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Eighth Aerodynamics Prediction Challenge (APC-8)
1C10

Aerodynamics prediction of CRM-HL using RANS by TAS code

TASによるCRM-HLのRANS定常空力解析

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Cases calculated

- **Test Cases**
  - Case1: $C_{L,max}$ study (warm & cold starts)
  - Case3: Flap deflection study
  - Case4: Turbulence model study in 2D simulation (SA-noft2-R(C_{rot}=1) & SA)

	Case 1	Case 3	Case 4
Geometry	3D CRM-HL		2D CRM-HL
Flap deflection (inboard/outboard)	40°/37°	43°/40°	–
AoA	(2.78°) 7.05° (11.29°) 17.05° 19.57° 21.47°	7.05° 17.05°	16.00°
Grid	240-JAXA-unstructured*1	2.2-Pointwise-Unstr-PrismTet-V2_43/40*1	Family 1*2
Grid Level	C-level*3	D-level*3	L1～7*4

*1 Grid downloaded from HLPW-4 website
*2 Grid provided by NASA TMR
*3 A-level (coarsest) to D-level (finest)
*4 L1 (coarsest) to L7 (finest)

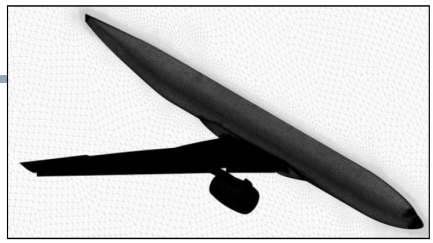
Computational condition & Numerical methods 3

- **Computational conditions**
  - Case1, 3
    - Mach = 0.2, Re = 5.49 x 10^6 (C_{ref} = 275.8 in), T_{ref} = 289.4K
  - Case4
    - Mach = 0.2, Re = 5.00 x 10^6 (C_{ref} = 1), T_{ref} = 272.1K
- **Numerical methods**

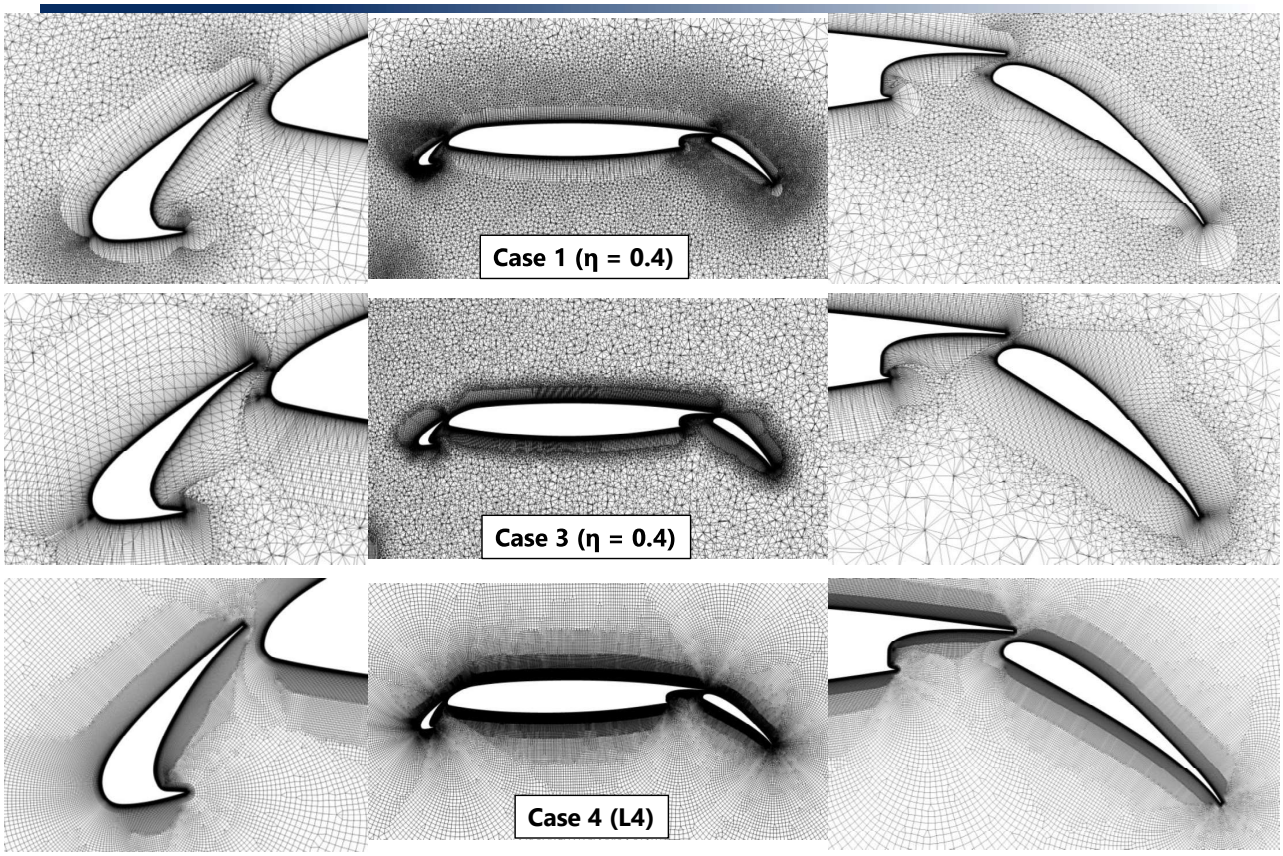
Code	TAS
Governing Equations	RANS (Reynolds Averaged Navier-Stokes) Eq.
Discretization	Cell-vertex finite volume method
Convection term	HLLEW (Harten-Lax-vanLeer-Einfeldt-Wada)
Reconstruction method	2nd order Unstructured MUSCL
Time integration	LU-SGS implicit
Turbulence model	SA-noft2-R (C_{rot}=1) (fully turbulent) SA (fully turbulent) for Case 4

- **Computational Resources**
  - JAXA Supercomputer System generation 3 (JSS3) was used for these computations.

Surface grids (Cases 1 & 3)

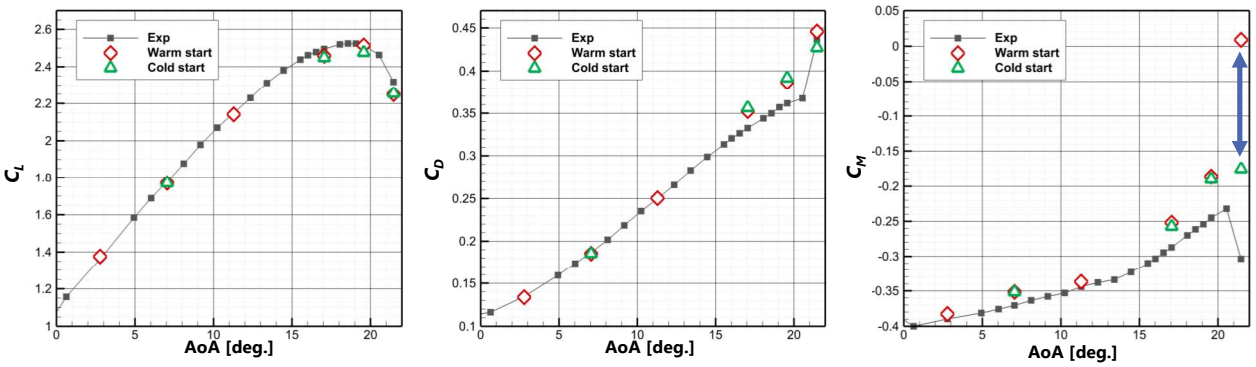


Sectional views of grids (Cases 1, 3 & 4) 5

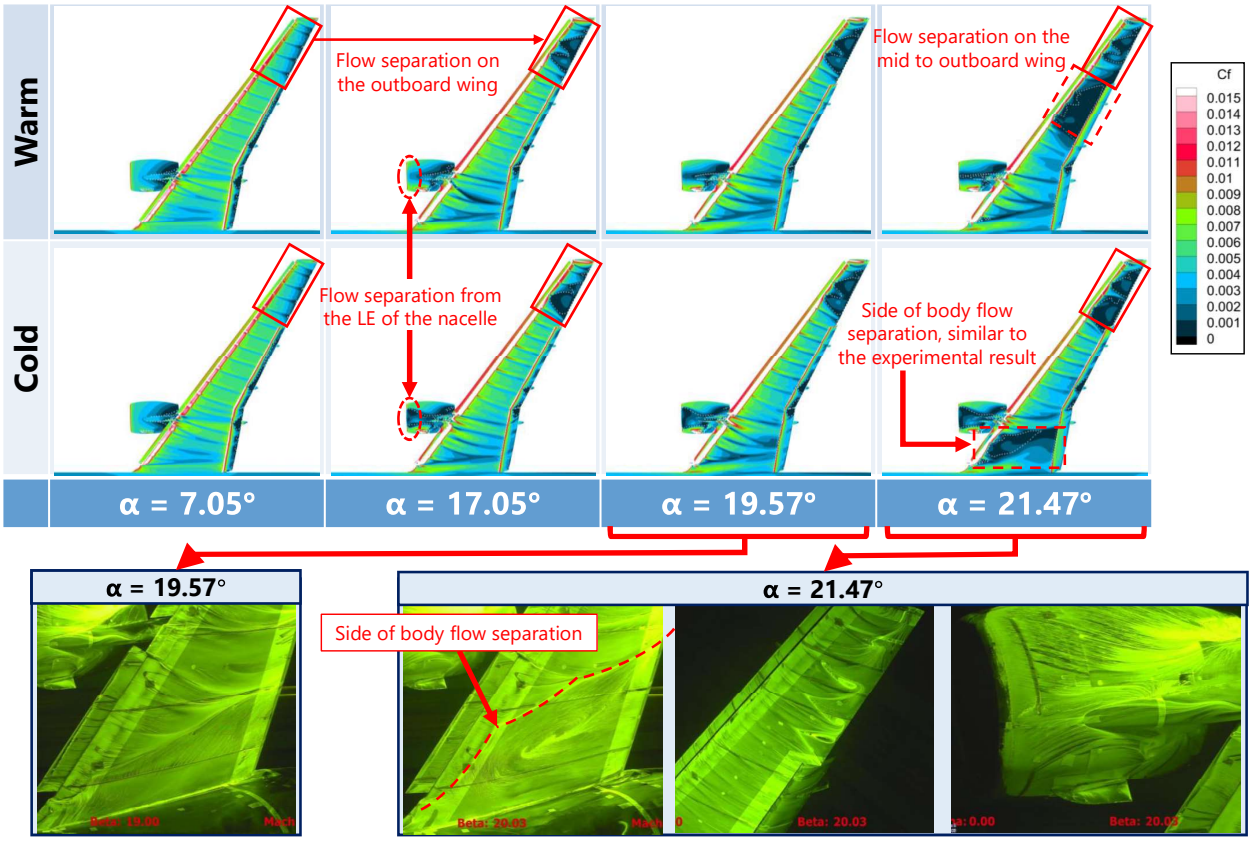


Aerodynamic coefficients (Case 1) 6

- **CFD results with warm and cold starts are compared with experiment.**
- **Compared with experiment, CFD tends to predict lower C_L, and higher C_D and C_M at high angles of attack.**
- **CFD with warm and cold starts provides different results at high angles of attack. CFD with warm starts predicts**
  - Slightly higher C_L, lower C_D and higher C_M before the stall occurs.
  - Significantly higher C_M after the stall occurs.
- **CFD with warm starts seems to provide better results before the stall occurs. Flow fields are compared in the following slides.**

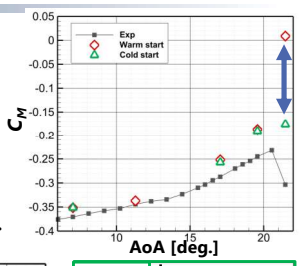


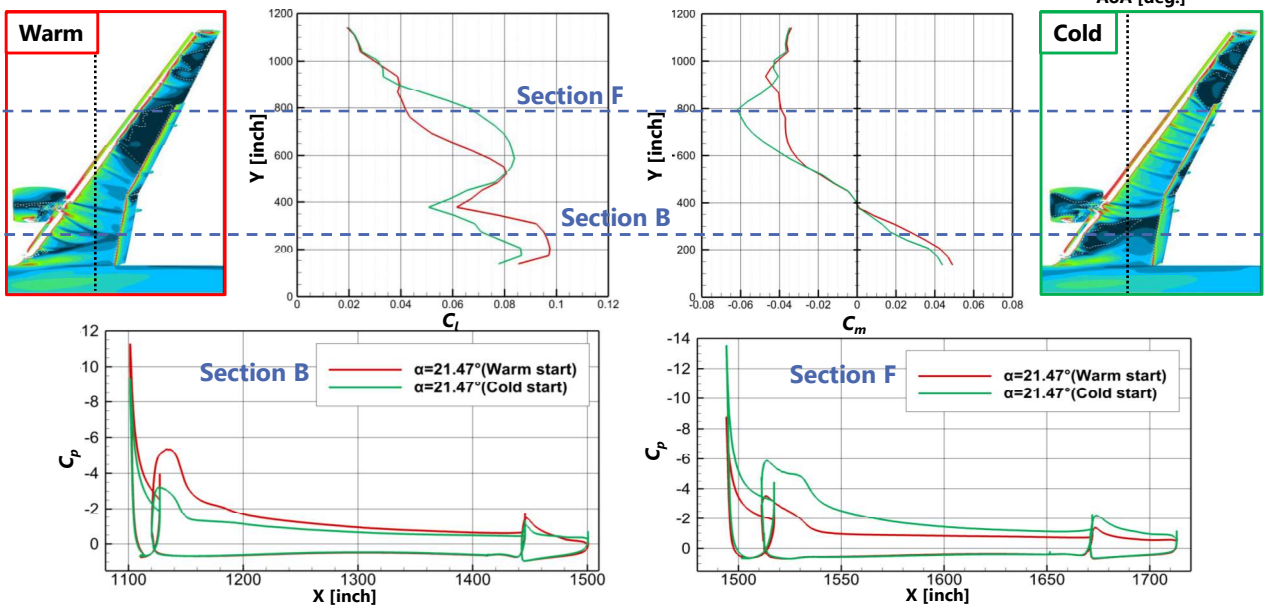
Surface Cf contours (Warm vs Cold starts) 7



Spanwise sectional C_l & C_m distributions at α=21.47° 8

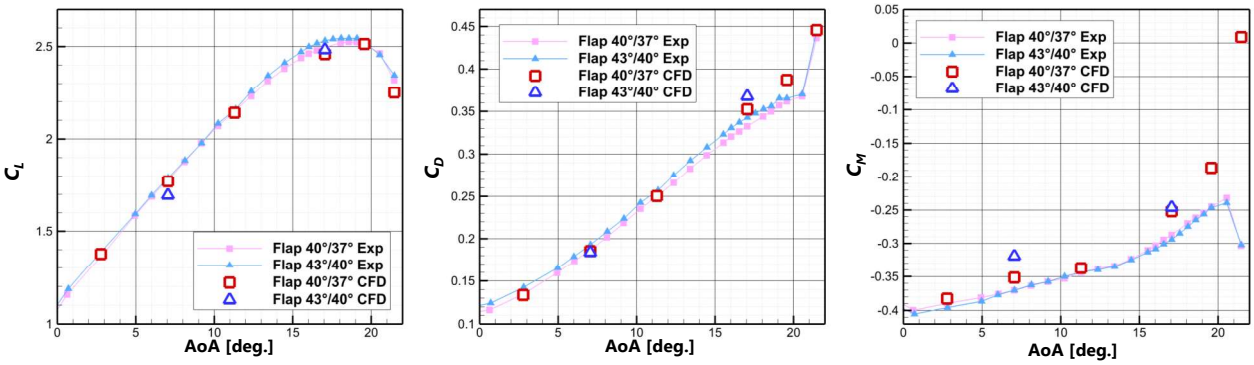
- **Compared CFD results with cold start, warm start result predicts**
  - Lower C_l at the mid to outboard wing and higher C_l at the inboard wing.
  - Higher C_m due to the larger separation on the mid to outboard wing and smaller separation on the inboard wing and outboard flap.





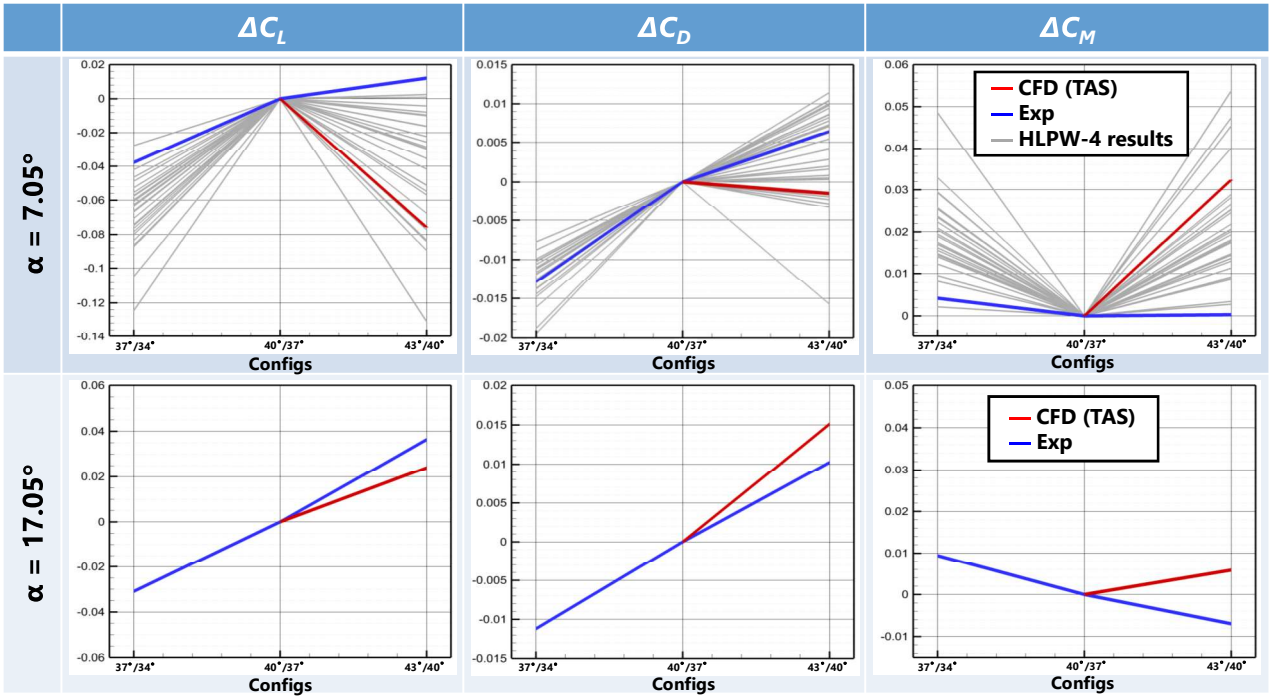
Aerodynamic coefficients (Case 3) 9

- **CFD results only with Warm starts for the flap 40°/37° & 43°/40° configs are compared with experiment.**
- **For the flap 43°/40° config, compared with experiment, CFD predicts**
  - Lower C_L & higher C_M at α = 7.05 & 17.05°.
  - Comparable C_D at α = 7.05° & higher C_D at α = 17.05°
- **Compared with CFD result of the flap 40°/37° config, that of the flap 43°/40° config provides**
  - Lower C_L and C_D at α = 7.05°, while higher C_L and C_D at α = 17.05°.
  - Higher C_M at α = 7.05°, but comparable C_M at α = 17.05°.

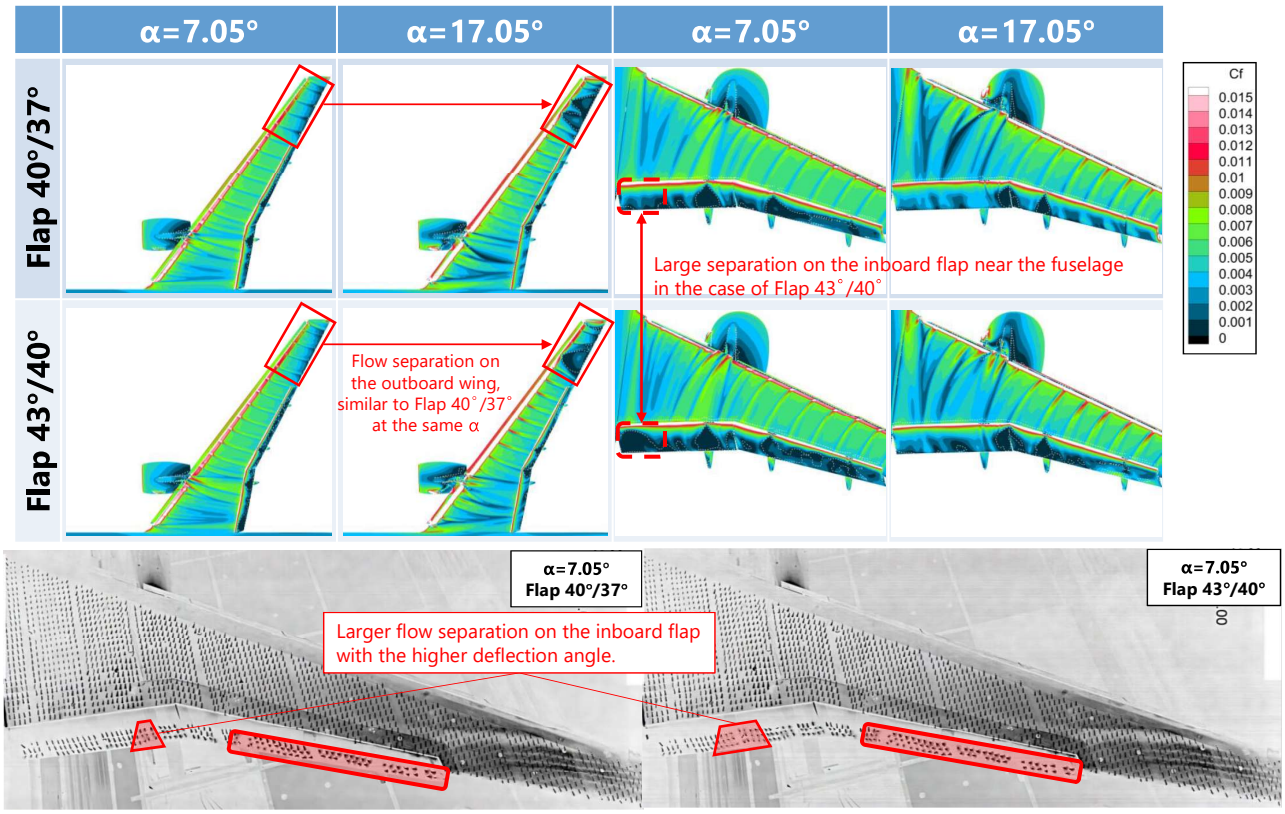


Aerodynamic coefficients (Case 3) 10

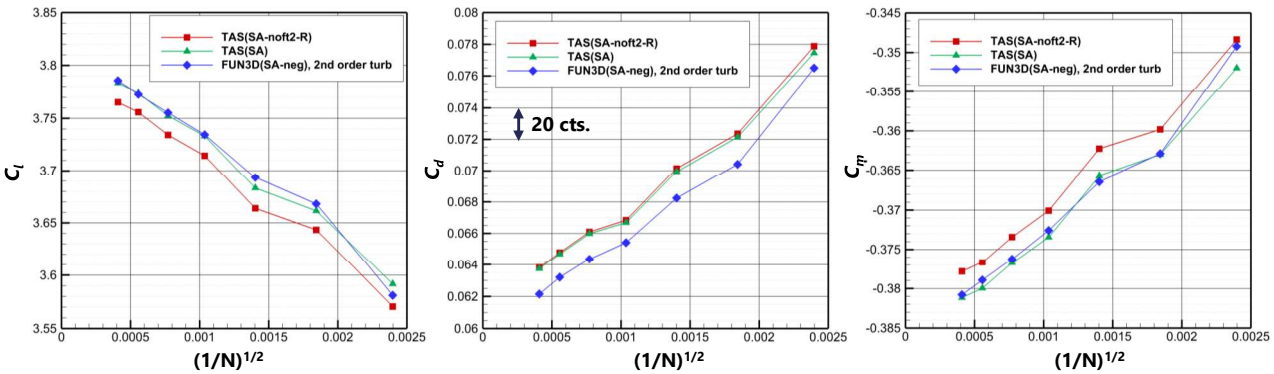
- Compared with experiment, TAS code predicts lower ΔC_L of the 43°/40° config at α = 7.05°. This trend is similar to results of other CFD codes participating in HLPW-4.
- Aerodynamic coefficients predicted by TAS code at α = 17.05° are closer to the experimental result than those at α = 7.05°.

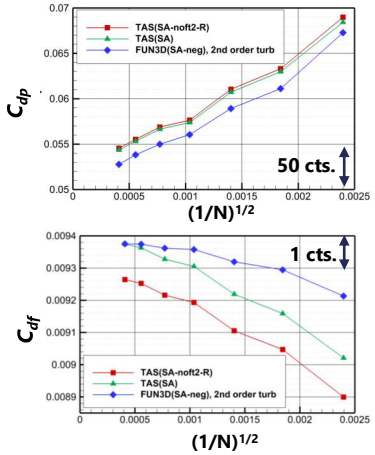


Surface Cf contours (flap 40°/37° vs 43°/40° configs) 11



Aerodynamic coefficients (Case 4) 12





- **Compared to FUN3D, TAS with SA predicts**
  - Similar C_l & C_m at all grid levels
  - 10~17 cts. larger C_d & C_{dp} at all grid levels
  - C_{df} converged at the finest grid
- **Compared to TAS with SA, TAS with SA-noft2-R predicts**
  - 0.018~0.021 lower C_l & 0.0032~0.0036 higher C_m in all grid levels
  - Similar C_d & C_{dp} at all grid levels
  - About 1 cts. lower C_{df} at all grid levels

Summary 13

- **$C_{L,max}$ study**
  - CFD results were obtained with warm and cold starts.
  - Compared with experiment, CFD results with both warm and cold starts predicted lower C_L, and higher C_D and C_M.
  - Compared with CFD with cold starts, CFD with warm starts provided results closer to the experiment before the stall occurred.
- **Flap deflection study**
  - For the flap 43°/40° config, compared with experiment, CFD predicts
    - Lower C_L & higher C_M at α = 7.05 & 17.05°.
    - Comparable C_D at α = 7.05° & higher C_D at α = 17.05°
  - Compared with experiment, TAS code predicted lower ΔC_L of the 43°/40° config at α = 7.05°. This trend was similar to results of other CFD codes participating in HLPW-4.
- **Turbulence model study in 2D simulation**
  - SA in TAS code were verified by comparison with FUN3D results.
  - Compared to SA in TAS code, SA-noft2-R(C_{rot}=1) shows
    - Lower C_l, C_{df} and higher C_m
    - Similar C_d and C_{dp}