Shock control bump optimization on a transonic laminar flow airfoil

A Test Case for Database Workshop for Multiphysics Software Validation
16 March 2009, Agora, Jyvaskyla, Finland

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The Airfoil – RAE5243

- Natural laminar flow airfoil at transonic condition
- Shock wave at $M = 0.68$ and $C_L = 0.82$
The bump design

- 4 design variables: bump height, position, length and crest position
- Bump added to the airfoil shape
- Tangent at connection points and at the crest
The Test Cases

- Experiments were tripped for full turbulent flow
- Both full turbulent flow and fixed transition cases

<table>
<thead>
<tr>
<th>Aerofoil</th>
<th>$M_\infty$</th>
<th>$Re_{c,\infty}$</th>
<th>$C_l$</th>
<th>Flow condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>RAE5243</td>
<td>0.68</td>
<td>$1.9 \times 10^7$</td>
<td>0.82</td>
<td>Fully turbulent</td>
</tr>
<tr>
<td>RAE5243</td>
<td>0.68</td>
<td>$1.9 \times 10^7$</td>
<td>0.82</td>
<td>45%c transition</td>
</tr>
</tbody>
</table>
The optimization problem

- Optimization problem

  Minimize the total drag of the airfoil

  \[ \min C_d = C_{d,\text{pressure}} + C_{d,\text{friction}} \]

  Under the constraint: \( C_l = 0.82 \)

- Design variable bounds

  - Bump crest position: \( 0 < X_{\text{cre}}/C < 1, \)
  - Bump starting point to crest: \( 0 < X_{\text{bumprelative}}/C < X_{\text{bumplength}}/C \)
  - Bump total length: \( 0 < X_{\text{bumplength}}/C < 0.4 \)
  - Bump height: \( 0 < \Delta Y_{h}/C < 0.05 \)