Large eddy simulation of one diffusion swirling flame

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Introduction

Stabilized combustion is widely used when the flame needs to be anchored at a desired location and is resistant to flash back, lift off or blow off in operating range. There are two aerodynamic ways, one is to stabilize flame in the wake of bluff-body, and one is to stabilize flame in the low-velocity region of swirling flow. Here report one numerical study of a diffusion flame with both two mechanisms. This research chose one middle swirling case (SM1) from Sydney swirling flame series.

This burner is built up base on a bluff-body burner with diameter D=50mm. Swirling flow, which is generated aerodynamically upstream, comes out from annular exhaust with width d=5mm. Fuel jet comes from central hole in bluff-body with diameter d'=3.6mm. Velocity and composition measurements are resolved separately in several cross sections. Main properties of SM1 are summarized in table below.

<table>
<thead>
<tr>
<th>Case</th>
<th>Fuel</th>
<th>Uf (m/s)</th>
<th>Us (m/s)</th>
<th>Ws (m/s)</th>
<th>Ur (m/s)</th>
<th>S</th>
<th>Re</th>
<th>Re_r</th>
</tr>
</thead>
<tbody>
<tr>
<td>SM1</td>
<td>methane</td>
<td>32.7</td>
<td>38.2</td>
<td>19.1</td>
<td>20</td>
<td>0.5</td>
<td>7200</td>
<td>75900</td>
</tr>
</tbody>
</table>

Numerical method

This research use large eddy simulation (LES) in software ANASYS FLUENT. Simulation domain is a cylinder with diameter of 200mm and length of 240mm. It starts from the exit of the burner. Hexagonal grid divides the domain as spatial filter in implicit LES. There are total 2.42M cells. The size of the cell is decided by Kolmogorov scale from previous RANS results. Pave mesh is used in central region while the stretching is less than 8% in the environment flow field. Complex velocity inlet is used for fuel-jet and swirling flow: 1/7-power law profile with turbulent profile (turbulent-energie- and turb-diss-rate). Spectral synthesizer method is used to generate pseudo-fluctuation. Discretization scheme used in LES has second order. Numerical models are summarized below.

models used in LES

<table>
<thead>
<tr>
<th>Closure term</th>
<th>Sub-grid scale</th>
<th>chemistry</th>
<th>Turb.-chem. interaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dynamic Sma-</td>
<td>16 species</td>
<td>Probability density function (PDF)</td>
<td>GRI-2.11 Steady flamelet</td>
</tr>
<tr>
<td>gorinsky-Lilly</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Reference


Acknowledgements

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Results

Validation study

Ensemble average and root-mean-square (RMS) results are shown below. Statistical results covered physical time of 75ms. Selected cross-sections locate in two low-velocity regions. Considerable agreement is achieved except some deviations in the swirling low-velocity region. Good agreement of mixture fraction proves conserved scalar is resolved accurately even use simple model.

![Mean temperature contour and validation results (mean and RMS of axial and tangential velocity)](image)

![Mean axial velocity contour and validation results (mean and RMS of axial and tangential velocity)](image)

Instantaneous field

Qualitative description of flame shows below using contour plot of temperature. Black line indicates instantaneous stoichiometric mixture fraction. The right one uses GRI-2.11 chemistry model and steady flamelet model. The left one uses simple chemistry and interaction model.

![Instantaneous field](image)

Conclusion

Different interaction models show similar flame location and length. High-temperature combustion mainly happen just outside the swirling low-velocity region.

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