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Test cases of Fifth Aerodynamics Prediction Challenge (APC-V)

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APC committee

Test case of APC-V

- Aerodynamics/Aeroacoustics prediction of 30P30N
  Case１: Prediction of aerodynamics
  Case２: Prediction of flow separation at flap
  Case３: Prediction of aeroacoustics（near/far field）
  Case４: Free topic

- Geometry
  30P30N（modified_slat_configF）
  30P35N（modified_slat_configF）

- Flow condition（same with BANC workshop※1）
  M = 0.17, Re = 1.71 x 10^6, Tinf=295.56K
  α = 5.5deg, 9.5deg

※1　URL http://aeroacoustics2016.com/banc-iv-workshop/

Case1：Prediction of aerodynamics

- Aims
  - Compare Cp/CL obtained by 2D steady or 2.5D steady/unsteady flow simulation with experimental data[1]
  - Check the dependency of flow solver, grid, and turbulence model

- Recommendation
  - use periodic boundary condition to spanwise direction in case of 2.5D simulation[2]

[1] Murayama, M., Nakakita, K., Yamamoto, k., Ura, H., Ito, Y., and Choudhari, M.M., "Experimental Study on Slat Noise from 30P30N Three-Element High-Lift Airfoil at JAXA Hard-Wall Lowspeed Wind Tunnel", AIAA 2014-2080
[2] Sakai, R., Ishida, T., Murayama, M., Ito, Y., and Yamamoto, K., "Effect of Subgrid Length Scale in DDES on Aeroacoustic Simulation around Three-Element Airfoil," AIAA 2018-0756, 2018.

Case1-1：2D steady flow simulation

• Geometry	30P30N_modified_slat_configF
• Grid※1	provided（required：L2，optional：L1,L3~L5）or custom
• Condition	M = 0.17，Re = 1.71 x 10^6
• AoA[degree]	0/4/5.5/8/9.5/12/14/16/20/22/24/26 （red: required, black：optional）
• Turbulence model	free
• List of data※2	①Aerodynamic coefficients (C_D,C_L,C_m),C_p,C_f ②Contours of μ_t/μ ③Spatial streamlines ④Velocity profiles

※1 The size of custom grid should be equivalent to provided grids.

※2 ②～④ are required for AoA=5.5 and 9.5.
Submit aerodynamic coefficients for each component.

Case1-2 : 2.5D steady flow simulation

- Geometry — 30P30N_modified_slat_configF
- Grid※1 — provided（required : L2, optional : L1,L3~L5） or custom
- Condition — M = 0.17, Re = 1.71 x 10^6
- AoA[degree] — 0/4/5.5/8/9.5/12/14/16/20/22/24/26
  （red : required, black : optional）
- Turbulence model — free
- List of data※2 — ①Aerodynamic coefficients(C_D,C_L,C_m),C_p,C_f
  ②Surface contours of C_p,C_f
  ③Surface streamlines
  ④Contours of μ_t/μ
  ⑤Spatial streamlines
  ⑥Velocity profiles

※1 The size of custom grid should be equivalent to provided grids.

※2 ②～⑥ are required for AoA=5.5 and 9.5.
Submit aerodynamic coefficients for each component.

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Case1-3 : 2.5D unsteady flow simulation

- Geometry — 30P30N_modified_slat_configF
- Grid※1 — provided（required : L2, optional : L1,L3~L5） or custom
- Condition — M = 0.17, Re = 1.71 x 10^6
- AoA[degree] — 5.5/9.5
- Turbulence model — free
- List of data※2 — ①Aerodynamic coefficients(C_D,C_L,C_m),C_p,C_f
  ②Surface contours of C_p,C_f
  ③Surface streamlines
  ④Contours of μ_t/μ
  ⑤Spatial streamlines
  ⑥Velocity profiles

※1 The size of custom grid should be equivalent to provided grids.

※2 Submit aerodynamic coefficients for each component.
Submit time-averaged data.
Cp and Cf are desirable to take both time and spanwise average.

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Case2 : Prediction of flow separation at flap

- Aim
  - Predict flow separation at flap to change flap deflection angle
  - Compare the result of 2D steady or 2.5D steady/unsteady flow simulation [1]

[1]Terracol, M., and Manoha, M., "Wall-resolved Large Eddy Simulation of a highlift airfoil: detailed flow analysis and noise generation study", AIAA 2014-3050

Case2-1 : 2D steady flow simulation

• Geometry	30P35N_modified_slat_configF
• Grid※1	provided（required : L2, optional : L1,L3~L5） or custom
• Condition	M = 0.17, Re = 1.71 x 10^6
• AoA[degree]	5.5
• Turbulence model	free
• List of data※2	①Aerodynamic coefficients (C_D,C_L,C_m),C_p,C_f ②Contours of μ_t/μ ③Spatial streamlines ④Velocity profiles

※1 The size of custom grid should be equivalent to provided grids.

※2 Submit aerodynamic coefficients for each component.

Case2-2 : 2.5D steady flow simulation

- Geometry 30P35N_modified_slat_configF
- Grid※1 provided（required : L2, optional : L1,L3~L5） or custom
- Condition M = 0.17, Re = 1.71 x 10^6
- AoA[degree] 5.5
- Turbulence model free
- List of data※2
  ①Aerodynamic coefficients(C_D,C_L,C_m),C_p,C_f
  ②Surface contours of C_p,C_f
  ③Surface streamlines
  ④Contours of μ_t/μ
  ⑤Spatial streamlines
  ⑥Velocity profiles

※1 The size of custom grid should be equivalent to provided grids.

※2 Submit aerodynamic coefficients for each component.
Cp and Cf are desirable to take spanwise average.

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Case2-3 : 2.5D unsteady flow simulation

- Geometry 30P35N_modified_slat_configF
- Grid※1 provided（required : L2, optional : L1,L3~L5） or custom
- Condition M = 0.17, Re = 1.71 x 10^6
- AoA[degree] 5.5
- Turbulence model free
- List of data※2
  ①Aerodynamic coefficients(C_D,C_L,C_m),C_p,C_f
  ②Surface contours of C_p,C_f
  ③Surface streamlines
  ④Contours of μ_t/μ
  ⑤Spatial streamlines
  ⑥Velocity profiles

※1 The size of custom grid should be equivalent to provided grids.

※2 Submit aerodynamic coefficients for each component.
Submit time-averaged data.
Cp and Cf are desirable to take both time and spanwise average.

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Case3 : Prediction of aeroacoustics

- Aims
  - Compare the wall pressure variation at slat/main by 2.5D unsteady flow simulation with experiment[1,2]
  - Compare the far field acoustics by FW-H with experiment[3]
  - Check the effect of AoA for the Narrow Band Peaks (NBPs) and the peak from slat trailing edge

- Recommendation
  - use periodic boundary condition to spanwise direction [4]

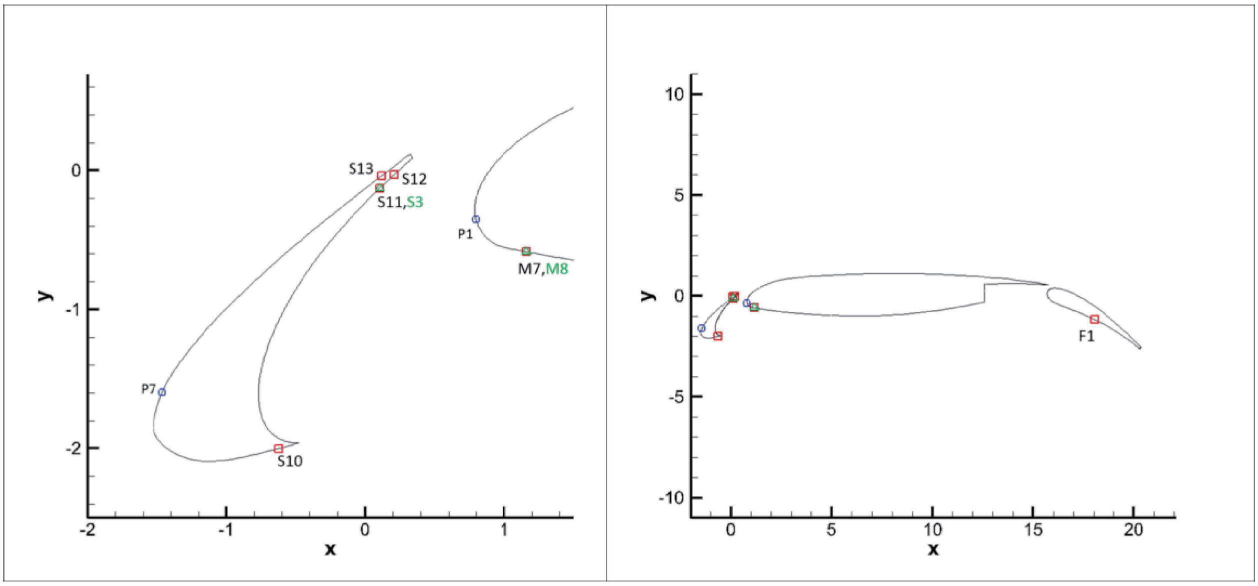
[1] Murayama, M., Nakakita, K., Yamamoto, k., Ura, H., Ito, Y., and Choudhari, M.M., "Experimental Study on Slat Noise from 30P30N Three-Element High-Lift Airfoil at JAXA Hard-Wall Lowspeed Wind Tunnel", AIAA 2014-2080
[2] Terracol, M., Manoha, E., Murayama, M., and Yamamoto, K., "Aeroacoustic Calculations of the 30P30N High-lift Airfoil using Hybrid RANS/LES methods: Modeling and Grid Resolution Effects", AIAA 2015-3132
[3] Choudhari, M.M., and Lockard, D.P., "Assessment of Slat Noise Predictions for 30P30N High-Lift Configuration from BANC-III Workshop", AIAA 2015-2844
[4] Sakai, R., Ishida, T., Murayama, M., Ito, Y., and Yamamoto, K., “Effect of Subgrid Length Scale in DDES on Aeroacoustic Simulation around Three-Element Airfoil,” AIAA 2018-0756, 2018.

Case3-1 : Near field acoustics

•	Geometry	30P30N_modified_slat_configF
•	Grid※1	provided（required:L2, optional : L3） or custom
•	Condition	M = 0.17, Re = 1.71 x 10^6
•	AoA[degree]	5.5/9.5/14（red: required, black: optional）
•	Turbulence model	free
•	List of data	①PSD of wall pressure@S10, S11, S12, S13, M7, F1, P1, P7, S3, M8
		②Contours of spanwise vorticity
		③Contours of time-averaged 2D TKE
		④Contours of Cp_{rms}
		⑤Coherence data@S11-S3, M7-M8

※1 The size of custom grid should be equivalent to provided grids.

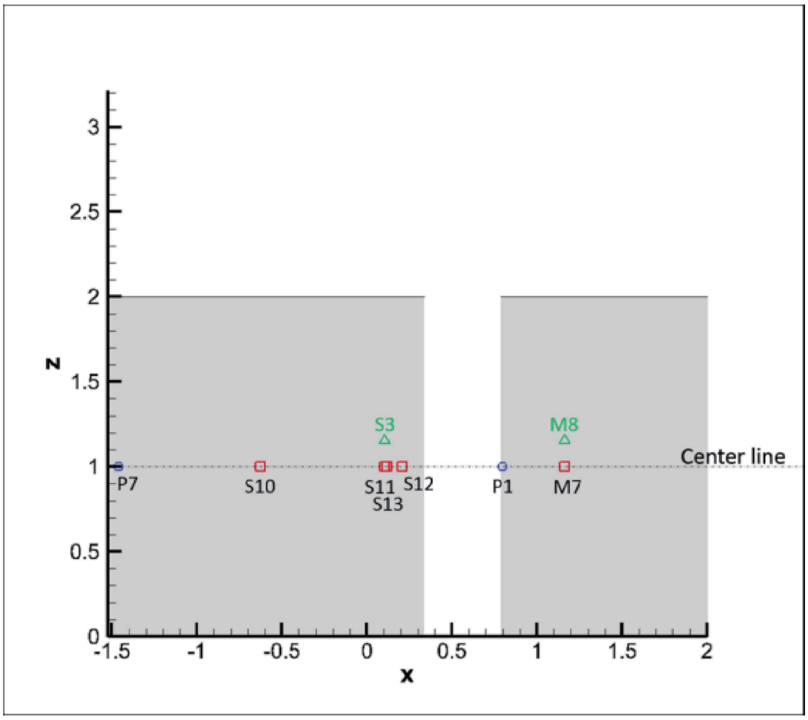
Case 3-1 : Sampling position of PSD



Sample data where Z = 1[inch] on the center line of wing span and Z = 1.156[inch]

Z = 1< Slat : 5point, Main : 2point, Flap : 1point >
Z = 1.156< Slat : 1point(S3), Main : 1point(M8) >

Case 3-1 : Sampling position of Coherence



Sample data are S11-S3@Slat and M7-M8@Main

Case3-2 : Far field acoustics

- Geometry 30P30N_modified_slat_configF
- Grid※1 provided (required : L2, optional : L3) or custom
- Condition M = 0.17, Re = 1.71 x 10^6
- AoA[degree] 5.5/9.5/14 (red: required, black: optional)
- Turbulence model free
- List of data PSD@135deg,249deg, 270deg, 291deg at 10c position

※1 The size of custom grid should be equivalent to provided L2 grid.

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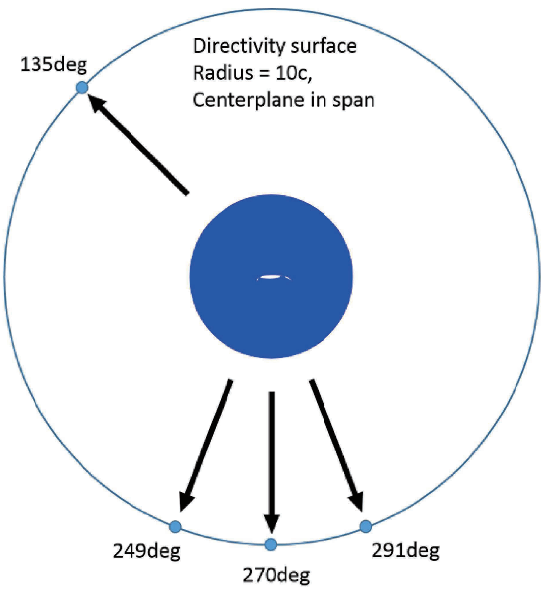
Case 3-2 : Sampling position of PSD



(a) The acoustic measurements are reported for three different observer locations. Specifically, for comparison with CFD, these microphone locations are denoted as 10c249deg, 10c270deg, 10c291deg, 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 SD3+FD3 regions using microphone array were normalized to 1m location from the model rotation center (see attached 2018 AIAA 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(=2.63358c_stowed)
2. 270deg (Center)
   X=±0mm, Y=+1204.1mm ->R=1204.10mm(=2.63364c_stowed)
3. 291deg (Downstream)
   X=-431.5mm, Y=+1124.1mm ->R=1204.07mm(=2.63358c_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 slat 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.

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Case4 : Free topic

- Geometry 30P30N_modified_slat_configF
- Grid※1 free
- Condition free
- AoA[degree] free
- Turbulence model free
- List of data Not needed

Example

- Compare solution adaptive refinement grids with provided grids (grid family) in terms of convergence.
- Compare data of DDES, Zonal, wall-modeled, wall-resolved and so on.
- Survey the relationship between initial results and converged results in CFD. (Hysteresis)
- Compare NS with LBM in terms of costs.
- Etc.

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Guideline for unsteady flow simulation

Parameters

- Dt CFL=O(1) at slat cove region
- Transient computation monitor the history of aerodynamic coefficients and judge after initial unphysical pulse pass through flap
- Sampling time more than 80ms（~10c/Uinf）

PSD processing

- Data overlapping 50%
- Window function Hanning
- Averaging data more than 10

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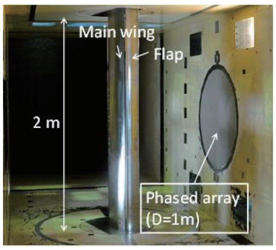
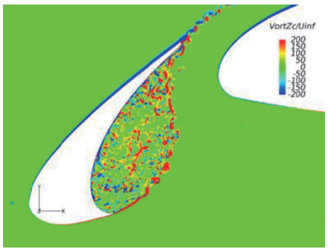
APC Website

- Geometry (formats: .igs, .stp, .crv)
  - 30P30N and 30P35N are available
- Grid (structured type, formats: .p3d, .fsgrid, .cgns)
  - 30P30N and 30P35N are available
- Please see the APC website for more information
  - https://cfdws.chofu.jaxa.jp/apc/





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