UTCartを用いた30P30N高揚力装置周りの非定常流れ場解析

Simulation of Unsteady Flows around the 30P30N High-Lift System using UTCart

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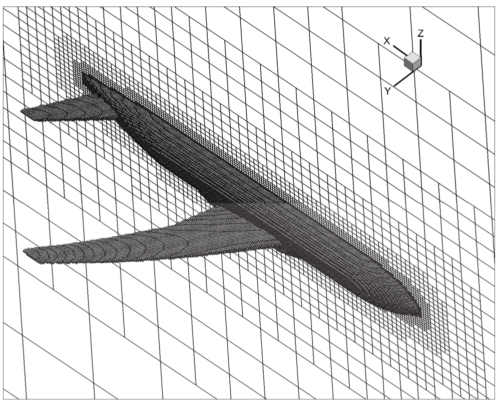
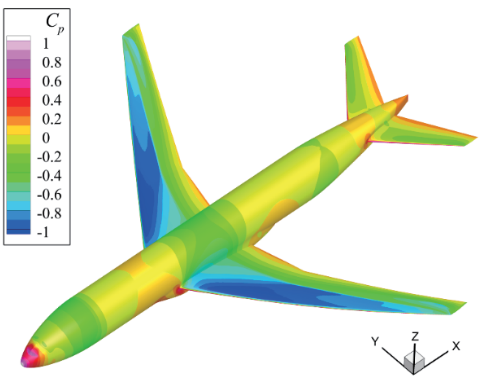
UTCart

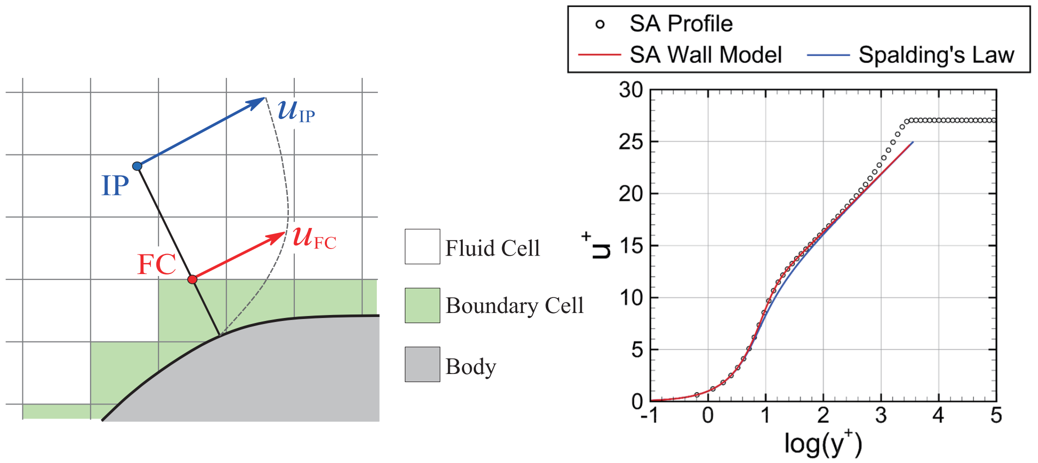
- The University of Tokyo Cartesian grid based automatic flow solver
- ✓ Platform for aerodynamic designing
- ✓ Completely automatic grid generation using quad/oct-tree structure (complex geometry)
- ✓ Immersed Boundary Method + Wall function





Immersed boundary method

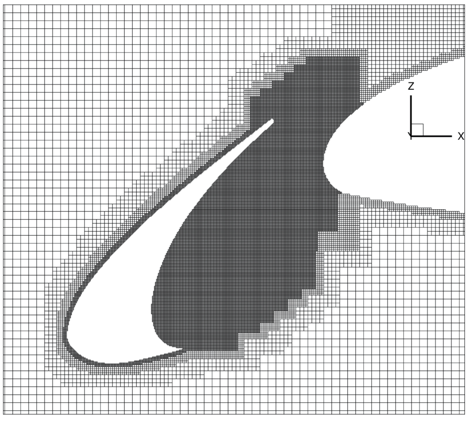
- Boundary condition is extrapolated from IP
- Wall function is used to determine the wall shear stress



*) Tamaki, et al. AIAA J. 2018

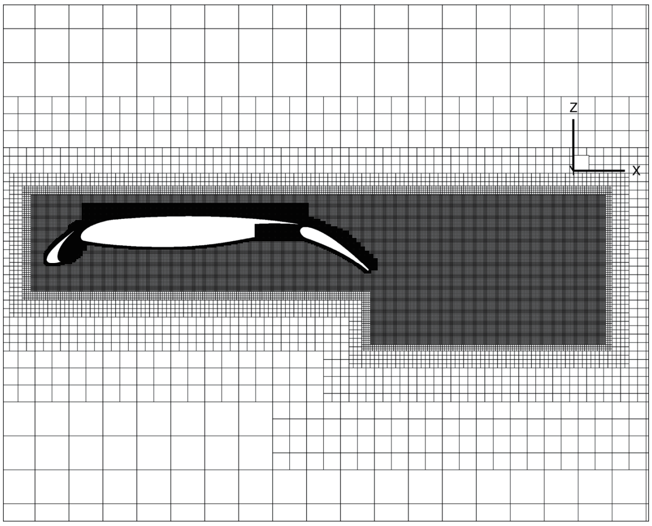
Objectives

- Case 3-1 (Near-field unsteadiness)
- Demonstrate potential capability of Cartesian grid with Immersed Boundary method in unsteady flow simulation
  - ✓ Easy resolution control (cove, propagation region, etc.)
  - ✓ Use of explicit time integration method



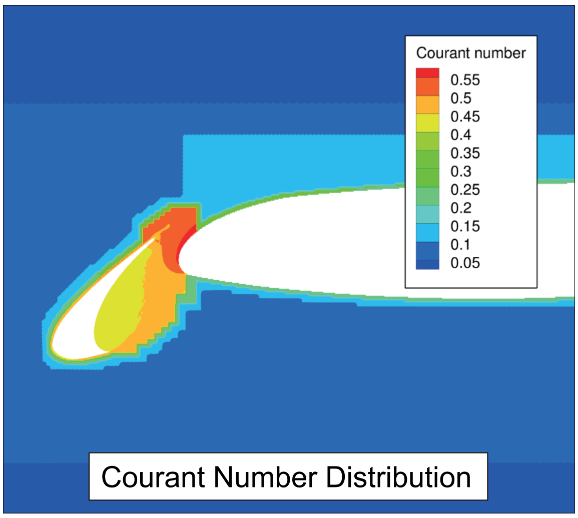
Computational Grid

- Oct-tree Cartesian grid
  - ✓ $\Delta x_{wall}/c = 5.0\times10^{-4}$ ($y^+<50$)
  - ✓ Span : 0.128*c* (2.3 inch), 256 cells ($\Delta z/c=5.0\times10^{-4}$)
  - ✓ 14,700,179 cells, 288 domain MPI



Methodology(1/2)

- Time Integration
  - 3rd order TVD-RK (Explicit time integration)
  - $\Delta t a_\infty / c = 2.0\times10^{-4}$
- Spatial accuracy
  - 4th order upwind-biased scheme for advection term



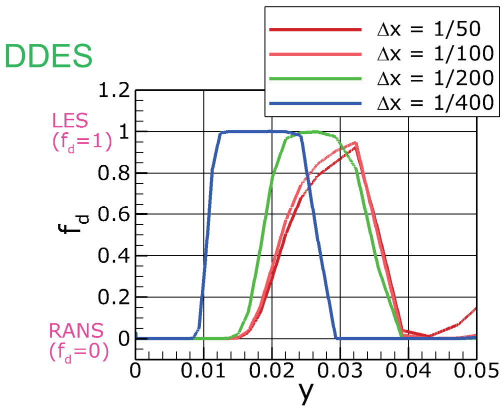
Methodology(2/2)

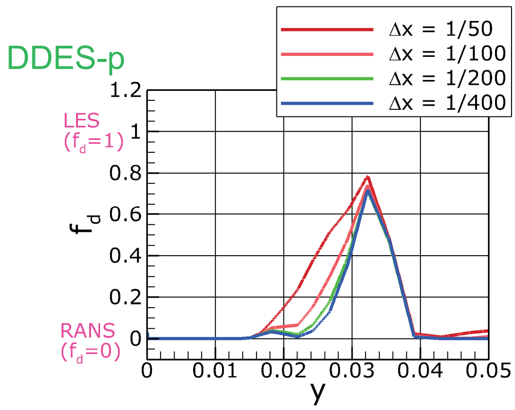
- SA-DDES-p*)
  - ✓ Modification for DDES
  - ✓ RANS region is protected even when the stream-wise grid size is very small (suitable for Cartesian grid)

$$f_d' \equiv 1 - \tanh\left((8r_d')^3\right), \qquad r_d' \equiv \frac{\nu + \nu_t}{S\kappa^2 d\, l_{DDES}}$$

Original DDES length scale

$$l'_{DDES} \equiv (1 - \min(f_d, 0.5))\, l_{RANS} + \min(f_d, 0.5)\, l_{DES}$$





*) 玉置、今村、航空宇宙学会年会、2018

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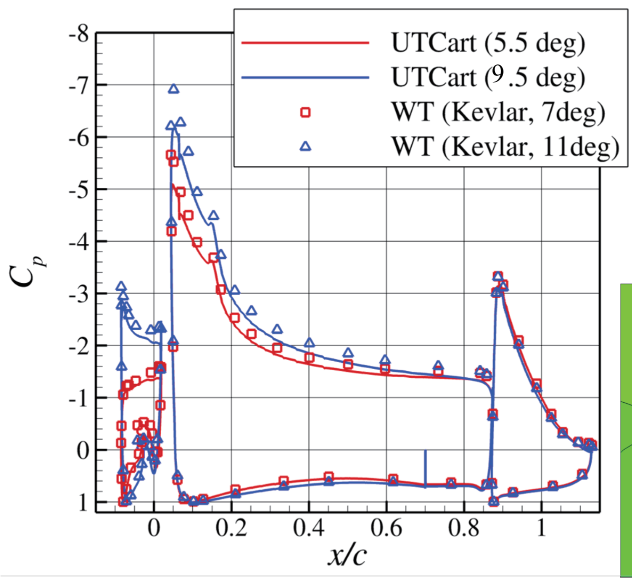
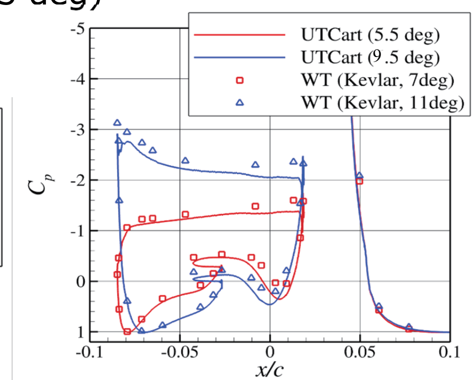
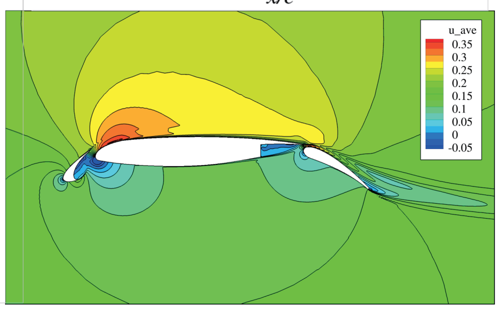
Time Averaged flow

- Cl = 2.822 (5.5 deg), 3.233 (9.5 deg)







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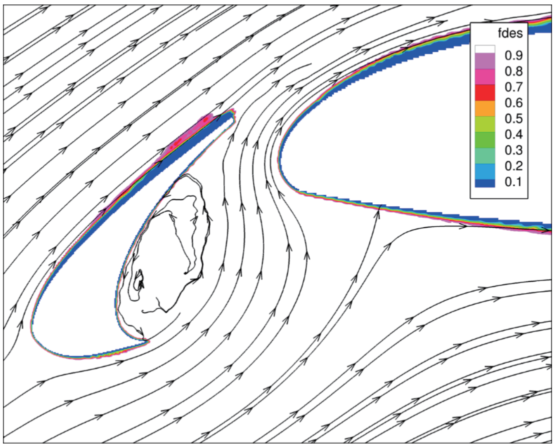
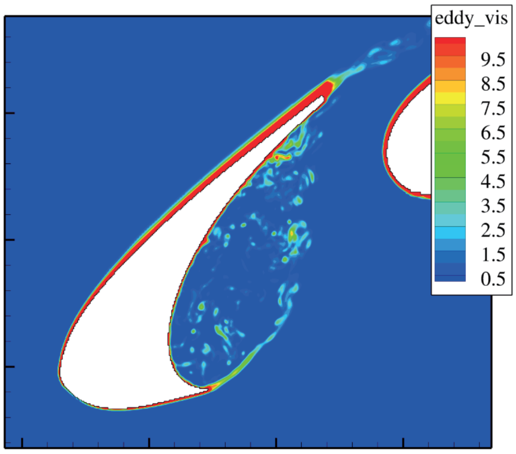
DDES-p Switching

- Correctly switched to LES in the separated region (cf. cove)



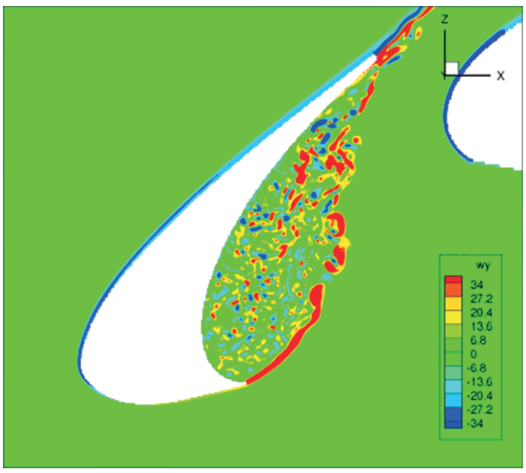
Switching between RANS and LES
fdes distribution



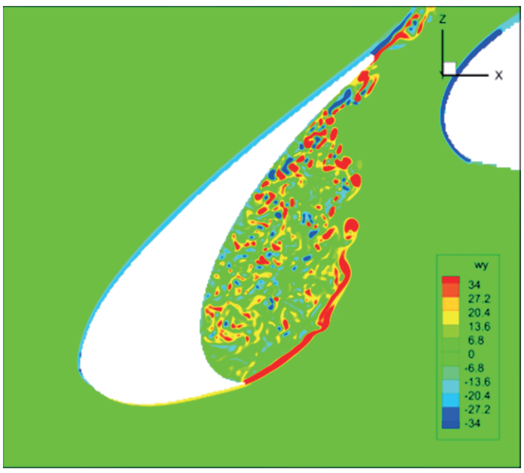
Eddy viscosity distribution

Instantaneous flow

Span-wise vorticity



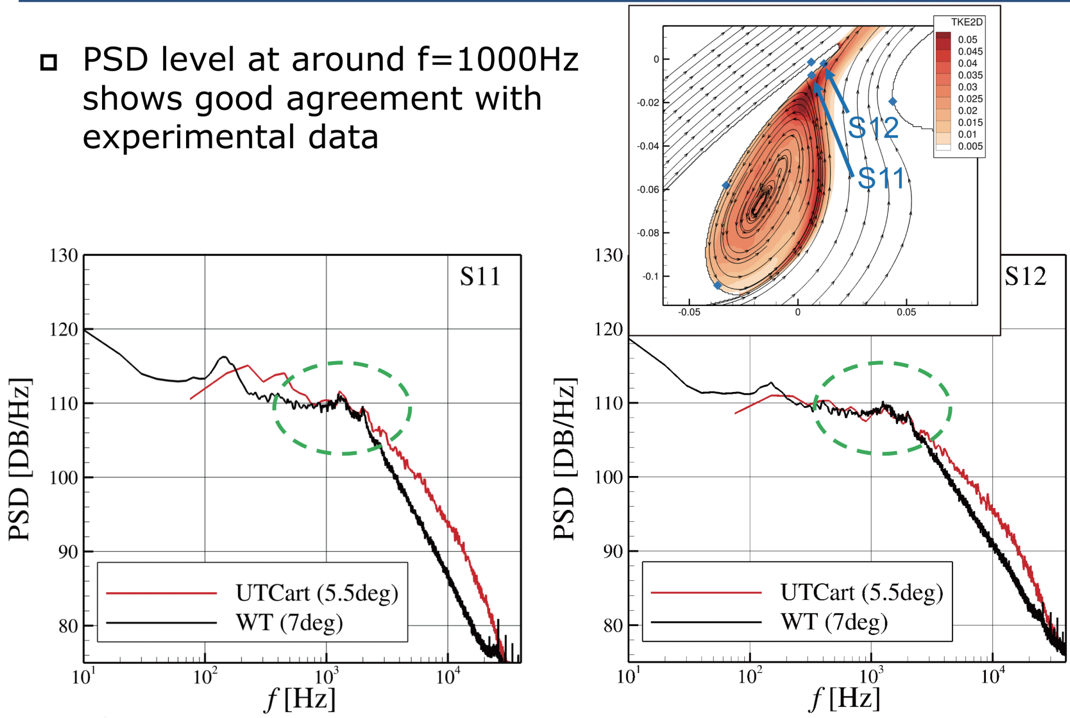
α = 5.5 deg



α = 9.5 deg

PSD of surface pressure (5.5 deg)

- PSD level at around f=1000Hz shows good agreement with experimental data



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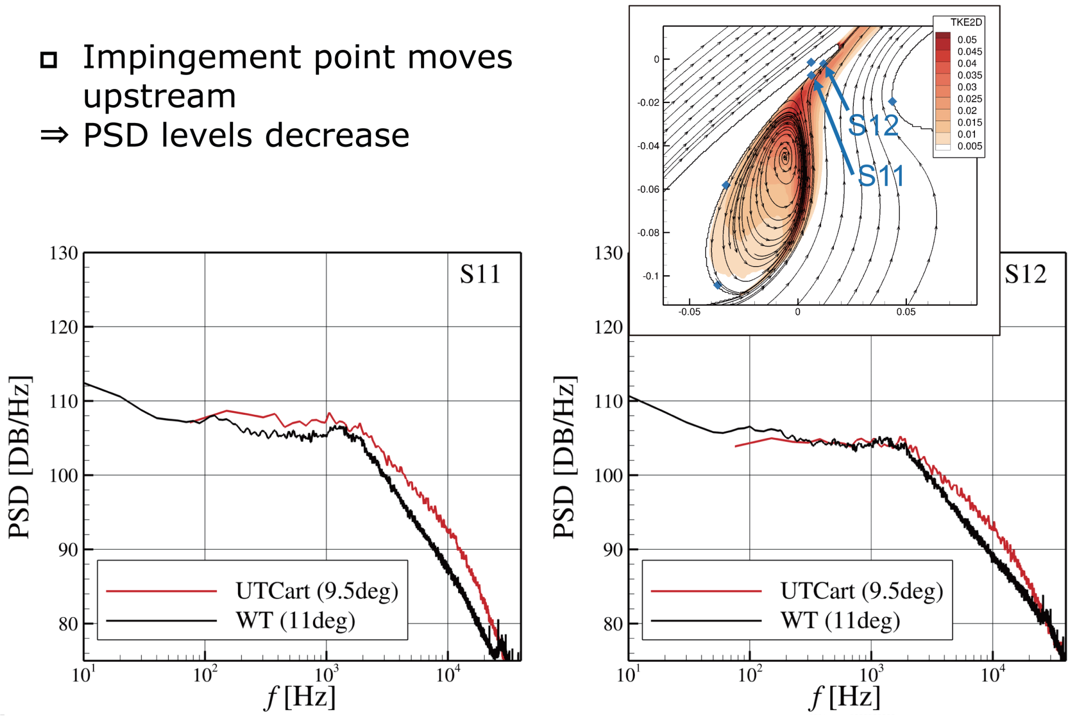
PSD of surface pressure (9.5 deg)

- Impingement point moves upstream

⇒ PSD levels decrease



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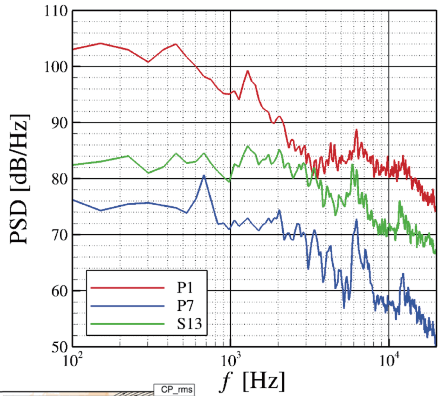
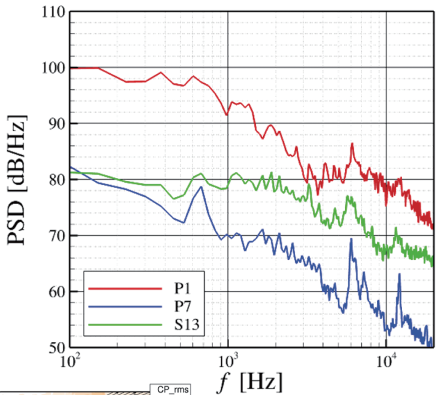
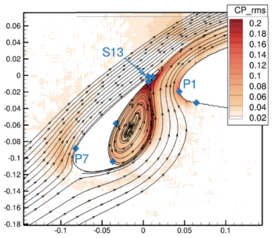
PSD of surface pressure

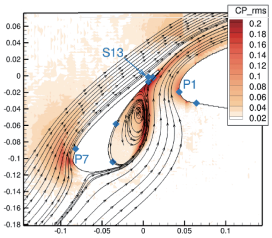
- PSD levels at the other points also decrease by ~ 5dB
- Pressure fluctuation in the cove is lower







5.5 deg



9.5 deg

Conclusions

- Unsteady flow simulation was conducted by UTCart
  - Isotropic uniform grid in cove
  - Explicit time integration, high-order scheme
  - DDES-p turbulence model
- PSD levels decrease at the higher angle (5.5deg⇒9.5 deg)
  - Fair agreement with experimental data at S12
  - Lower pressure fluctuation in the cove