



FaSTARを用いた低速・高迎角条件における NASA-CRM解析の格子依存性調査

Grid dependency Study on NASA-CRM computation with FaSTAR at low speeds and high angles of attack

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Matsuzaki Tomoaki(AdvanceSoft),

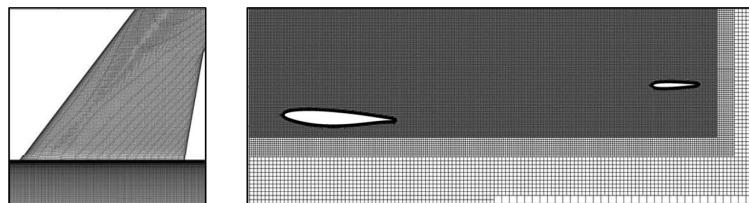
Nakamoto Keita, Hayashi Kenji(Ryoyu Systems)

Computational Grid

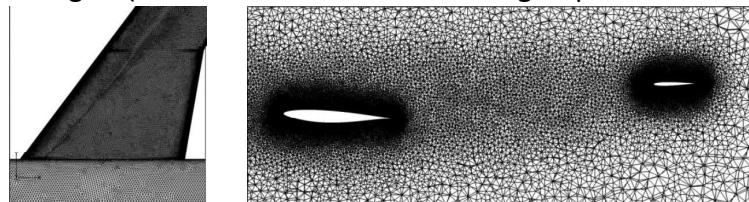


- The following three grids are used.

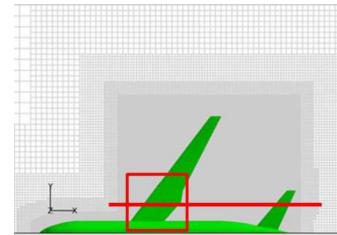
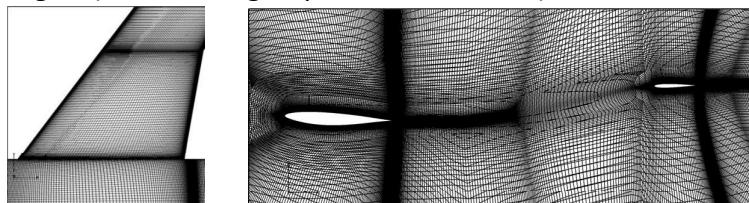
BOXFUN grid (Hexahedral unstructured grid provided at APC-6): 39M cells



MEGG3D grid (Mixed-element unstructured grid provided at APC-3): 35M nodes



UPACS grid (Structured grid provided at APC-3): 30M cells



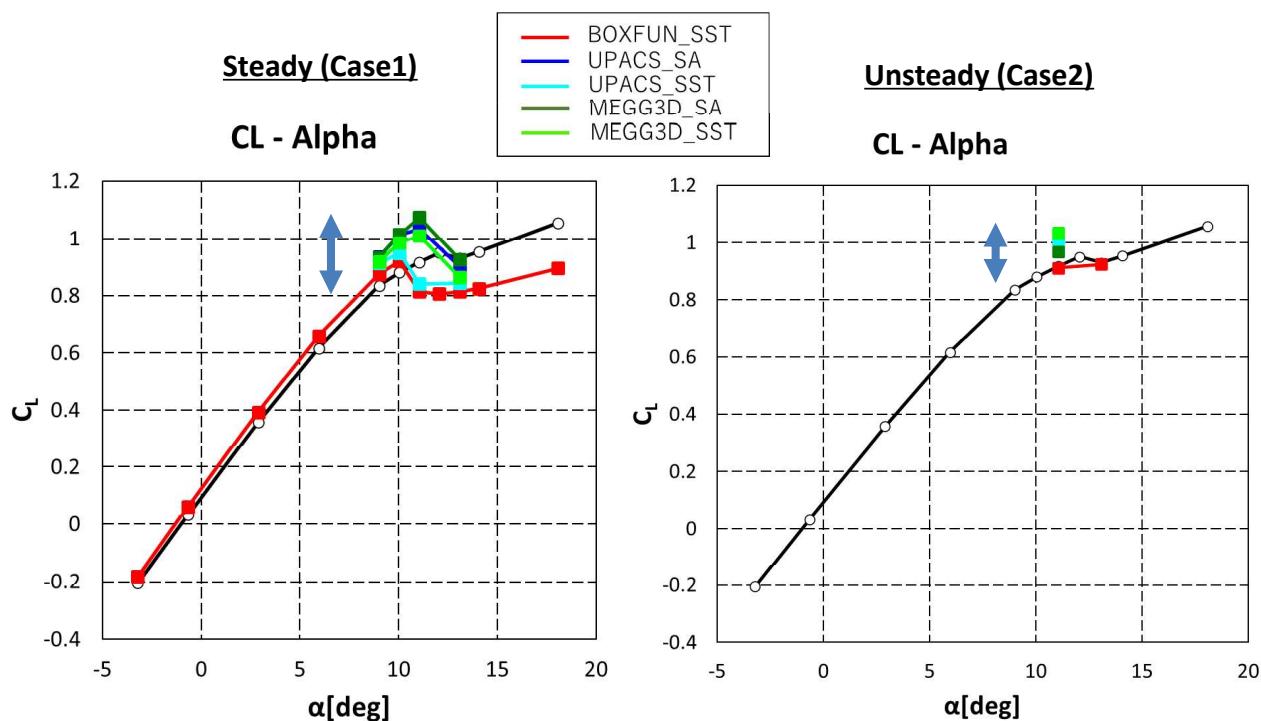
Computational conditions, methods



- Computational conditions
 - $M = 0.168$, $Re_c = 1.06 \times 10^6$, $T_{ref} = 310K$
 - $AoA = 9.01^\circ, 10.03^\circ, 11.05^\circ, 13.08^\circ$ for steady computation
 - $AoA = 11.05^\circ$ for unsteady computation
- Computational methods
 - Code: FaSTAR
 - Discretization: Cell-center for BOXFUN and UPACS grids
Cell-vertex for MEGG3D grid
 - Inviscid flux: SLAU
 - Gradient: GLSQ, Limiter: Hishida(van Leer)
 - Spatial accuracy: Second order with MUSCL
 - Time integration: LU-SGS
 - Turbulence model:
SST-2003 and SA-noft2-R for steady computation,
SST-2003-IDDES and SA-noft2-R-IDDES for unsteady computation

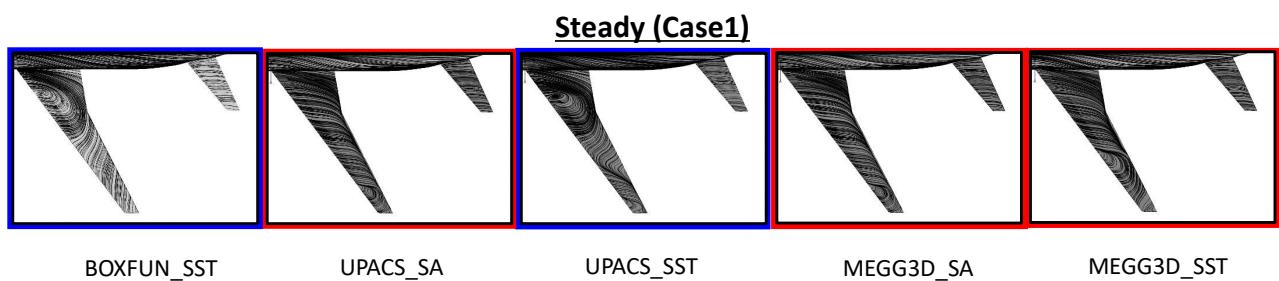
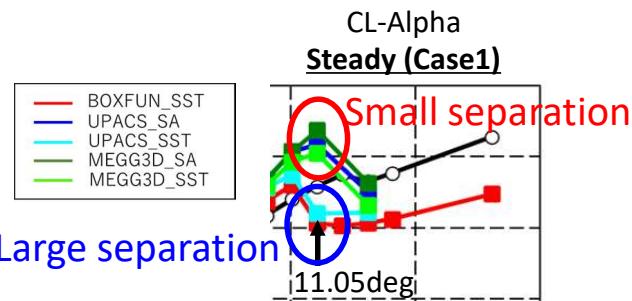
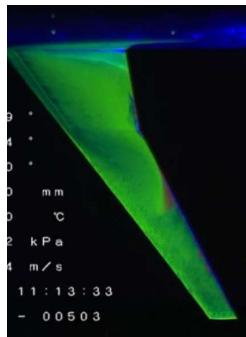
3

CL-alpha



- The lift is affected by the grids and turbulence models.
- The range of prediction is reduced by using the unsteady computation.

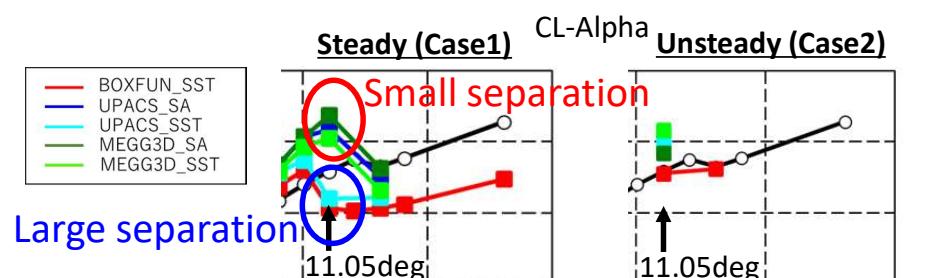
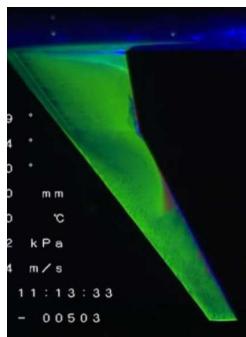
Surface streamline(11.05deg)



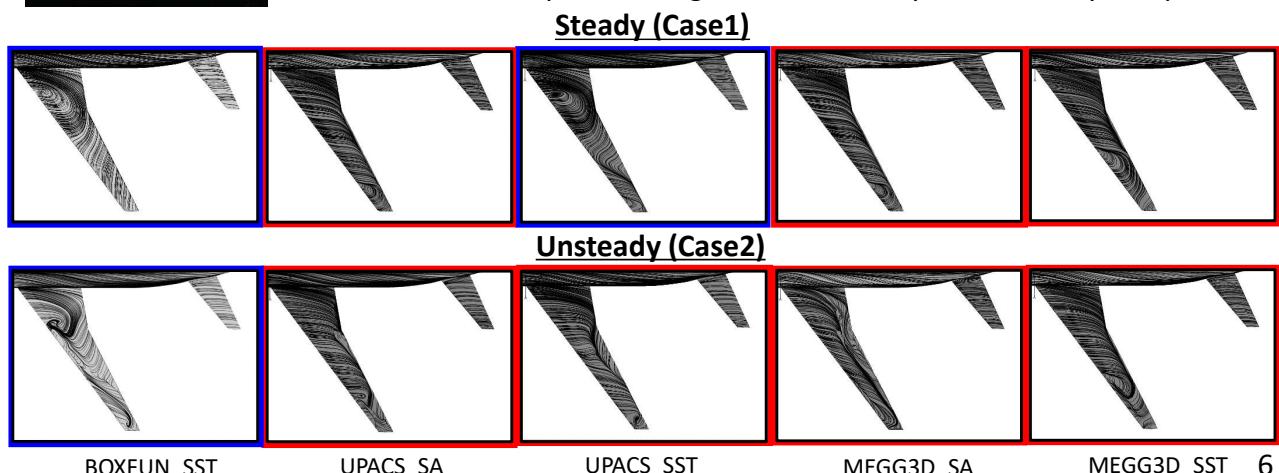
- The large separation is observed for SST model
- The small separation is observed for MEGG3D grid

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Surface streamline(11.05deg)

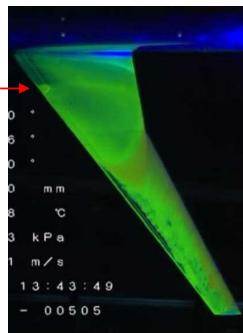


The separation region is reduced by the unsteady computation



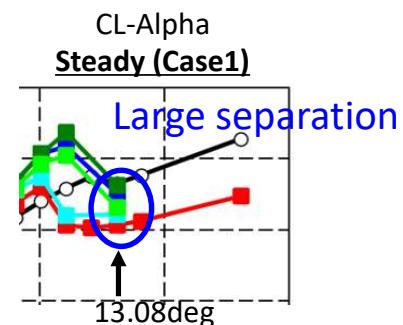
6

Surface streamline(13.08deg)

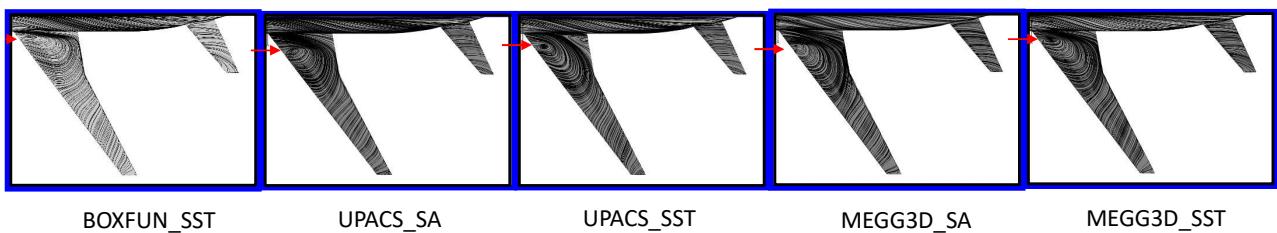


T. Uchiyama, et al.,
AIAA 2019-2190

- BOXFUN_SST
- UPACS_SA
- UPACS_SST
- MEGG3D_SA
- MEGG3D_SST

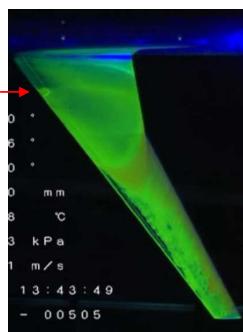


Steady (Case1)



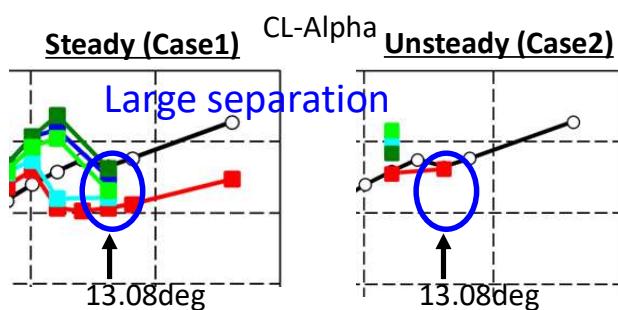
7

Surface streamline(13.08deg)



T. Uchiyama, et al.,
AIAA 2019-2190

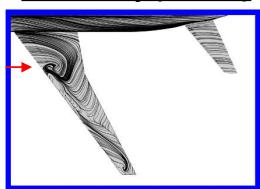
- BOXFUN_SST
- UPACS_SA
- UPACS_SST
- MEGG3D_SA
- MEGG3D_SST



Steady (Case1)



Unsteady (Case2)



The separation region is reduced by the unsteady computation

BOXFUN_SST

UPACS_SA

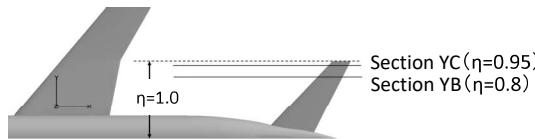
UPACS_SST

MEGG3D_SA

MEGG3D_SST

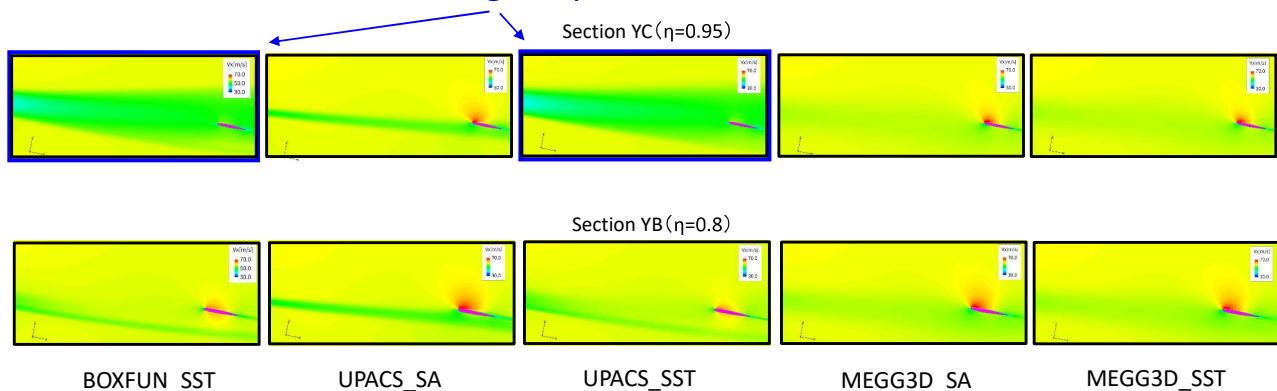
8

Wake interference with tail (11.05deg)



Steady (Case1)

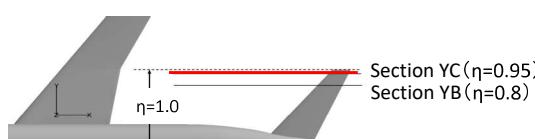
Large separation



- The large separation is observed for SST model
- The wake is diffused for MEGG3D grid

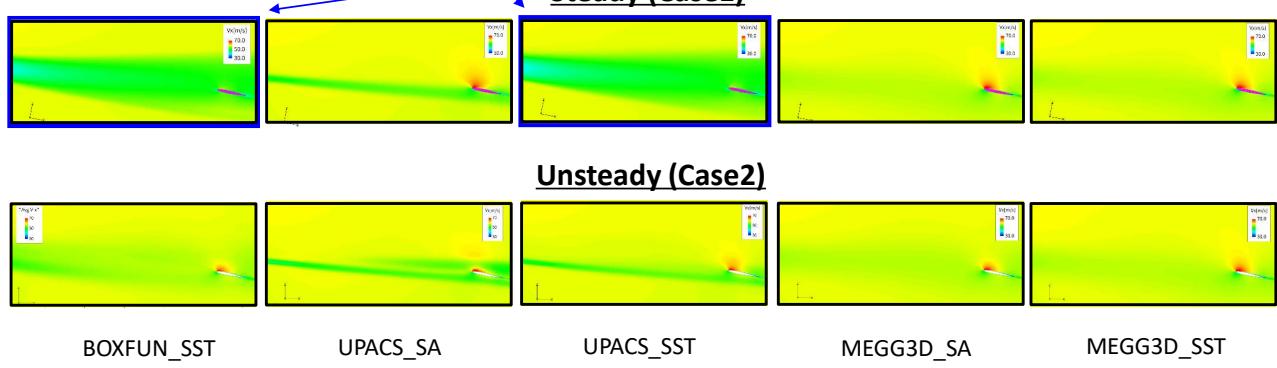
9

Wake interference with tail (11.05deg)



Large separation

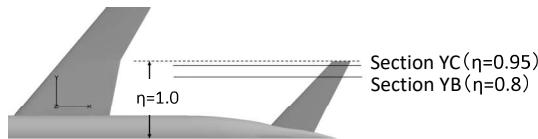
Steady (Case1)



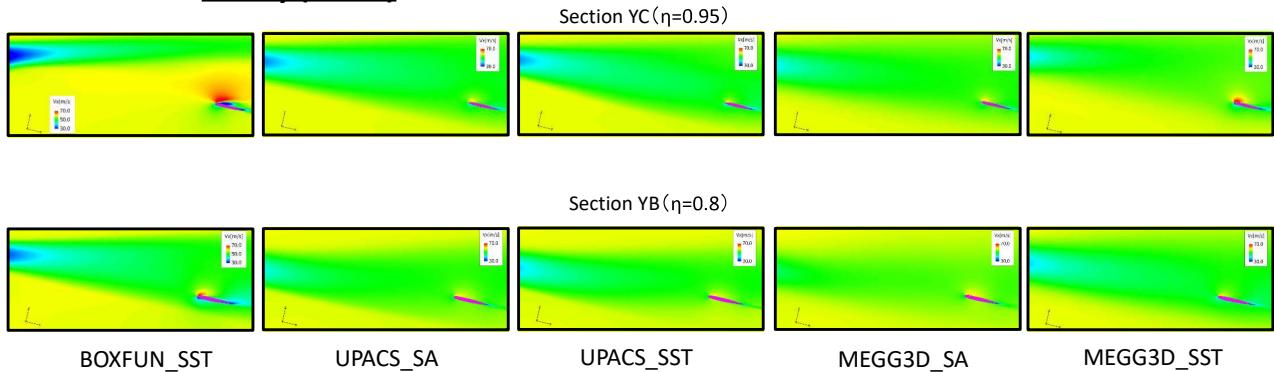
The separation region is reduced by the unsteady computation

10

Wake interference with tail (13.08deg)



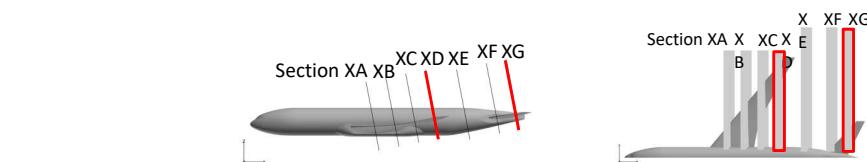
Steady (Case1)



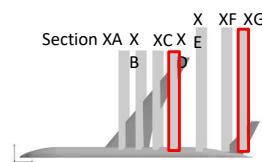
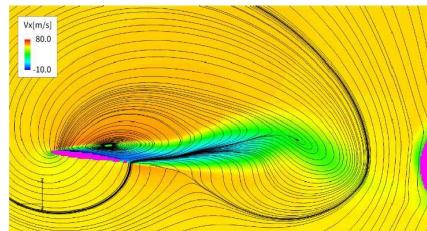
- The wake velocity distributions are similar except for BOXFUN grid

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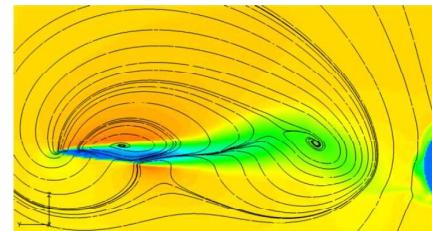
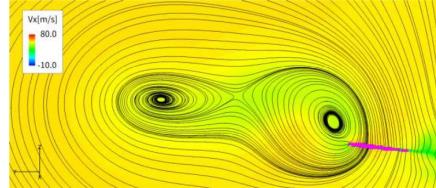
Velocity contours (13.08deg)



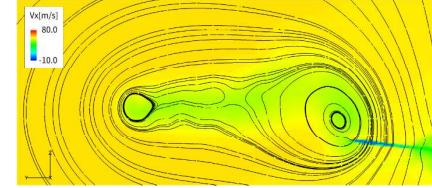
Section XD



Section XG



MEGG3D_SA_STEADY



BOXFUN_SST_UNSTEADY

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We selected the two cases that the predicted lift is close to the experiment.
The almost same velocity contours are shown.

Summary

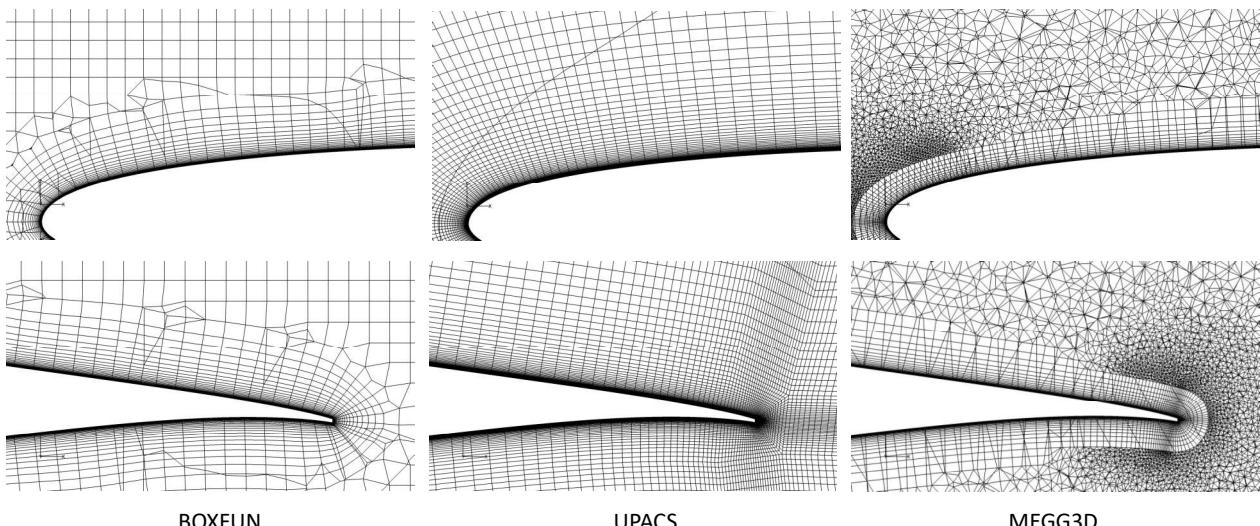
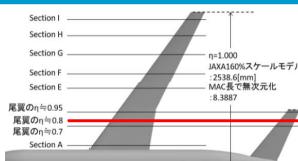


- The stall prediction is largely affected by the grid type and turbulence model. The separation is large when the hexahedral grid is used. The SST model predicts the stall at lower AoA than the SA model.
- The range of predicted CL is reduced by using the unsteady computation. Generally, the separation region is smaller when the unsteady computation is used.
- The wake is diffused for the mixed-element grid. The hexahedral or a finer mixed-element grid is recommended to simulate the wake interaction.

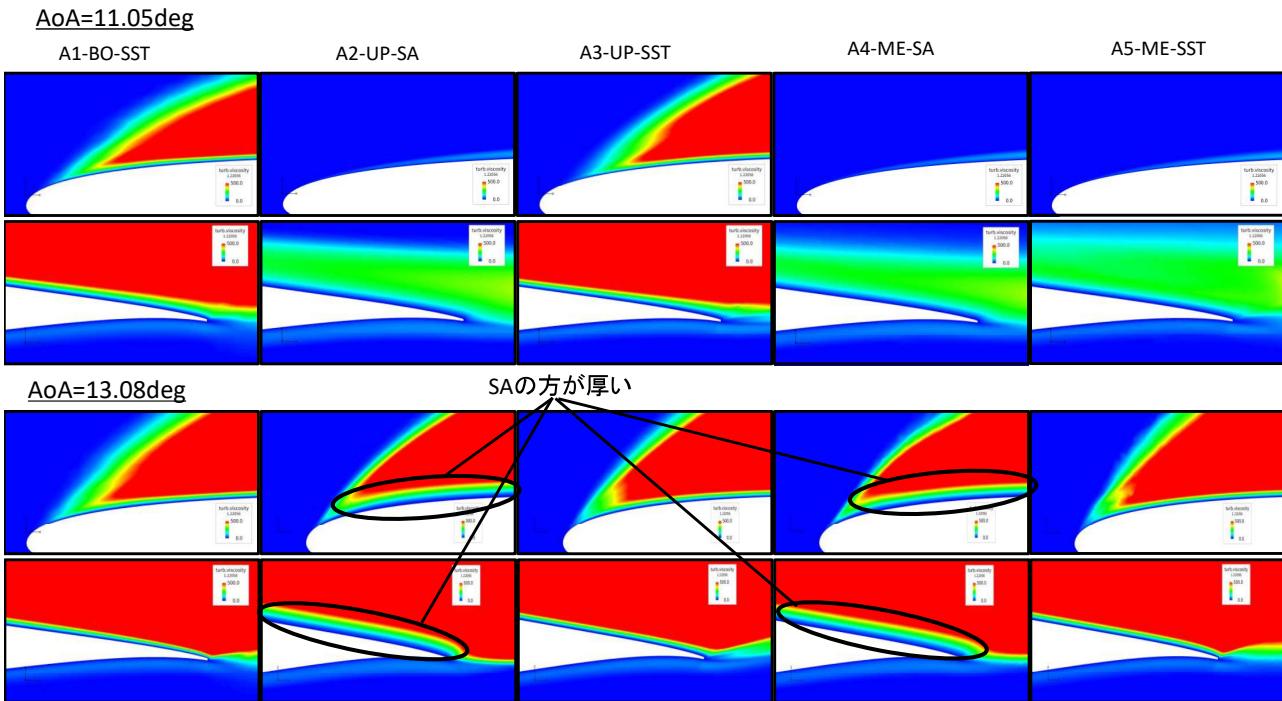
13



Grid (Wing, Section C)



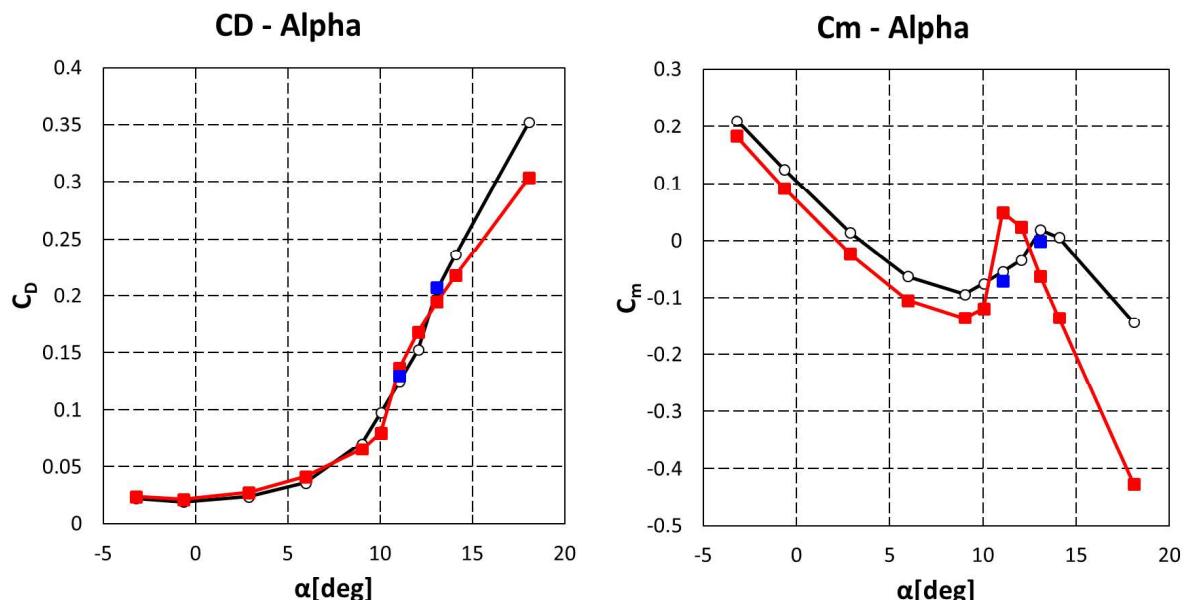
14



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CD-alpha, CM-alpha

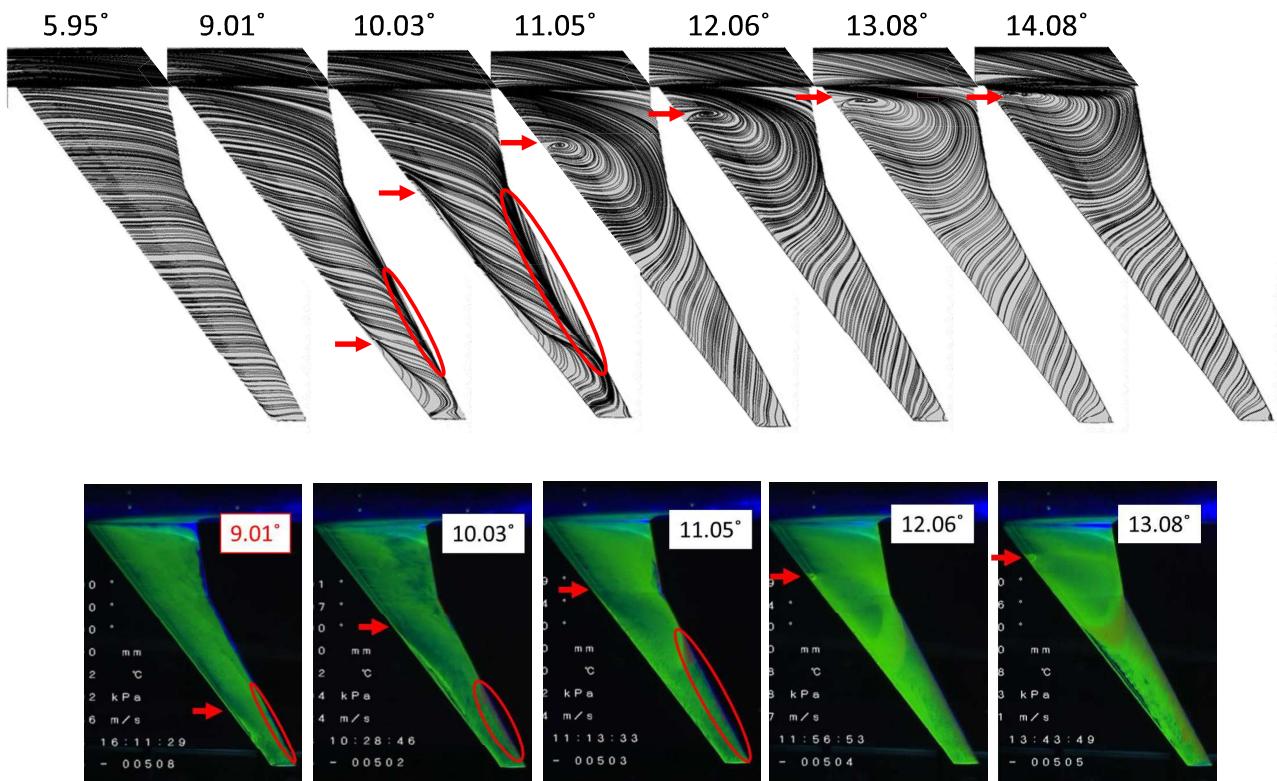


- Steady
- Unsteady
- Exp

The accuracy of drag and pitching moment prediction is also improved with unsteady computation.

Streamline (Steady)

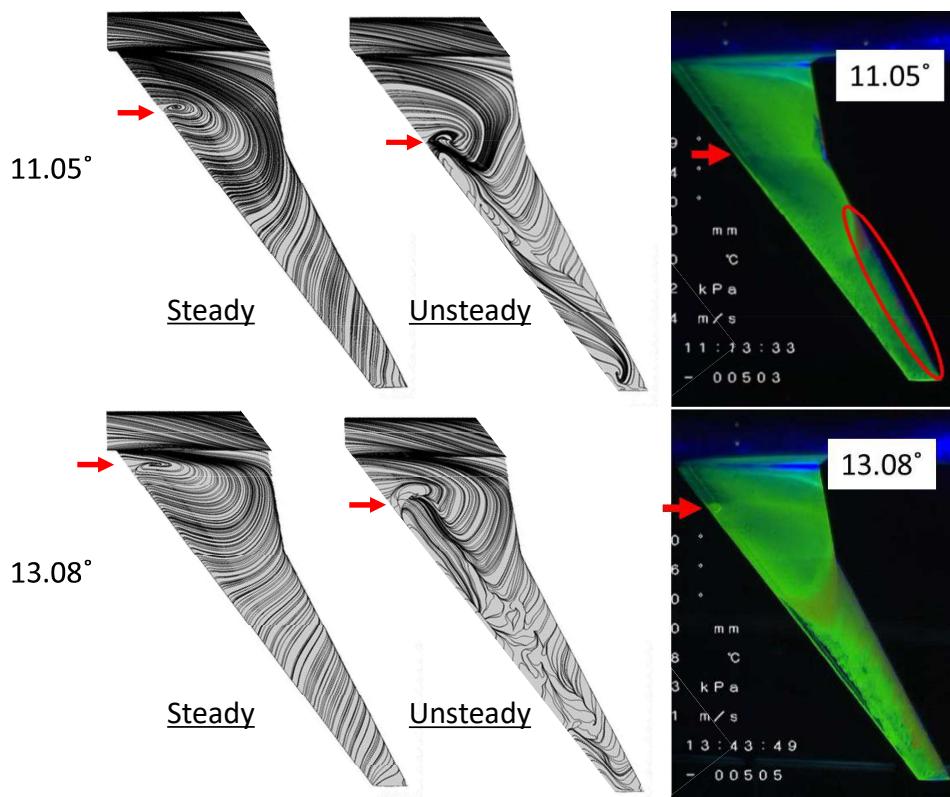
APC
9.01deg



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Streamline (Steady vs Unsteady)

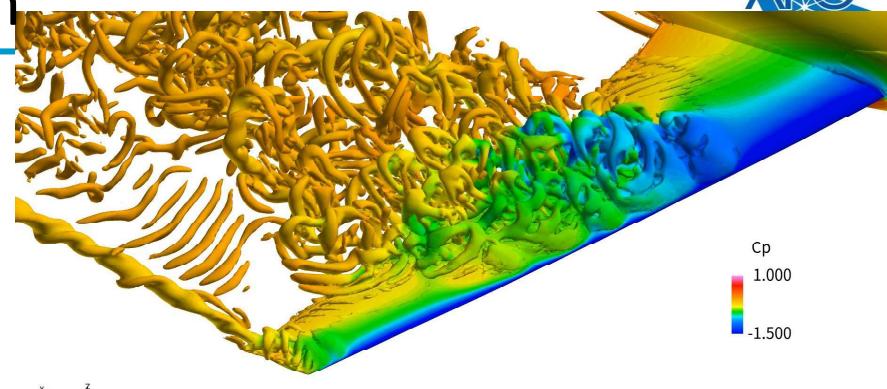
APC
9.01deg



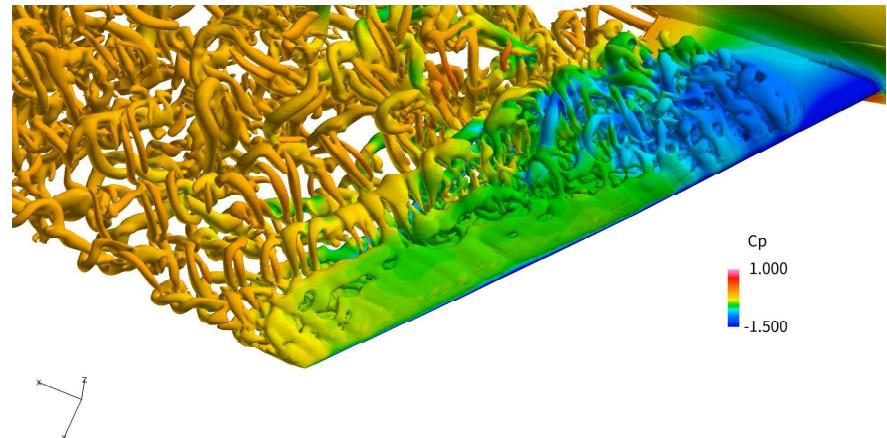
18

Q criterion

11.05deg

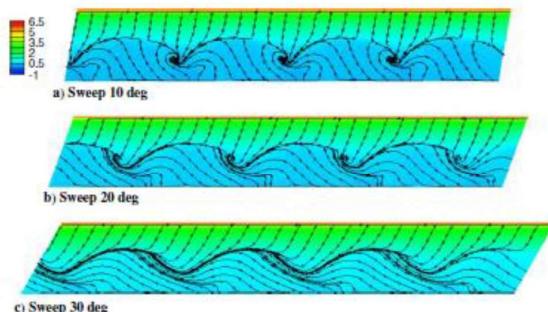
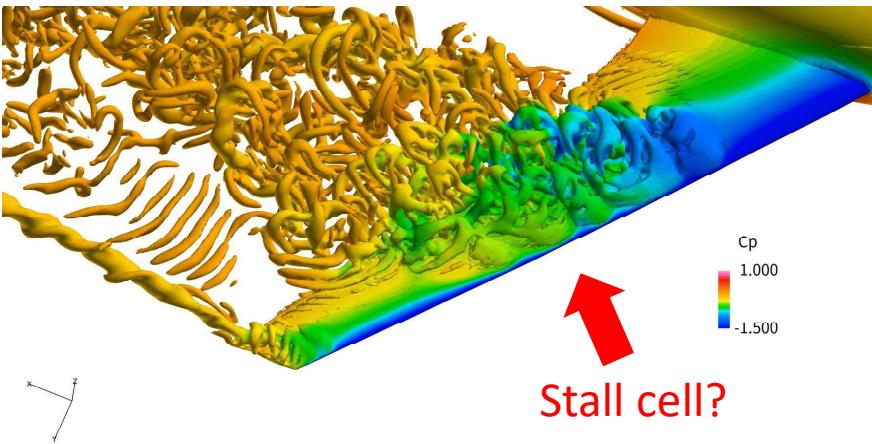


13.08deg



Q criterion

11.05deg



Frédéric Plante, et al., "Similarities Between Cellular Patterns Occurring in Transonic Buffet and Subsonic Stall," AIAA JOURNAL Vol. 58, No. 1, January 2020.



Case1: Steady Computation

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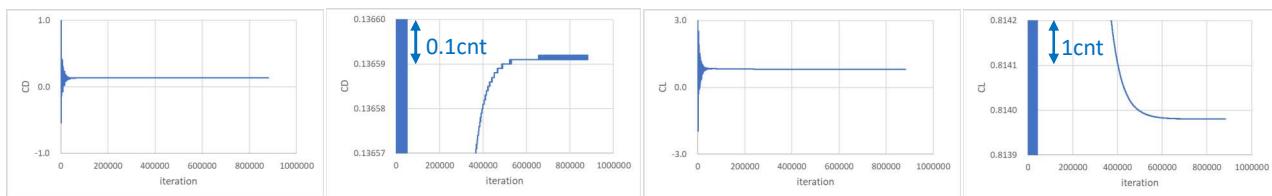
BOXFUN_SST

AoA=11.05deg

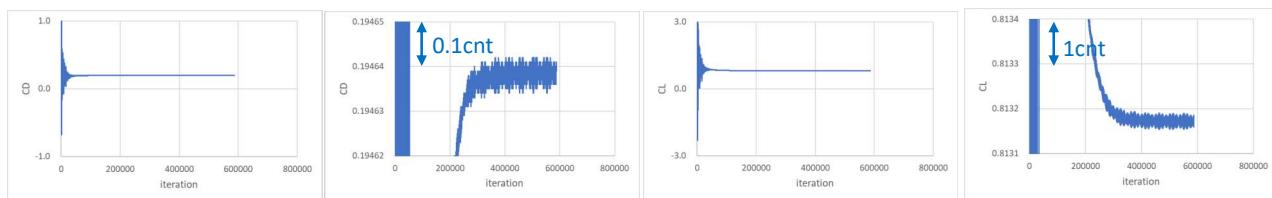
CDの収束は、
 (a) グラフ全体を見て値が一定になっていること
 (b) グラフの最小値と最大値を変更して、
 振動が0.1~0.2cnt以内程度に収まっていること

CLの収束は、
 (a) グラフ全体を見て値が一定になっていること
 (b) グラフの最小値と最大値を変更して、
 振動が1cnt以内程度に収まっていること

1cnt=0.0001



AoA=13.08deg

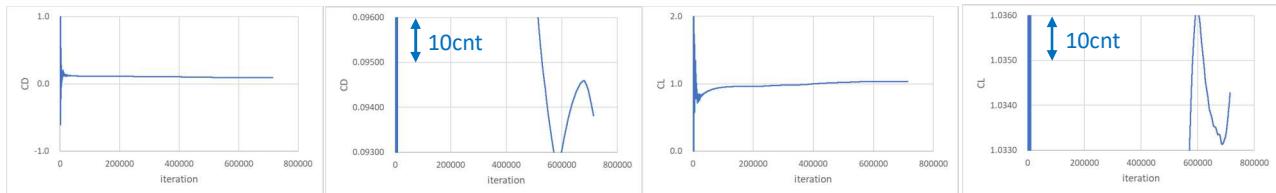


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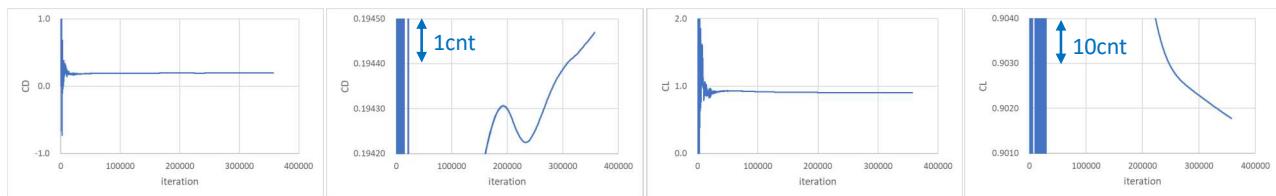
UPACS_SA

1cnt=0.0001

AoA=11.05deg



AoA=13.08deg

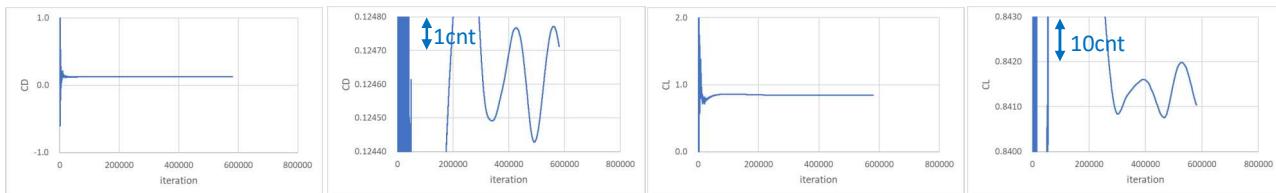


23

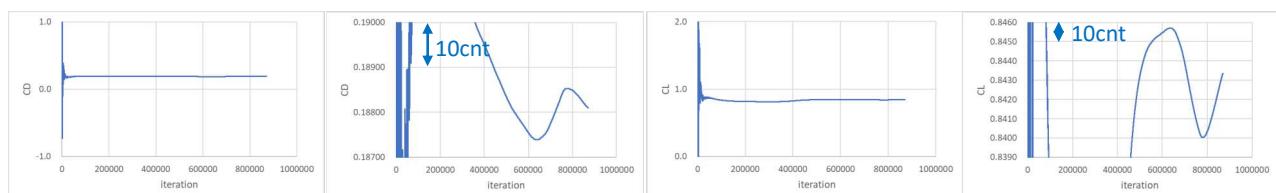
UPACS_SST

1cnt=0.0001

AoA=11.05deg



AoA=13.08deg

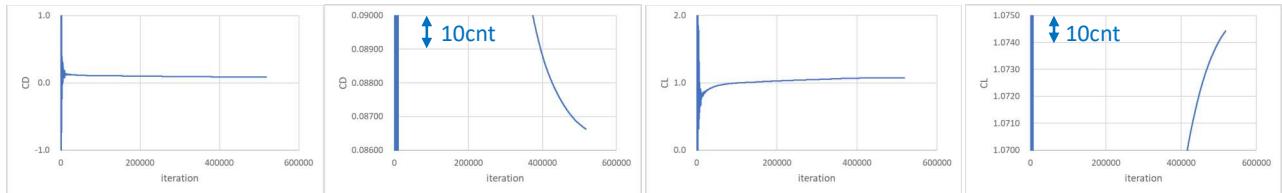


24

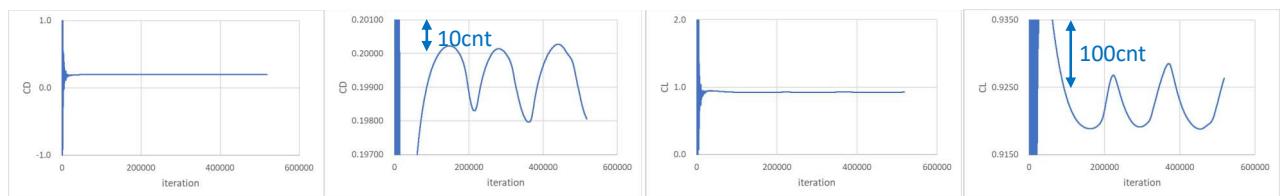
MEGG3D_SA

1cnt=0.0001

AoA=11.05deg



AoA=13.08deg

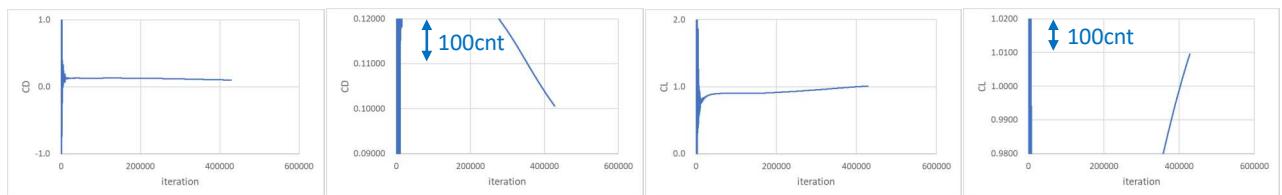


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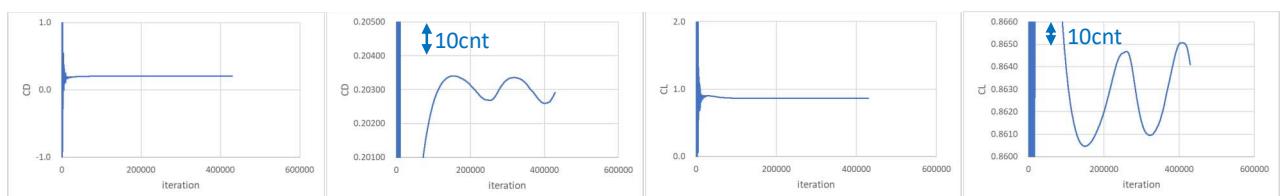
MEGG3D_SST

1cnt=0.0001

AoA=11.05deg



AoA=13.08deg



26



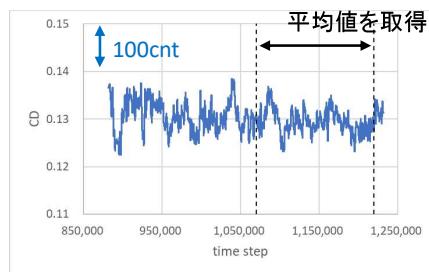
Case2:Unsteady Computation

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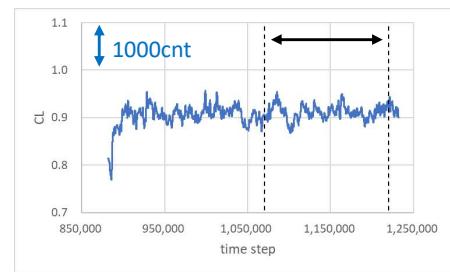


BOXFUN_SSTIDDES

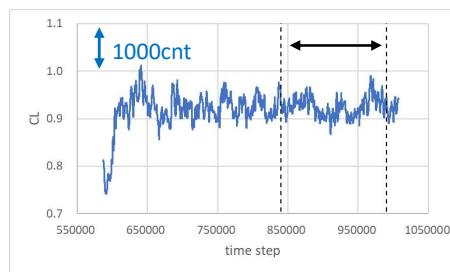
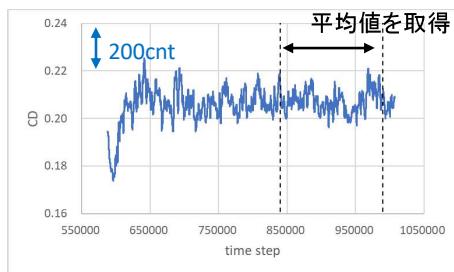
AoA=11.05deg



1cnt=0.0001



AoA=13.08deg

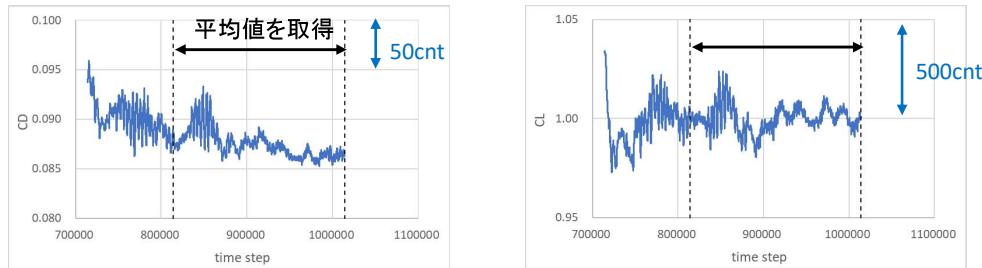


28

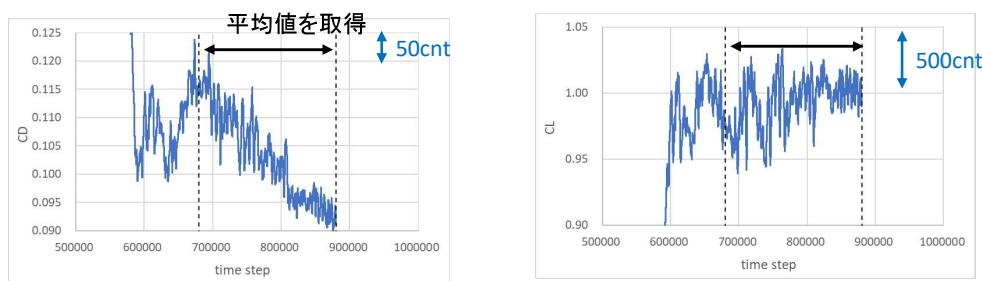
UPACS_SADDES

AoA=11.05deg

1cnt=0.0001

UPACS_SSTDDES

AoA=11.05deg

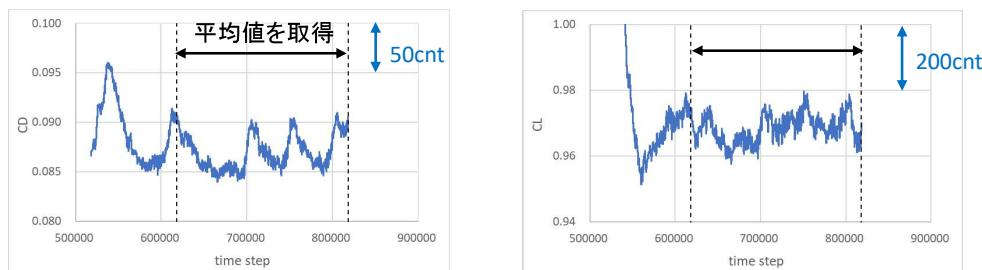


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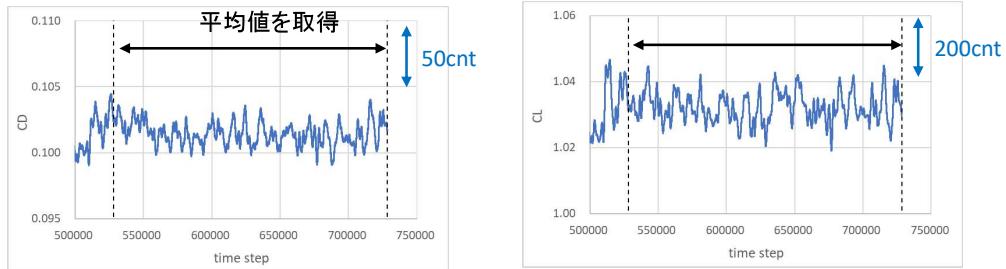
MEGG3D_SADDES

AoA=11.05deg

1cnt=0.0001

MEGG3D_SSTDDES

AoA=11.05deg



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