LFC AIRFOIL DEVELOPMENT

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LFC AIRFOIL DESIGN CONSIDERATIONS

- Large chord (7 foot) model spans the tunnel
- Nontapered, swept about 25 degrees and trailing-edge flaps
- Interchangable upper surface porous/slotted suction panels
- Lower surface slotted suction, no leading-edge suction slots
- Leading-edge shaping to reduce boundary layer instabilities
- Shockless with performance similar to turbulent airfoils
- Upper surface maximum local Mach number $< 1.12$
- Supersonic bubble should not impact opposite tunnel wall
LFC AIRFOIL
FOR A SWEPT WING

AIRFOIL DEVELOPMENT

- TRANSONIC DESIGN
- TRANSONIC ANALYSIS
  DESIGN POINT
  OFF DESIGN
  TURBULENT

SUCTION REQUIREMENTS

- BOUNDARY LAYER ANALYSIS
- STABILITY ANALYSIS
  TOLLMIEN–SCHLICHTING
  CROSS–FLOW
  TAYLOR–GOERTLER
EVOLUTION OF LFC AIRFOIL TO BE TESTED
IN AMES' 12 FOOT PRESSURE WIND TUNNEL

$M_\infty = 0.756$
$C_L = 0.56$
$t/c = 13.1\%$
$M_{\text{max}} = 1.19$  

$M_\infty = 0.720$
$C_L = 0.580$
$t/c = 13.4\%$
$M_{\text{max}} = 1.07$

$M_\infty = 0.73$
$C_L = 0.589$
$t/c = 12.6\%$
$M_{\text{max}} = 1.15$

$M_\infty = 0.725$
$C_L = 0.6$
$t/c = 12.8\%$
$M_{\text{max}} = 1.12$
VARIATION OF PRESSURE DISTRIBUTION WITH MACH NUMBER AT DESIGN LIFT COEFFICIENT ($C_L = 0.60$)

$M = 0.730$

$M = 0.735$

$M = 0.740$

$M = 0.750$
DESIGN OF AIRFOIL A

\[ M_n = 0.730, \quad c_l = 0.60 \]
OFF DESIGN FOR AIRFOIL A

c_1 = 0.60

\[ M_n = 0.60 \]

\[ M_n = 0.70 \]

SUPERSONIC REGION

\[ C_{p,\text{sonic}} \]

\[ M_n = 0.73 \]

\[ M_n = 0.75 \]
TURBULENT LIFT RECOVERY

AIRFOIL A, $M_n = 0.730$

INVISCID
$\alpha = 0.1^\circ$
$c_l = 0.60$

$R_c = 10 \times 10^6$
$\alpha = 0.1^\circ$
$c_l = 0.28$

$R_c = 10 \times 10^6$
$\alpha = 1.8^\circ$
$c_l = 0.60$

$R_c = 10 \times 10^6$
$\alpha = 0.1^\circ$, $\beta = 8.0^\circ$
$c_l = 0.60$
AIRFOIL REDESIGN

<table>
<thead>
<tr>
<th>Airfoil</th>
<th>t/c</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>0.131</td>
</tr>
<tr>
<td>A</td>
<td>.135</td>
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</tbody>
</table>
DRAG RISE AT $c_l = 0.60$

![Diagram showing the drag rise at $c_l = 0.60$. The graph plots $c_{d,w}$ against $M_n$. There are two curves, one solid and one dashed, representing different airfoils labeled B and A.](image-url)
EFFECT ON PRESSURE DISTRIBUTION

$c_l = 0.60$

$C_p, \text{ sonic}$

$C_p$

Airfoil | $M$
--- | ---
B | 0.755
A | 0.730
PRESSURE DISTRIBUTION REFINEMENT

\[ M_n = 0.755, \quad c_l = 0.55 \]
SELECTION OF DESIGN CONDITION

\[ C_p \]

- \( M_n = 0.755 \)
  - \( c_l = 0.55 \)
  - WIND TUNNEL MODEL DESIGN

- \( M_n = 0.758 \)
  - \( c_l = 0.58 \)
  - MAXIMUM SHOCKLESS DESIGN

- \( M_n = 0.760 \)
  - \( c_l = 0.60 \)
  - \( C_{p,\text{sonic}} \)

- \( M_n = 0.765 \)
  - \( c_l = 0.65 \)
  - SUPERSONIC REGIONS
CONCLUSION

- Long and torturous development of final airfoil geometry
- Final design condition similar to those of turbulent airfoils
- Design condition chosen so "bubble-off-the-wall" condition met
- Extensive off-design studies of supercritical behavior
- Use of trailing-edge flap for lift recovery demonstrated
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