Computational Investigation of Drag Reduction by means of Two-Dimensional Roughness on the Suction Surface: Effect of Position

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1. INTRODUCTION & OBJECTIVE

The flow separates on the suction surface of the airfoils at and near the stall angle of attack... Extensive investigations were carried out to reduce flow separation on the suction surface of the airfoils and turbomachine blades. These include active devices, complex three-dimensional passive devices and simple two-dimensional devices. Sitaram et al. (1) used two-dimensional roughness elements in the form of simple round tubes placed on the suction surface of the blades to reduce flow separation and losses by 8%. Similar investigations were carried out by Sitaram et al. (2) to reduce flow separation and losses by suitably placing three dimensional roughness elements in the separation region. Volino (3) performed cascade experiments with two-dimensional rectangular bars (similar to trips) placed on suction surface to control the boundary layer transition and reattachment under LP turbine conditions. Bar performance is dependent on the height and position of the rectangular bar on the suction surface. Bars located near the suction surface peak velocity are most effective. He found that large bars trip the boundary layer to turbulent flow and prevent separation, but create unnecessarily high losses. He concluded that the smaller bars were effective under both high and low free-stream turbulence conditions. Losses appear to be minimized when a small separation bubble is present, so long as reattachment begins far enough upstream for the boundary layer to recover from the separation. In spite of the favorable effects of simple two-dimensional roughness elements, very little work, either computational or experimental was undertaken.

Hence the present computational investigations are undertaken to systematically investigate the effect of two-dimensional round roughness elements in reducing flow separation and losses in airfoils. The NACA0012 airfoil investigated by Li et al. (4) is utilized for the computational investigation.

2. RESULTS & HIGHLIGHTS OF IMPORTANT POINTS

Madan Raj et al. (5) had investigated the effect of size of the roughness element placed at 30% chord on the suction surface of the airfoil. Figure 1 shows the computational grid for the two-dimensional roughness element placed on the suction surface of the airfoil. The roughness element reduces both lift and drag coefficients for all configurations. However, it was found that a roughness element of 1 mm dia. (0.1% Chord) at 30% of chord increases lift drag ratio by about 13.6% near stall angle (Table 1). It was also found that the roughness elements reduces lift drag ratio at lower angles of attack. Hence the present investigation are undertaken with a roughness element of 1 mm dia. (0.1% Chord) at 10% and 20% and multiple roughness elements to identify optimum position. Computational investigations are carried out at different angles of attack up to stall angle of attack. From these investigations, lift and drag coefficients, lift drag ratio, surface static pressure and skin friction coefficients at different angles of attack are presented to identify the optimum position to place the optimum roughness element.

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REFERENCES


Table 1 Comparison of Lift Drag Ratio for Various Configurations

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Position</th>
<th>Diameter, d (mm)</th>
<th>$\alpha=10^\circ$</th>
<th>$\alpha=16^\circ$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>$C_L/C_D$</td>
<td>$\Delta C_L/C_D$</td>
</tr>
<tr>
<td>1</td>
<td>0.3 of chord</td>
<td>2 d</td>
<td>57.3</td>
<td>-1.2</td>
</tr>
<tr>
<td>2</td>
<td>0.3 of chord</td>
<td>1.5 d</td>
<td>48.6</td>
<td>-9.6</td>
</tr>
<tr>
<td>3</td>
<td>0.3 of chord</td>
<td>1.25 d</td>
<td>48.6</td>
<td>-9.3</td>
</tr>
<tr>
<td>4</td>
<td>0.3 of chord</td>
<td>1 d</td>
<td>49.1</td>
<td>-8.5</td>
</tr>
<tr>
<td>5</td>
<td>0.3 of chord</td>
<td>0.75 d</td>
<td>54.2</td>
<td>1.2</td>
</tr>
<tr>
<td>6</td>
<td>Without roughness</td>
<td>3</td>
<td>53.6</td>
<td>13.6</td>
</tr>
</tbody>
</table>

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