Numerical Analysis of Conjugate Heat Transfer in a Combustion Chamber and Firetubes

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Introduction: COMSOL was used to verify handbook predictions from Heat Transfer Research Inc. (HTRI) for the heat transfer coefficient for a combustion chamber and its firetubes.

Computational Methods: Conjugate heat transfer (conduction, convection + surface radiation) was used. The Navier Stokes solver in COMSOL was used in conjunction with the Heat Transfer Equations:

\[ \rho c_p \bar{u} \cdot \nabla T + \nabla \cdot \bar{q} = Q, \bar{q} = -k \nabla T \]

\[ \hat{n} \cdot \bar{q} = \varepsilon (G - e_b(T)) \]

\[ (1 - \varepsilon)G = J - \varepsilon e_b(T) \]

\[ G = G_m(J) + G_{amb} + G_{exit} \]

\[ G_{amb} = F_{amb}e_b(T_{amb}) \]

\[ e_b(T) = n^2 \sigma T^4 \]

Results:

<table>
<thead>
<tr>
<th>Component</th>
<th>h (W/m²-K)</th>
<th>COMSOL / HTRI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chamber</td>
<td>44.8 / 45.2</td>
<td></td>
</tr>
<tr>
<td>Firetubes</td>
<td>62.5 / 62.06</td>
<td></td>
</tr>
</tbody>
</table>

Conclusions: COMSOL heat transfer coefficient agrees within 2%. COMSOL back pressure agrees within 6%.