Simulation of Hydrogen Flame Acceleration by using XiFoam

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During a severe accident in a nuclear power plant, hydrogen could be generated by oxidation of the fuel-cladding and released into the containment. In this unwanted situation, it is important to know flame speed and pressure rise if a combustible mixture is ignited. The present study employs XiFoam [1], which is successfully validated against experimental data from ENACCEF facility appropriate for predicting phenomena in full-scale geometries [2]. Three validation cases are chosen. For case 1, uniform 13% hydrogen exists in the containment. For non-uniform hydrogen distributions along the acceleration tube, case 2 has negative gradient from 13.2% to 10.7% and case 3 has positive gradient from 10.7% to 12.4%. The appropriate combustion models of XiFoam are applied for fully- and partially-premixed flames respectively. 2D axisymmetric grid is used and turbulence is calculated by using the standard k-e model.

In Figure 1, the quantitative comparisons with measured flame speeds have been made for different hydrogen distributions. The predictions seem to be reasonable except for over-prediction in the dome region. The simulations of other research group also showed similar trends and it seems that experimental uncertainties may exist in the larger volume region, dome. In uniform and negative hydrogen gradient cases, the maximum flame speed is above 600 m/s, but in positive cases, around 400m/s. The flame propagation at selected times are shown in Figure 2. It is clearly seen that turbulent enhancement accelerates the flame propagation rapidly in obstacle regions. After obstacles, the flame is almost flat and the speed is decreased. When the flame penetrates the unburned mixture in the larger volume, the speed is increased rapidly but decreased soon. The shape becomes more complex due to the sudden expansion of pressure.

REFERENCES


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Figure 1 Comparisons of flame speed along centreline in (a) uniform, (b) negative and (c) positive gradient cases.

Figure 2 Temperature distributions at different flame propagation times in uniform 13% hydrogen case.