Aerodynamic prediction of 30P30N airfoil using 2D BCM
（BCMを用いた30P30Nの2次元空力予測）

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Case

1. Aerodynamic prediction of 30P30N airfoil
   1-1 2D steady analysis

2. Flap separation prediction of 30P35N airfoil
   2-1 2D steady analysis

3. Noise prediction of 30P30N airfoil
   (near and far field)
Flow solver

• BCM (Building Cube Method)
  - Cartesian mesh based solver

  ![BCM mesh around NACA0012 airfoil](image)

  - Merits
    • Easy parallel computation
    • Easy grid generation for complex shapes
    • Higher order spatial accuracy

  - Demerits
    • Shape reproducibility
    • Difficulty in resolving the boundary layer

Computational method

<table>
<thead>
<tr>
<th></th>
<th>BCM-NS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Governing Eq.</td>
<td>Compressible NS Eq.</td>
</tr>
<tr>
<td>Discretization</td>
<td>Cell-centered finite volume</td>
</tr>
<tr>
<td>Inviscid Flux</td>
<td>SLAU 3rd-order MUSCL</td>
</tr>
<tr>
<td>Viscous Flux</td>
<td>2nd-order central difference</td>
</tr>
<tr>
<td>Time integration</td>
<td>LU-SGS</td>
</tr>
<tr>
<td>Turbulence model</td>
<td>SA-noft2-R</td>
</tr>
</tbody>
</table>

Wall boundary treatment
• Immersed boundary method (Ghost cell approach)
  Density & pressure → Zeroth-order interpolation
  Velocity → Linear interpolation
Grid

<table>
<thead>
<tr>
<th></th>
<th>Coarse</th>
<th>Medium</th>
<th>Fine (L1)</th>
<th>Extra Fine (L2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum grid size</td>
<td>9.54e-5</td>
<td>4.77e-5</td>
<td>2.38e-5</td>
<td>1.19e-5</td>
</tr>
<tr>
<td>Total cube number</td>
<td>8,259</td>
<td>15,645</td>
<td>15,645</td>
<td>15,645</td>
</tr>
<tr>
<td>Total cell number in Cube</td>
<td>16*16</td>
<td>16*16</td>
<td>32*32</td>
<td>64*64</td>
</tr>
<tr>
<td>Total cell number</td>
<td>2,114,304</td>
<td>4,005,120</td>
<td>16,020,480</td>
<td>64,081,920</td>
</tr>
</tbody>
</table>

5.5 deg | ○ | ○ | ○ | ○ |
9.5 deg | - | - | ○ | ○ |
14.0 deg | - | - | ○ | - |
20.0 deg | - | - | ○ | - |
24.0 deg | - | - | ○ | - |

Cube allocation
Grid (comparison L1 grid)

* Show cube boundaries

Each cube has 16×16, 32×32 or 64×64 cells

Black : L1 grid provided by JAXA
Blue  : BCM
Separation occurs at a high angle of attack.
→ Min cell size?, Cube allocation?...

$C_l - \alpha$

$C_l, C_d, C_m$

![Graph showing $C_l, C_d, C_m$](image)


**Cp (AoA 5.5deg)**

![Graph showing Cp (AoA 5.5deg)](image)
Conclusion

We analyzed 30P30N airfoil by BCM

- The Fine(L1) grid and Extra Fine(L2) grid analysis result shows the same tendency as the experiment at the low angle of attack.
- These fine grids simulations could not predict precisely at the high angle of attack. (Separation occurs in the simulations)
  → Revise Cube allocation and Analysis conditions.
- The aerodynamic coefficient is estimated to be large.
- The trend of the pressure coefficient distribution differs at the trailing edge of the flap in experiment and simulation.
  → Due to two dimensional analysis?