Summary of Fourth Aerodynamics Prediction Challenge (APC-IV)

Takashi Ishida (JAXA)
APC committee

Contents

• Participants
• Test case 1
• Test case 2
• Test case 3
• Summary
Statistics of submitted data

- Organizations and number of submitted data (total 26 data)
  - National research institutes: JAXA(4)
  - Universities: TAT(1), Tohoku Univ./KIT(1), Tohoku Univ.(1), Univ. of Tokyo(1)
  - Aerospace industries: KHI(4), MHI(1)
  - Vendors: Ryoyu systems(9), Siemens(2), Cradle(2)

- Grids
  - JAXA: 17
  - Customs: 10

- Codes
  - Structured solver(8), Unstructured solver(13)
  - Cartesian: LBM(2), BCM(1), UTCart(2)

- Turbulence models
  - Steady: SA(16)
  - Unsteady: DDES(SA)(16), IDDES(SA)(1), IDDES(SST)(1), ILES(2)

Participants of case 1-1

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<td>UTCart</td>
<td>Custom (直交格子)</td>
<td>SA-DDES-p</td>
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Participants of case 3-2

<table>
<thead>
<tr>
<th>ID</th>
<th>Name</th>
<th>Organization</th>
<th>Code</th>
<th>Grid</th>
<th>Turbulence Model</th>
<th>Note</th>
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<tbody>
<tr>
<td>A2</td>
<td>田中 健太郎</td>
<td>喜友システムズ</td>
<td>UPACS (structured solver)</td>
<td>JAXA</td>
<td>SA-noft2 DDES (strain rate)</td>
<td>3rd SLAU</td>
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<td>A3</td>
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<td></td>
<td></td>
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<td>SA-noft2 DDES (strain rate)</td>
<td>5th Roe</td>
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<tr>
<td>A6</td>
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<td>SA-noft2 DDES (strain rate)</td>
<td>5th SLAU</td>
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<td>A7</td>
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<td></td>
<td>SA-noft2 DDES (strain rate)</td>
<td>5th SLAU wiggle-sensor</td>
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<tr>
<td>A8</td>
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<td>SA-noft2 DDES (strain rate)</td>
<td>5th SLAU wiggle-sensor skewsym</td>
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<td>B1</td>
<td>坂井 玲太郎</td>
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<td>SA-noft2-R DDES</td>
<td>dmax</td>
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<td>SA-noft2-R DDES</td>
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<tr>
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<td>上野 陽亮</td>
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<td>SA-noft2 DDES</td>
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<tr>
<td>H1</td>
<td>Peter Burns</td>
<td>Siemens PLM Software</td>
<td>Simcenter STAR-CMM+ (unstructured solver)</td>
<td>Custom</td>
<td>(trimmed)</td>
<td>SA IDDES</td>
</tr>
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</table>
Case 1-1: α - sweep

The variation was larger than past APC series even though SA turbulence model was mainly used.

Case 1-1: α - sweep

The variation was larger than past APC series even though SA turbulence model was mainly used.
$\alpha$–sweep of APC-III

$\alpha$–sweep of APC-II
Case 1-1: $\alpha$ - sweep

The variation was larger than past APC series even though SA turbulence model was mainly used.

Case 1-1: $\alpha$ - sweep

Comparison of pressure/friction force

Although pressure force was dominant, friction force had some variation due to grid type.
Case 1-1: α - sweep

Comparison by grid type

There was large influence on grid type.

Case 1-1: α - sweep

Comparison by grid type

There was large influence on grid type.
Case 1-1: $\alpha$ - sweep

Comparison by grid resolution: provided grid

**L1**

<table>
<thead>
<tr>
<th>CL - Alpha (L1)</th>
<th>CL - CD (L1)</th>
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<table>
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<th>$\alpha$[deg]</th>
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<th>$C_D$</th>
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**L2**

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<th>$C_l$</th>
<th>$C_D$</th>
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<tr>
<td>30</td>
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</table>
Case 1-1: $\alpha$ - sweep

Comparison by grid resolution: provided grid

**L3**

<table>
<thead>
<tr>
<th>CL - Alpha(L3)</th>
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</tr>
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<tr>
<td><img src="image1" alt="Graph 1" /></td>
<td><img src="image2" alt="Graph 2" /></td>
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**L4**

<table>
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<th>CL - Alpha(L4)</th>
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<tr>
<td><img src="image3" alt="Graph 3" /></td>
<td><img src="image4" alt="Graph 4" /></td>
</tr>
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</table>
Case 1-1: $\alpha$ - sweep

Comparison by grid resolution: provided grid

**Case 1-1**

Comparison with exp:

All results showed good agreement with experiment.
Case 1-1: Cp

AoA=5.5deg, Comparison with exp.: provided grid

All the results of suction peak at main wing were underestimated in provided grid.

Case 1-1: Cp

AoA=9.5deg, Comparison with exp.

All results showed good agreement with experiment.
Case 1-1: Cp

AoA=14deg, Comparison with exp.

All results showed good agreement with experiment.

Case 1-1: Cp

AoA=24deg, Comparison of high-AoA Cp

Cp profile differed by the existence of flow separation at slat leading edge.
Case 1-1: $\tilde{\nu}/\nu$

**AoA=5.5deg, Comparison of grid type**

**Provided grid**
- H1/provided(L2)/SA

**Custom grid**
- H2/custom(L2,polyhedral)/SA
- I1/provided(L2)/SA
- I2/custom(L2,polyhedral)/SA

The influence of grid topology was large.

---

**Case 1-1: $\tilde{\nu}/\nu$**

**AoA=5.5deg, Comparison of SA and SA-R**

**SA**
- A4
- E1
- H1

**SA-R**
- I1
- M1
- K1

Rotation correction suppressed the development of turbulent viscosity.
Case 1-1: $\tilde{v}/v$

**AoA=5.5deg, Comparison of SA and SA-R**

**Case 1:** Prediction of aerodynamics

– **Case 1-2:** 2.5D steady flow simulation
  
  • Geom.: 30P30N (modified_slat-configF)
  
  • Grid: provided (required: L2, optional: L1, L3~L5) or custom
  
  • Cond.: $M = 0.17$, $Re = 1.71 \times 10^6$
  
  • AoA: $0/4/5.5/8/9.5/12/14/16/20/22/24/26 \ [\text{deg}]$
  
  • List of data:  
    – Aerodynamic coefficients ($C_D, C_L, C_m, C_p, C_f$)
    – Surface contours of $C_p, C_f$
    – Surface streamline
    – Contours of $\tilde{v}/v$
    – Spatial streamlines
    – Velocity profiles

Rotation correction suppressed the development of turbulent viscosity.
Case 1-2: Aerodynamic coefficients

Comparison with 2D simulation

There was little difference between 2D and 2.5D simulations.

Case 1-2: Cf

AoA=5.5deg

The fluctuation of Cf distribution along the spanwise direction disappeared by use of periodic boundary condition.
Case 1-2: Streamlines on flap

$\text{AoA}=5.5\text{deg}$

The fluctuation of streamlines along the spanwise direction disappeared by use of periodic boundary condition.

Case 1: Prediction of aerodynamics

– Case1-3: 2.5D unsteady flow simulation
  
  • Geom.: 30P30N (modified_slat_configF)
  
  • Grid: provided (required: L2, optional: L1, L3~L5) or custom
  
  • Cond.: $M=0.17$, $Re=1.71 \times 10^6$
  
  • AoA: 5.5/9.5 [deg]
  
  • List of data (time averaged):
    
    – Aerodynamic coefficients($C_D, C_L, C_m, C_p, C_f$
    
    – Surface contours of $C_p, C_f$
    
    – Surface streamline
    
    – Contours of
    
    – Spatial streamline
    
    – Velocity profiles
Case 1-3: Cp (unsteady)

AoA=5.5deg, Comparison with steady solution

Unsteady results underestimated Cp profile compared to steady solutions.

Case 1-3: Cp (steady)

AoA=5.5deg

Unsteady results underestimated Cp profile compared to steady solutions.
Case 1-3: Cp(Slat)

AoA=5.5deg, Comparison of each parts

Steady simulations showed good agreement with experiment at upper surface. Unsteady simulations underestimated Cp at upper surface but show better agreement with experiment at lower surface. LBM overestimated Cp.

Case 1-3: Cp(Main)

AoA=5.5deg, Comparison of each parts

NS results underestimated the suction peak. Some steady flow simulation results captured the suction peak by use of custom grid. LBM results showed better agreement with experiment.
Case 1-3: Cp(Flap)

AoA=5.5deg, Comparison of each parts

Case 1-3: Cp(unsteady)

AoA=9.5deg, Comparison with steady solution

Steady flow simulation by NS showed good agreement with experiment, but unsteady flow simulation by NS underestimated Cp. LBM results overestimated Cp at upper surface, but the suction peak was better than NS.

Same trend with AoA=5.5degree was observed.
Case 1-3: $C_p$ (steady)

AoA=9.5deg, Comparison with steady solution

Same trend with AoA=5.5degree was observed.

Case 1-3: Cf distribution

AoA=5.5deg, Comparison by solver type

The variation was large and LBM overestimated Cf.
Case 1-3: The position of velocity profile comparison

Case 1-3: Velocity profiles (unsteady)

Velocity profiles differed between steady and unsteady flow simulations, and also between NS and LBM.
Case 1-3: Velocity profiles (steady)

Velocity profiles differed between steady and unsteady flow simulations, and also between NS and LBM.

Case 1-3: Streamlines on flap (L1)

AoA=5.5deg, provided grid, comparison of L1

The position of flow separation moved forward by increasing grid resolution.
Case 1-3: Streamlines on flap (L2)

AoA=5.5deg, provided grid, comparison of L2

The position of flow separation moved forward by increasing grid resolution.

Case 1-3: Streamlines on flap (L3)

AoA=5.5deg, provided grid, comparison of L3

The position of flow separation moved forward by increasing grid resolution.
Case 1-3: $\tilde{v}/v$ (L1)

AoA=5.5deg, provided grid, comparison of L1

Turbulent viscosity decreased in L3 grid.

Case 1-3: $\tilde{v}/v$ (L2)

AoA=5.5deg, provided grid, comparison of L2

Turbulent viscosity decreased in L3 grid.
Case 1-3: $\tilde{v}/\nu$ (L3)

AoA=5.5deg, provided grid, comparison of L3

Turbulent viscosity decreased in L3 grid.

Case 1  Summary

- Case 1-1: 2D RANS
  - The variation in results was significant compared with past APC series.
  - There was large influence on type of grid (Cartesian or Unstructured) and flow solver (NS or LBM).
  - Good agreement with experiment was obtained.
  - $C_p$ (especially around the suction peak) was underestimated by the provided grid.
  - The variation was large at high-AoA results with the existence of large separation at slat.
  - Turbulent viscosity was suppressed by rotation correction for SA.

- Case 1-2: 2.5D RANS
  - Spanwise distribution was disappeared by use of periodic boundary condition.
  - The position of flow separation at flap was almost same in each group due to the use of same turbulence model.

- Case 1-3: 2.5D unsteady flow simulation
  - Time-averaged $C_p$ by unsteady flow simulation was relatively smaller than RANS.
  - Slat $C_p$ computed by unsteady flow simulation showed good agreement with experiment.
  - $C_p$ by NS < $C_p$ by LBM
  - Velocity profiles showed different trend between NS and LBM.
  - The position of flow separation at flap moved forward by increasing grid resolution.
  - L3 grid produced smaller turbulent viscosity than L2 grid.
Case 2: Prediction of flow separation at flap

– Case2-1: 2D steady flow simulation
  - Geom.: 30P35N (modified_slat_configF)
  - Grid: provided (required: L2, optional: L1, L3~L5) or custom
  - Cond.: $M = 0.17$, $Re = 1.71 \times 10^6$
  - AoA: 5.5 [deg]
  - List of data:
    - Aerodynamic coefficients $(C_D, C_L, C_m)$, $C_p$, $C_f$
    - Contours of $\tilde{\nu}$ / $\nu$
    - Spatial streamlines
    - Velocity profiles

Legend (participant ID / grid type); provided by JAXA, C: custom

- EXP(30P30N) – A1/J-L2
- E1/J-L2 – E1/J-L3
- H1/J-L2 – H2/C-L1
- H2/C-L2 – I1/J-L2
- I2/C-L2 – K1/C-L1

Comparison with 30P30N

CD of 30P35N increased compared to result of 30P30N.
The variation increased due to flow separation at flap.
Case 2-1: $C_L$

**Comparison with 30P30N**

$C_L$ of 30P35N showed different trend in each ID. The variation increased due to flow separation at flap.

Case 2-1: $C_m$

**Comparison with 30P30N**

$C_m$ of 30P35N showed different trend in each ID. The variation increased due to flow separation at flap.
Case 2-1: Cp (Slat)

AoA=5.5deg, Comparison of each parts

The variation of 30P35N was larger than 30P30N.

Case 2-1: Cp (Main)

AoA=5.5deg, Comparison of each parts

The variation of 30P35N was larger than 30P30N.
**Case 2-1 : Cp(Flap)**

AoA=5.5deg, Comparison of each parts

※All the submitted data is shown

The variation of 30P35N was larger than 30P30N.

**Case 2-1 : Cf (Slat)**

AoA=5.5deg, Comparison of each parts

※All the submitted data is shown

The variation of Cf was large between the type of solver.
Case 2-1: Cf(Main)

AoA=5.5deg, Comparison of each parts

※All the submitted data is shown

The variation of Cf was large between the type of solver.

Case 2-1: Cf(Flap)

AoA=5.5deg, Comparison of each parts

※All the submitted data is shown

The variation of Cf was large between the type of solver.
Case 2-1: Cf(Slat)

AoA=5.5deg, Comparison of each parts

The Cf variation of 30P35N was larger than that of 30P30N.

Case 2-1: Cf(Main)

AoA=5.5deg, Comparison of each parts

The Cf variation of 30P35N was larger than that of 30P30N.
Case 2-1: Cf(Flap)

AoA=5.5deg, Comparison of each parts

※IDs which submit both Case1-1 and Case2-1 are shown

Flap

30P35N

AoA=5.5deg, Comparison with 30P30N

The Cf variation of 30P35N was larger than that of 30P30N.

Case 2-1: Contours of $\tilde{v} / \nu$(30P35N)

AoA=5.5deg, Comparison with 30P30N
Case 2-1: Contours of $\bar{v} / \nu(30P30N)$

AoA=5.5deg, Comparison with 30P30N

Case 2-1: Contours of $\bar{v} / \nu(30P35N)$

AoA=5.5deg, Comparison with 30P30N
Case 2-1: Contours of $\tilde{v} / \nu(30P30N)$

AoA=5.5deg, Comparison with 30P30N

Case 2-1: Spatial streamlines(30P35N)

AoA=5.5deg, Comparison with 30P30N
Case 2-1: Spatial streamlines(30P30N)

AoA=5.5deg, Comparison with 30P30N

Case 2-1: Spatial streamlines(30P35N)

AoA=5.5deg, Comparison with 30P30N
Case 2-1: Spatial streamlines (30P30N)

AoA=5.5deg, Comparison with 30P30N

Case 2: Prediction of flow separation at flap

– Case 2-2: 2.5D steady flow simulation
  • Geom.: 30P35N (modified_slat_configF)
  • Grid: provided (required: L2, optional: L1,L3~L5) or custom
  • Cond.: M = 0.17, Re = 1.71 x 10^6
  • AoA: 5.5 [deg]
  • List of data:
    – Aerodynamic coefficients (C_D, C_L, C_m)
    – Surface contours of C_p, C_f
    – Surface streamlines
    – Contours of \( \bar{v} \)/\( v \)
    – Spatial streamlines
    – Velocity profiles
Case 2-2: Surface streamlines on flap(30P35N)

AoA=5.5deg, Comparison with 30P30N

Case 2-2: Surface streamlines on flap(30P30N)

AoA=5.5deg, Comparison with 30P30N
Case 2: Prediction of flow separation at flap

– Case 2-3: 2.5D unsteady flow simulation
  • Geom.: 30P35N (modified_slat_configF)
  • Grid: provided (required: L2, optional: L1, L3~L5) or custom
  • Cond.: M = 0.17, Re = 1.71 x 10^6
  • AoA: 5.5 [deg]
  • List of data (time averaged):
    – Aerodynamic coefficients (C_D, C_L, C_m, C_p, C_f)
    – Surface contours of C_p, C_f
    – Surface streamlines
    – Contours of \( \vec{v} / \nu \)
    – Spatial streamlines
    – Velocity profiles

Legend (participant ID / grid type)
- EXP(30P30N)
- A3/J-L2
- A6/J-L2
- C1/J-L2
- E1/J-L1
- E1/J-L2
- E2/C-L2
- H1/C-L2

Case 2-3: Contours of \( \vec{v} / \nu \) (30P35N)

AoA=5.5deg, Comparison with 30P30N

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This document is provided by JAXA.
Case 2-3: Contours of $\tilde{\nu} / \nu(30P30N)$

AoA=5.5deg, Comparison with 30P30N

Case 2-3: Spatial streamlines(30P35N)

AoA=5.5deg, Comparison with 30P30N
Case 2-3: Spatial streamlines (30P30N)

AoA=5.5deg, Comparison with 30P30N

Case 2-3: Surface streamlines on flap (30P35N)

AoA=5.5deg, Comparison with 30P30N
Case 2-3: Surface streamlines on flap (30P30N)

AoA=5.5deg, Comparison with 30P30N

Case 2 Summary

- Prediction of flow separation at flap (30P35N)
  - CD increased in all participants compared to 30P30N. But CL and Cm showed different behavior. The position of flow separation at flap also varied by flow solvers.

- The computational results seemed to be affected by periodic boundary condition.
Case 3: Prediction of aeroacoustics

— Case 3-1: Near field acoustics

- Geom.: 30P30N (modified_slat_configF)
- Grid: provided (required: L2, optional: L3) or custom
- Cond.: $M = 0.17, \ Re = 1.71 \times 10^6$
- AoA: $5.5/9.5/14 \ [\text{deg}]$ (red: required, black: optional)
- List of data:
  - PSD of Pressure
  - Contours of spanwise vorticity
  - Contours of time-averaged 2D TKE
  - Contours of $C_{prms}$

Legend (participant ID / grid type [J: provided by JAXA, C: custom] - grid resolution [L1~L5]):

Sample data where $Z = 1$ [inch] on the center line of wing span
Slat: 5 point, Main: 2 point, Flap: 1 point
Case 3-1: PSD

AoA=5.5deg, Comparison with experiment ※Probe point of H1 is different from set point

NBPs were well captured in each CFD result. The variation of the peak around 20kHz was large.

Case 3-1: PSD

AoA=5.5deg, Comparison with experiment ※Probe point of H1 is different from set point

CFD results showed good agreement with experiment.
Case 3-1: PSD

AoA=5.5deg, Comparison with experiment

CFD results showed good agreement with experiment.

Case 3-1: PSD

AoA=5.5deg, Comparison with experiment ※Probe point of H1 is different from set point

NBPs were well captured in each CFD result.
The variation of the peak around 20kHz was large.
Case 3-1: PSD

AoA=5.5deg, Comparison with experiment

NBPs were well captured in each CFD result.
The variation of the peak around 20kHz was large.

Case 3-1: PSD(L2)

AoA=5.5deg, Comparison by grid resolution

※Probe point of H1 is different from set point

L2 grid overestimated the level of NBPs.
There were some results which couldn’t predict the peak around 20kHz.
Case 3-1: PSD (L3)

AoA=5.5deg, Comparison by grid resolution

L3 grid successfully predicted the level of NBPs. Almost all results captured the peak around 20kHz.

Case 3-1: PSD (L2)

AoA=5.5deg, Comparison by grid resolution

※Probe point of H1 is different from set point

L2 grid overestimated the level of NBPs. There were some results which couldn’t predict the peak around 20kHz.
Case 3-1: PSD(L3)

AoA=5.5deg, Comparison by grid resolution

L3 grid successfully predicted the level of NBPs. Almost all results captured the peak around 20kHz.

Case 3-1: z-vorticity (without peak from slat-TE)

AoA=5.5deg, L2 grid

No/Small Karman vortex shedding from slat TE
Case 3-1: z-vorticity (with peak from slat-TE)

AoA=5.5deg, L3 grid

Karman vortex shedding from slat-TE

High order/resolution schemes could capture vortex shedding from slat-TE with L2 grid.
Case 3-1: TKE2D (without peak from slat-TE)

AoA=5.5deg, L2 grid

Case 3-1: TKE2D (with peak from slat TE)

AoA=5.5deg, L3 grid
Case 3-1: TKE2D (with peak from slat-TE)

\[ \text{AoA} = 5.5 \text{deg}, \text{L2 grid} \]

\[ \text{A8(L2)} \]
\[ \text{A7(L2)} \]
\[ \text{A6(L2)} \]
\[ \text{A3(L2)} \]
\[ \text{F2(L2)} \]
\[ \text{H1(L2)} \]

High order/resolution schemes can capture vortex shedding from slat-TE with L2 grid.

Case 3-1: Contours of Cp rms (No peak)

\[ \text{AoA} = 5.5 \text{deg}, \text{Comparison by the existence of high frequency peak} \]

\[ \text{A2(L2)} \]
\[ \text{C1(L2)} \]
\[ \text{F1(L2)} \]
\[ \text{F2(L2)} \]
\[ \text{G1(L2)} \]
\[ \text{H1(L2)} \]
\[ \text{J1(L3)} \]
\[ \text{L1(L2)} \]

L2 grid couldn’t capture the high frequency peak from slat TE due to the lack of resolution.
Case 3-1: Contours of $C_p$ rms (with peak)

AoA=5.5deg, Comparison by the existence of high frequency peak: L3 grid

L3 grid could capture the high frequency peak from slat TE.

Case 3-1: Contours of $C_p$ rms (with peak)

AoA=5.5deg, Comparison by the existence of high frequency peak: L2 grid

High order/resolution schemes could capture the high frequency peak from slat TE with L2 grid.
Case 3-1: PSD

AoA=9.5deg, Comparison with experiment

※Probe point of H1 is different from set point

NBPs were well captured in each CFD result. The variation of the peak around 20kHz was large.

Case 3-1: PSD

AoA=9.5deg, Comparison with experiment

※Probe point of H1 is different from set point

CFD results showed good agreement with experiment.
Case 3-1: PSD

AoA=9.5deg, Comparison with experiment

CFD results showed good agreement with experiment.

Case 3-1: PSD

AoA=9.5deg, Comparison with experiment

※Probe point of H1 is different from set point

NBPs were well captured in each CFD result.
The variation of the peak around 20kHz was large.
Case 3-1: PSD

AoA=9.5deg, Comparison with experiment

NBPs were well captured in each CFD result. The were large differences at high frequency region.

Case 3-1: PSD

AoA=14deg, Comparison with experiment

※Probe point of H1 is different from set point

CFD results captured NBPs but there was no NBPs in experiment.
Case 3-1: PSD

AoA=14deg, Comparison with experiment

CFD results showed good agreement with experiment.

Case 3-1: PSD

AoA=14deg, Comparison with experiment

CFD results showed good agreement with experiment.
Case 3-1: PSD

AoA=14deg, Comparison with experiment

@M7(α=14)

CFD results captured NBPs but there was no NBPs in experiment.
There was no peak at high frequency region in experiment.

Case 3-1: PSD

AoA=14deg, Comparison with experiment

@F1(α=14)

There was no NBPs in experiment.
The were large differences at high frequency region.
Case 3: Prediction of aeroacoustics

— Case 3-2: Far field acoustics

- Geom.: 30P30N (modified_slat_configF)
- Grid: provided (required: L2, optional: L3) or custom
- Cond.: M = 0.17, Re = 1.71 x 10^6
- AoA: 5.5/9.5/14 [deg] (red: required, black: optional)
- List of data:
  - PSD of Pressure

Legend (participant ID / grid type [J: provided by JAXA, C: custom] - grid resolution [L1~L5])

|----------|---------|---------|---------|---------|---------|

(a) The acoustic measurements are reported for three different observer locations. Specifically, for comparison with CFD, these microphone locations are denoted as 10c: 340deg, 10c: 270deg, 10c: 291deg, respectively.

The following sequence of steps was applied during the data reduction of the acoustic measurements:

(i) First, the data obtained by the integration of 503+F03 regions using microphone array were normalized to 1m location from the model rotation center (see attached 2018 JAXA Paper by Murayama et al. for further details).

Microphone array locations:

1. 249deg (Upstream of 270 deg location)
   X = 431.5mm, Y = 1124.1mm, R = 1204.07mm, ±2.63355m (stowed)
2. 270deg (Center)
   X = 0mm, Y = 1204.1mm, ± R = 1204.10mm, ±2.63364m (stowed)
3. 291deg (Downstream)
   X = 431.5mm, Y = 1124.1mm, ± R = 1204.07mm, ±2.63355m (stowed)

(ii) The data was normalized to 1-inch spanwise width of the source region.

(iii) Finally, the data was adjusted to account for the attenuation of acoustic signal from 1m to 10c.

(b) The definition of center of directivity for CFD (rotation center when AoA changes) is trailing-edge of flat or the origin of geometry/mesh data. The directivity in CFD was defined so that a reference angle of 0 deg. corresponds to the flow direction.

(c) The definition of center of directivity (rotation center when AoA changes) for wind tunnel data is 0.4c. The microphone was fixed and the model was rotated. The center location is slightly different from CFD, so the angles of directivity are slightly different from the CFD definition.

Also, the difference between uncorrected and corrected angles of attack is approximately 1.5 to 2.0deg. Therefore, a difference of 1.5 deg to 2 deg, with respect to the desired directivity angle may occur.

(d) The datafiles currently provided in this folder do not include coherence data based on the measurements of surface pressure fluctuations. They will be included at a later date.
Case 3-2: PSD

AoA=5.5deg, Comparison with experiment

※Probe point of H1 is different from set point
Case 3-2: PSD

AoA=5.5deg, Comparison with experiment ※Probe point of H1 is different from set point

@270deg(α=5.5)

Case 3-2: PSD

AoA=5.5deg, Comparison with experiment ※Probe point of H1 is different from set point

@291deg(α=5.5)
Case 3-2: PSD(L2)

AoA=5.5deg, Comparison by grid resolution

※Probe point of H1 is different from set point

Case 3-2: PSD(L3)

AoA=5.5deg, Comparison by grid resolution
Case 3-2: PSD(L2)

AoA=5.5deg, Comparison by grid resolution
※ Probe point of H1 is different from set point

L2

Case 3-2: PSD(L3)

AoA=5.5deg, Comparison by grid resolution
Case 3-2: PSD(L2)

AoA=5.5deg, Comparison by grid resolution
※Probe point of H1 is different from set point

L2

@291deg(L2,α=5.5)

Case 3-2: PSD(L3)

AoA=5.5deg, Comparison by grid resolution

L3

@291deg(L3,α=5.5)
Case 3-2: PSD

AoA=9.5deg, Comparison with experiment

※Probe point of H1 is different from set point
Case 3-2: PSD

AoA=9.5deg, Comparison with experiment

※Probe point of H1 is different from set point

@270deg(α=9.5)

@291deg(α=9.5)
Case 3-2: PSD

AoA=14deg, Comparison of results

![Graph showing PSD at 135deg(α=14)]

Case 3-2: PSD

AoA=14deg, Comparison with experiment

![Graph showing PSD at 249deg(α=14)]
Case 3-2: PSD

AoA=14deg, Comparison with experiment

@270deg(\(\alpha=14\))

[Graph showing PSD comparison with experiment, frequency range 100 to 10000 Hz]

@291deg(\(\alpha=14\))

[Graph showing PSD comparison with experiment, frequency range 100 to 10000 Hz]
Case 3  Summary

• Near/Far field acoustic prediction
  – Submitted near field data (PSD) showed good agreement with experiment.
  
  – In L2 grid, NBPs (1k~10kHz) were overestimated and the peak from slat TE (20kHz) was not captured by low-resolution schemes.
  
  – High-resolution/order scheme and high-resolution grid enabled the capturing of the peak from slat TE. These results showed good agreement with experiment.

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