HOKKAIDO UNIVERSITY

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Team : Hokkaido

AoA dependency of BSCW flutter at transonic flow

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Cases

Case 1

- 3D simulation
- Mach : 0.80
- AoA : 0 – 6 deg

Case 2

- 3D simulation
- Mach : 0.74, 0.76, 0.78
- AoA : 3 deg

Case 3

- 2D simulation
- Mach : 0.80
- AoA : 0 – 6 deg

+

How the kick affect to the flutter boundary?

Computational setup and model

3D-URANS

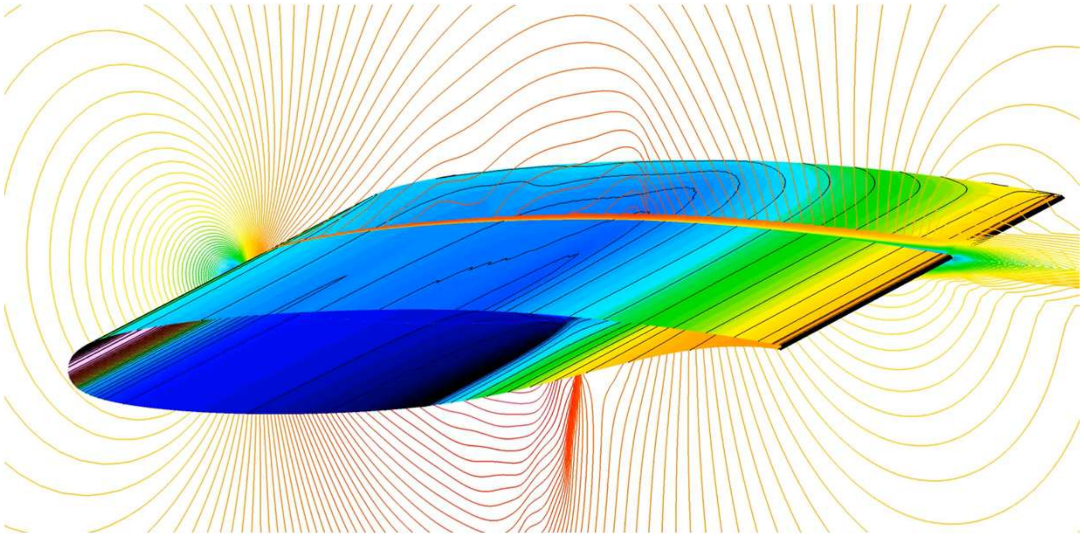
$$\frac{\partial \boldsymbol{Q}}{\partial t} + \frac{\partial \boldsymbol{F}_j}{\partial x_j} = \frac{\partial \boldsymbol{F}_{v,j}}{\partial x_j}$$

Weakly coupling

Equation of Motion(2-DoF)

$$[M]\{\ddot{q}\} + [D]\{\dot{q}\} + [K]\{q\} = \{Q\}$$

Turbulence model	**Spalart-Allmaras**[1]
Inviscid flux	**SHUS(3rd MUSCL)**
Time integration	**DP-LUR** [2]
Inner iteration	5
Reynolds number	$O(10^5) \sim O(10^6)$
Time step	5×10^{-3}



[1] : Spalart, P., and Allmaras, S., 1992, AIAA Paper
[2] : Graham V. Candler et,. al. 1994, AIAA Journal

How to compute the unsteady situation

Steady flow

Direct

Flutter computation

- Start the flutter computation without subtraction of aero coefficient

$$\boldsymbol{Q} = \frac{V^{*2}}{\pi}\begin{Bmatrix} -(C_l) \\ 2(C_m) \end{Bmatrix}$$

Aero-coefficient

Flutter computation

- Subtract the initial aero coefficient from equation of motion.
- Initial position will be the center of the motion

$$\boldsymbol{Q} = \frac{V^{*2}}{\pi}\begin{Bmatrix} -(C_l - C_{l,0}) \\ 2(C_m - C_{m,0}) \end{Bmatrix}$$

AoA = Equilibrium angle

Eq. position

Equilibrium position

- Find the position where forces on the wing is equilibrium.

Flutter computation

- Start the flutter computation from the equilibrium position.
- Initial position will be the center of the motion.

How to compute the unsteady situation

Steady flow

Aero-coefficient

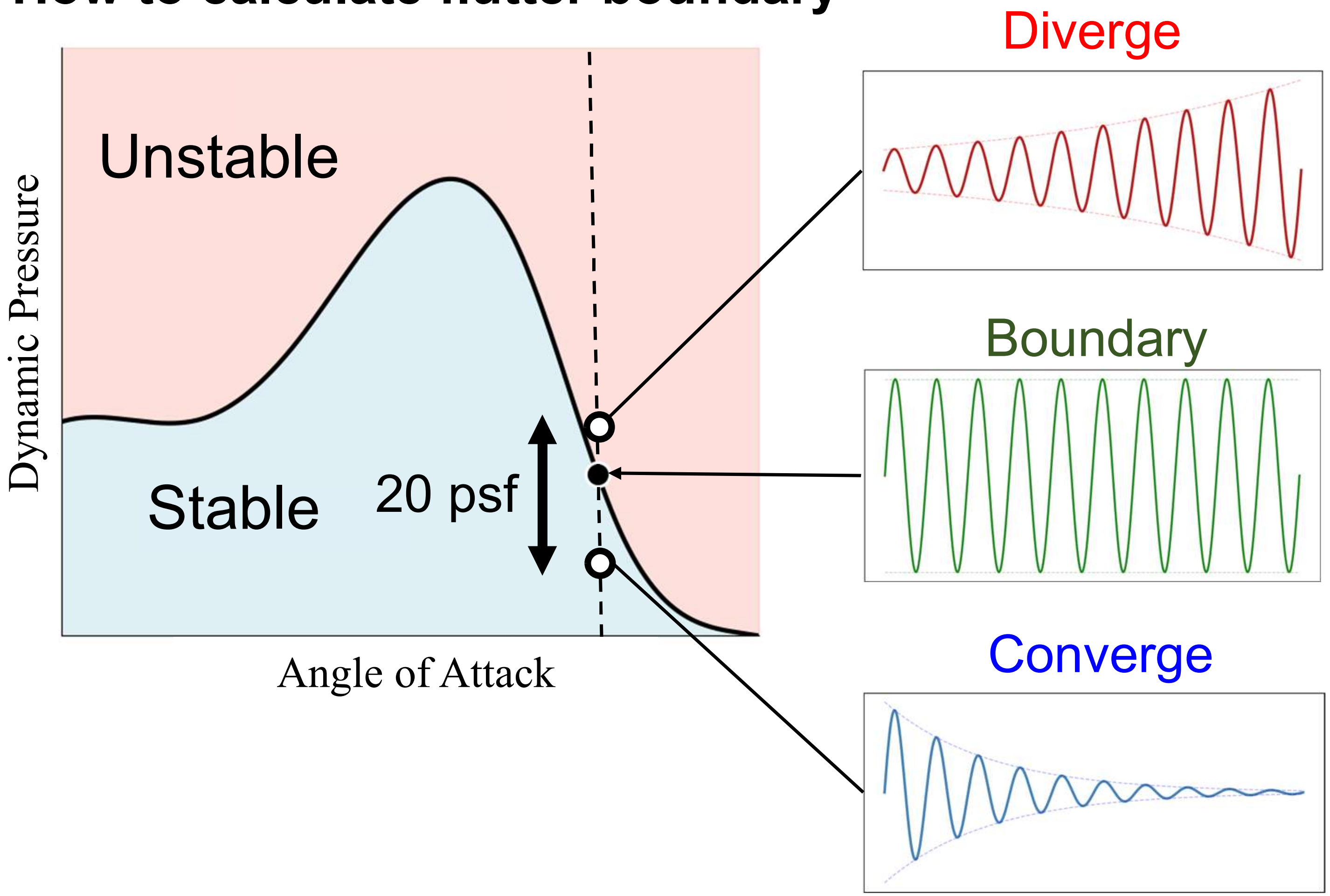
Flutter computation

- Subtract the initial aero coefficient from equation of motion.
- Initial position will be the center of the motion.

$$\boldsymbol{Q} = \frac{{V^*}^2}{\pi}\begin{Bmatrix} -\left(C_l - C_{l,0}\right) \\ 2\left(C_m - C_{m,0}\right) \end{Bmatrix}$$

AoA = Equilibrium angle

How to calculate flutter boundary



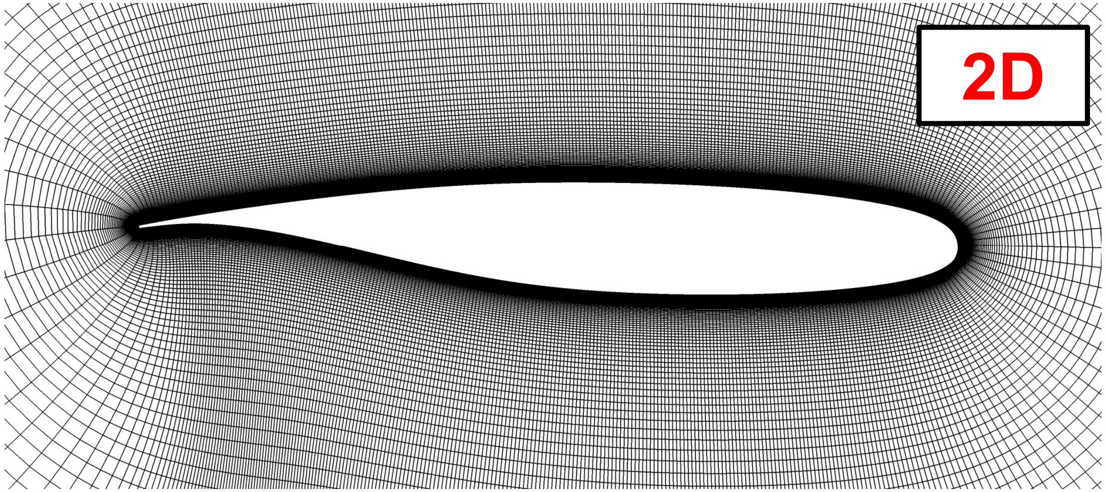
Computational conditions

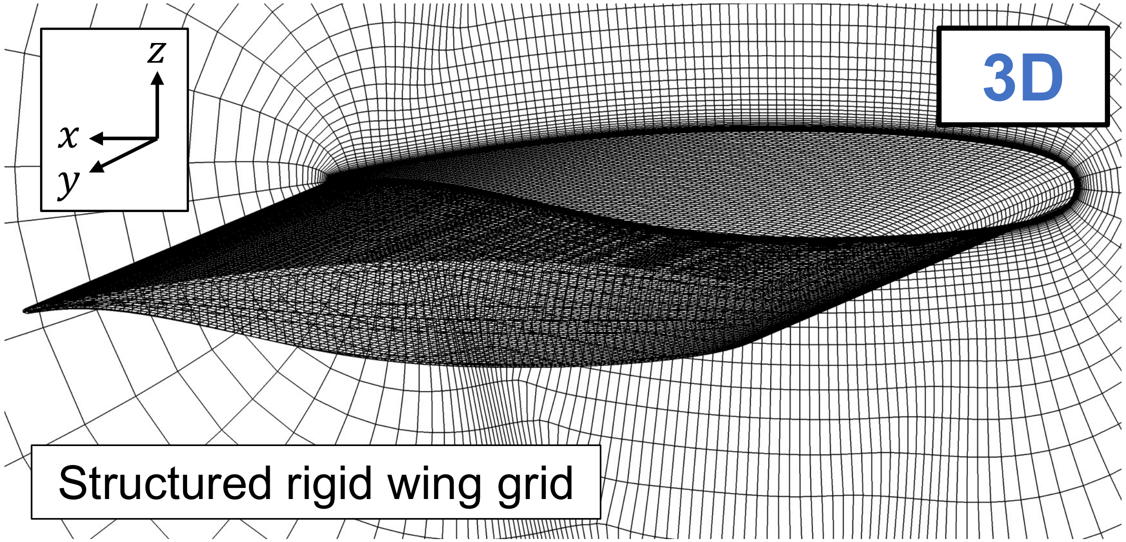
Condition

Airfoil	SC2-0414
Aspect ratio	2 (only for 3D grid)
Min. grid spacing	5×10^{-6}
y^+	0.2
Domain size	$50c$
Kick ($d\alpha/dt$)	1.745×10^{-3}

Grid Size

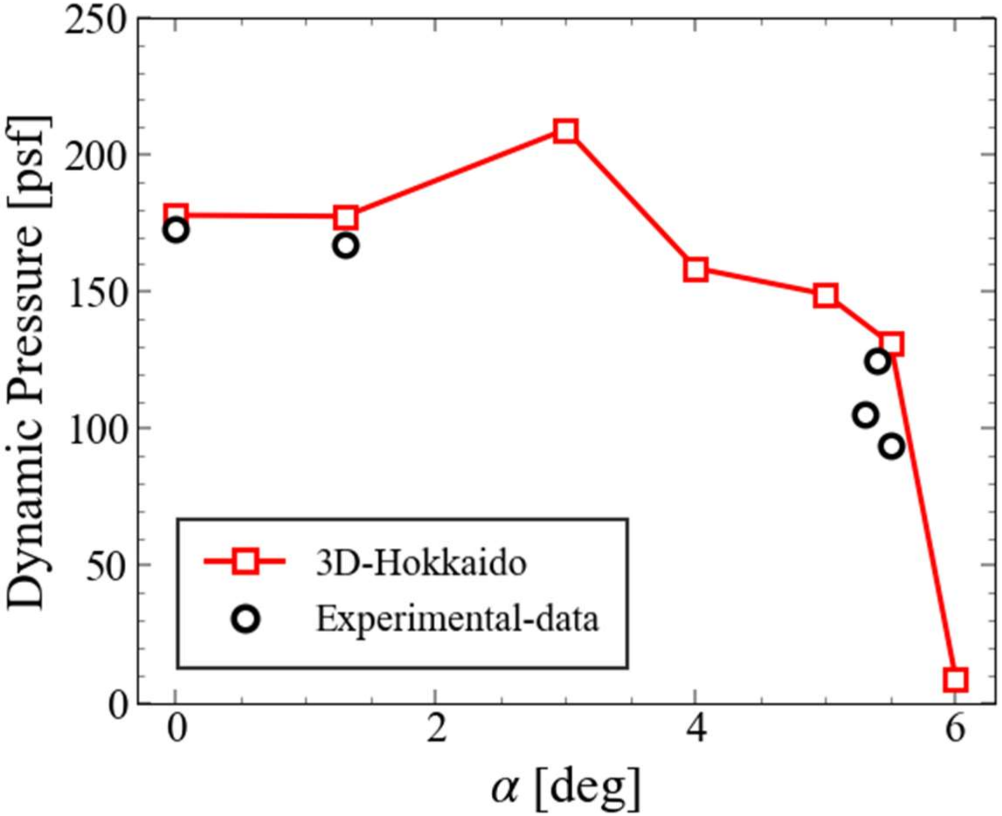
Grid	Code	Span	Radius	Total
2D-coarse	503	11	200	1.1 M
2D-fine	1403	11	560	8.6M
3D	603	261	250	39.3 M



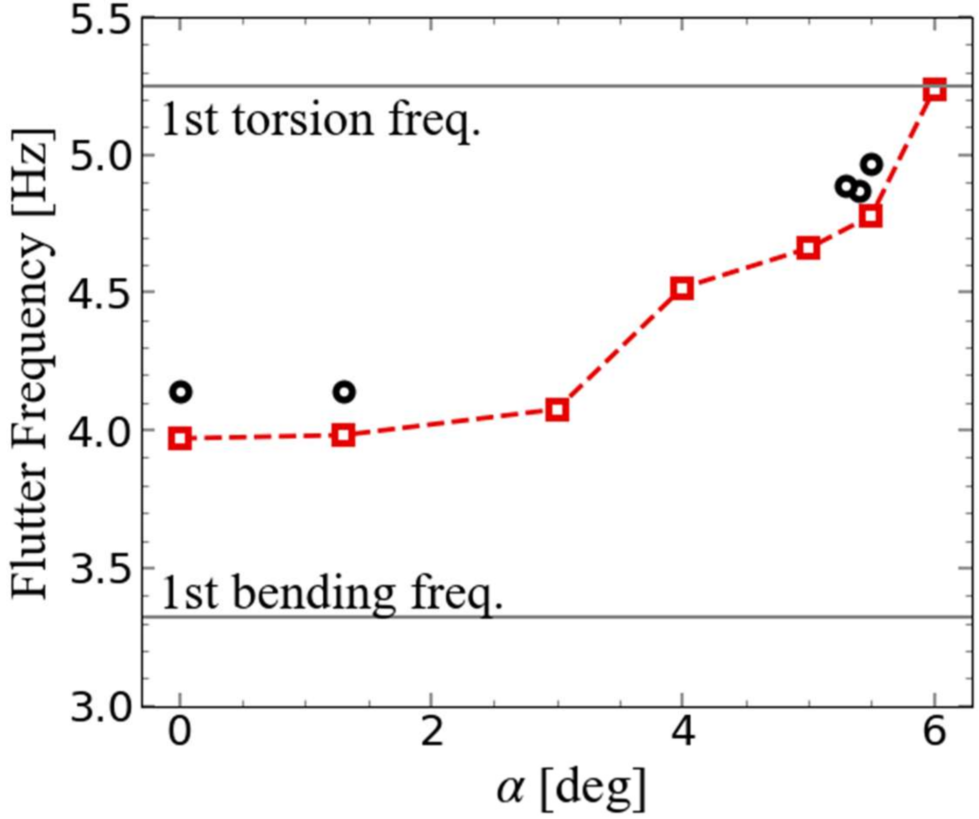


Case 1 : Results

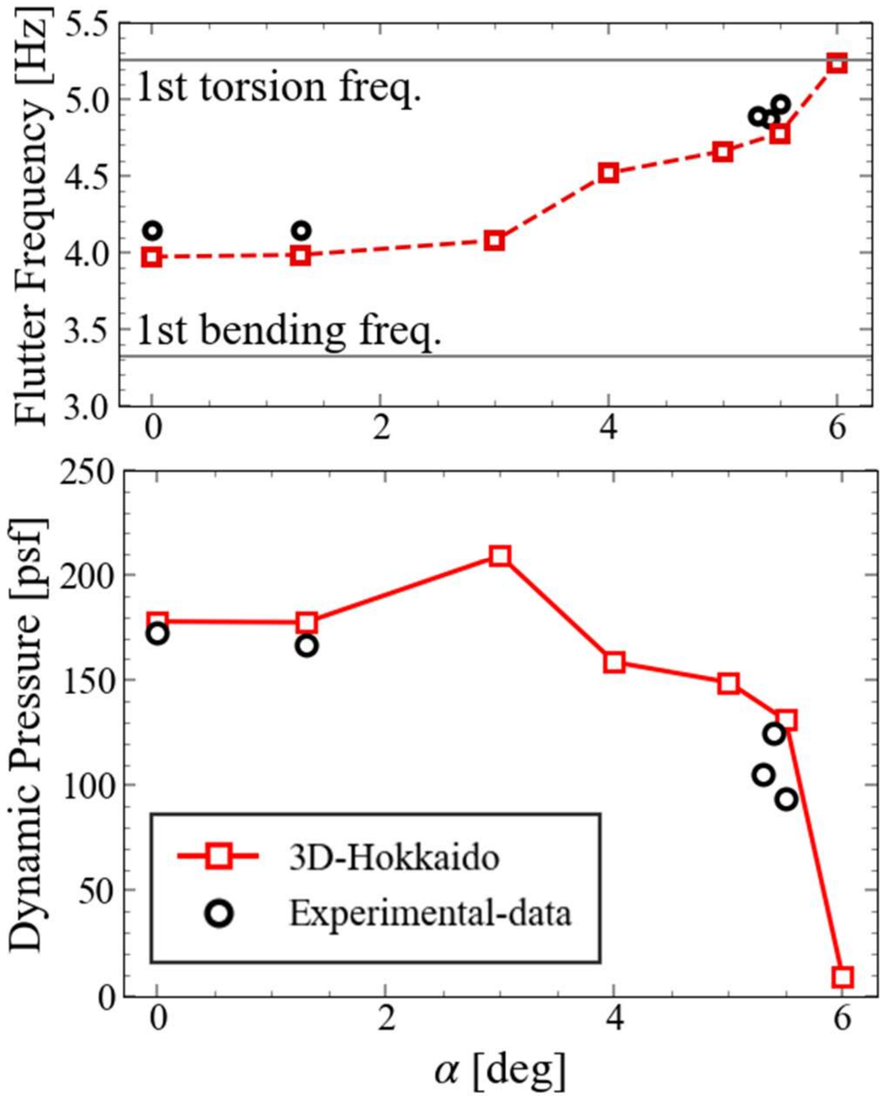
Flutter boundary

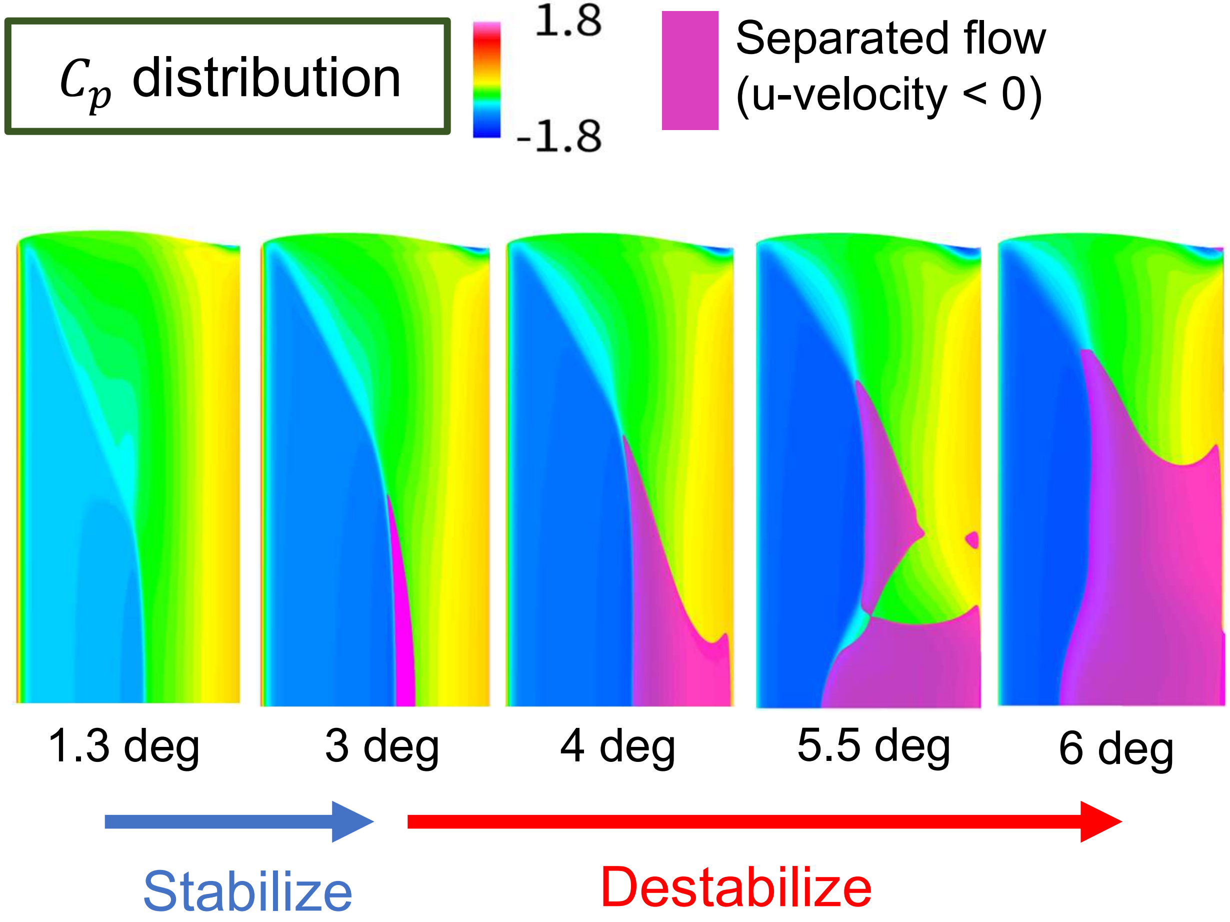


Flutter frequency

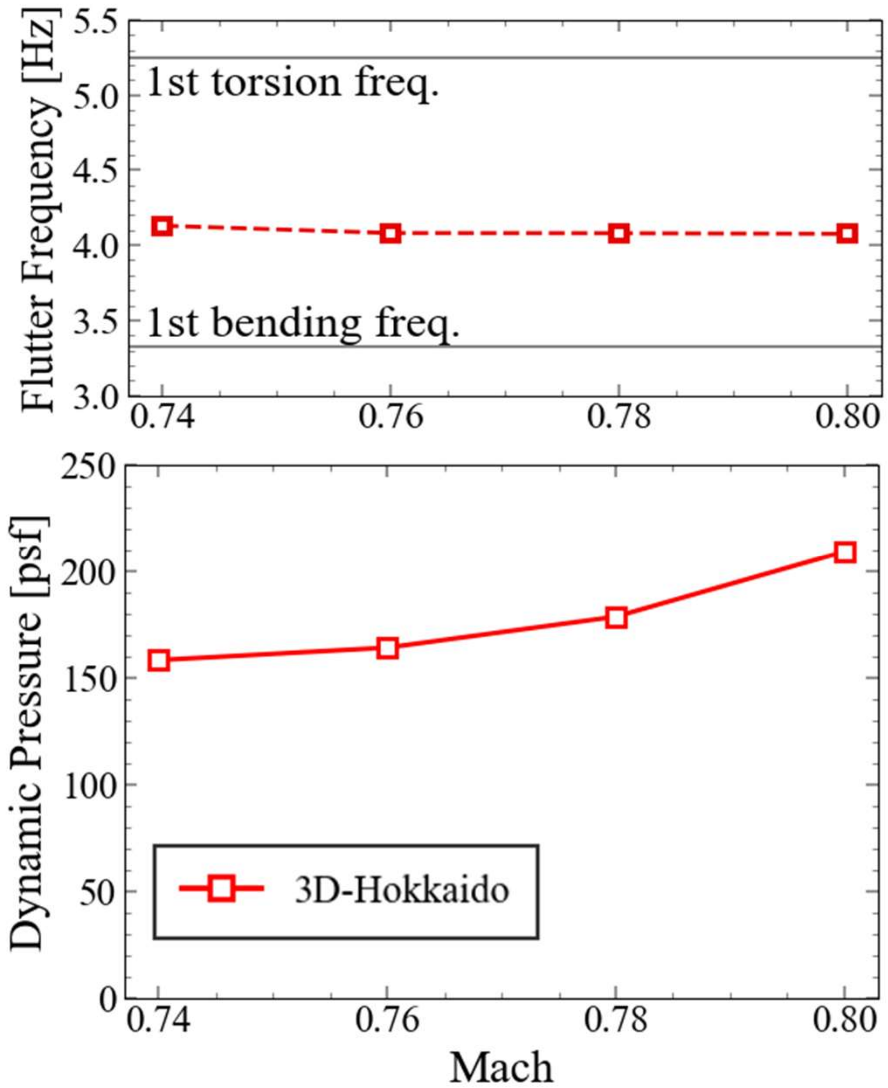


Case 1 : Results and flow field on the upper surface

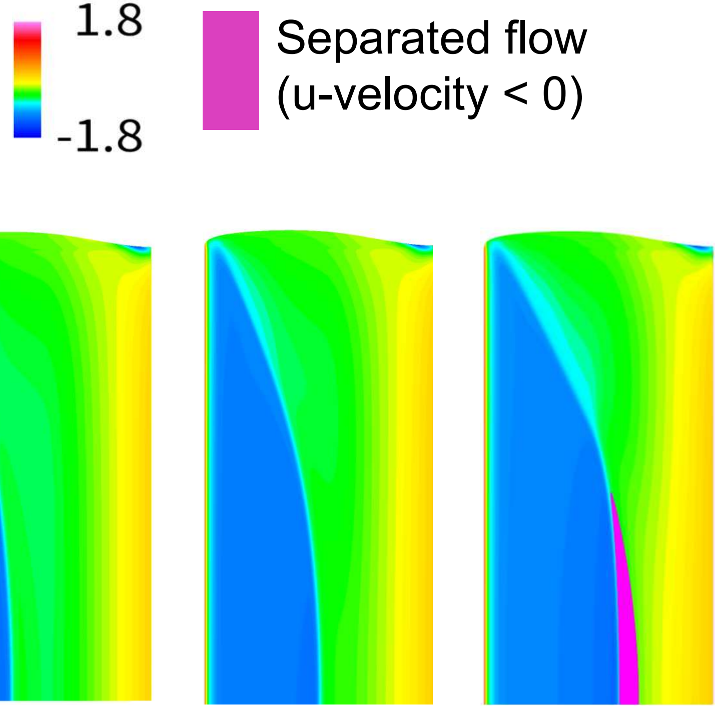




Case 2 : Results and flow field on the upper surface



C_p distribution

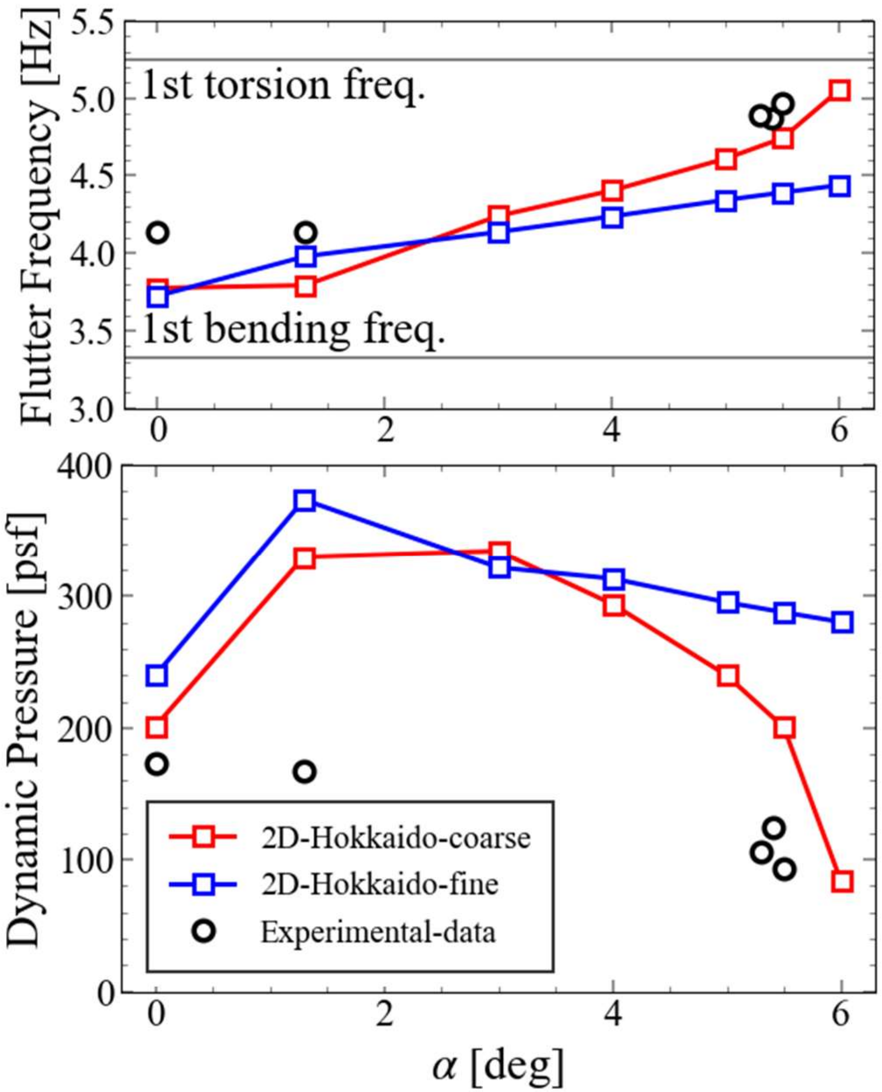


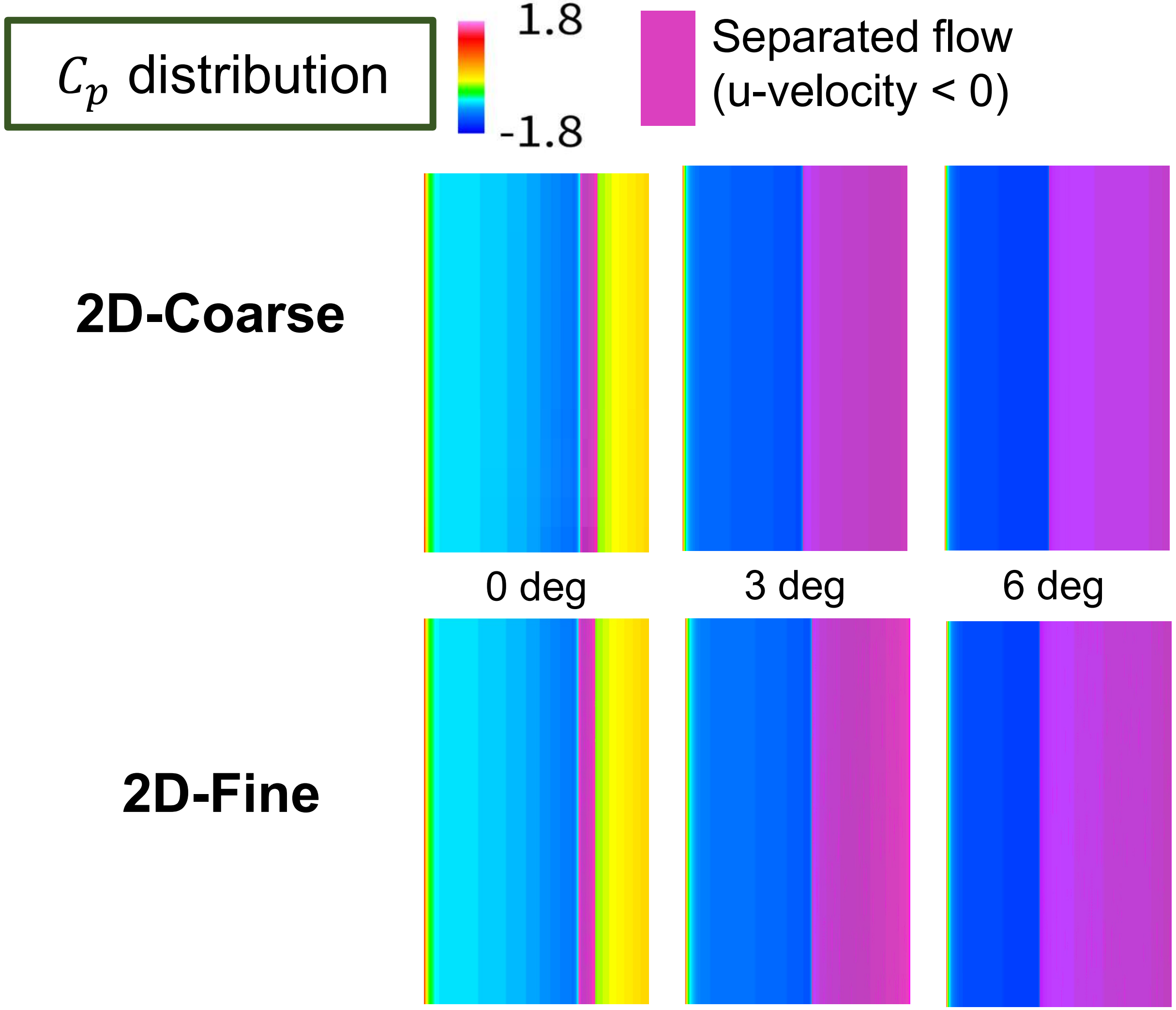
Stabilize

- Separated flow occurs → Stabilize [3]

[3] : Oyeniran N et al., 2022, AIAA Jornal

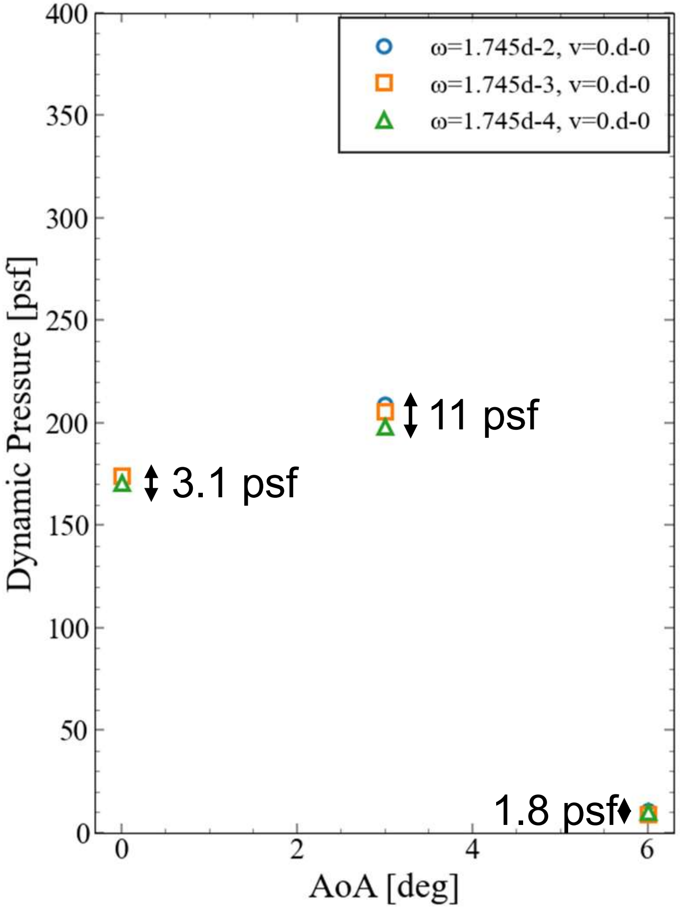
Case 3 : Results and flow field on the upper surface



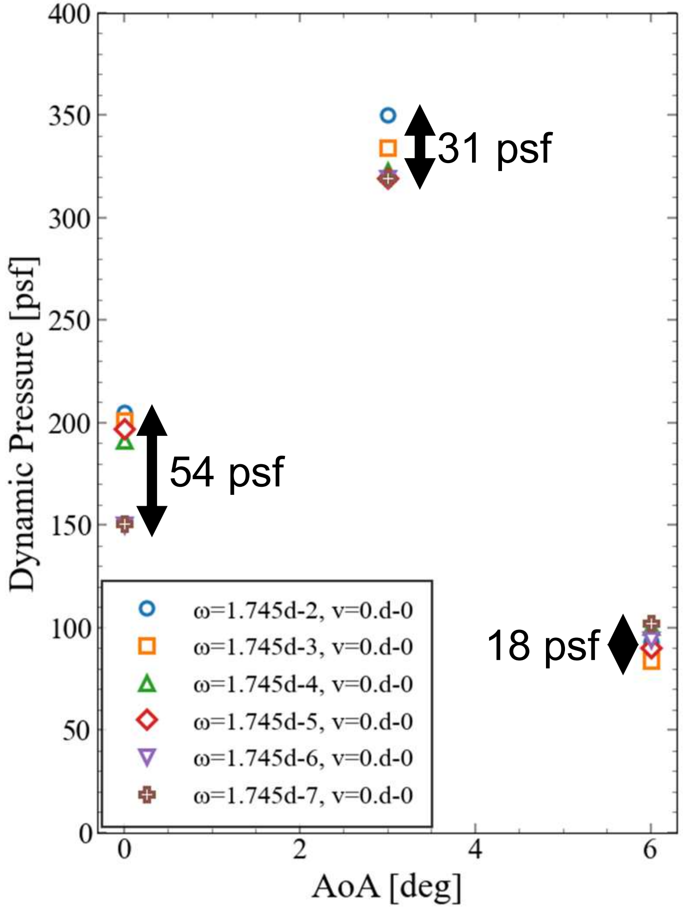


Kick size dependency on 3D prediction

3D-Angular velocity



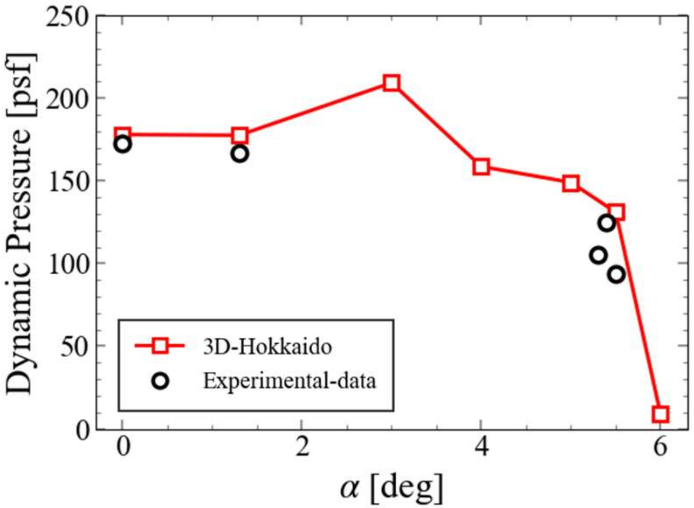
2D-Angular velocity



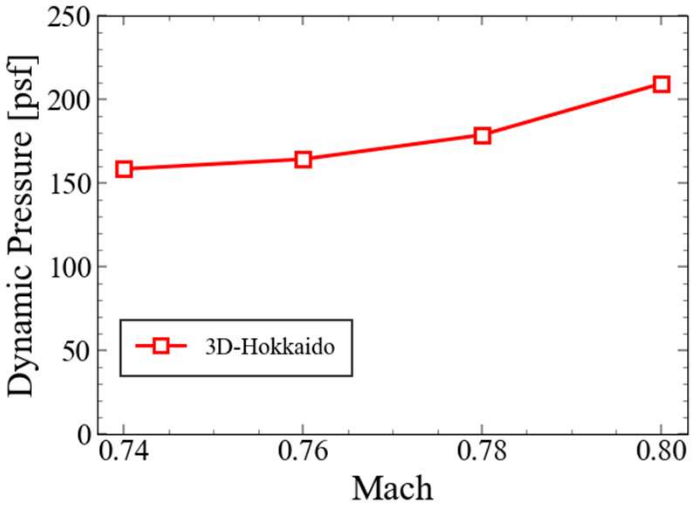
Less kick impact in 3D prediction

Conclusion

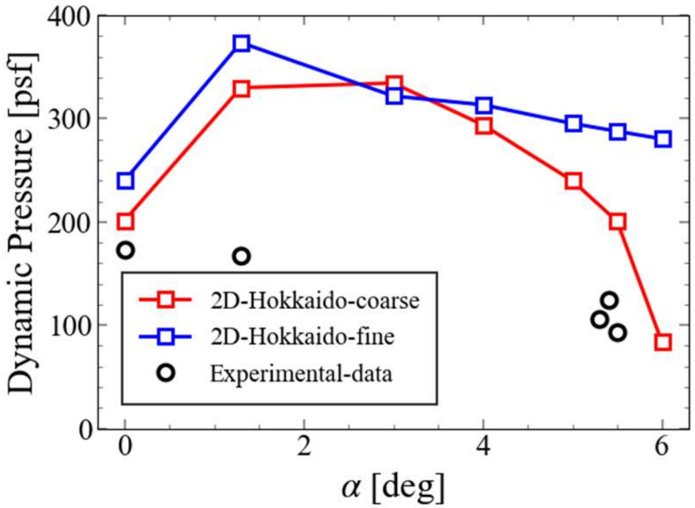
Case 1



Case 2



Case 3



- Case 1 : Good agreement with the experimental data
- Case 2 : Flutter boundary linearly increases with the AoA
- Case 3 : Different trend with different grid size → Need to get the converged solution

- 2D prediction has strong dependency on kick size, but Less kick impact at 3D prediction

Substracting C_l & C_m or equilibrium position?