Erosion of a Stratified Layer by a Buoyant Jet in a Large Vessel

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Dimensions and Geometry

The fine mesh was a polyhedral mesh with a 20 million cell count. Refinement areas were created and applied as required areas in the mixing region of the jet and stratified layer. The fine mesh is shown in Figure 2.

Physics and Turbulence Modeling

The segregated implicit solver with the SST- k-ω, Realizable k-ε and Reynolds Stress turbulent models were used to validate and compare the CFD results. The air-helium mixture was simulated using a Multi-Component Gas model with an Ideal gas law by using STAR-CCM+ CFD tool.

Experimental Initial & Boundary Conditions

The simulations were run using 600 cores on the Texas A&M Super Computer, an Ada Cluster. The real run time of the simulation was approximately 6 days. The time steps used are summarized in the Table 1 and each time step required approximately 15 seconds of real time. The iterations per time step was between 7-15 depending on the time which allowed for a 4 to 6 orders of magnitude drop in monitored residuals.

Mesh

The inlet had a time dependent temperature condition applied to it. Linear interpolation was used to fill in the points as needed as shown in Figure 5. The inlet mass flow rates of the Helium and Air is shown in Table 2.

Table 1 – Time Step Size for the Corresponding Time Range

<table>
<thead>
<tr>
<th>Time Range (Seconds)</th>
<th>Time Step Size (Seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0-1.0</td>
<td>0.0005</td>
</tr>
<tr>
<td>1.0-10.0</td>
<td>0.005</td>
</tr>
<tr>
<td>10.0-100.0</td>
<td>0.05</td>
</tr>
<tr>
<td>100.0 to 7200.0</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Table 2 – Inlet Mass Flow Rates for Helium and Air

<table>
<thead>
<tr>
<th>Mass Flow Rate (kg/s)</th>
<th>Helium</th>
<th>Air</th>
</tr>
</thead>
<tbody>
<tr>
<td>HVY-1</td>
<td>0.003</td>
<td>0.005</td>
</tr>
<tr>
<td>HVY-2</td>
<td>0.003</td>
<td>0.005</td>
</tr>
<tr>
<td>HVY-3</td>
<td>0.003</td>
<td>0.005</td>
</tr>
<tr>
<td>HVY-4</td>
<td>0.003</td>
<td>0.005</td>
</tr>
</tbody>
</table>

Measurement Locations

Experimental velocity and mole fraction data collected using PIV and mass spectrometry is compared to CFD results for the same locations as shown in Figures 6, 7, and 8.

Helium Mole Fraction Results

Concentration measurements for evaluating the erosion of the stratification. The location of these elevations is shown in Figure 7. The threshold results are shown in Figure 9 and 12.

Velocity and Turbulent Kinetic Energy Results

The velocity and turbulent kinetic energy data are averaged over a time period of 204.6 s.. Solution time for HVY-3, HVY-5, VVY-1 and TKE-2 are 1213, 1795, 111, 1213 seconds respectively. The measurement locations are shown in Figure 8, and results in Figure 10.

Mole Fraction Results

Concentration measurements for evaluating the global mixing of helium and air. The location of these elevations is shown in Figure 6. The results are shown in Figure 11.

Helium Mole Fraction Results

Figure 6 – Monitor Locations for Global Mixing Mole Fraction Results
Figure 7 – Threshold (TR) Monitor Locations for Mole Fraction Results
Figure 8 – Monitor Locations for Time Averaged Velocity and Turbulent Kinetic Energy at Requested Lines
Figure 9 – Helium Mole Fractions vs. Time
Figure 10 – Velocity and Turbulent Kinetic Energy vs. Location (mm) Results
Figure 11 – Helium Mole Fractions vs. Time
Figure 12 – Helium Mole Fractions vs. Time
Figure 13 – Mole Fraction Contour Plots at Discrete Solution Times

Contour Plots of the Helium Mole Fraction were plotted on the vertical plane at different times 30 s. and 300 s. as shown in Figure 13.