The analysis of wing-body configuration by Building-Cube Method （BCMによる翼胴形態解析の現状）

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Cases

- APC-III Case 1

  NASA-CRM aerodynamic prediction at cruise and high AoA

  → **BCM-TAS coupling solver**

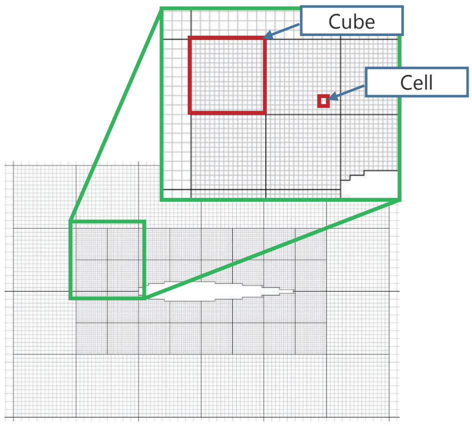
- APC-I Case2

  Wake of NASA-CRM wing-body configuration

  → **BCM solver**

Flow solver

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

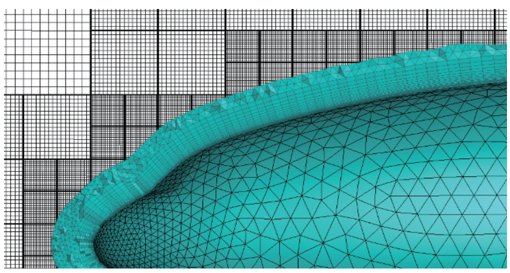


BCM mesh around NACA0012 airfoil

- Pros
  - Easy parallel computation
  - Easy grid generation for complex shapes
  - High-order spatial accuracy
- Cons
  - Shape reproducibility
  - **Difficulty in resolving boundary layer**

Near wall treatment

- BCM-TAS coupling solver
  - Efficient analysis near the wall: TAS*
  - Sufficient resolution in the far field: BCM



Coupling mesh around CRM

*TAS (Tohoku university Aerodynamic Simulation)

- Unstructured mesh solver

Case 1

NASA-CRM aerodynamic prediction at cruise and high AoA

- Geometry: wing, body, tail (ih = 0 deg)
- M = 0.847, $Re_c = 2.26 * 10^6$, T_{ref} = 284 K
- AoA: -1.79, -0.62, 0.32, 1.39, 2.47, 2.94, 3.55, 4.65, 5.72 deg

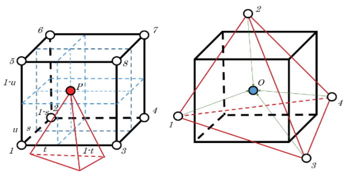
Case 1: Numerical methods

Solver : BCM-TAS coupling

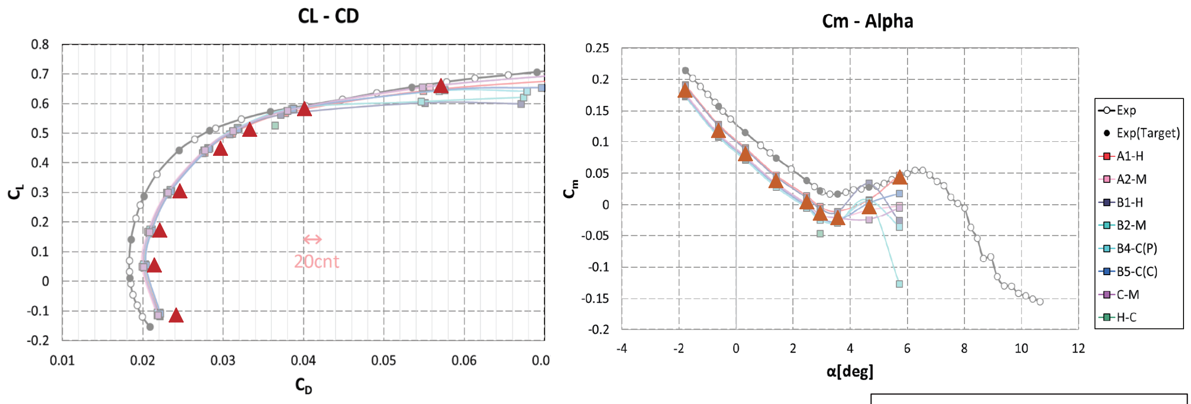
	TAS	BCM
Governing Eq.	Compressible NS Eq.	Compressible Euler Eq.
Discretization	Cell-vertex finite volume	Cell-centered finite volume
Inviscid Flux	HLLEW	HLLEW
Time integration	LU-SGS	LU-SGS
Turbulence model	SA-noft2	-

Grid : MEGG3D Medium mesh + BCM mesh

Linear interpolation between BCM and TAS



Case 1: Results



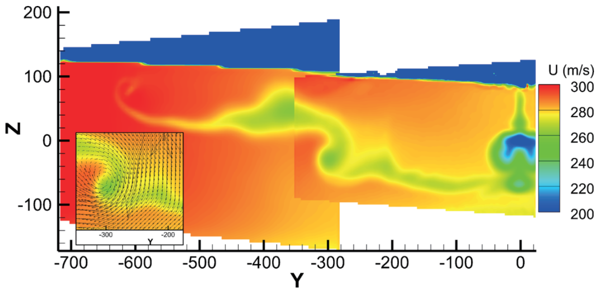
▲ BCM-TAS coupling

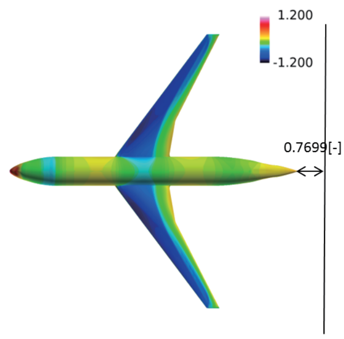
C_m : BCM-TAS is similar to FaSTAR-Hexagrid (A1-H)
C_D : BCM-TAS estimates about 20 counts larger C_D than other solvers
→ To be investigated in the future
(Turbulence model, grid, interpolation between TAS-BCM)

APC-I Case 2

Wake of NASA-CRM wing-body configuration

- M = 0.85, $Re_c = 2.26*10^6$, T_{ref} = 284 K
- AoA : 3.07, **4.84deg**
- Wing deformation considered





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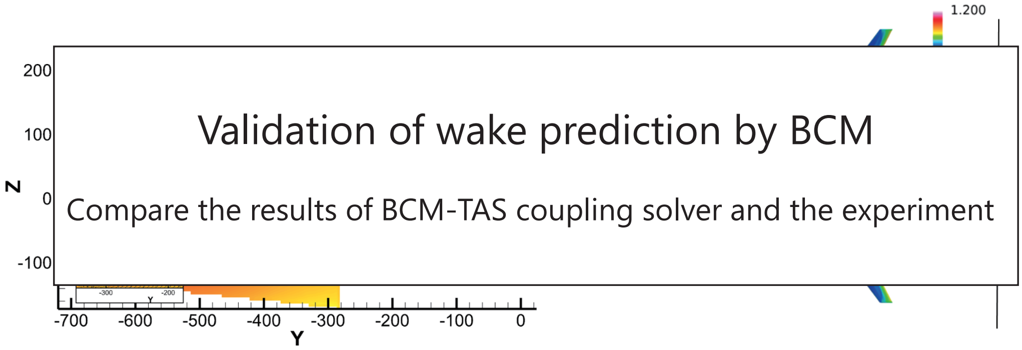


Validation of wake prediction by BCM

Compare the results of BCM-TAS coupling solver and the experiment

APC-I Case 2: Numerical methods

	BCM-NS	BCM-Euler
Governing Eq.	Compressible NS Eq.	Compressible Euler Eq.
Discretization	Cell-centered finite volume	Cell-centered finite volume
Inviscid Flux	SLAU	HLLEW
Time integration	LU-SGS	LU-SGS
Turbulence model	SA-noft2-R	-

Wall boundary treatment

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

APC-I Case 2: Computed cases

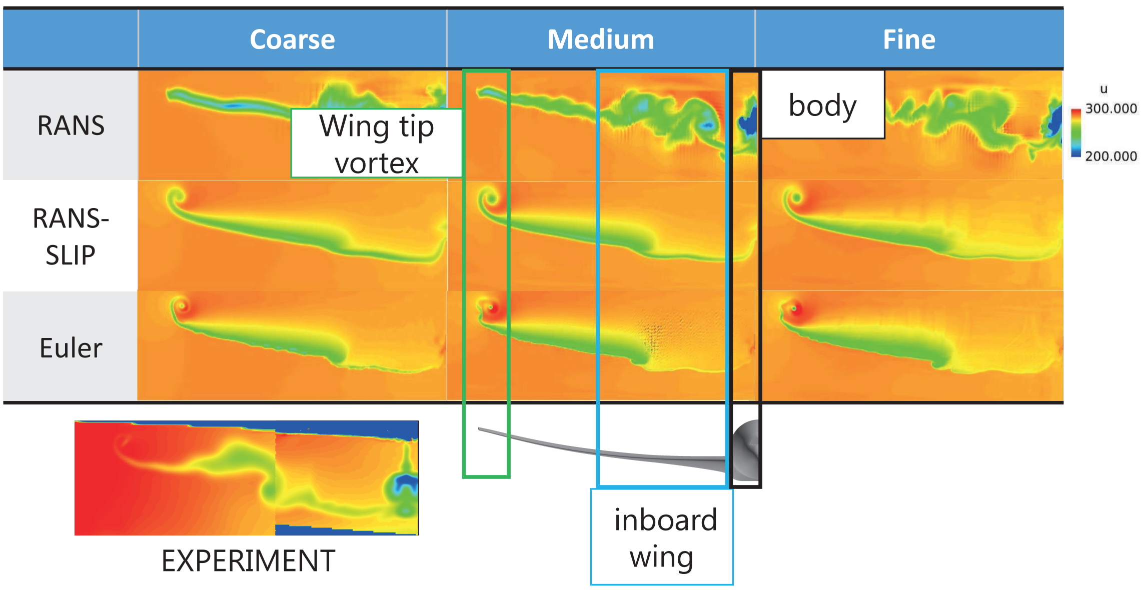
- Solvers

BCM-RANS	: NS solver / nonslip condition
BCM-RANS-SLIP	: NS solver / slip condition
BCM-Euler	: Euler solver
Coupling-Euler	: TAS(SA) / BCM Euler
Coupling-DES	: TAS(SA) / BCM (Lagrangian SGS)

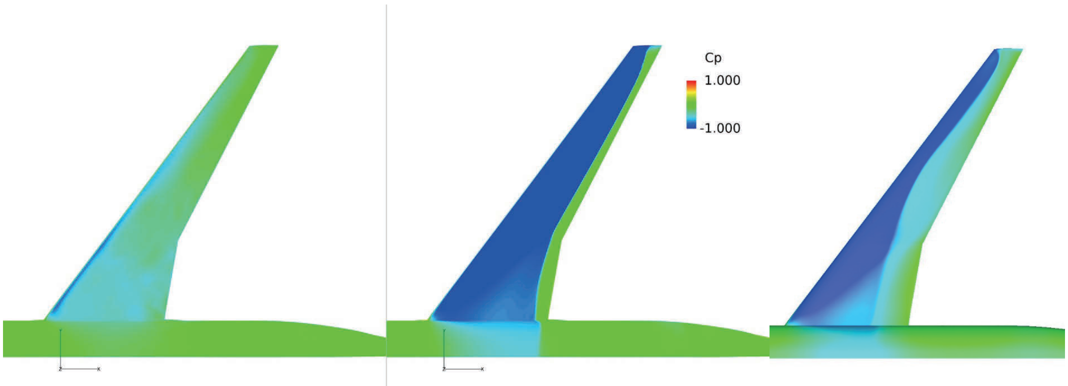
- Grid

	Coarse	Medium	Fine
Minimum grid size	0.0061035 (0.92mm)	0.0030518 (0.46mm)	0.0015259 (0.23mm)
Total cell number	253,468,672	1,425,592,320	1,459,552,256

APC-I Case 2 : Result (*u*)



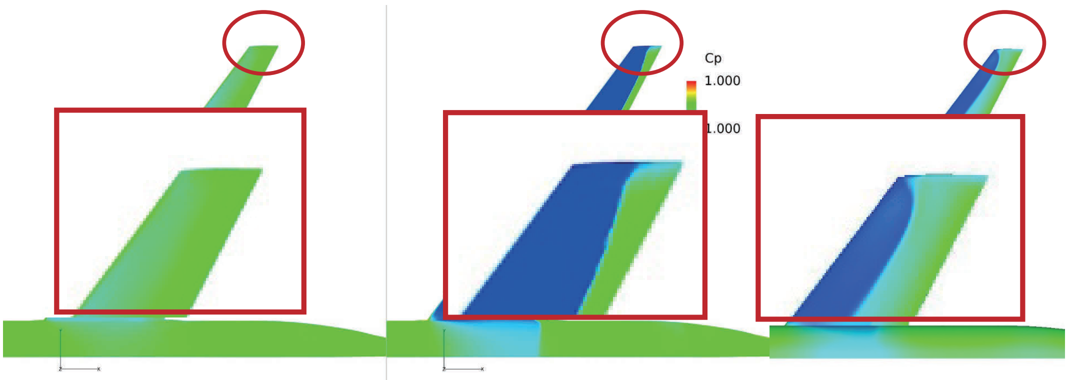
APC-I Case 2 : Result (C_p)



RANS (Fine) RANS-SLIP (Fine) Coupling-Euler

- The result of RANS does not have sufficient negative pressure to generate wing tip vortex

APC-I Case 2 : Result (C_p)



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APC-I Case 2 : Result (*w*)

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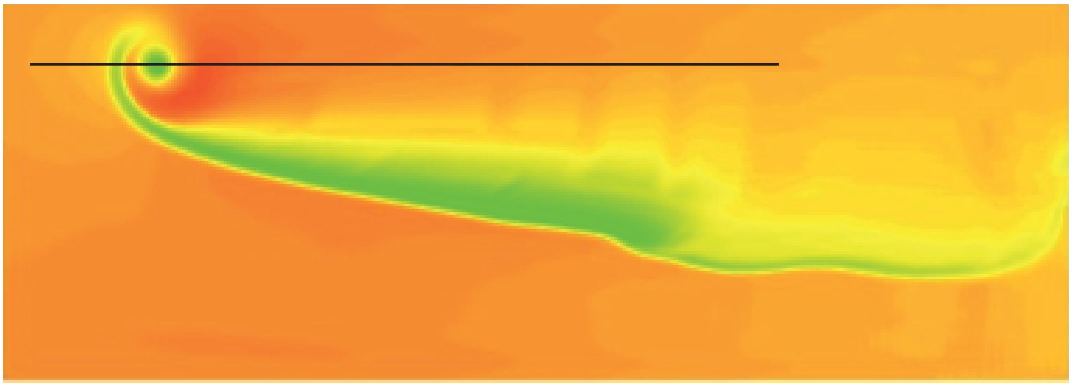

- Velocity profile along the horizontal line passing through wing-tip vortex center

APC-I Case 2 : Result (*w*)

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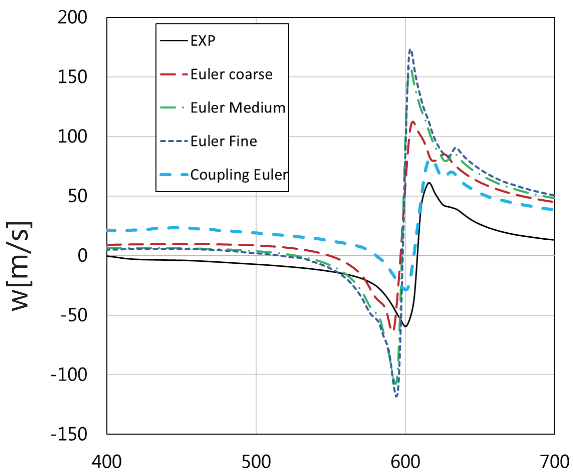
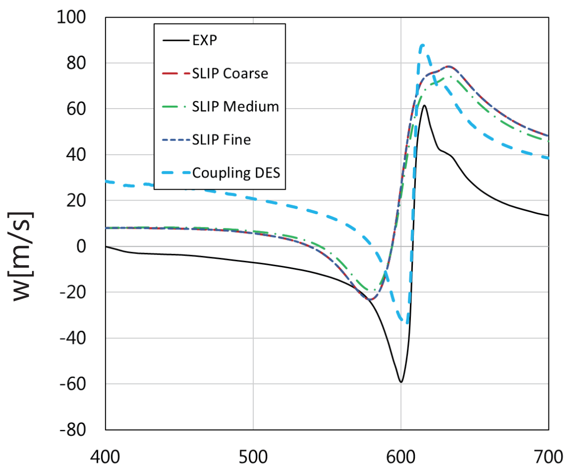


Y [mm]

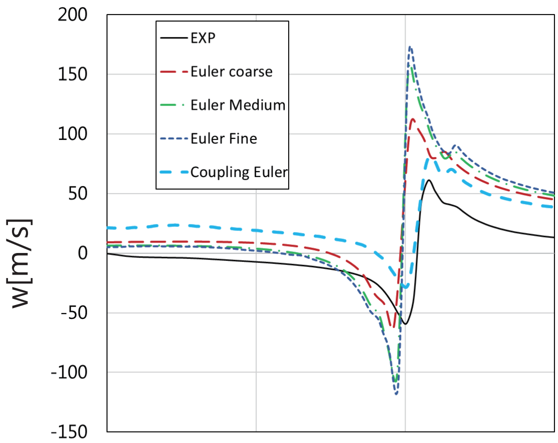
Euler

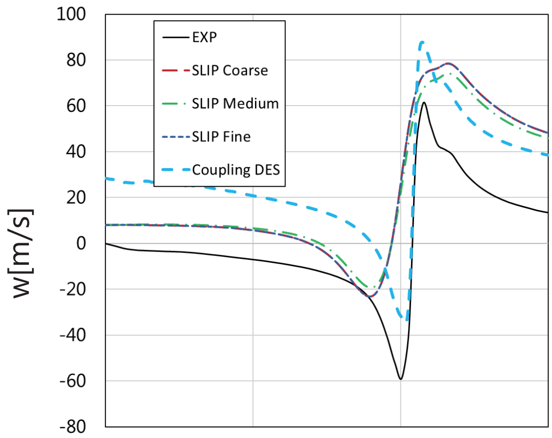


Y [mm]

RANS-SLIP

APC-I Case 2 : Result (*w*)





Euler : The peak tangential velocity is overestimated as the grid becomes fine
RANS-SLIP: Vortex core radius (velocity peak to peak distance) appears larger than the experimental and the coupling solver

- Estimated velocity is larger than the experiment

Conclusion

We analyzed APC-III Case 1 and APC-I Case 2 by BCM

- APC-III Case 1 (BCM-TAS coupling solver)
  - Good agreement with the experiment and other CFD solver for C_L and C_m
  - C_D appears larger than other solvers

  → Turbulence model? grid? interpolation between BCM-TAS?
- APC-I Case 2 (BCM solver)
  - The RANS solver did not generate a wing-tip vortex
  - BCM result could not capture separation around kink

  → It is necessary to properly resolve the surface of the object
  - Peak tangential velocity is overestimated in the BCM-Euler, and vortex core appears too large in the BCM-RANS-SLIP