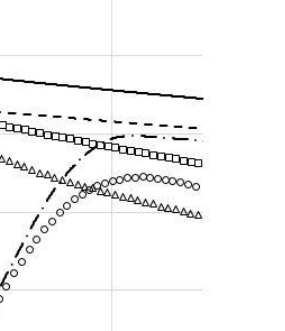
- THAI-HD test facility
- Ignition at the bottom

XiFoam

- OpenFOAM solver for compressible premixed/partially-premixed combustion
- Using flamelet combustion model (without solving chemical(reaction) kinetics)

- CFD Simulation set-up

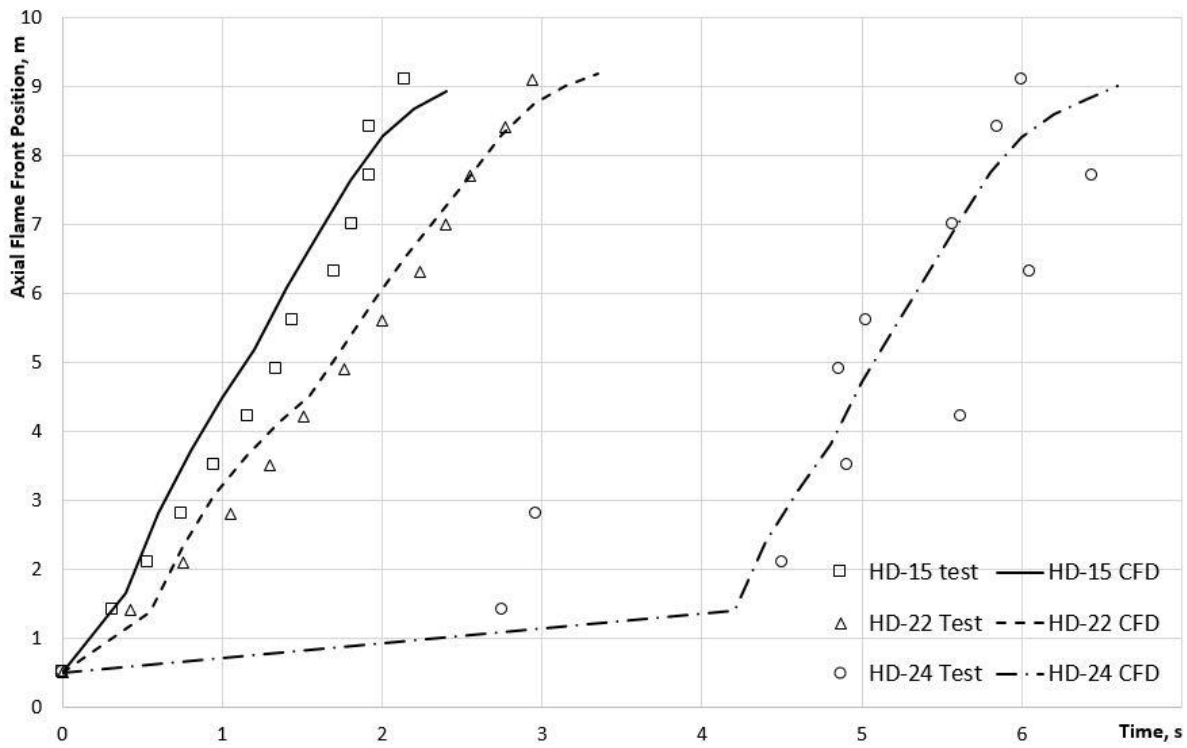
Solver	XiFoam
Combustion model	Flamelet
Turbulent model	k-omega SST
Radiation model	P1
Cells in mesh	936,246 (100% Hexahedral)
Unit cell size	40 mm



- Generated mesh of THAI-HD test facility

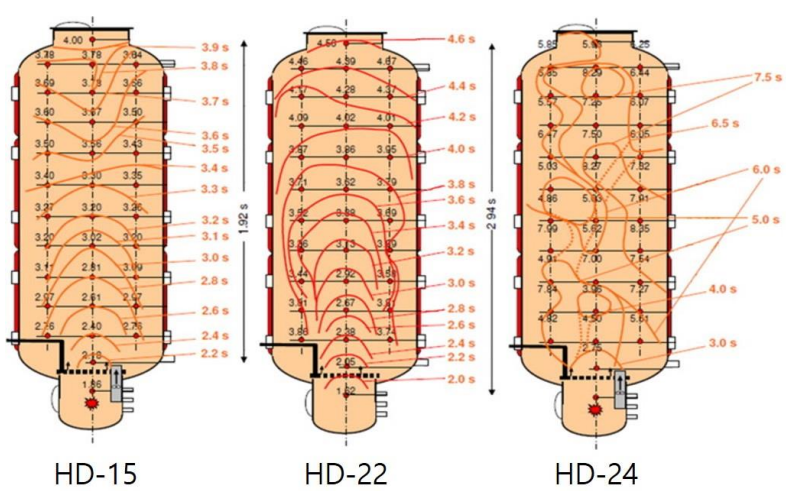
Results

Flame Propagation



Pressure Rising Trend

- As the amounts of water vapor increased, the propagation speed of the flame slowed down and the maximum pressure due to the flame inside the vessel decreased.
- This trend is also observed in simulation results using the modified XiFoam.



- Contours of flame propagation in Tests

Conclusion

- As part of a study on hydrogen flame behavior for NPP safety, a benchmark simulations of THAI HD-15, 22 and 24 experiments were performed using the modified XiFoam. Both the flame propagation speed and pressure results of the gas mixed with water vapor and hydrogen showed similar trends to the experiment. However, there was a difference due to the radiation effect and the heat transfer to the wall. The heat transfer area will be improved for more accurate hydrogen combustion simulation.