The 49th Fluid Dynamics Conference/ The 35th Aerospace Numerical Simulation Symposium
28 June 2017, National Olympics Memorial Youth Center, Tokyo, Japan

Summary of Third Aerodynamics Prediction Challenge (APC-III)

Atsushi Hashimoto (JAXA)
APC committee

Contents

- Participants
- Test case 1
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- Summary

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Statistics of submitted data

- Organizations and number of submitted data(total 53 data)
  - National research institutes : JAXA(29)
  - Universities: Tohoku Univ., Tohoku Univ./KIT(1), Univ. of Tokyo(1), Toyama Univ.(3), Hokkaido Univ.(2)
  - Aerospace industries: KHI
  - Commercial software: Exa(1), CD-adapco(1), Cradle(2), NUMECA(12), AdvanceSoft(1)
- Grids for test case 1
  - HexaGrid : 14
  - MEGG3D : 16
  - UPACS : 10
  - Custom : 11

  (HexaGrid, MEGG3D, UPACS: Provided by committee)
- Turbulence models
  - Test case 1 : SA(9), SST(23), EARSM(15), K-ε(2), BSL(1), SS/SST-2003 Hybrid(1)
  - Test case 3 : DES(2), VLES(1)

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Participants of case 1

ID	Name	Organization	Code	Grid	Turbulence Model
A ●	橋本　敦	JAXA	FaSTAR	HexaGrid	SA-noft2-R-QCR2000
					SST-2003
					SST-2003-sust
					SST-2003-sust-QCR2000
					EARSM
					EARSM(w/o nonlinear)
					EARSM-QCR2000 (w/o nonlinear)
				MEGG3D	SA-noft2-R-QCR2000
					SST-2003
					SST-2003-sust
					SST-2003-sust-QCR2000
					EARSM
					EARSM(w/o nonlinear)
					EARSM-QCR2000 (w/o nonlinear)

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Participants of case 1

ID	Name	Organization	Code	Grid	Turbulence Model
A	橋本　敦	JAXA	FaSTAR	UPACS	SA-noft2-R-QCR2000
					SST-2003
					SST-2003-sust
					SST-2003-sust-QCR2000
					EARSM
					EARSM(w/o nonlinear)
					EARSM-QCR2000 (w/o nonlinear)
				Custom (Cartesian based)	SA-noft2-R-QCR2000
					SST-2003
					SST-2003-sust
					SST-2003-sust-QCR2000
					EARSM
					EARSM(w/o nonlinear)
					EARSM-QCR2000 (w/o nonlinear)

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Participants of case 1

ID	Name	Organization	Code	Grid	Turbulence Model
C	佐々木　大輔	金沢工業大学	BCM-TAS カップリング	Custom (MEGG3D+BCM)	SA
D	玉置　義治	東京大学	UTCart	Custom (Octree Cartesian)	SA-noft2-R-QCR2000
E	松島　紀佐	富山大学	FaSTAR	HexaGrid	SST-2003
F	寺島　洋史	北海道大学	RG-FaSTAR	HexaGrid	SST-2003
					SS/SST-2003 Hybrid
I	曽我　匡統	CD-adapco	STAR-CCM+	Custom (polyhedra)	SST
J	中島　吉隆	ソフトウェアクレイドル	scFLOW	HexaGrid	SST
				Custom (polyhedra)	

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Participants of case 1

ID	Name	Organization	Code	Grid	Turbulence Model
K ●	岡 新一	NUMECA	FINE/Open	UPACS	SA-fv3(Cmat)
					SST-2003(Cmat)
					SSC-EARSM(Cmat)
				MEGG3D	SA-fv3(Cscal)
					SA-fv3(Cmat)
					SST-2003(Cscal)
					SST-2003(Cmat)
					SSC-EARSM(Cscal)
					SSC-EARSM(Cmat)
					KE-YS-1993(Cscal)
					KE-YS-1993(Cmat)
					S-BSL-EARSM(Cscal)
L ○	大西 陽一	アドバンスソフト	Advance/FrontFlow/red	HexaGrid	SST

Participants of case 1

ID	Name	Organization	Code	Grid	Turbulence Model
A1 ●	橋本 敦	JAXA	FaSTAR	Custom (HexaGrid)	SA-Zonal DES (Spanwise polynomialx1)
A2 ●	橋本 敦	JAXA	FaSTAR	Custom (HexaGrid)	SA-Zonal DES (Spanwise polynomialx6)
H ●	甲斐 寿 Ehab Fares	Exa Japan Exa Corp.	PowerFLOW	Custom (Cartesian LBM)	VLES

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Issues of APC-I and APC-II

- The variation of CFD is large for high angles of attack

→**Test case 1:** Investigation of grids and turbulence models for high angle-of-attack flows

→The committee recommends turbulence models other than SA

- The slight difference remains between CFD and experiment

→**Test case 2:** Discussion on the difference based on follow-up computations under arbitrary conditions

- Improvement of buffet prediction accuracy

→**Test case 3:** Comparison with unsteady pressure frequency spectra, unsteady PSP

→Unsteady pressure data and flow field data are submitted.

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Case 1: Alpha-sweep

- Model : NASA-CRM(i_H=0deg) without support device
- Grid: Medium(~10M)
- Conditions : M = 0.847, Re_c = 2.26 × 10^6, T_{ref} = 284K
- Angles : -1.79deg, -0.62deg, 0.32deg, 1.39deg, 2.47deg, 2.94deg, 3.55deg, 4.65deg, 5.72deg
- Data to be submitted :
  - Aerodynamic coefficients(C_D,C_L,C_m)
    - Decompose them into pressure and friction
    - Decompose them into parts (main wing, fuselage, tail)
  - Surface C_p distributions
    - Main wing
- Recommendations :
  - Usage of turbulence models other than SA
  - Discussion on high-angle-of-attack flows

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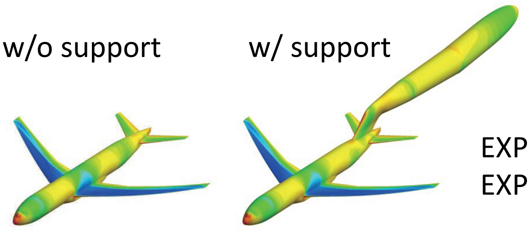
Support correction

- We added experimental data corrected by support interferences.
- The results of HexaGrid and FaSTAR are used for the correction.

w/o support w/ support



EXP(corrected)＝
EXP(uncorrected)-(CFD(w/ support)-CFD(w/ support))

AoA	CD (w support)	CD (wo support)	ΔCD	CL (w support)	CL (wo support)	ΔCL	Cm (w support)	Cm (wo support)	ΔCm
-1.79	0.0202	0.0221	-0.0019	-0.128	-0.117	-0.011	0.218	0.192	0.026
-0.62	0.0182	0.0202	-0.0020	0.031	0.045	-0.014	0.157	0.128	0.029
0.32	0.0187	0.0209	-0.0022	0.147	0.162	-0.015	0.121	0.091	0.030
1.39	0.0207	0.0231	-0.0024	0.277	0.294	-0.017	0.080	0.047	0.032
2.47	0.0248	0.0277	-0.0029	0.414	0.434	-0.020	0.048	0.014	0.034
2.94	0.0279	0.0311	-0.0033	0.478	0.499	-0.020	0.032	-0.003	0.035
3.55	0.0339	0.0377	-0.0038	0.551	0.568	-0.017	0.022	-0.011	0.033
4.65	0.0503	0.0549	-0.0045	0.628	0.643	-0.015	0.039	0.008	0.031
5.72	0.0692	0.0741	-0.0048	0.663	0.683	-0.020	0.078	0.047	0.030

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Case 1: List of data

- Alpha sweep (CL-α, CL-CD, Cm-α)
  - Comparison with APC-I and APC-II
  - Comparison between grids(HexaGrid, MEGG3D, UPACS, Custom)
  - Comparison between turbulence models(SA, SST, EARSM)
- Cruise condition (α=2.94deg)
  - Aerodynamics coefficients(CD, CL, Cm, CDi)
  - Cp distributions (Section A-I)
- High angle of attack (α=5.72deg)
  - Cp distributions (Section A-I)
  - Comparison between the results with and without SOB separation
  - Comparison between grids (HexaGrid, MEGG3D, UPACS, Custom)

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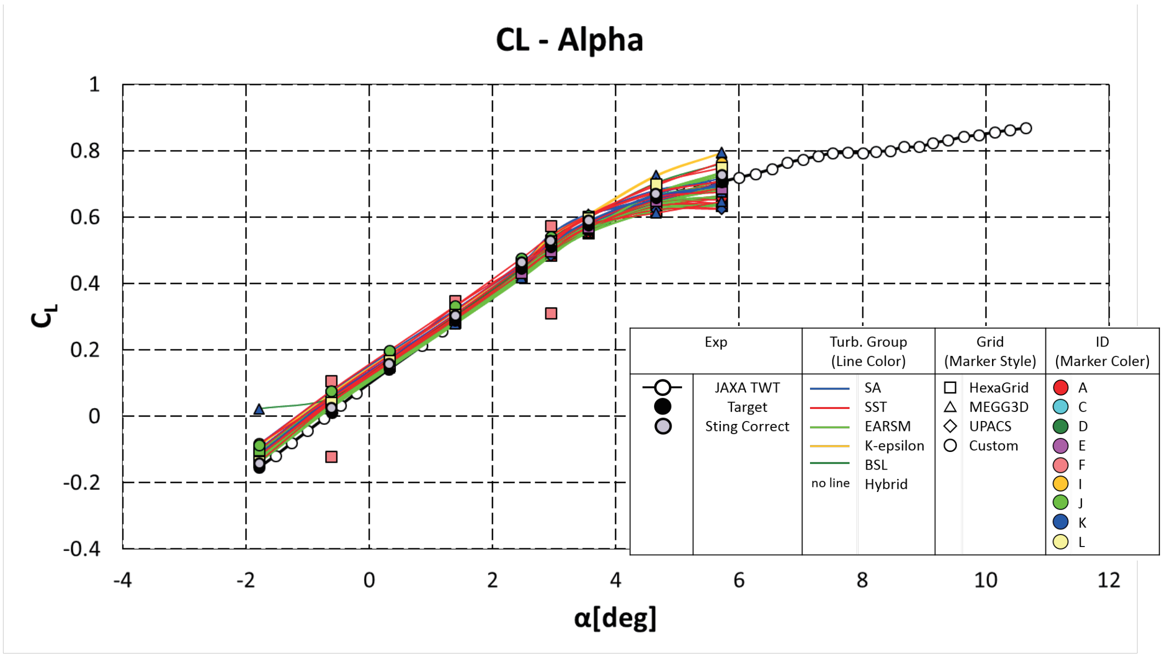
Case 1: Alpha sweep

Comparison with the previous results of APC-I and APC-II



The variation is larger than that of APC-I and APC-II especially for high angles of attack.
But the slope is almost same between turbulence models.

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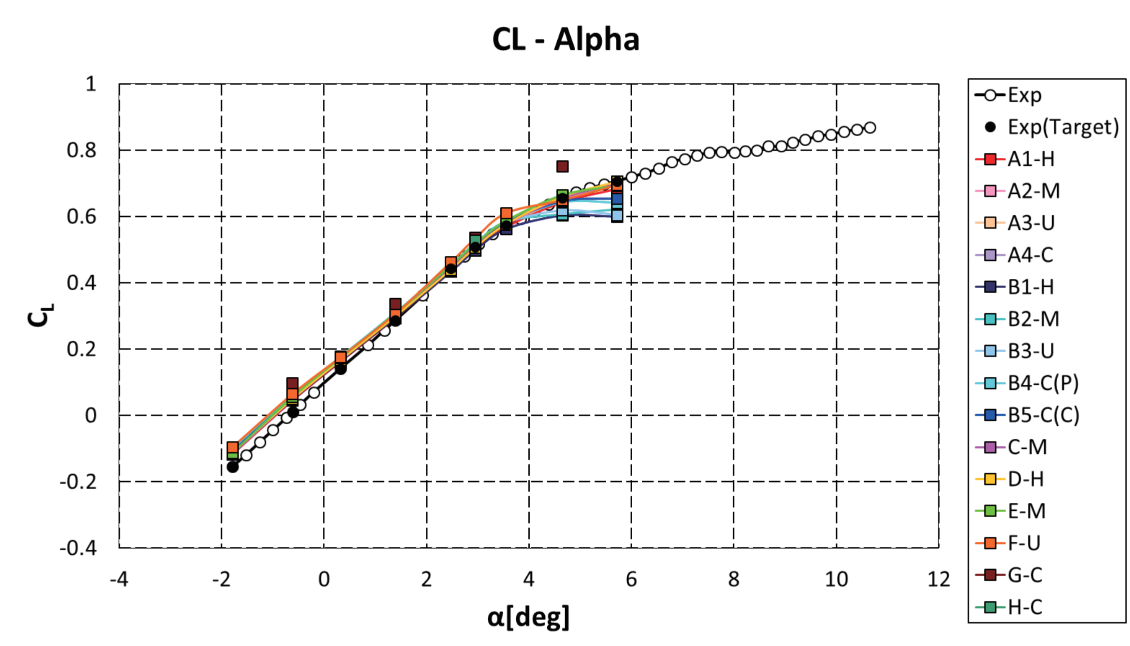
Alpha sweep of APC-II



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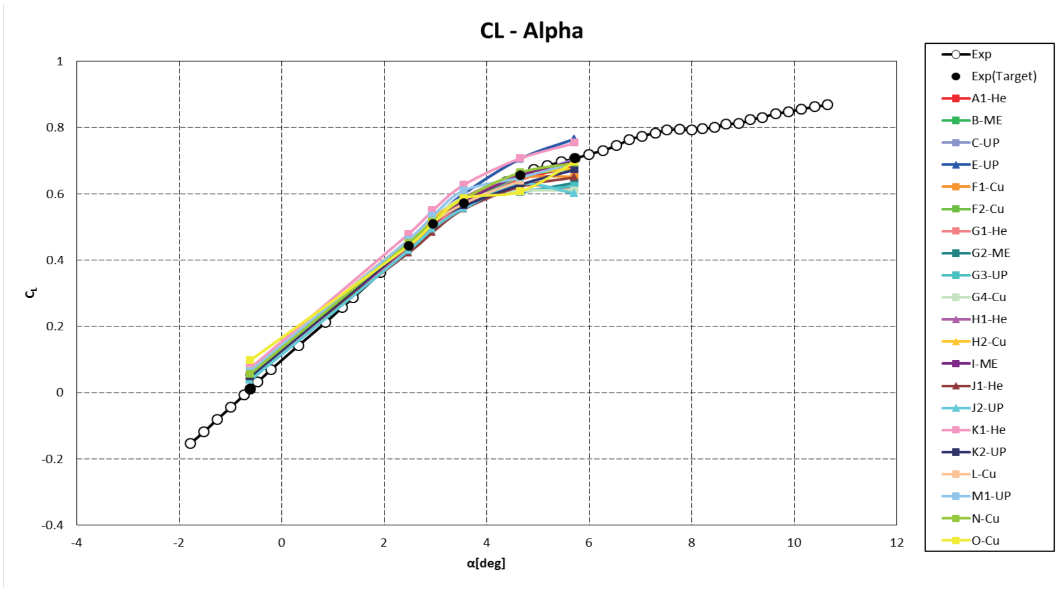
Alpha sweep of APC-I



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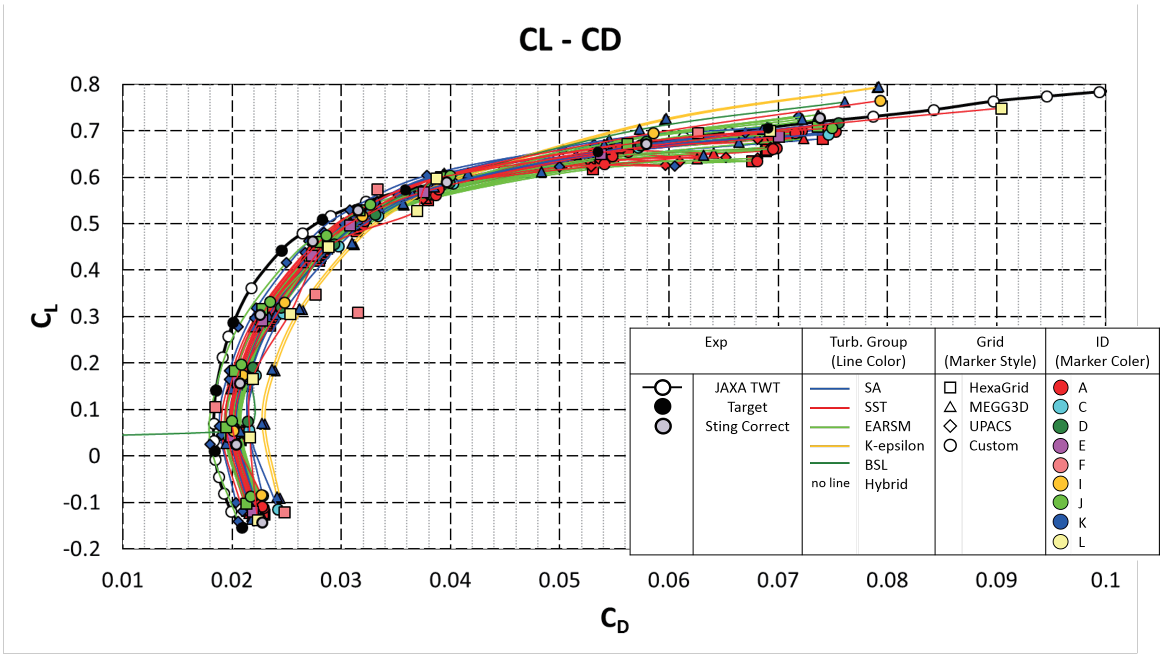
Case 1: Alpha sweep

Comparison with the previous results of APC-I and APC-II



The variation is larger than that of APC-I and APC-II.
But the trend is almost same between turbulence models.

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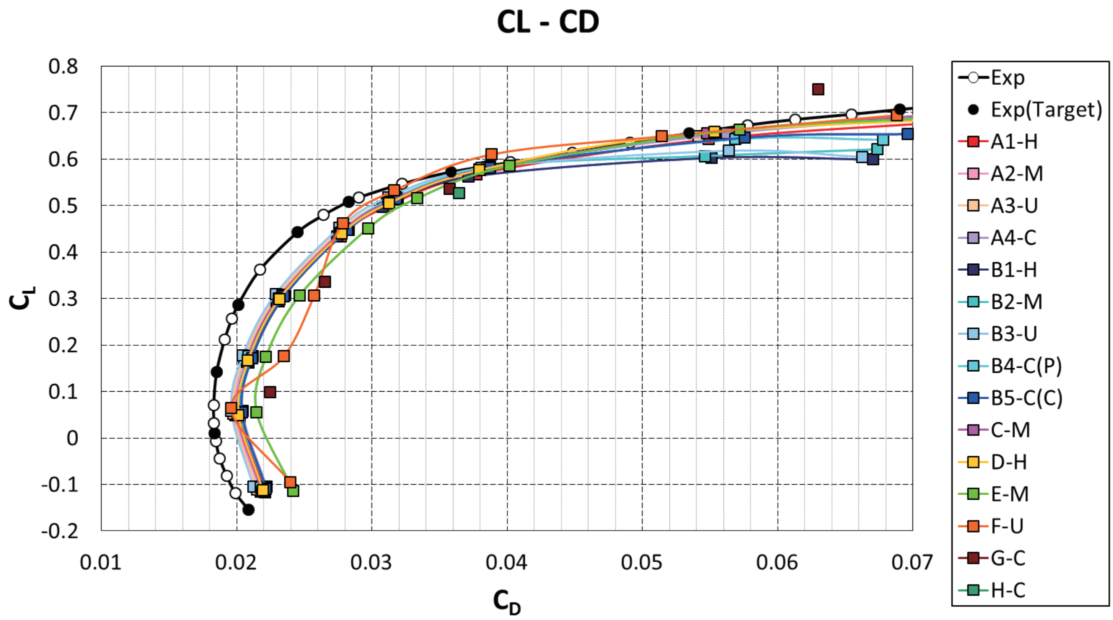
Alpha sweep of APC-II



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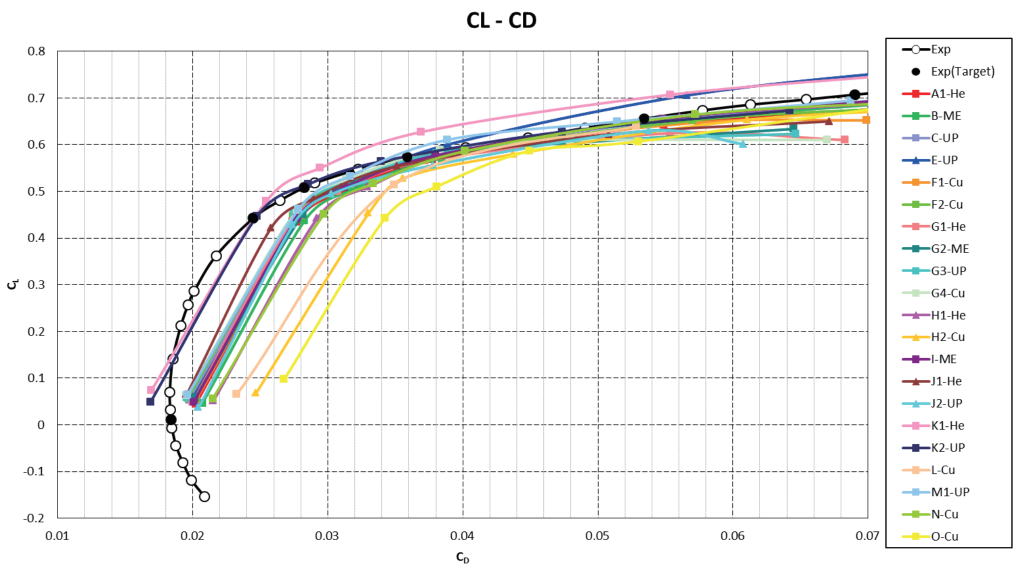
Alpha sweep of APC-I



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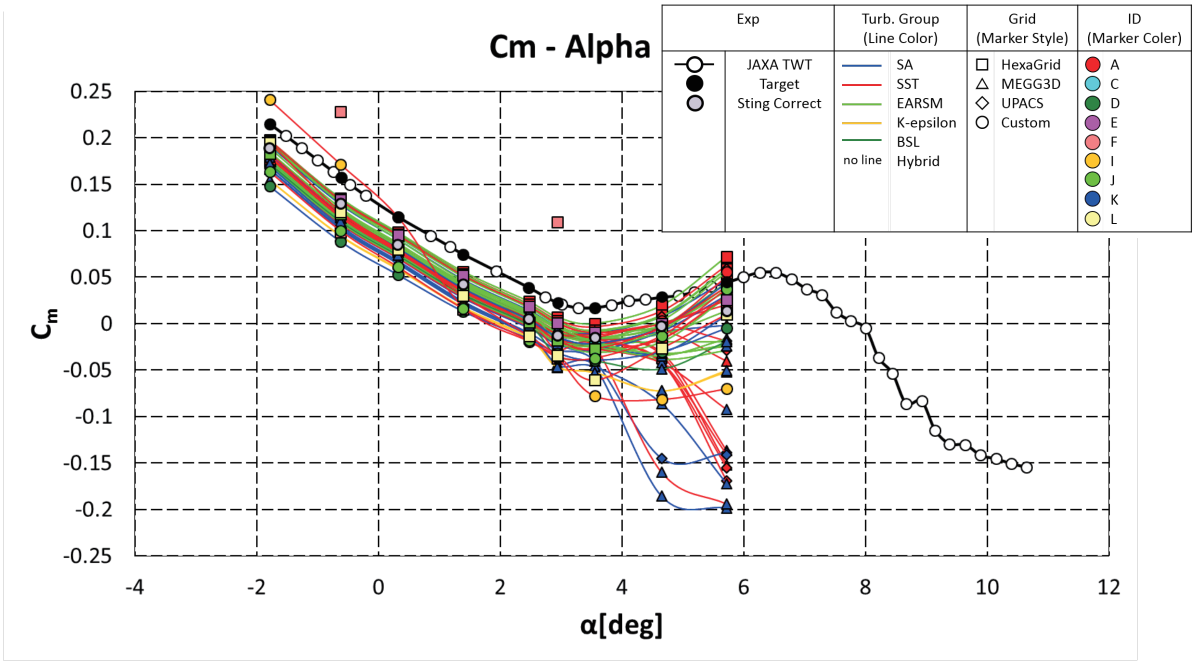
Case 1: Alpha sweep

Comparison with the previous results of APC-I and APC-II



The variation is larger than that of APC-I and APC-II especially for high angles of attack.
But the slope is almost same between turbulence models.

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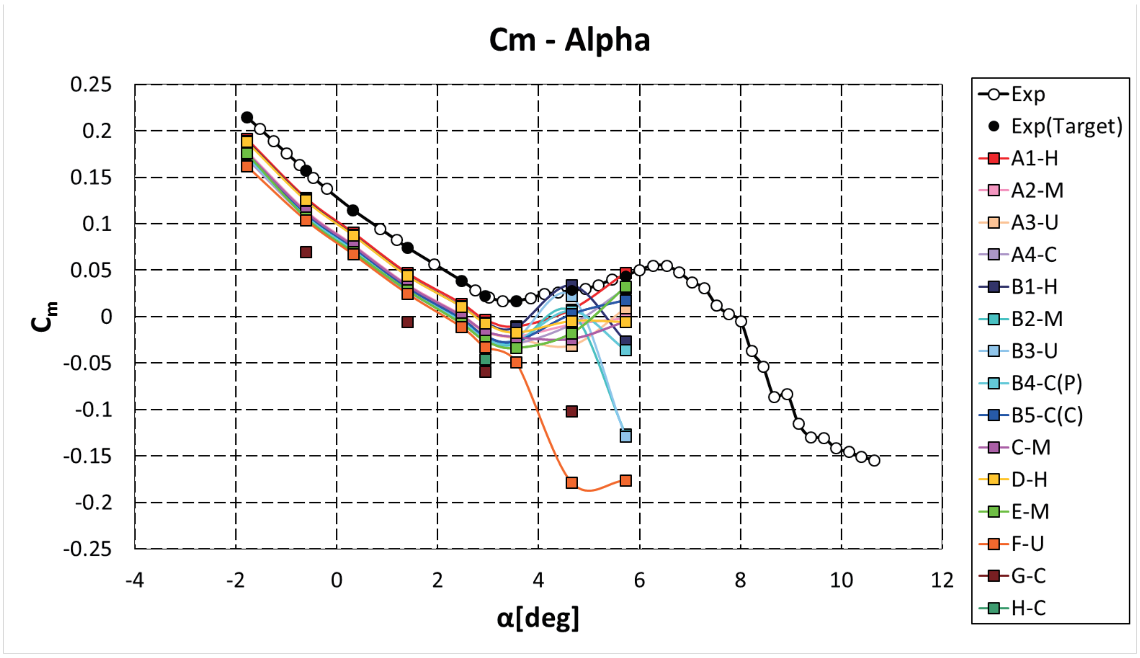
Alpha sweep of APC-II



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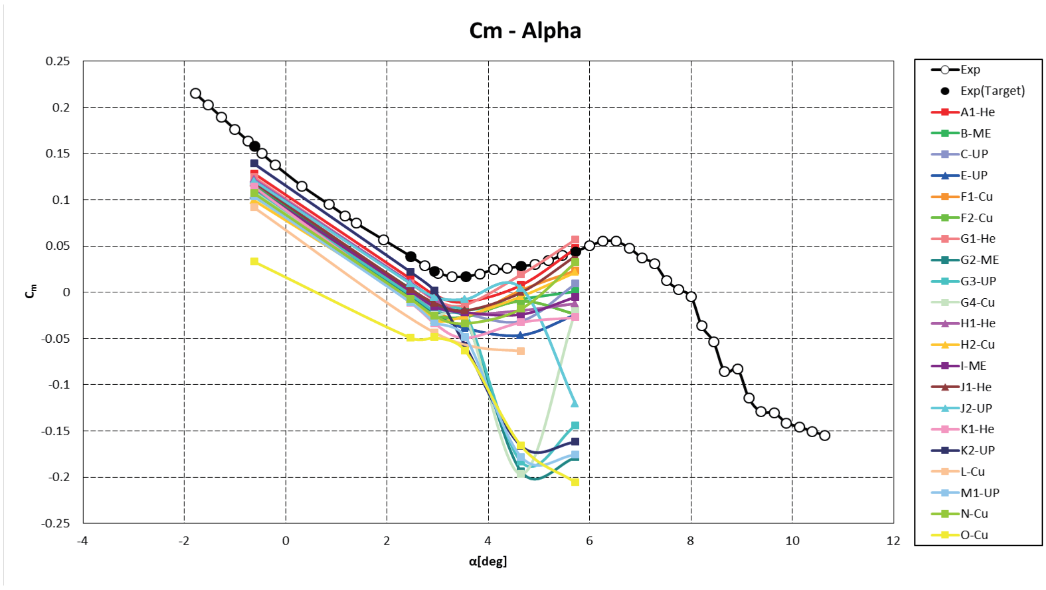
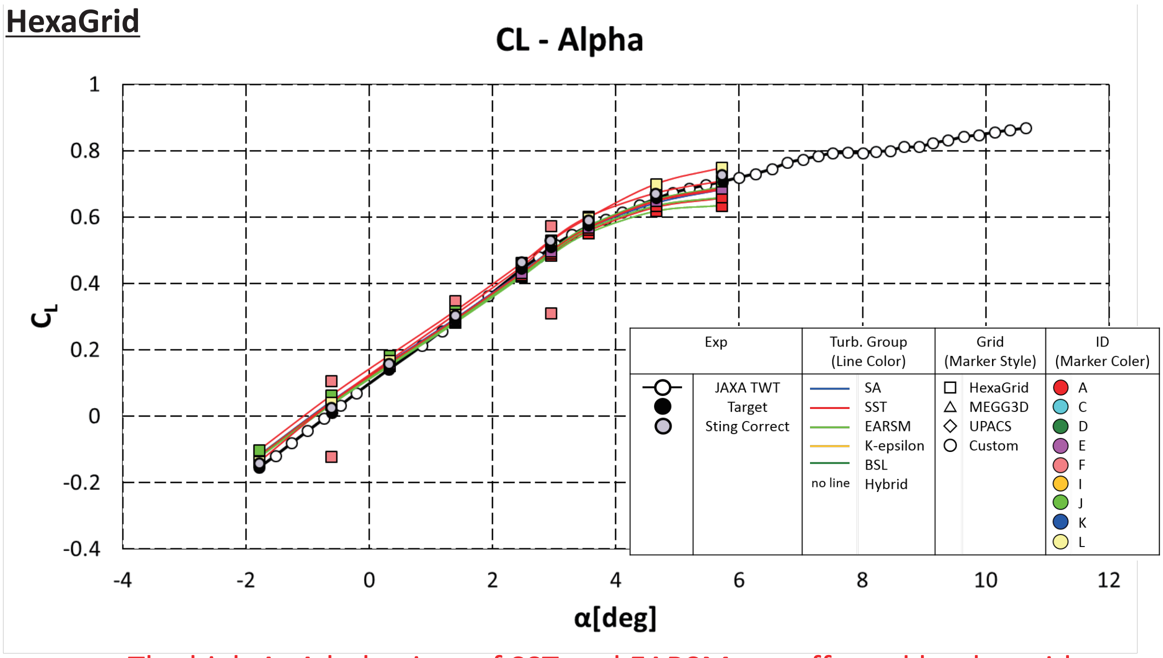
Alpha sweep of APC-I



Case 1: Alpha sweep

Comparison between grids

HexaGrid



The high AoA behaviors of SST and EARSM are affected by the grid

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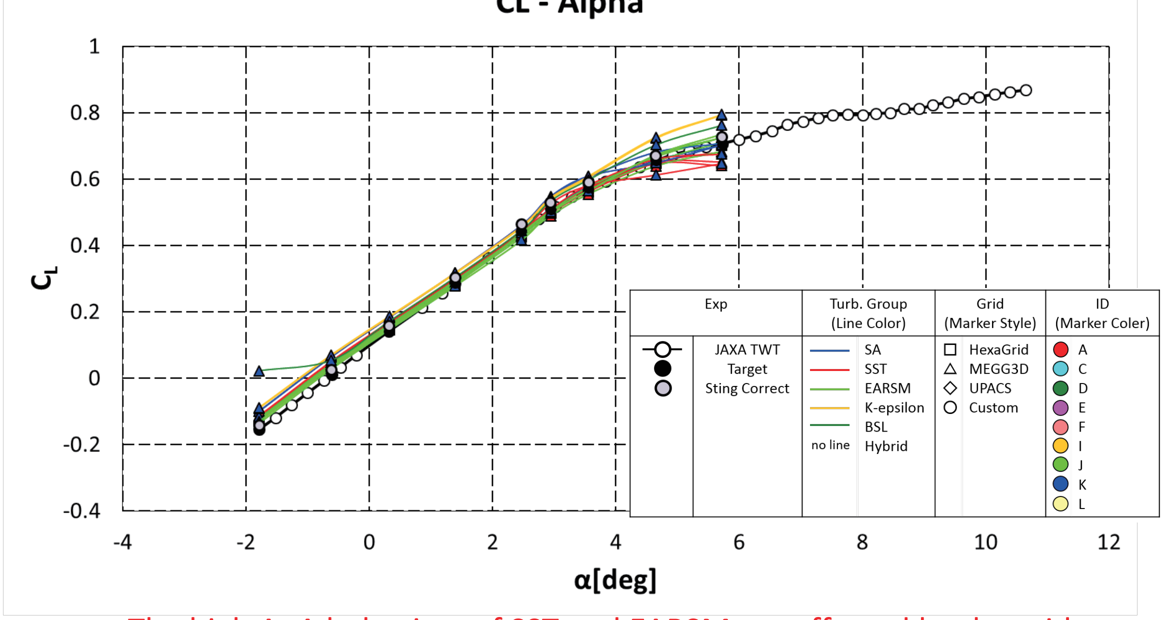
Case 1: Alpha sweep

Comparison between grids

MEGG3D

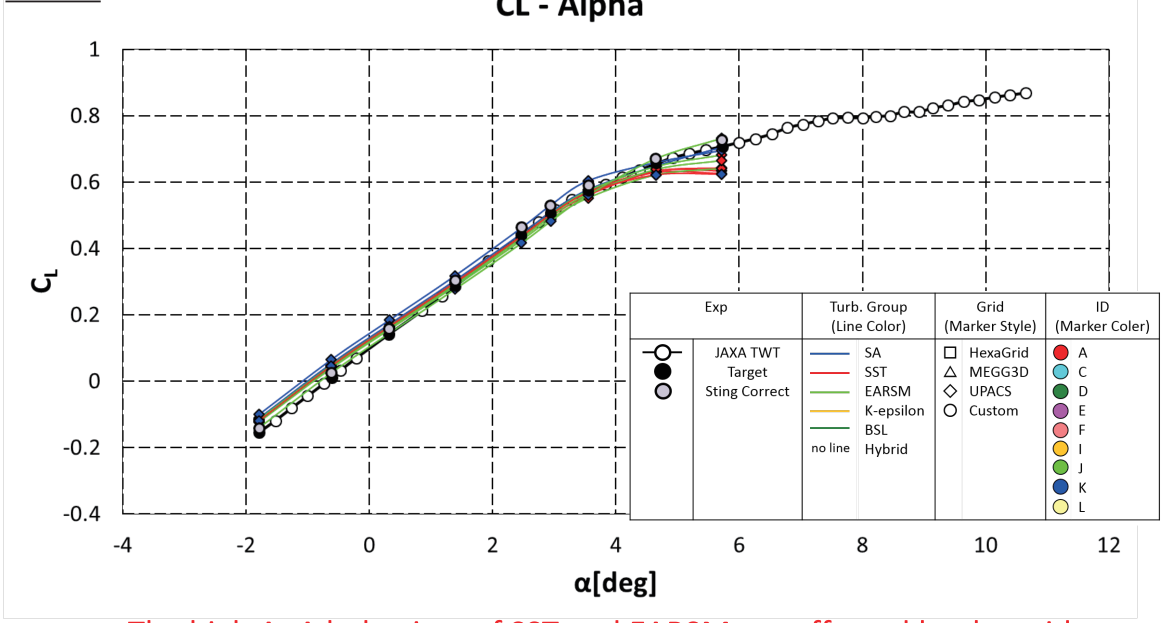


The high AoA behaviors of SST and EARSM are affected by the grid

Case 1: Alpha sweep

Comparison between grids

UPACS



The high AoA behaviors of SST and EARSM are affected by the grid

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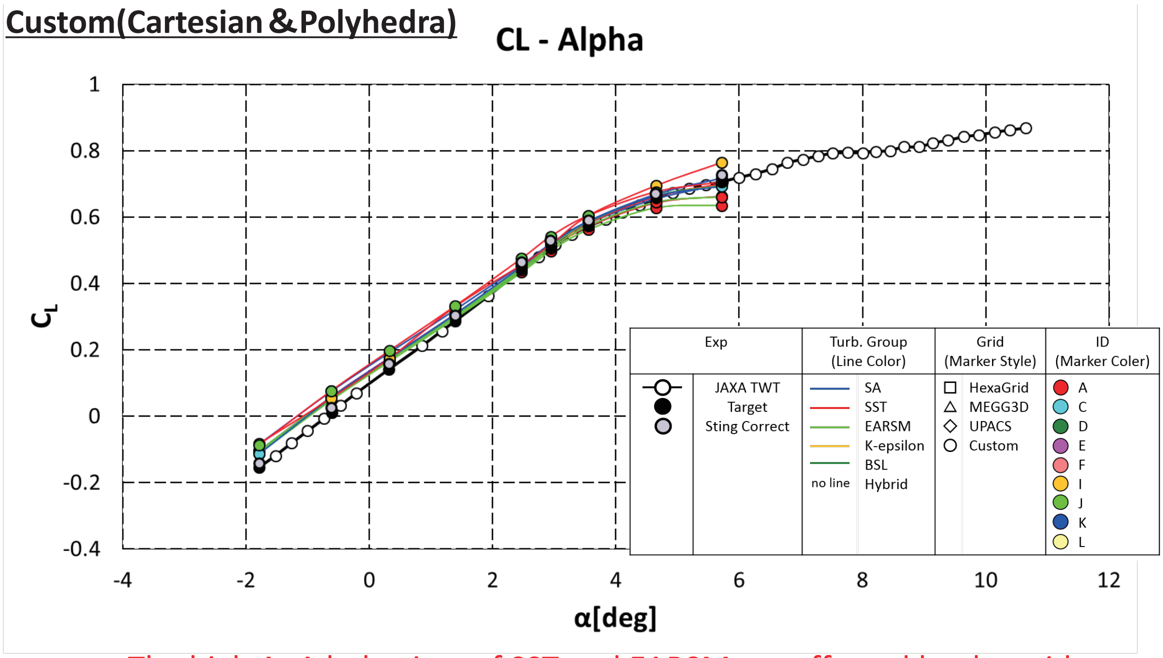
Case 1: Alpha sweep

Comparison between grids

Custom(Cartesian＆Polyhedra)

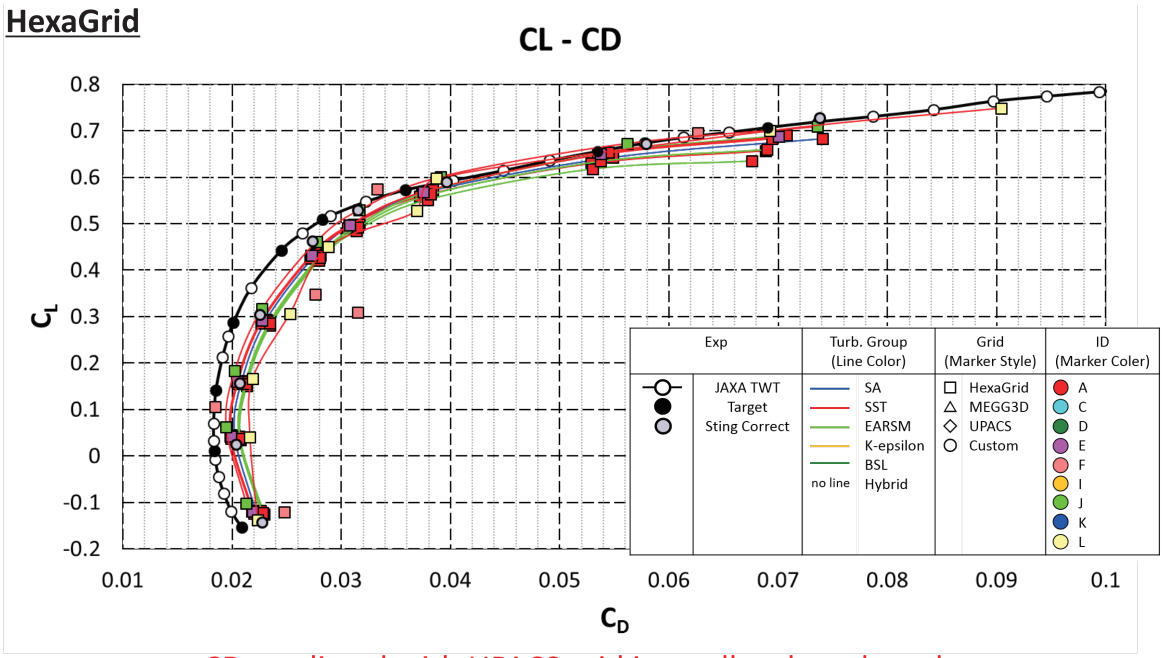


The high AoA behaviors of SST and EARSM are affected by the grid

Case 1: Alpha sweep

Comparison between grids

HexaGrid



CD predicted with UPACS grid is smaller than the others
(This may be caused by the turbulence models used with UPACS grid)

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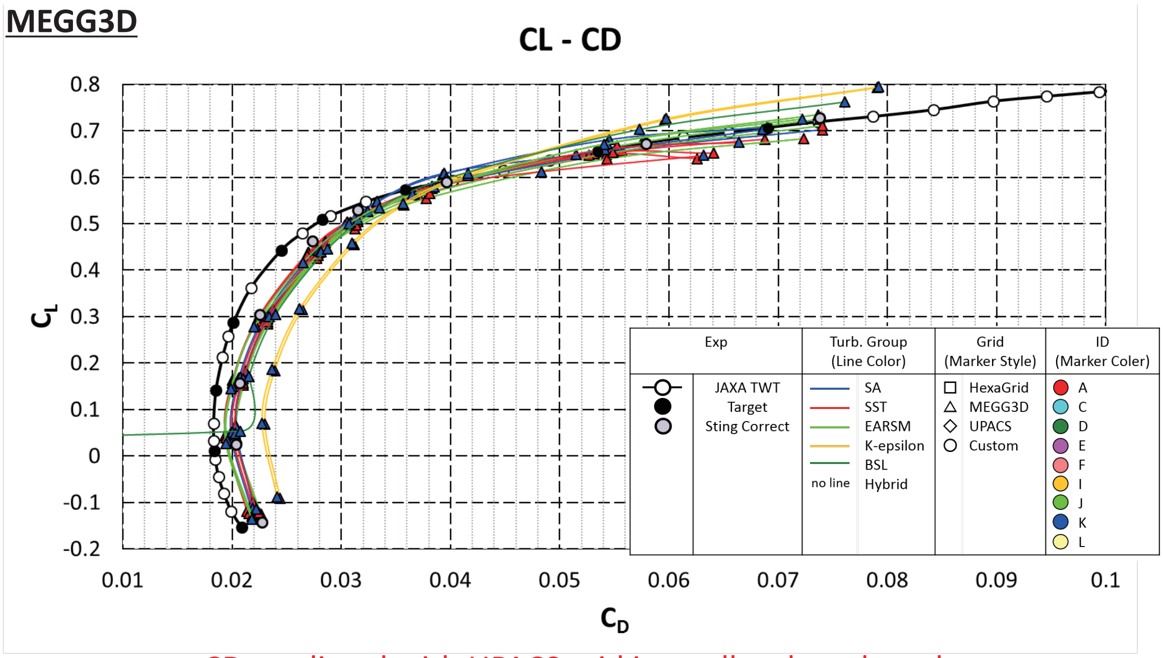
Case 1: Alpha sweep

Comparison between grids

MEGG3D



CD predicted with UPACS grid is smaller than the others
(This may be caused by the turbulence models used with UPACS grid)

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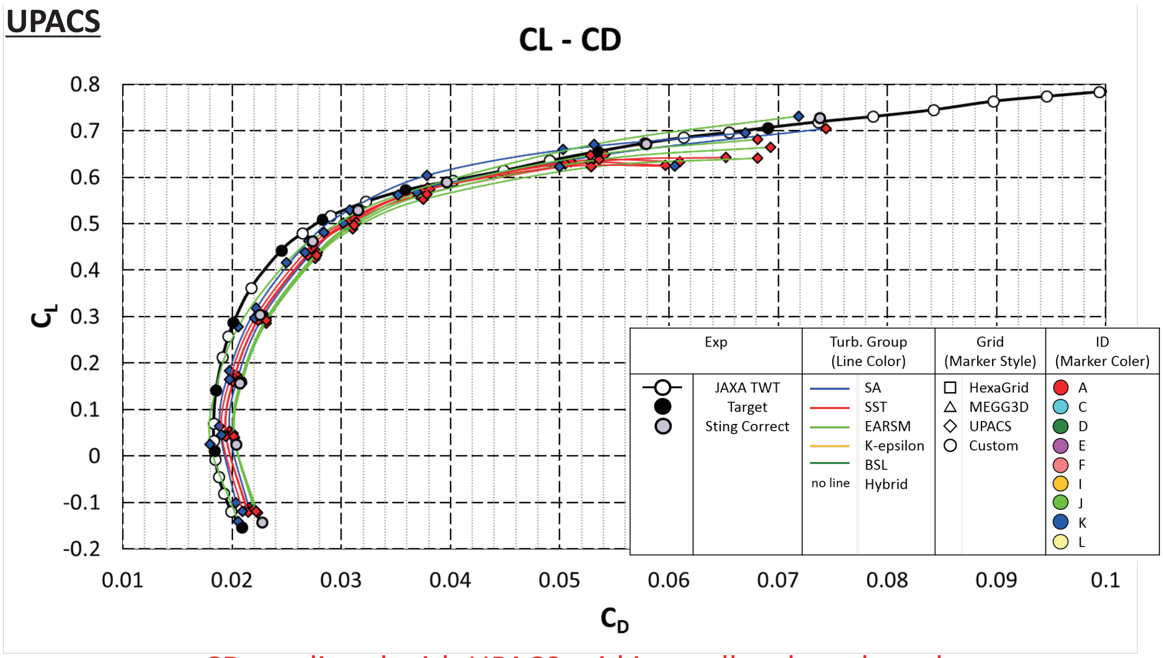
Case 1: Alpha sweep

Comparison between grids

UPACS



CD predicted with UPACS grid is smaller than the others
(This may be caused by the turbulence models used with UPACS grid)

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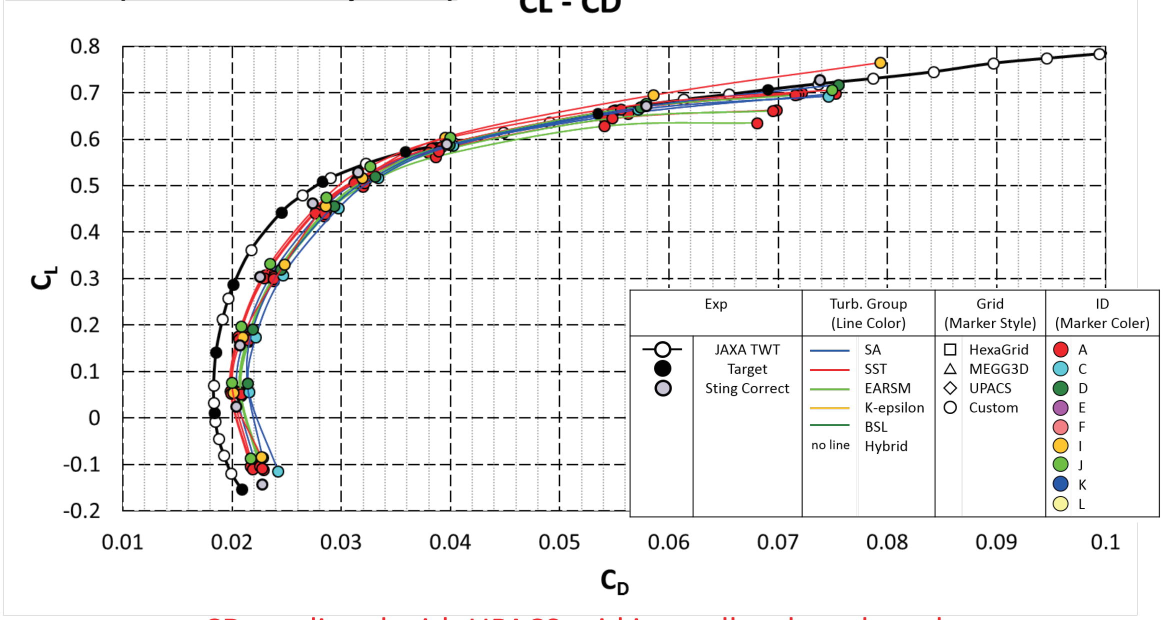
Case 1: Alpha sweep

Comparison between grids

Custom(Cartesian&Polyhedra)



CD predicted with UPACS grid is smaller than the others
(This may be caused by the turbulence models used with UPACS grid)

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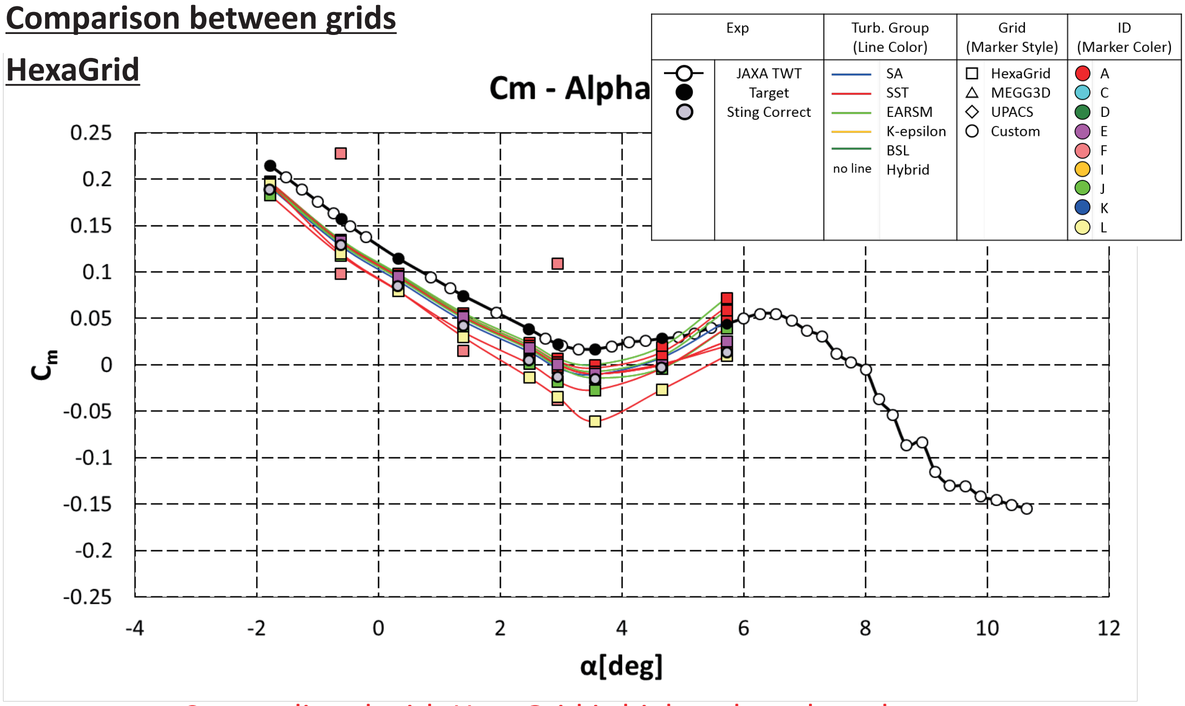
Case 1: Alpha sweep

Comparison between grids

HexaGrid



Cm predicted with HexaGrid is higher than the others
All data show the pitch-up characteristics for HexaGrid and Custom.

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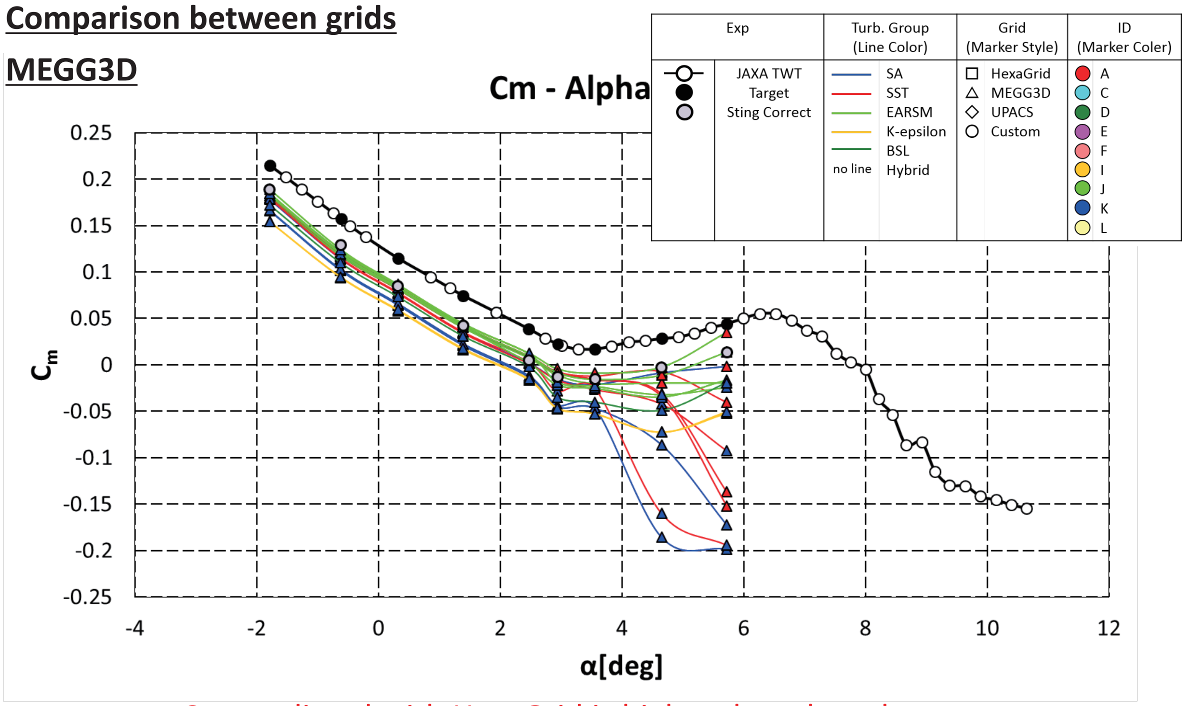
Case 1: Alpha sweep

Comparison between grids

MEGG3D



Cm predicted with HexaGrid is higher than the others

All data show the pitch-up characteristics for HexaGrid and Custom.

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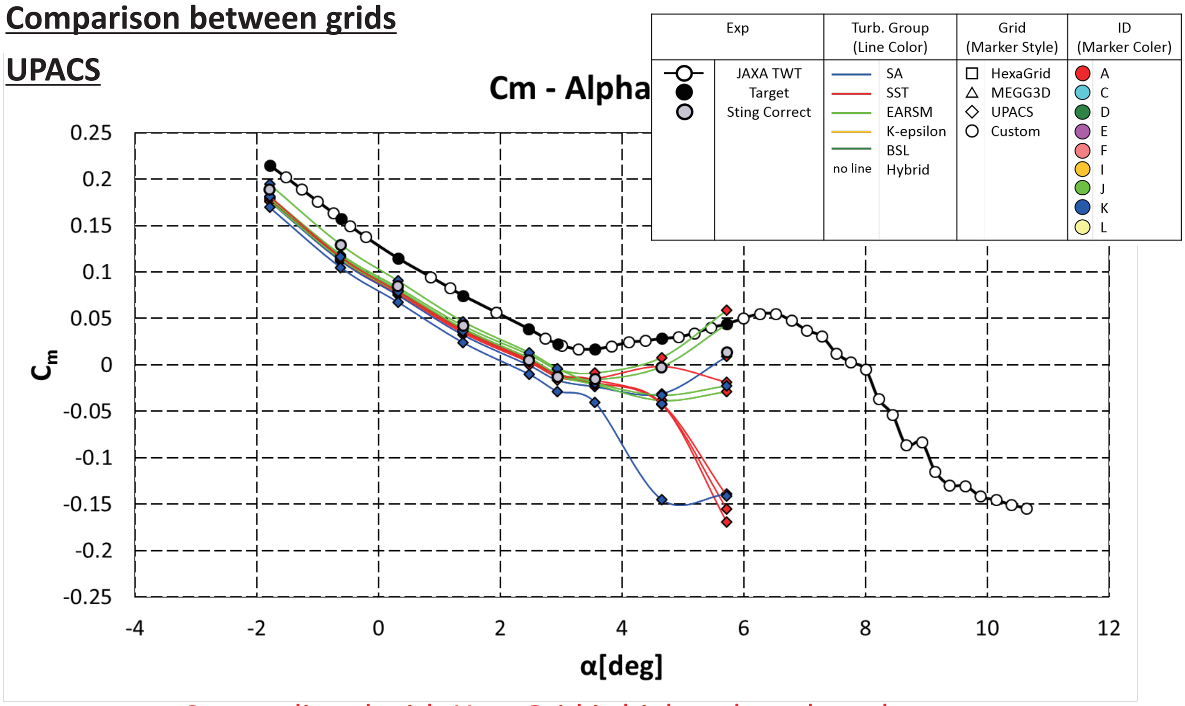
Case 1: Alpha sweep

Comparison between grids

UPACS



Cm predicted with HexaGrid is higher than the others

All data show the pitch-up characteristics for HexaGrid and Custom.

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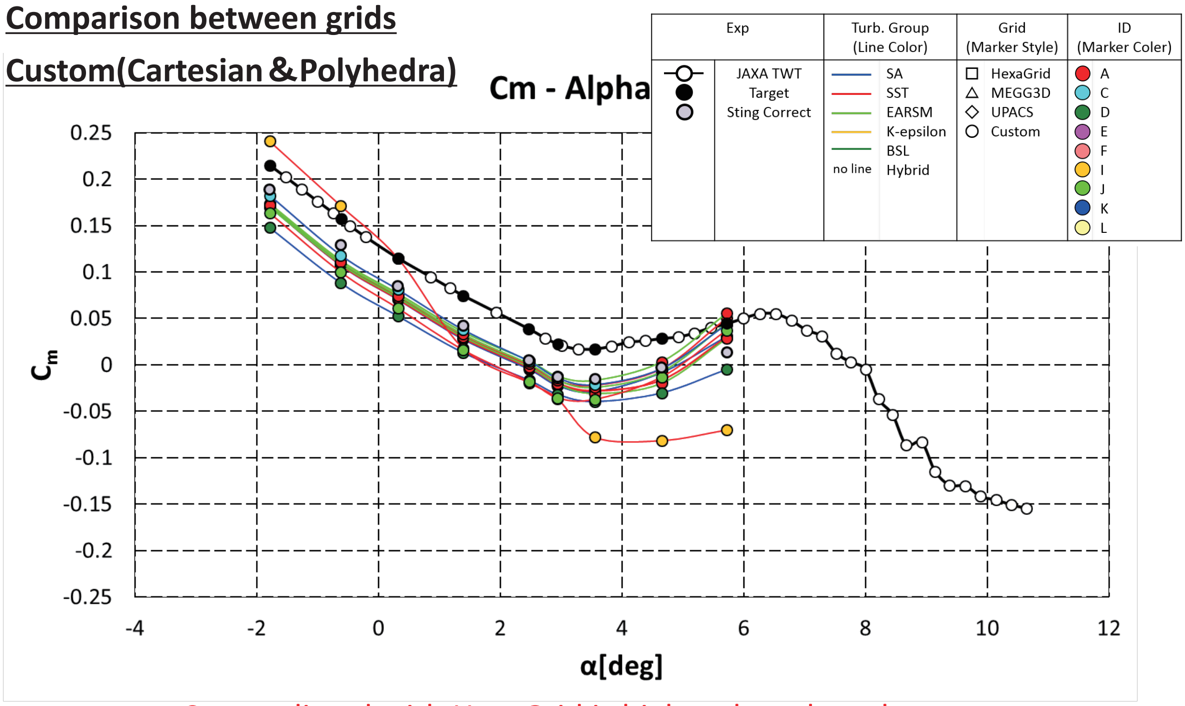
Case 1: Alpha sweep

Comparison between grids

Custom(Cartesian＆Polyhedra)



Cm predicted with HexaGrid is higher than the others

All data show the pitch-up characteristics for HexaGrid and Custom.

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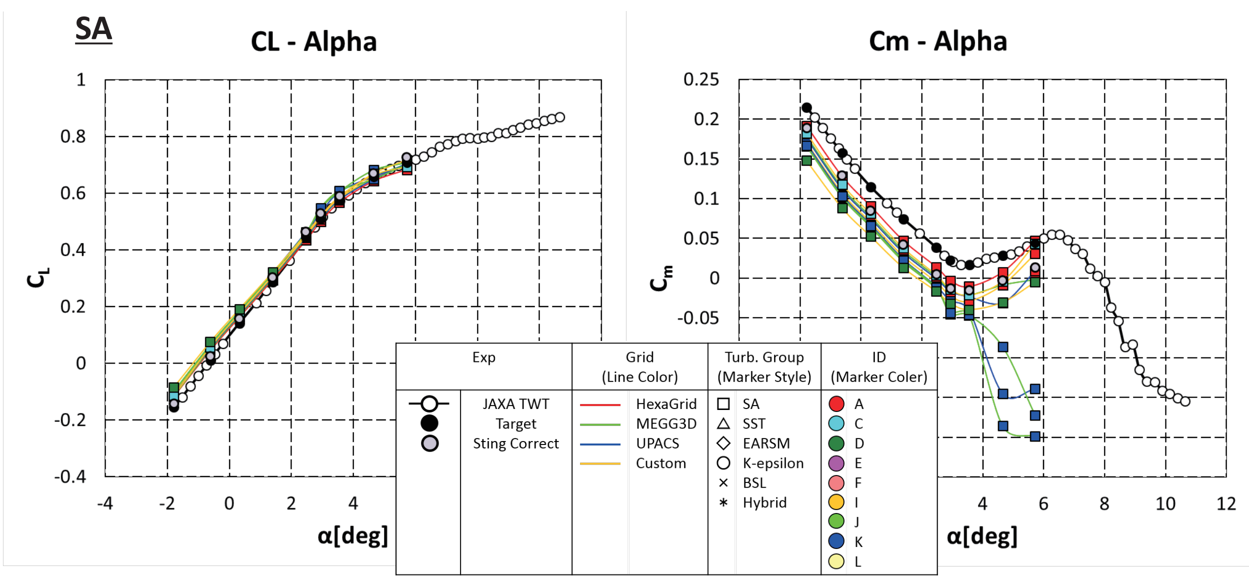
Case 1: Alpha sweep

Comparison between turbulence models



CL: SA > SST > EARSM

Cm: SA < SST < EARSM

EARSM shows pitch-up for high AoA

The shock moves forward for EARSM, backward for SA

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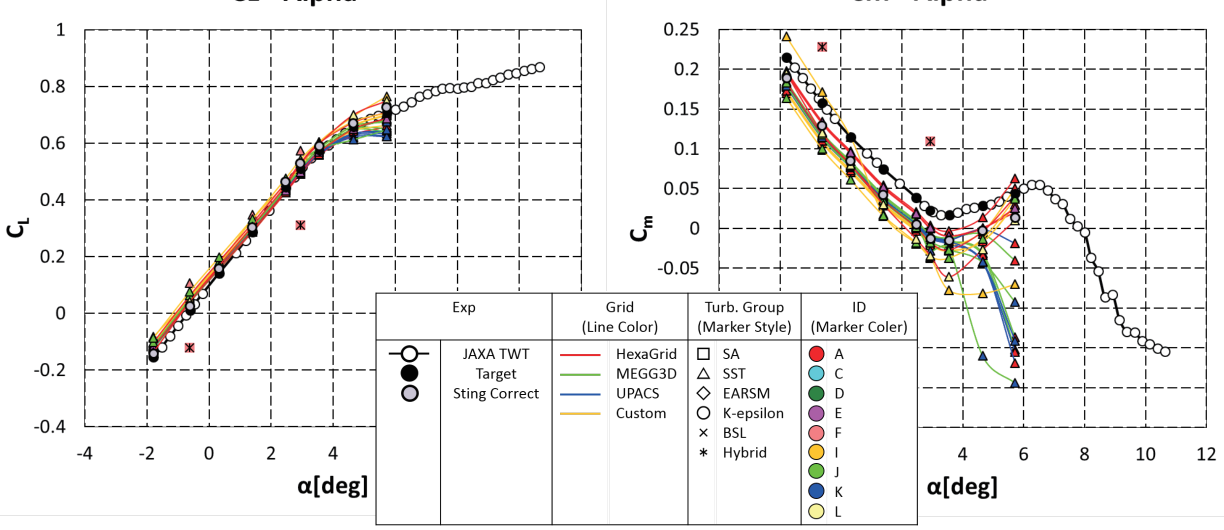
Case 1: Alpha sweep

Comparison between turbulence models

SST



CL: SA > SST > EARSM
Cm: SA < SST < EARSM
EARSM shows pitch-up for high AoA

The shock moves forward for EARSM, backward for SA

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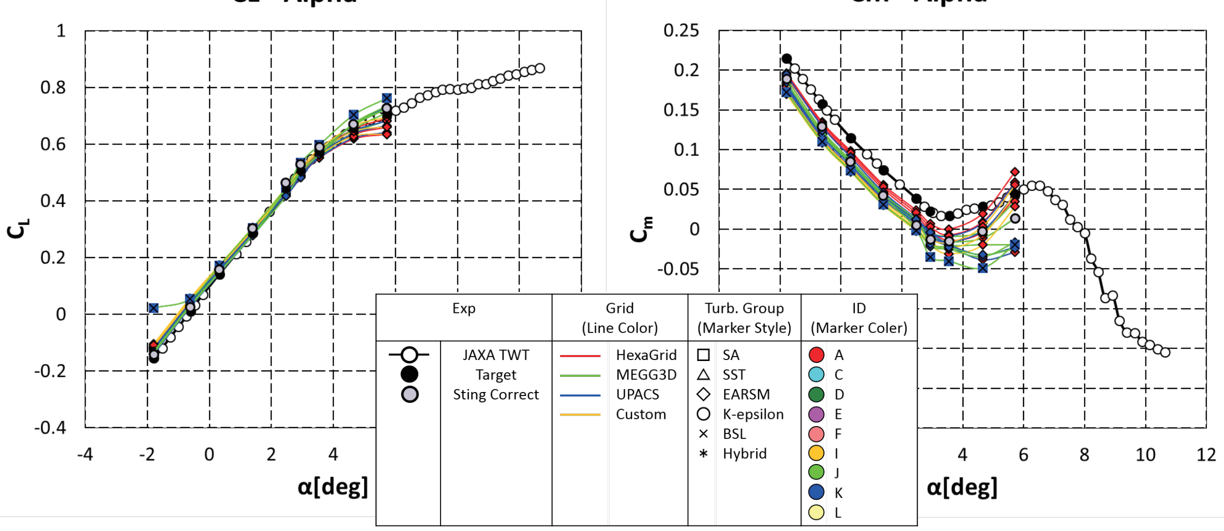
Case 1: Alpha sweep

Comparison between turbulence models

EARSM



CL: SA > SST > EARSM
Cm: SA < SST < EARSM
EARSM shows pitch-up for high AoA

The shock moves forward for EARSM, backward for SA

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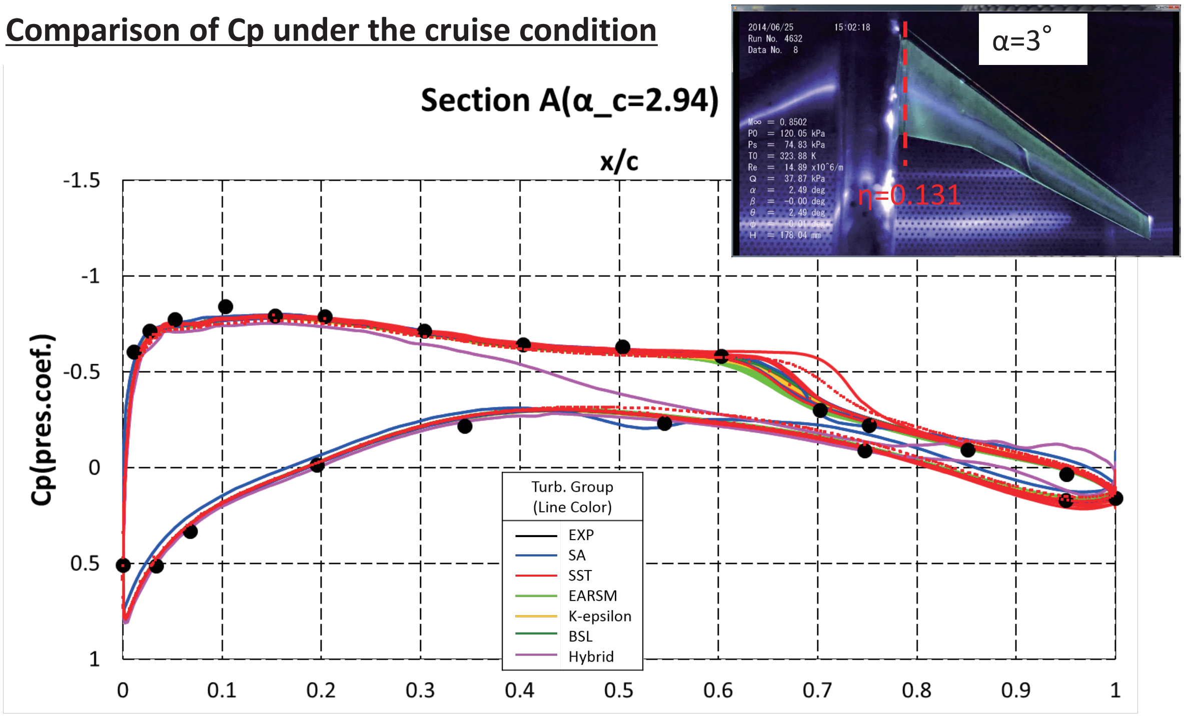
Case 1: Cp at cruise

Comparison of Cp under the cruise condition



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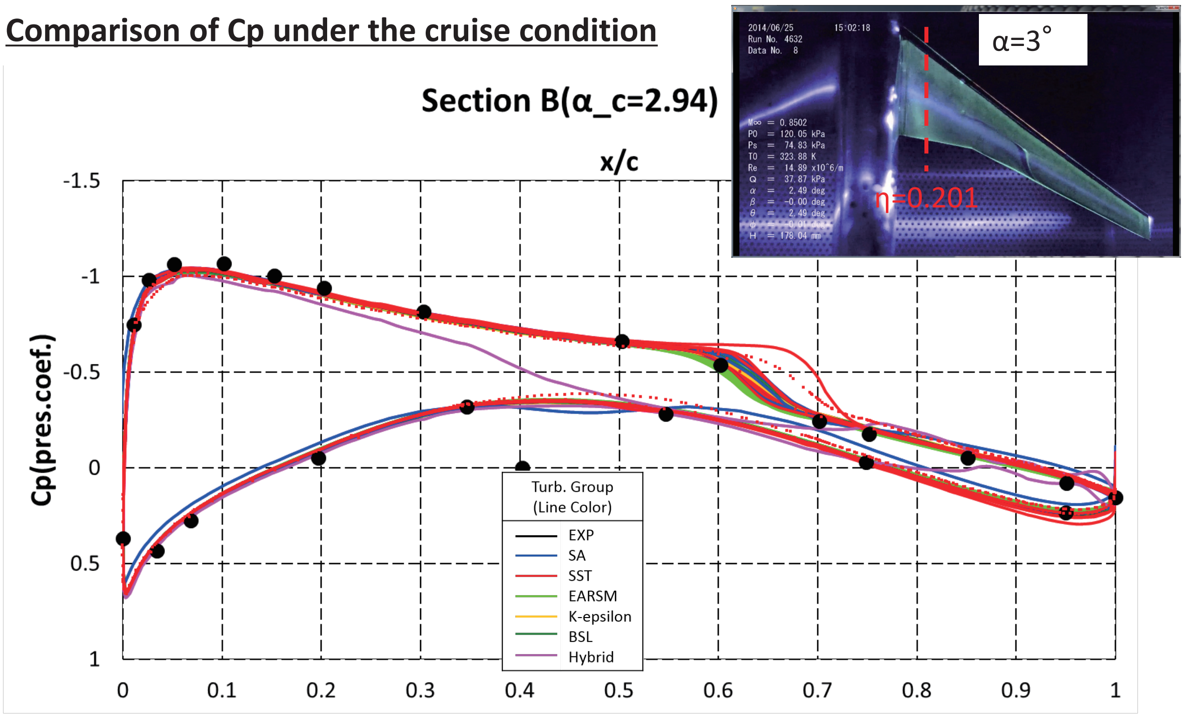
Case 1: Cp at cruise

Comparison of Cp under the cruise condition



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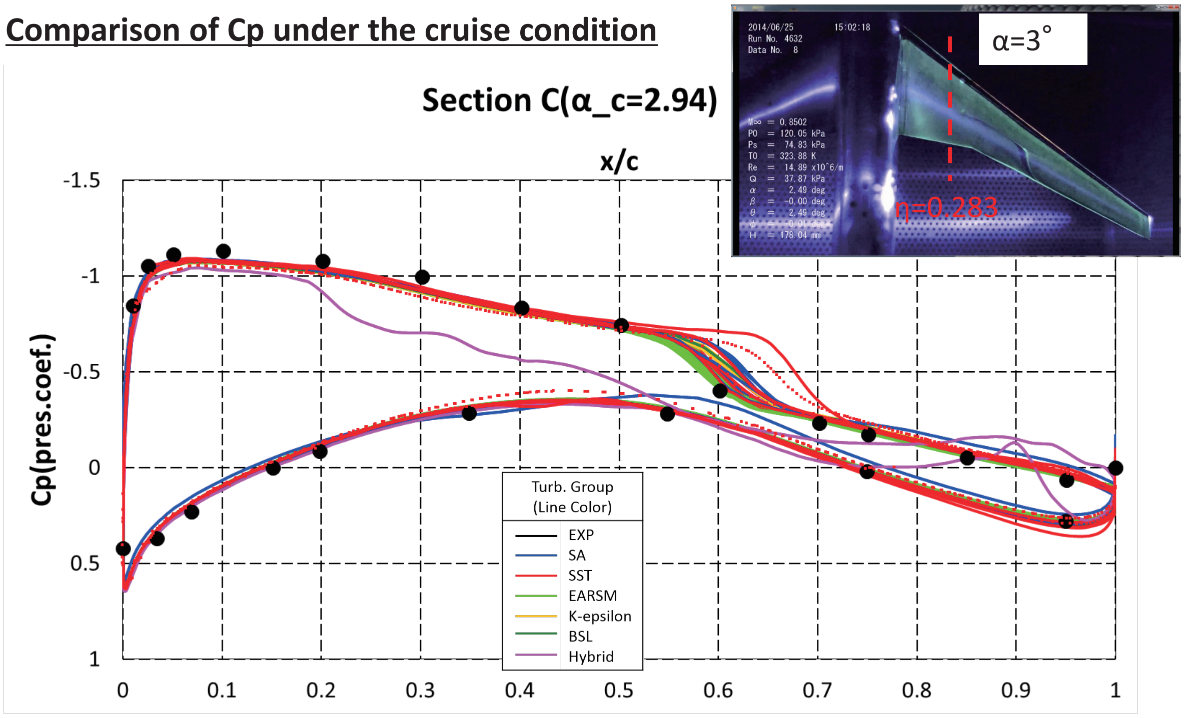
Case 1: Cp at cruise

Comparison of Cp under the cruise condition



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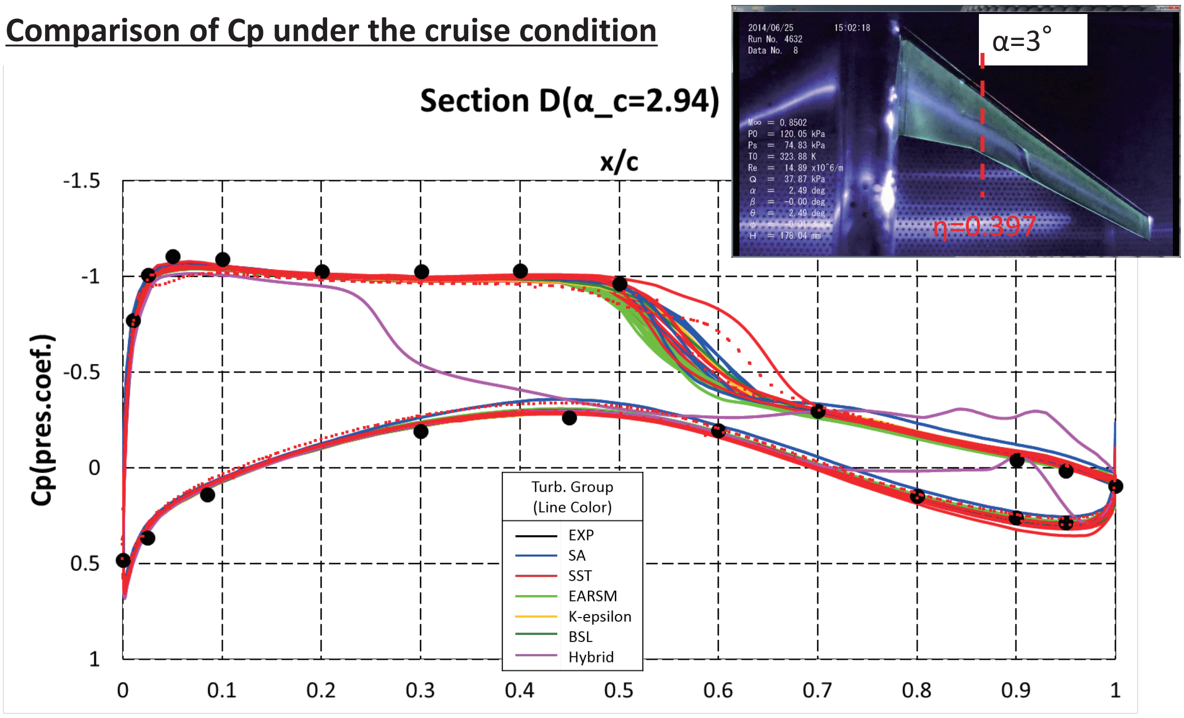
Case 1: Cp at cruise

Comparison of Cp under the cruise condition



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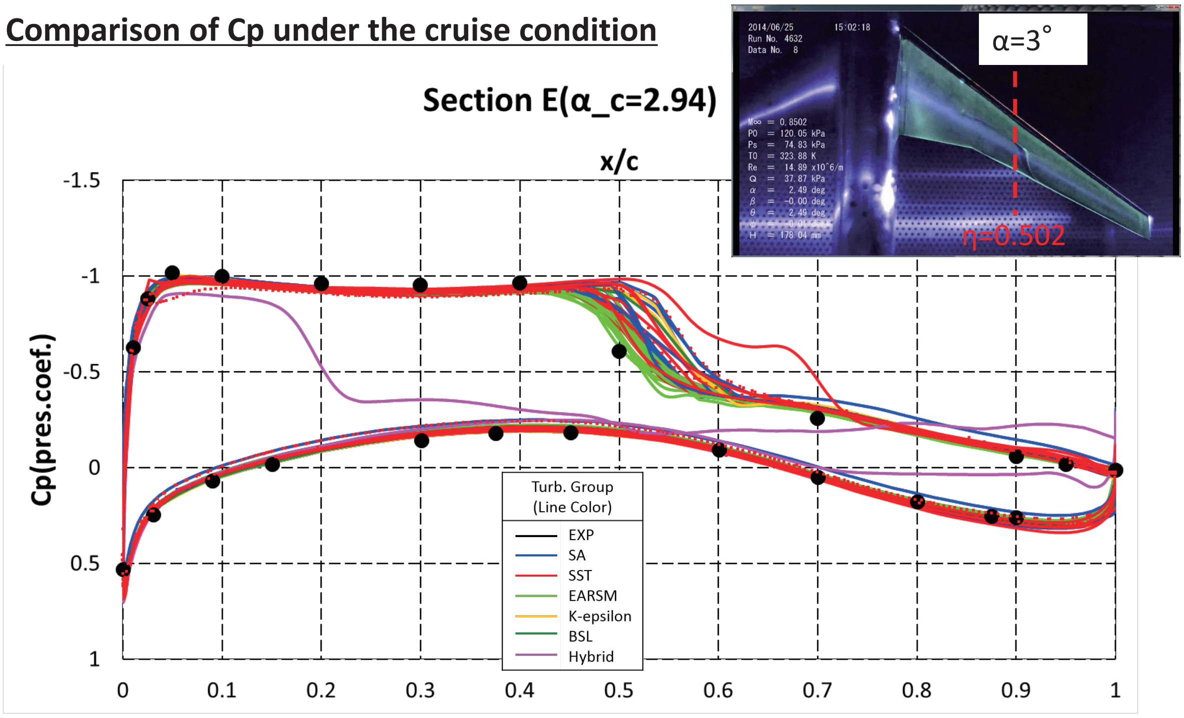
Case 1: Cp at cruise

Comparison of Cp under the cruise condition



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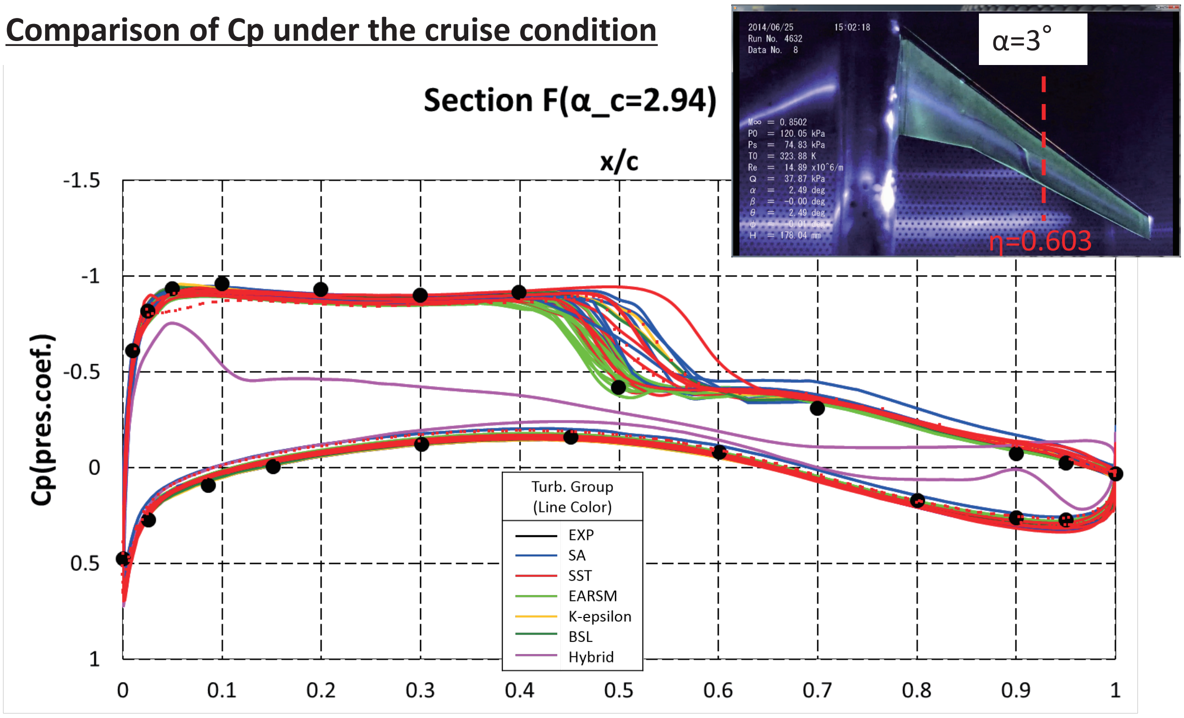
Case 1: Cp at cruise

Comparison of Cp under the cruise condition



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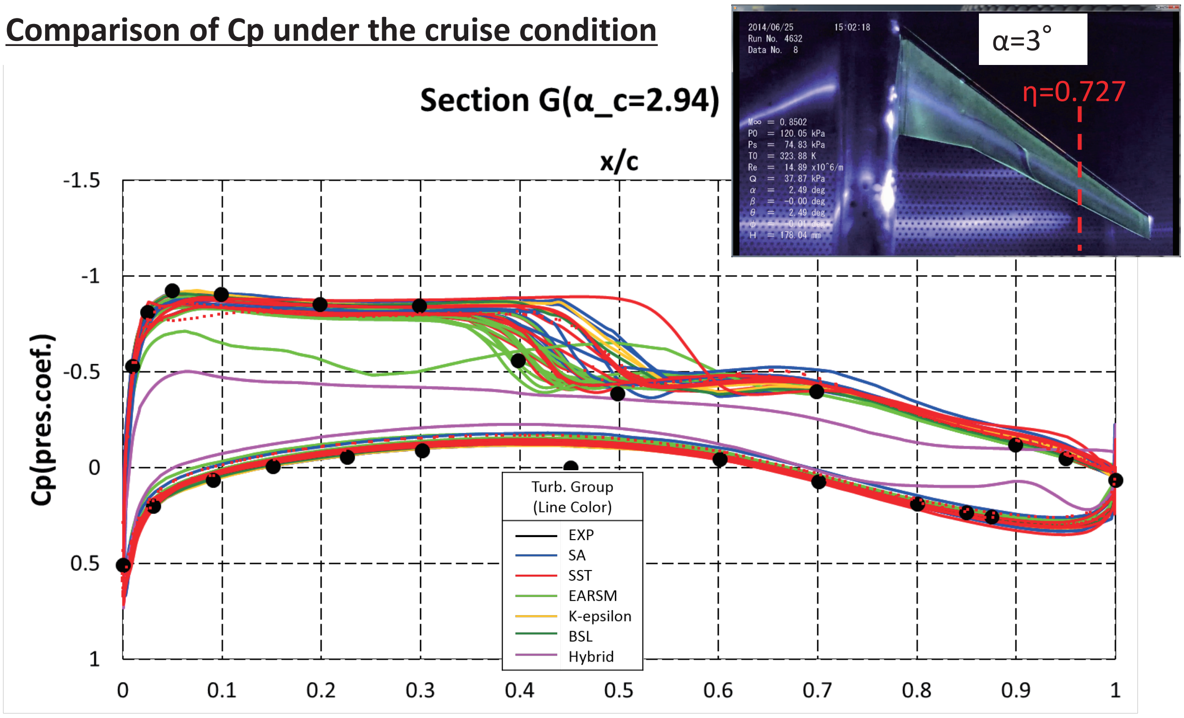
Case 1: Cp at cruise

Comparison of Cp under the cruise condition



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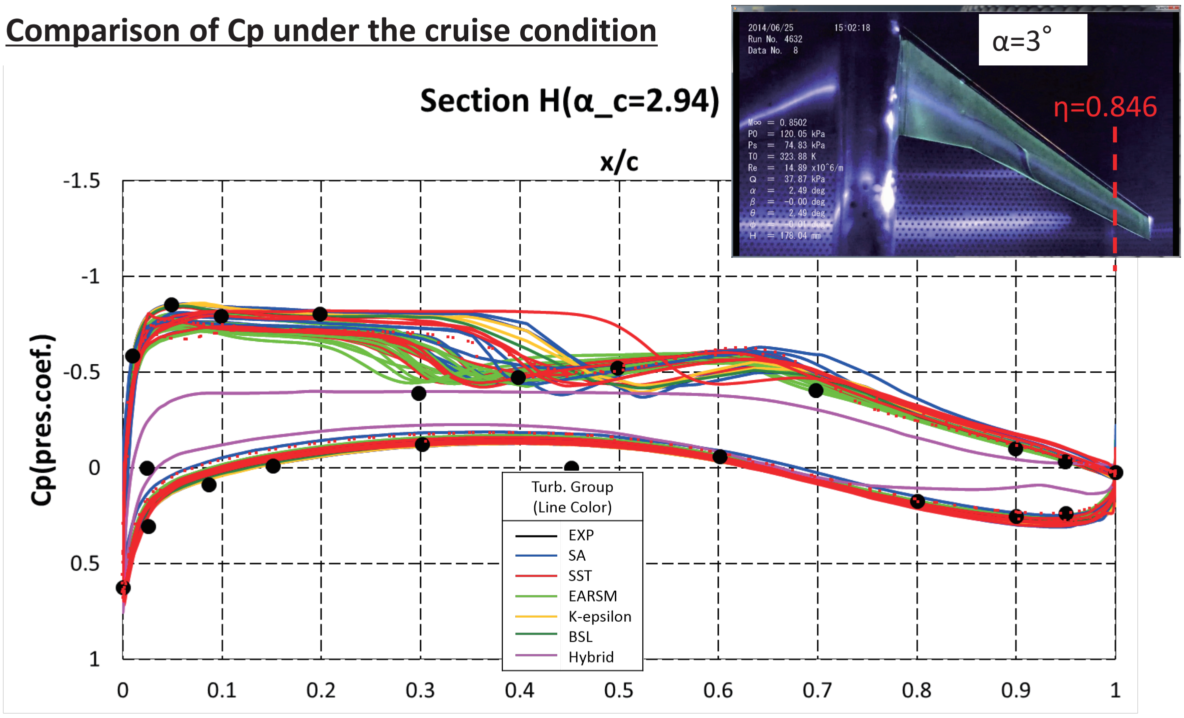
Case 1: Cp at cruise

Comparison of Cp under the cruise condition



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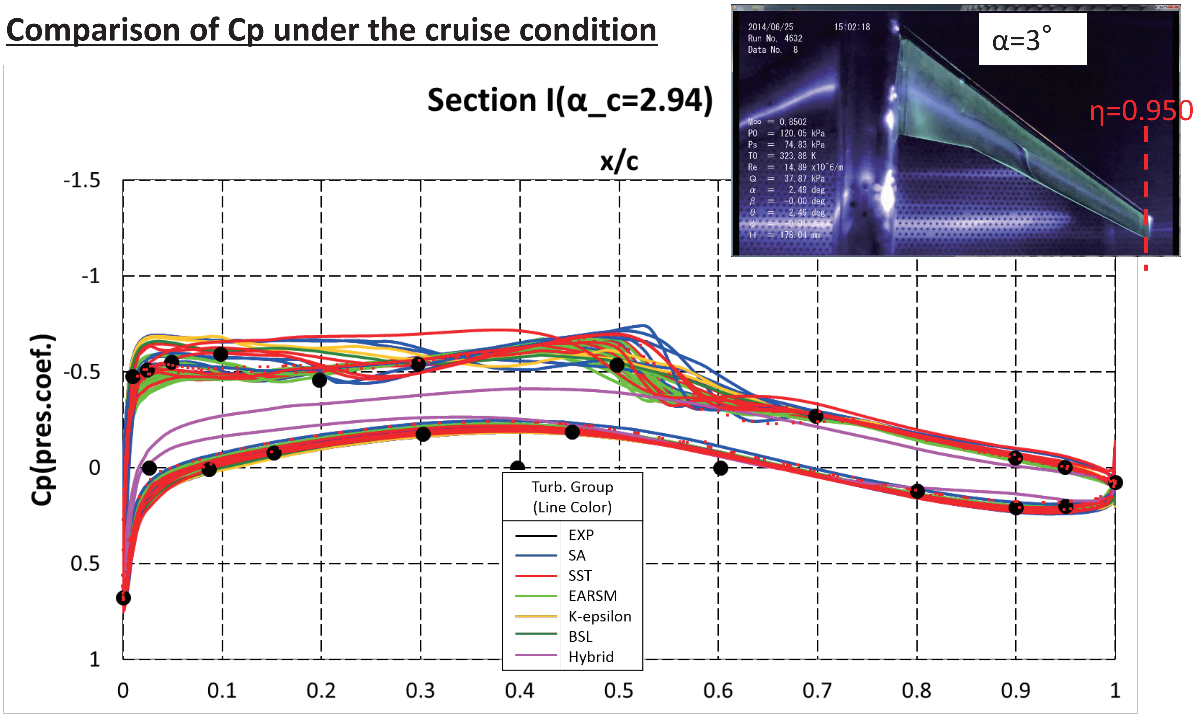
Case 1: Cp at cruise

Comparison of Cp under the cruise condition



EARSM predicts the shock location well for all cross sections.

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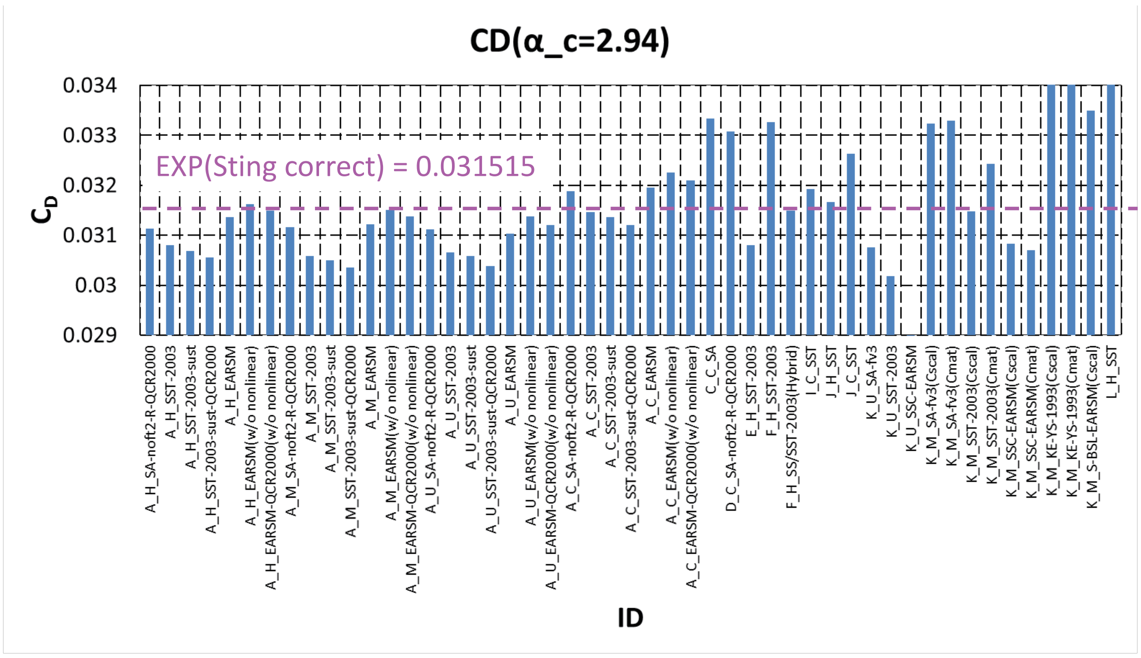
Case 1: Aerodynamic coefficients at cruise



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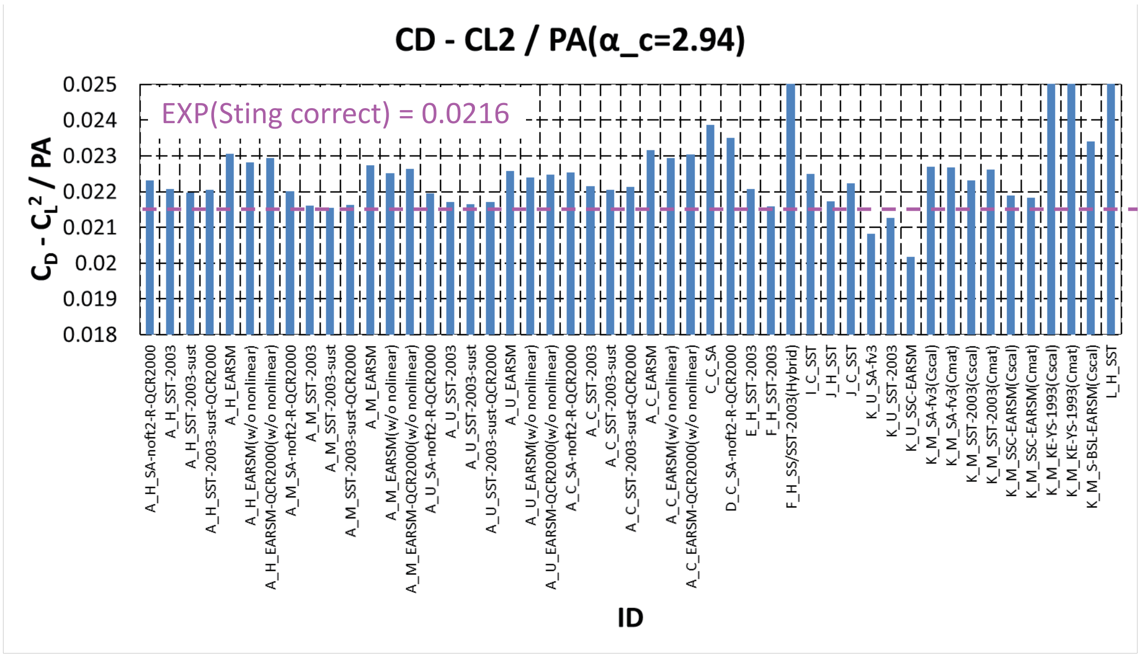
Case 1: Aerodynamic coefficients at cruise

Idealized profile drag CDi



CFD is higher than EXP.

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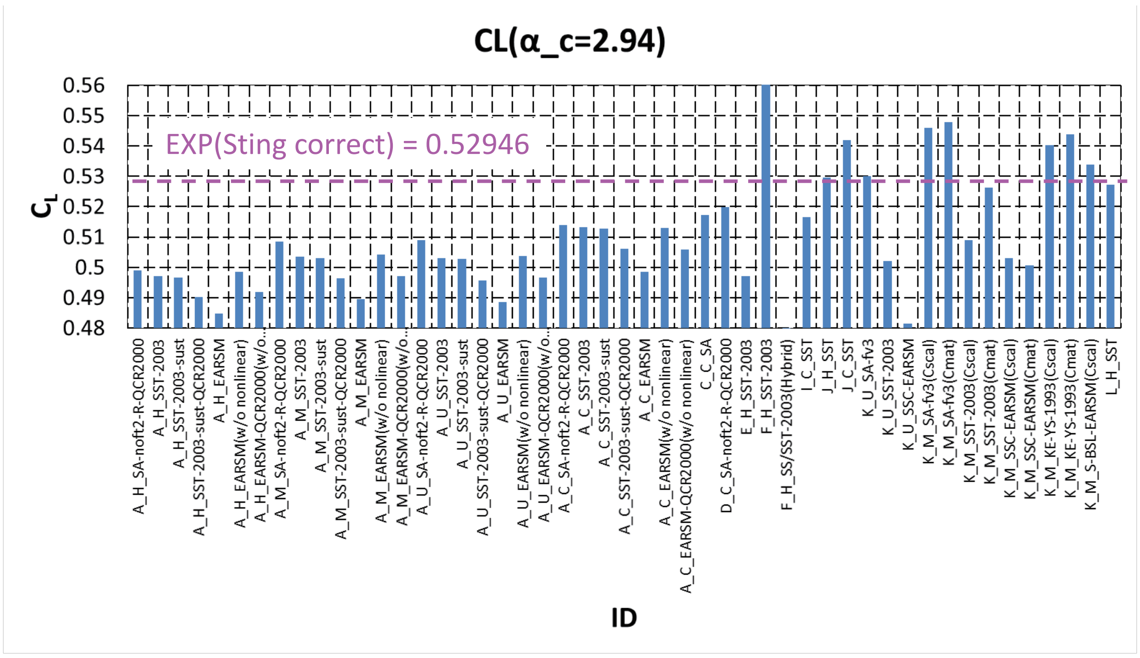
Case 1: Aerodynamic coefficients at cruise



CFD is lower than EXP.

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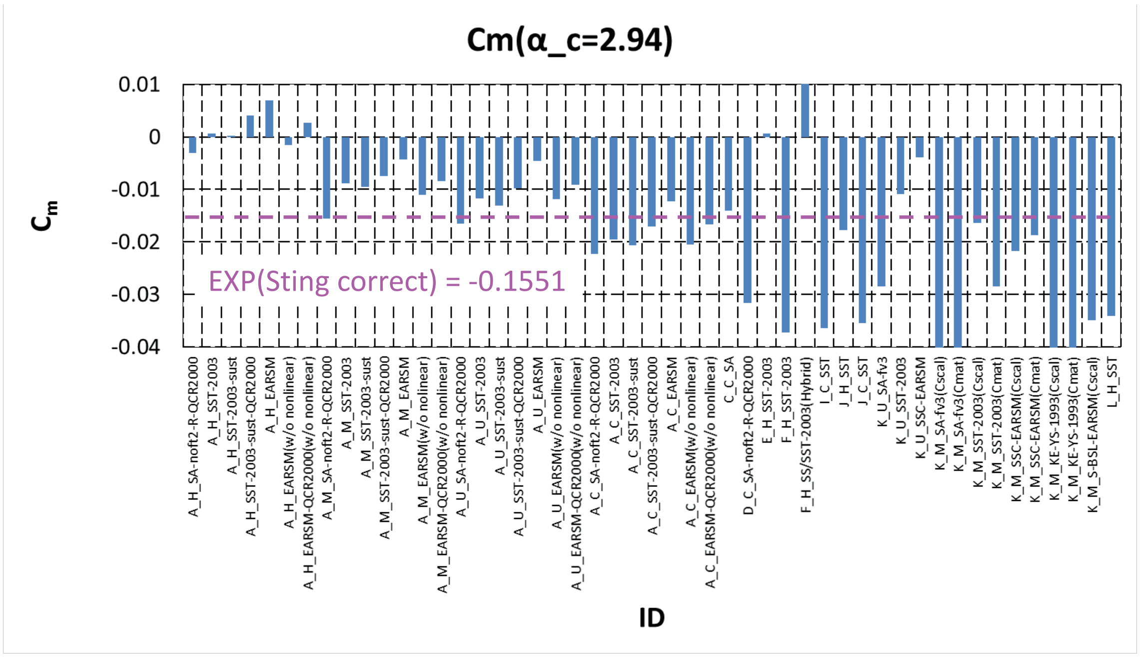
Case 1: Aerodynamic coefficients at cruise



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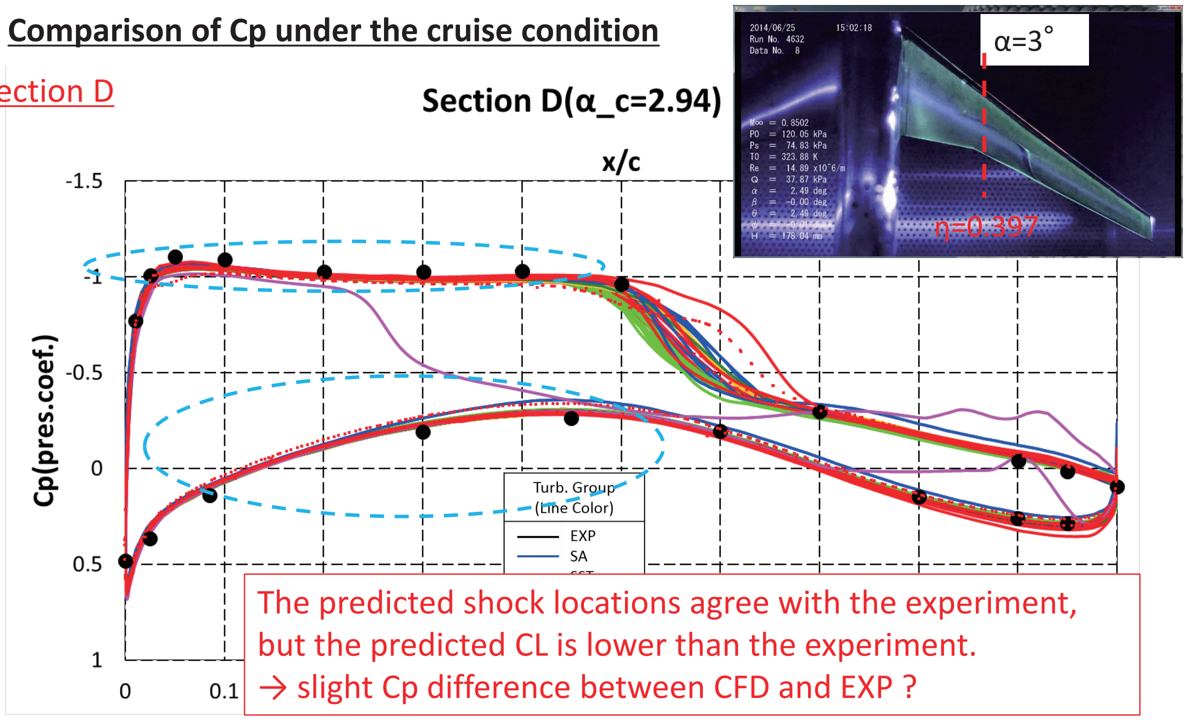
Case 1: Cp at cruise

Comparison of Cp under the cruise condition

Section D

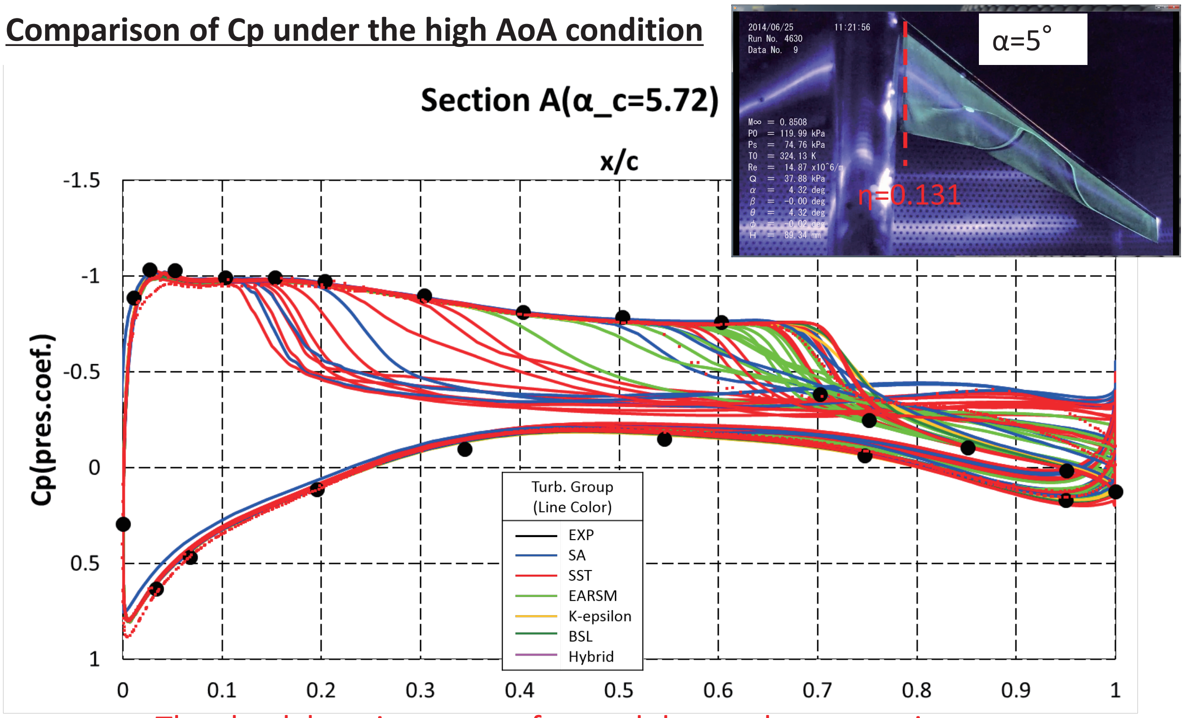


The predicted shock locations agree with the experiment, but the predicted CL is lower than the experiment.
→ slight Cp difference between CFD and EXP ?

50

Case 1: Cp at high AoA

Comparison of Cp under the high AoA condition

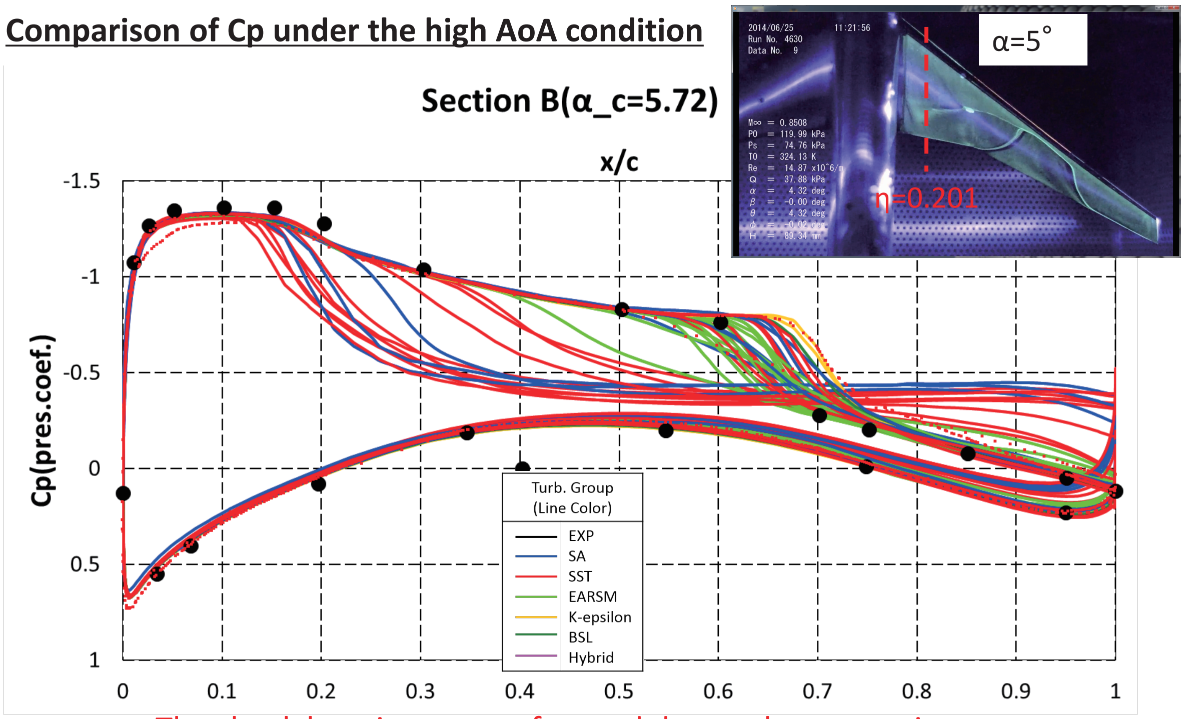


The shock location moves forward due to the separation.
The separation is small for EARSM

51

Case 1: Cp at high AoA

Comparison of Cp under the high AoA condition



The shock location moves forward due to the separation.
The separation is small for EARSM

52

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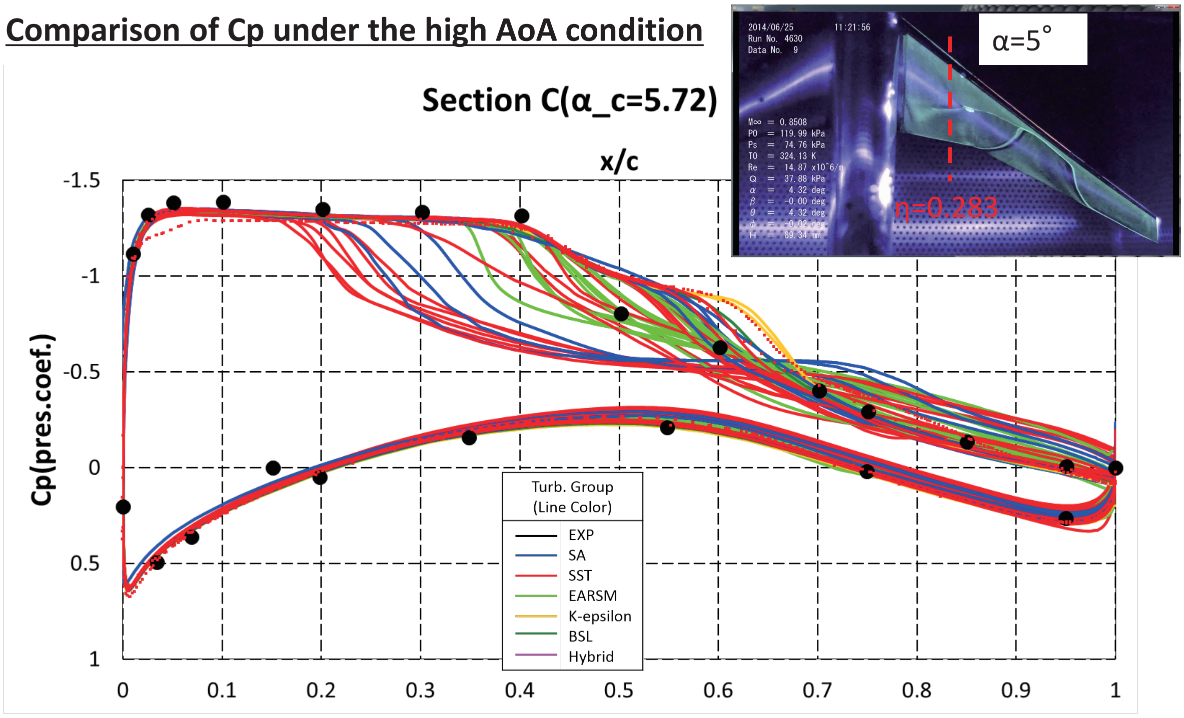
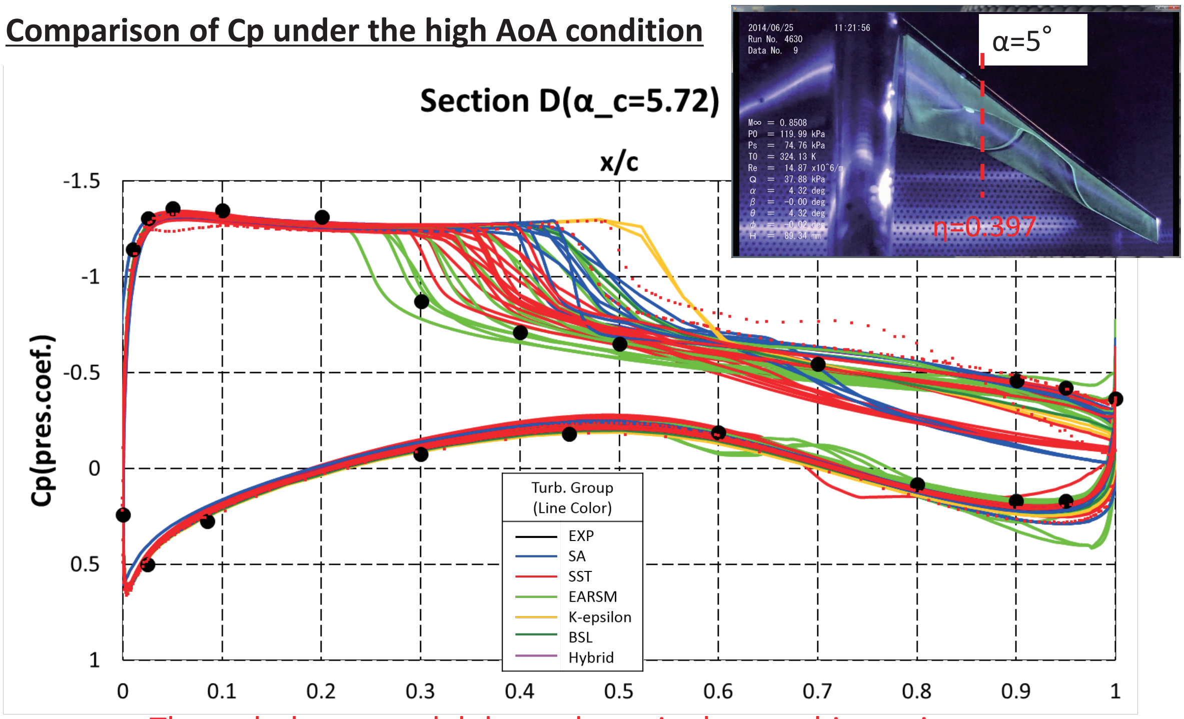
Case 1: Cp at high AoA

Comparison of Cp under the high AoA condition



Case 1: Cp at high AoA

Comparison of Cp under the high AoA condition



The turbulence model dependency is clear at this section.
The order of shock location is EARSM, SST, SA, k-ε.

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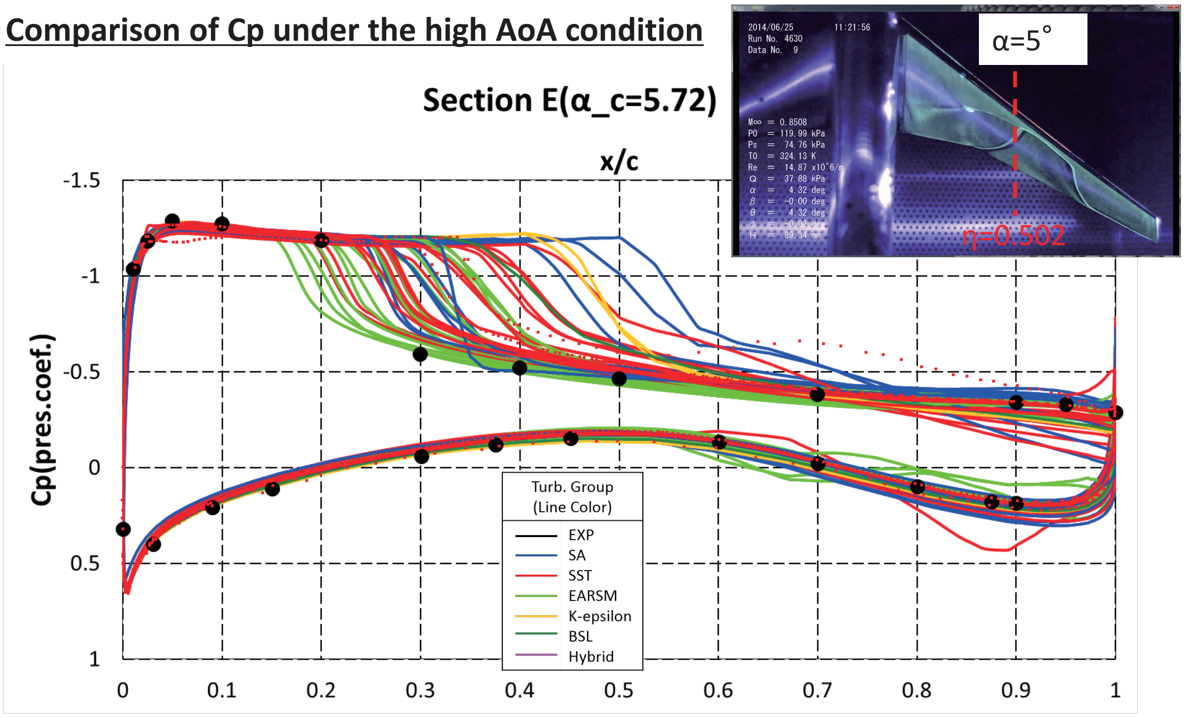
Case 1: Cp at high AoA

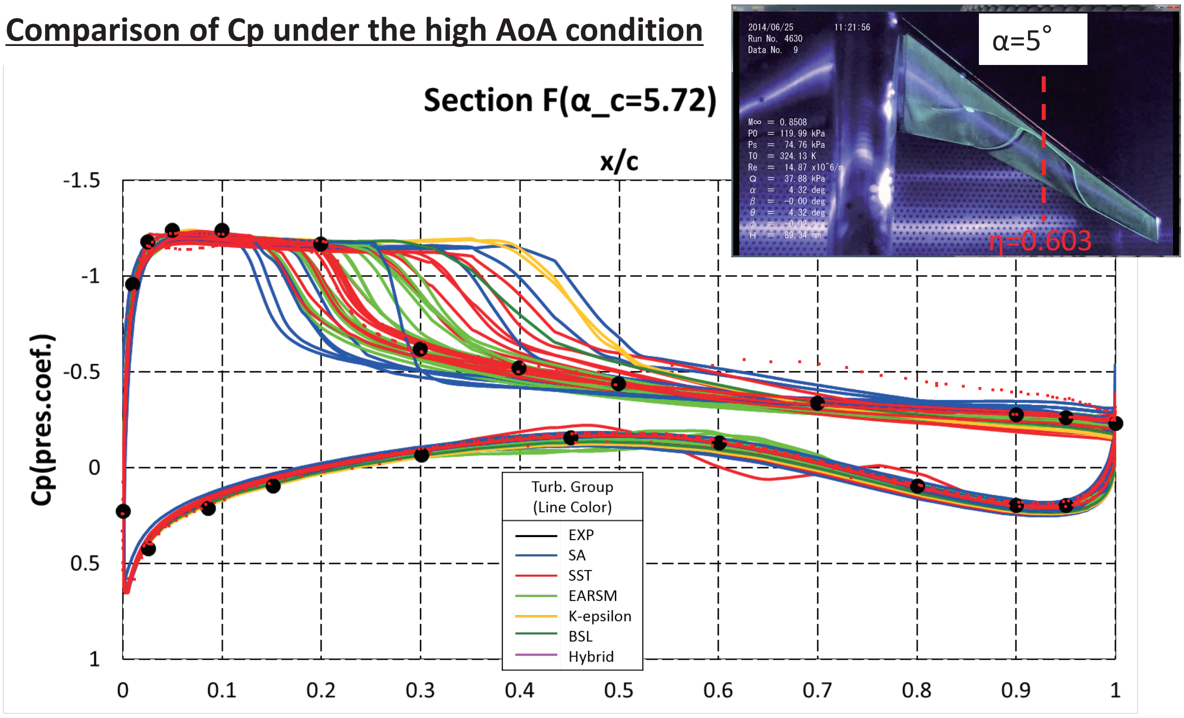
Comparison of Cp under the high AoA condition



55

Case 1: Cp at high AoA

Comparison of Cp under the high AoA condition



56

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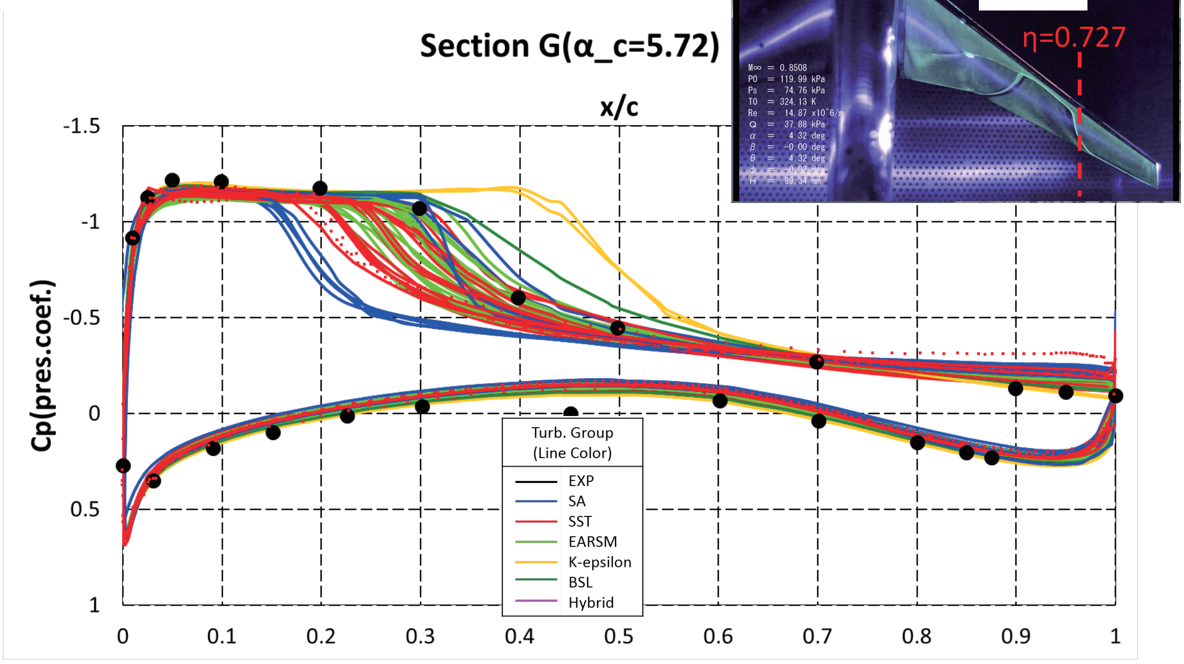
Case 1: Cp at high AoA

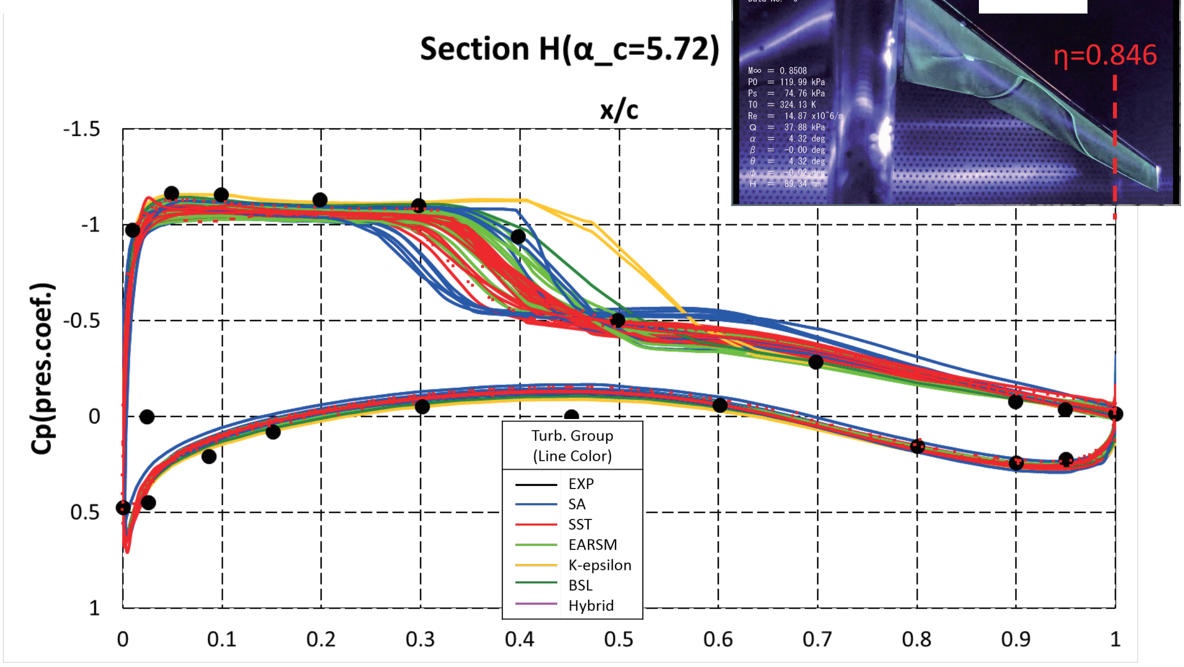
Comparison of Cp under the high AoA condition



57

Case 1: Cp at high AoA

Comparison of Cp under the high AoA condition



The variation is small for outboard sections (The flow is attached here).

58

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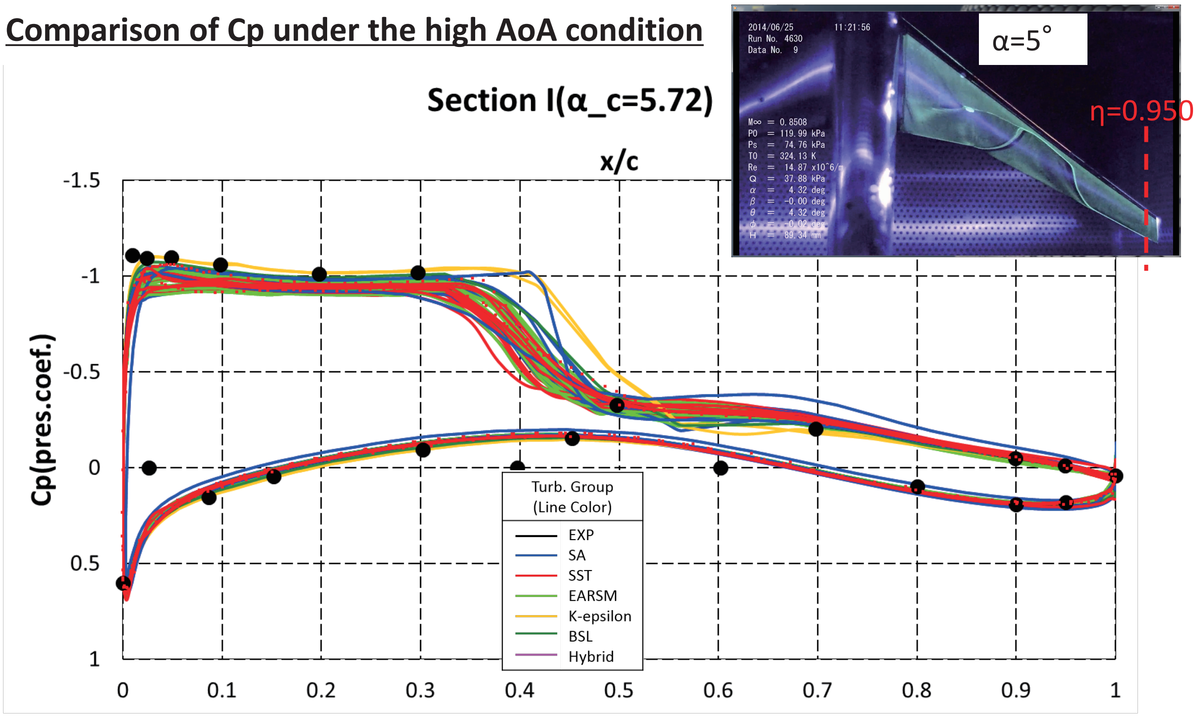
Case 1: Cp at high AoA

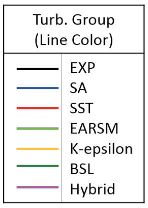
Comparison of Cp under the high AoA condition

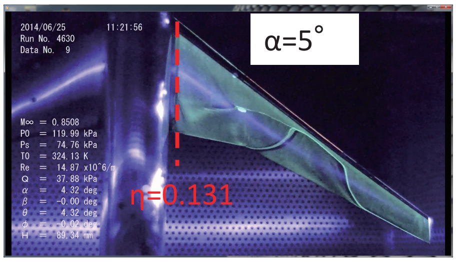


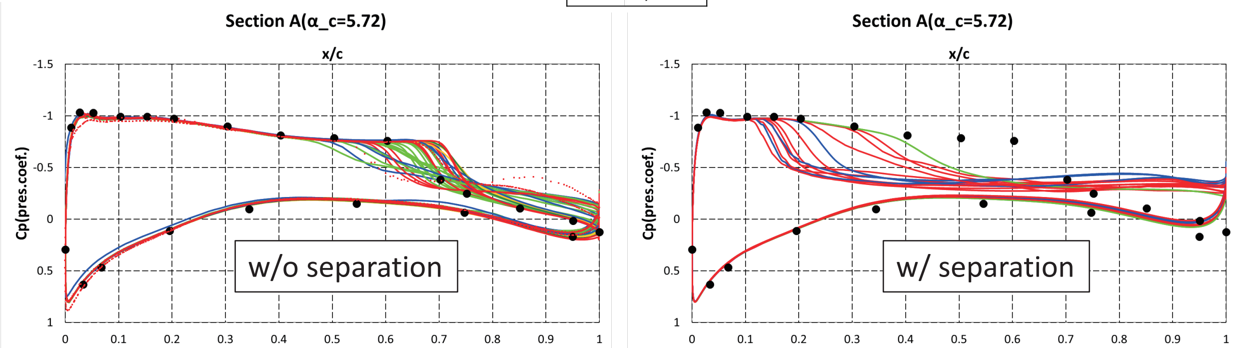
The variation is small for outboard sections (The flow is attached here).

Case 1: Cp at high AoA

Comparison between the results with and without SOB separation







We classify the results into two groups with and without the side-of-body separation.

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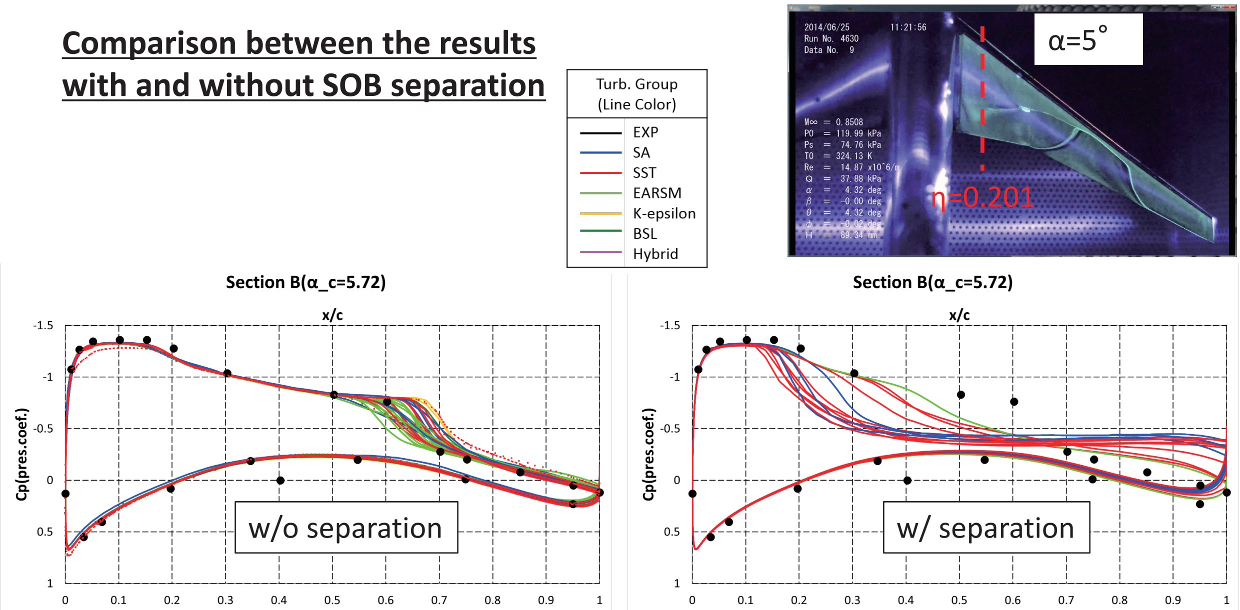
Case 1: Cp at high AoA

Comparison between the results with and without SOB separation



Case 1: Cp at high AoA

Comparison between the results with and without SOB separation

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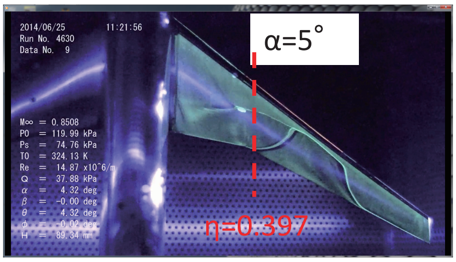
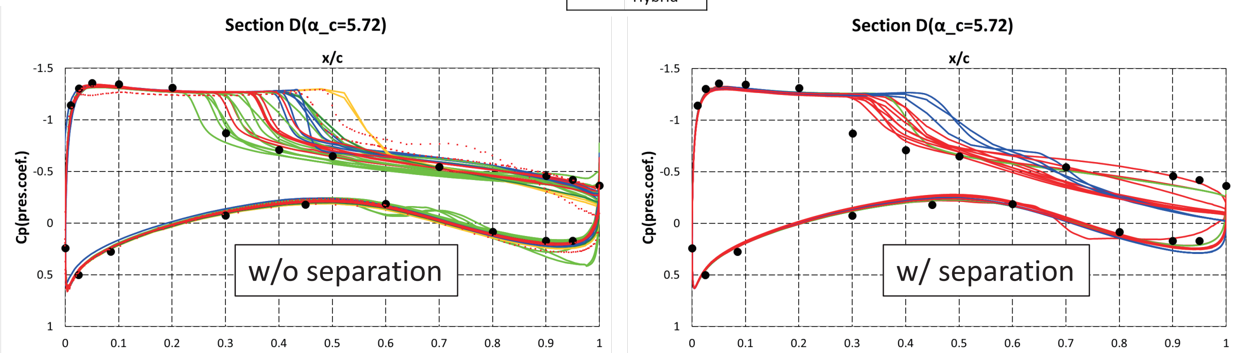
Case 1: Cp at high AoA

Comparison between the results with and without SOB separation

Turn. Group (Line Color)
- EXP
- SA
- SST
- EARSM
- K-epsilon
- BSL
- Hybrid





The shock wave locations are different even if the separation size is same at the wing root.

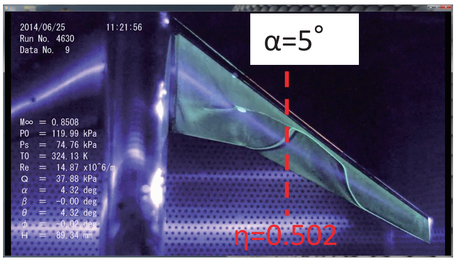
The order is EARSM, SST, SA, k-e.

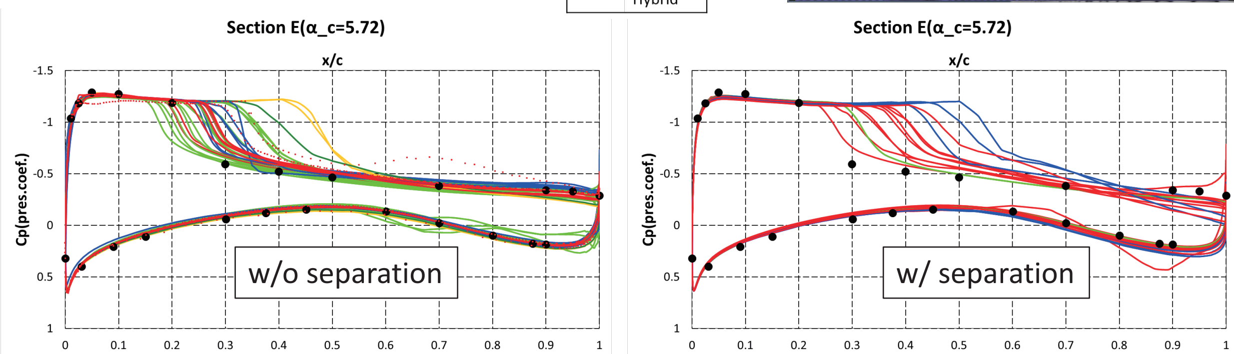
63

Case 1: Cp at high AoA

Comparison between the results with and without SOB separation

Turb. Group (Line Color)
- EXP
- SA
- SST
- EARSM
- K-epsilon
- BSL
- Hybrid





The order is EARSM, SST, SA, k-e.

64

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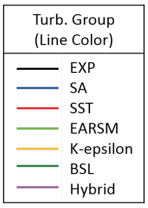
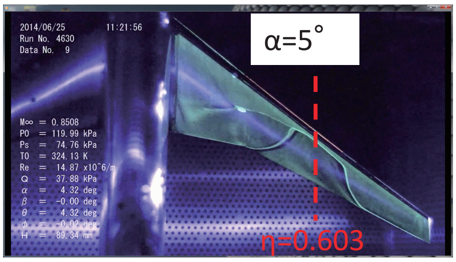
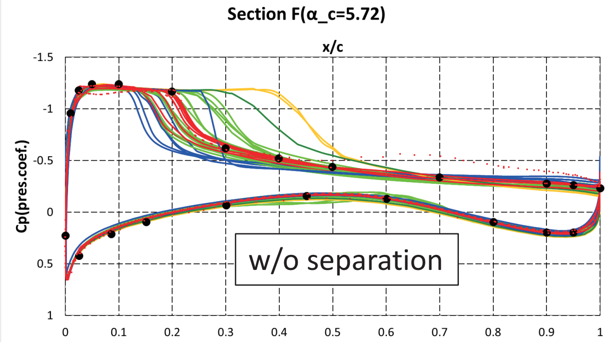
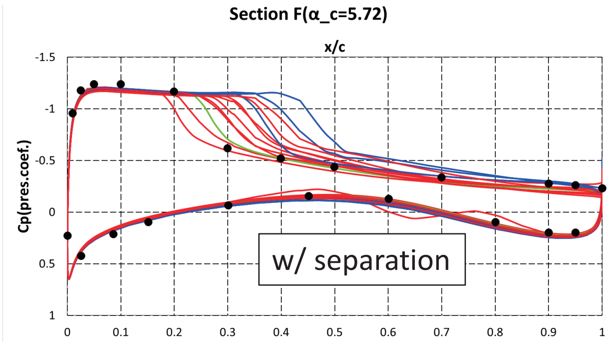
Case 1: Cp at high AoA

Comparison between the results with and without SOB separation







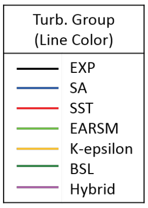


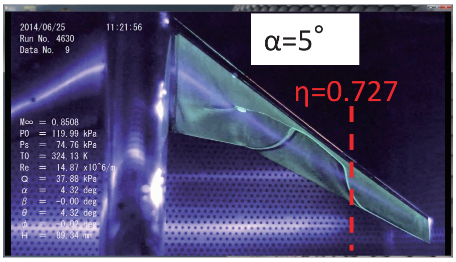
The order is SA, SST, EARSM, k-e.

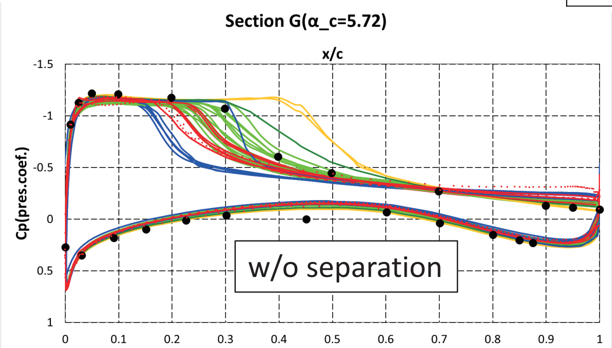
65

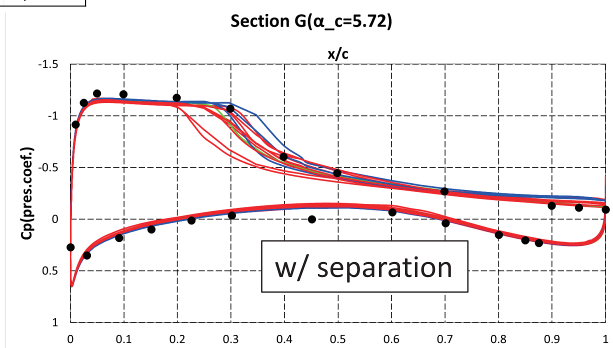
Case 1: Cp at high AoA

Comparison between the results with and without SOB separation









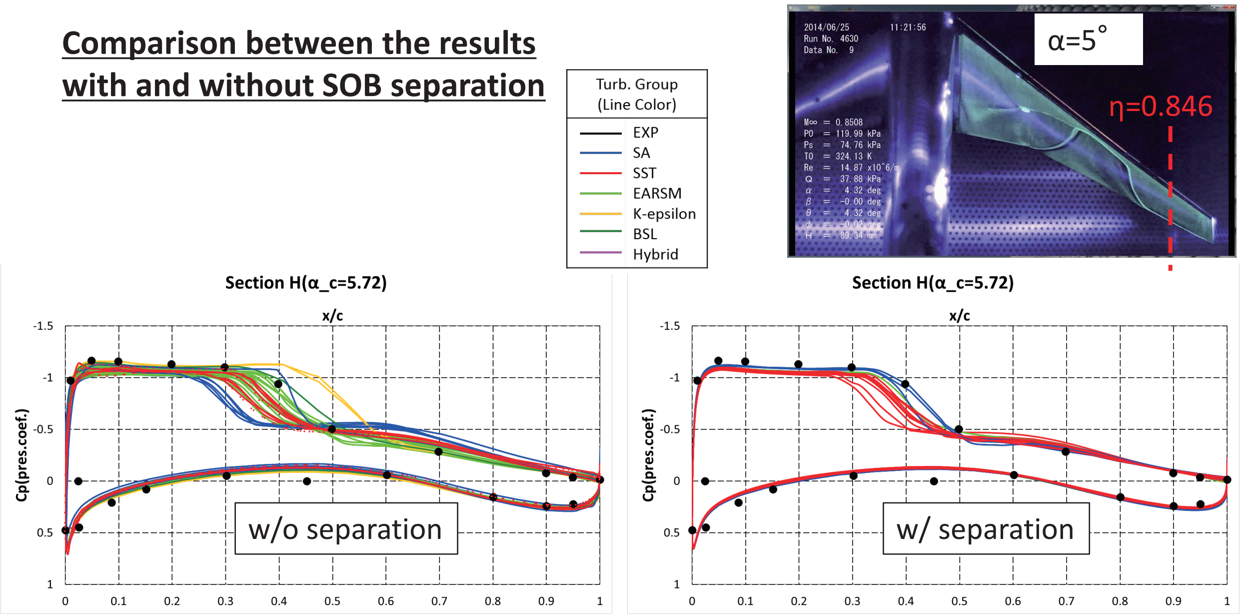
The order is SA, SST, EARSM, k-e.

66

This document is provided by JAXA.

Case 1: Cp at high AoA

Comparison between the results with and without SOB separation

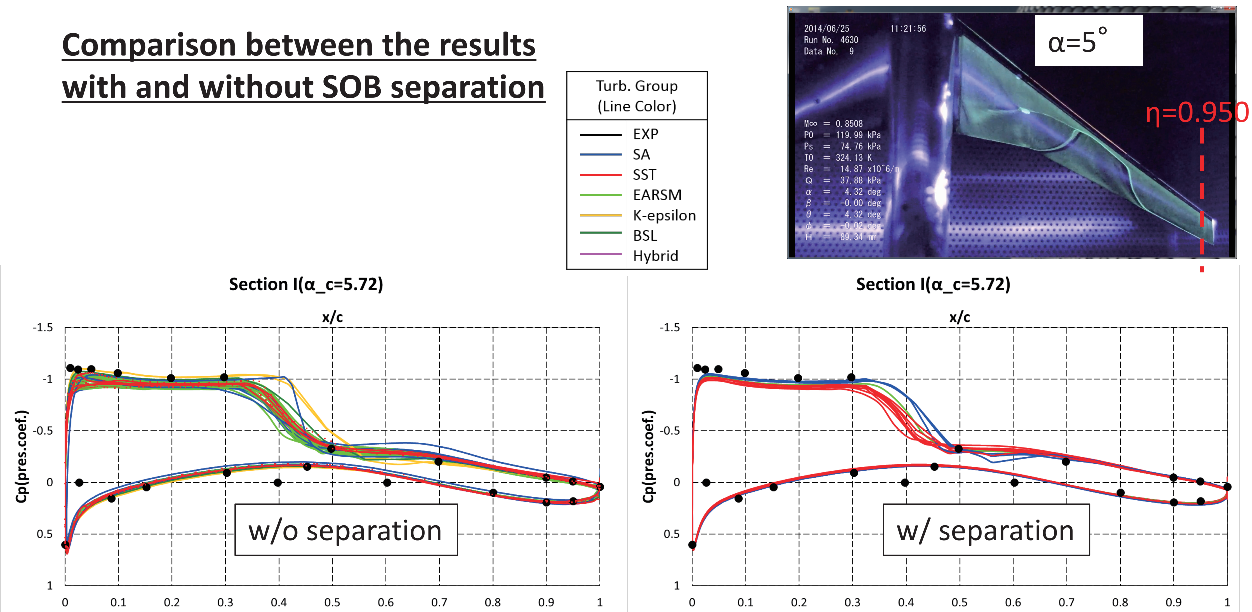


The order is SA, SST, EARSM, k-e.

67

Case 1: Cp at high AoA

Comparison between the results with and without SOB separation



EARSM predicts the shock location well for all cross sections.

68

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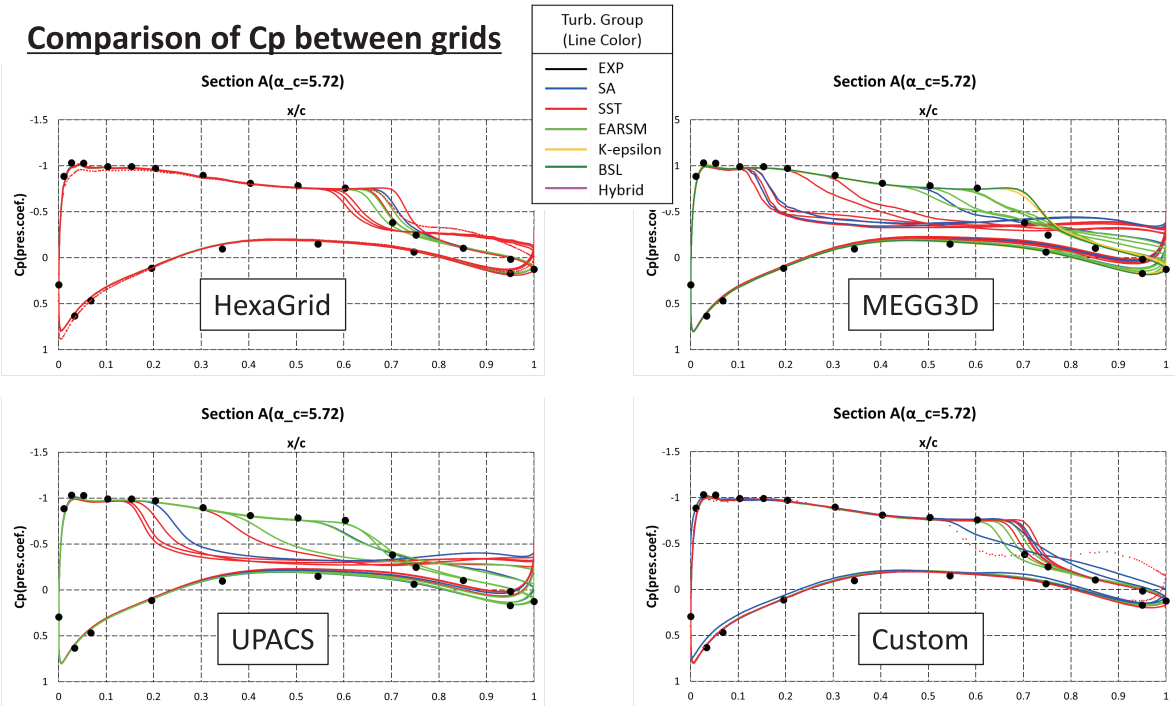
Case 1: Cp at high AoA

Comparison of Cp between grids

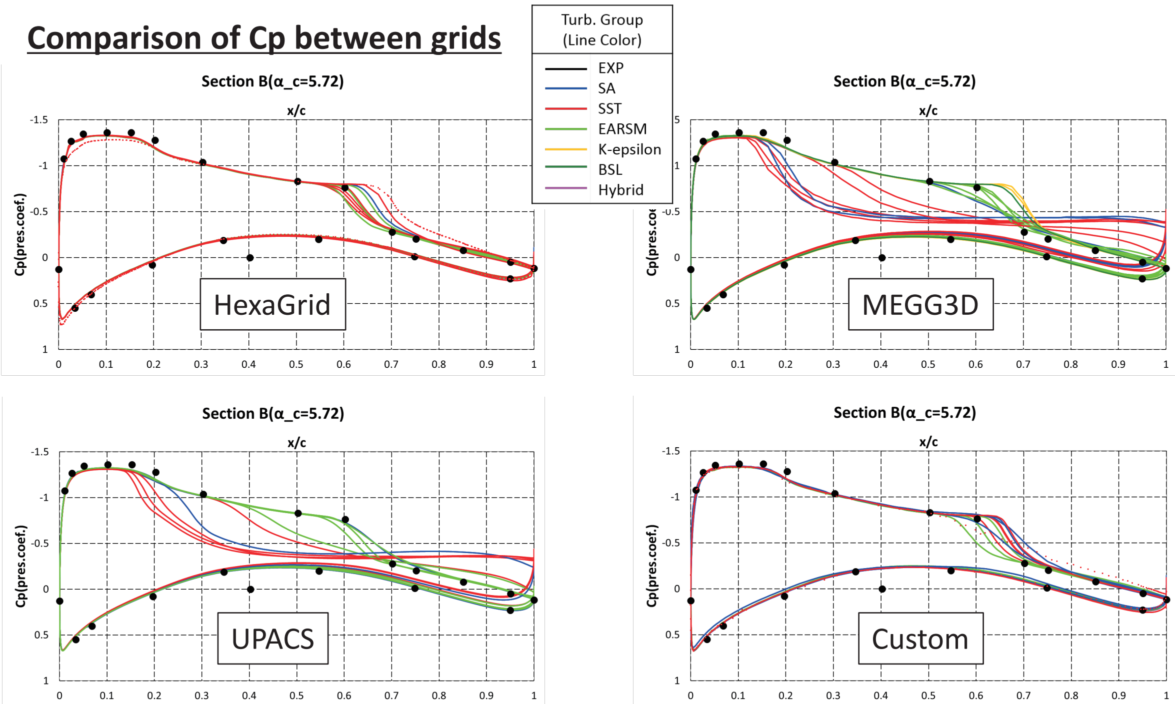


There are no side-of-body separations for HexaGrid
whereas there are side-of-body separations for MEGG3D and UPACS

69

Case 1: Cp at high AoA

Comparison of Cp between grids



There are no side-of-body separations for HexaGrid
whereas there are side-of-body separations for MEGG3D and UPACS

70

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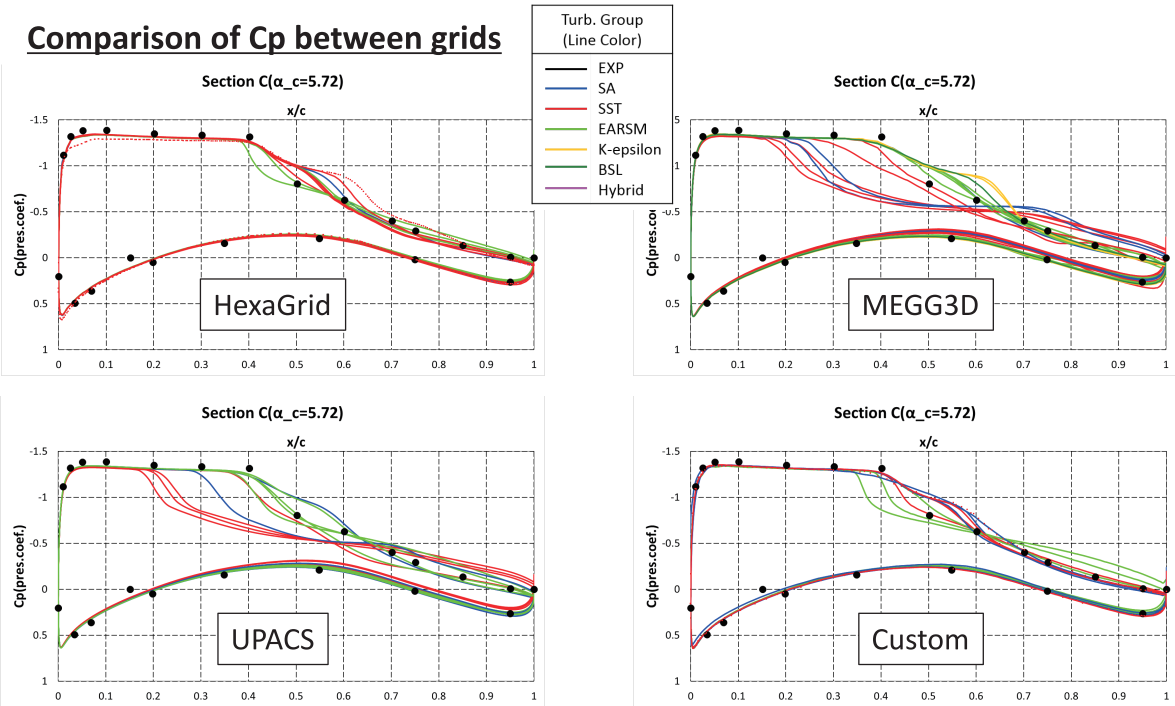
Case 1: Cp at high AoA

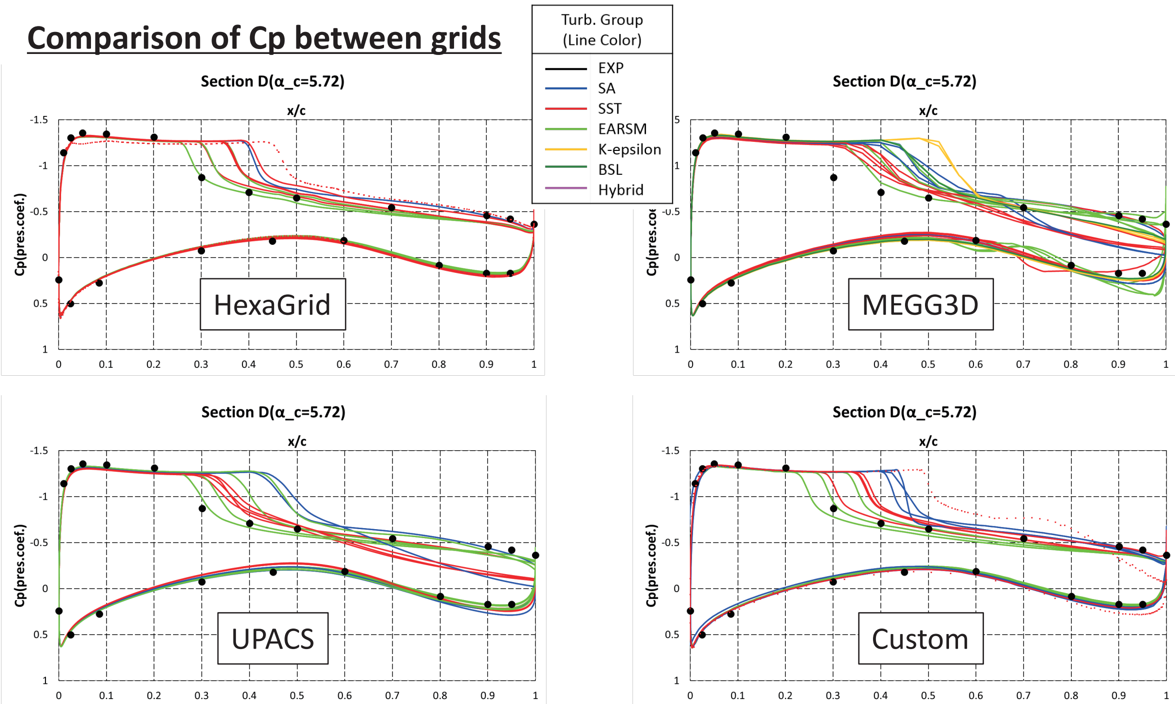
Comparison of Cp between grids



71

Case 1: Cp at high AoA

Comparison of Cp between grids



72

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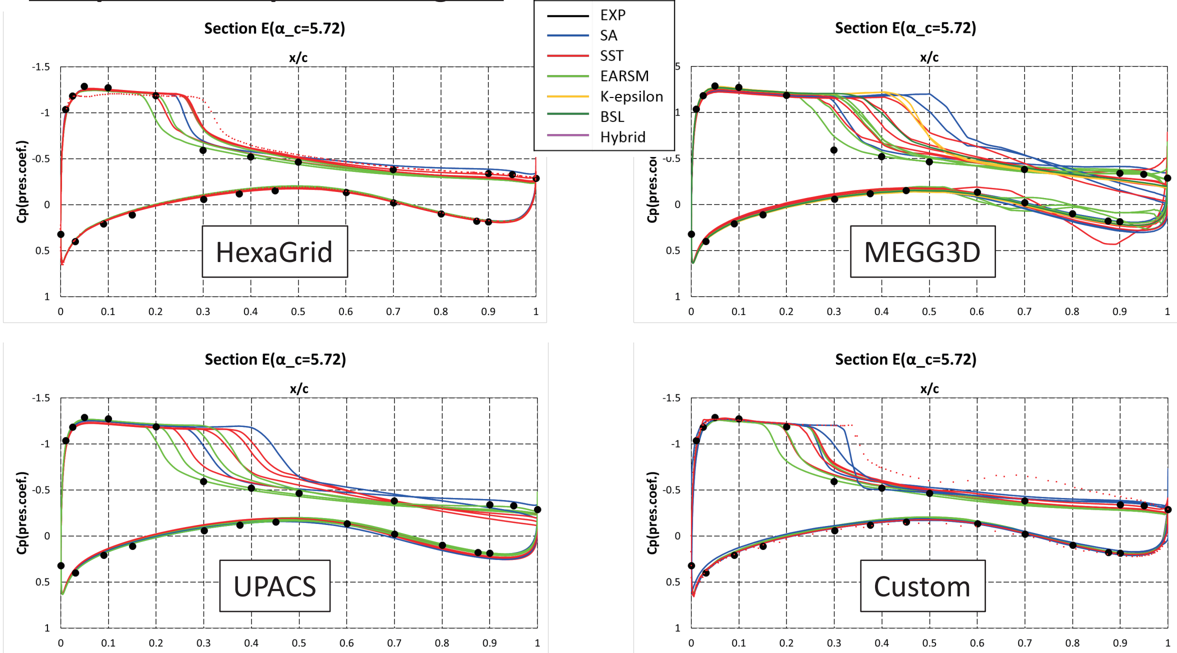
Case 1: Cp at high AoA

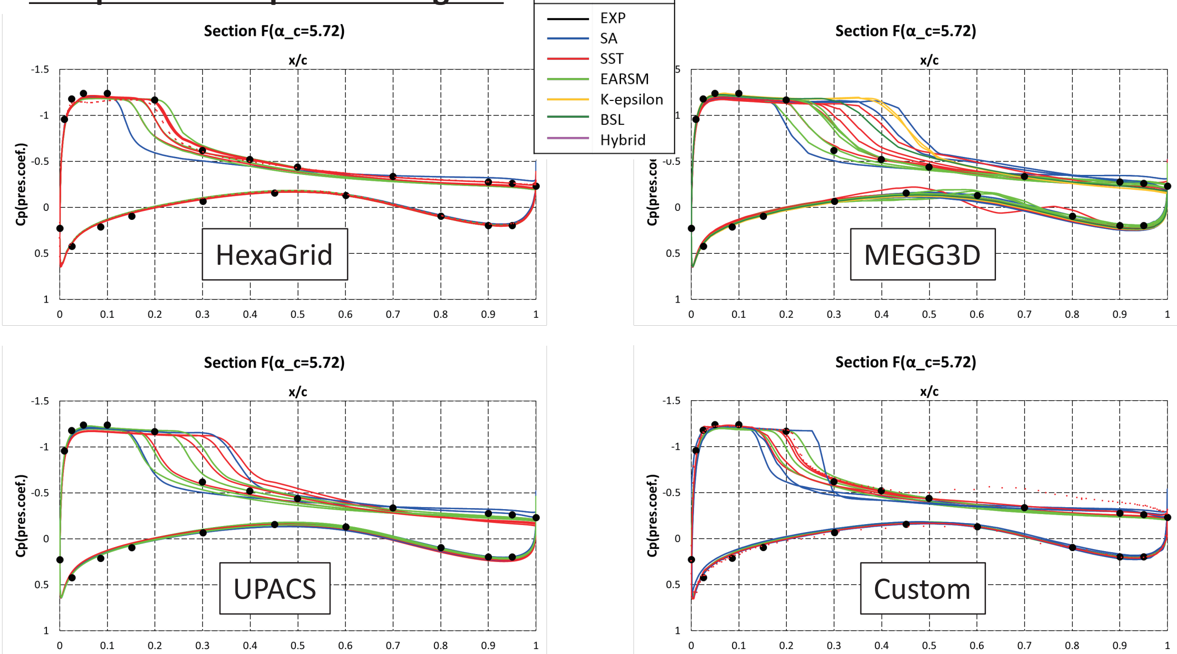
Comparison of Cp between grids



73

Case 1: Cp at high AoA

Comparison of Cp between grids



74

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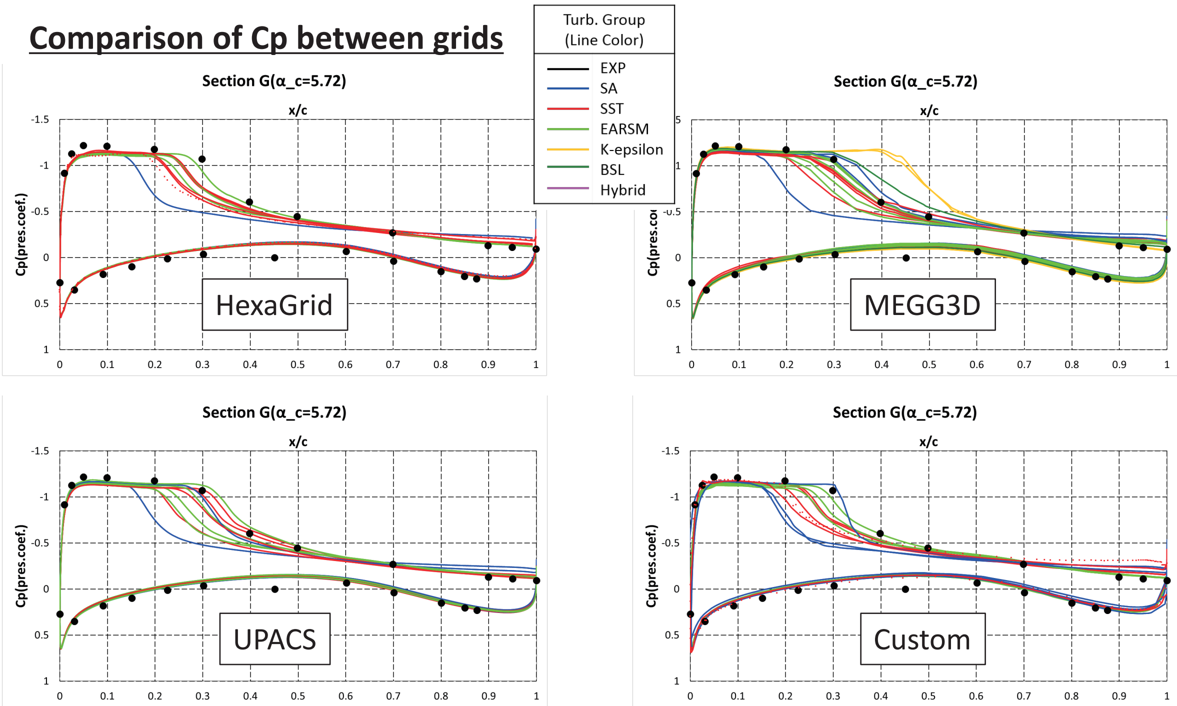
Case 1: Cp at high AoA

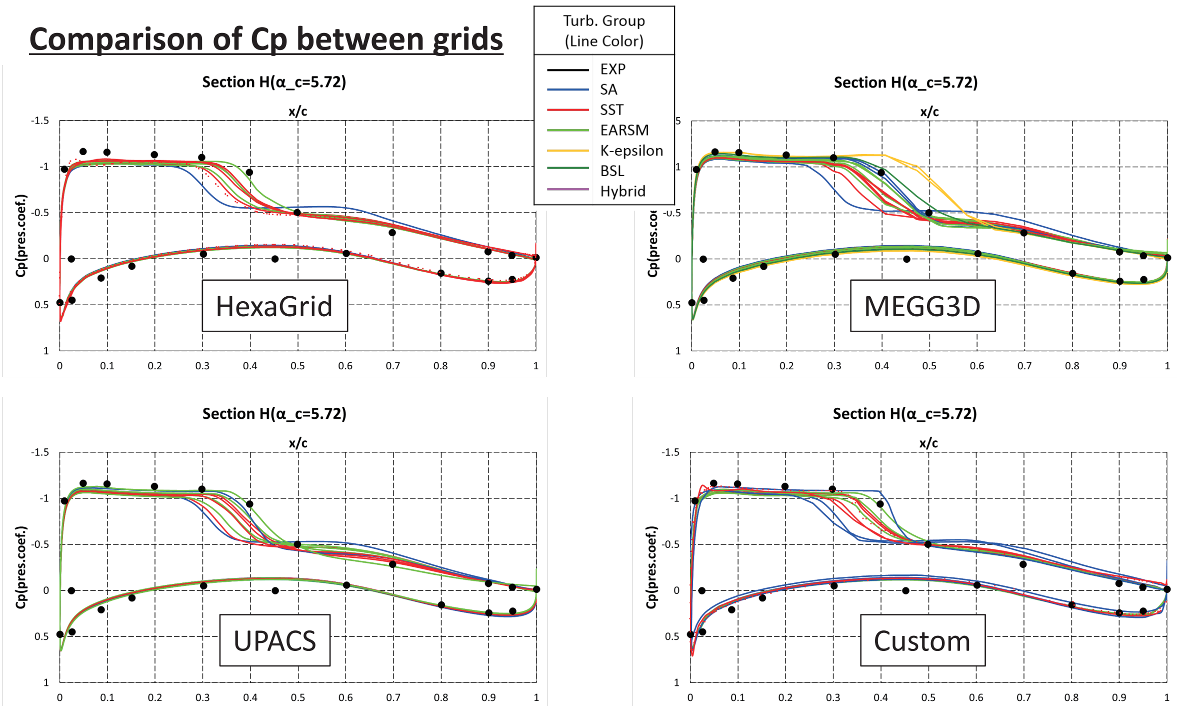
Comparison of Cp between grids



75

Case 1: Cp at high AoA

Comparison of Cp between grids



The peak of negative pressure is small for HexaGrid

76

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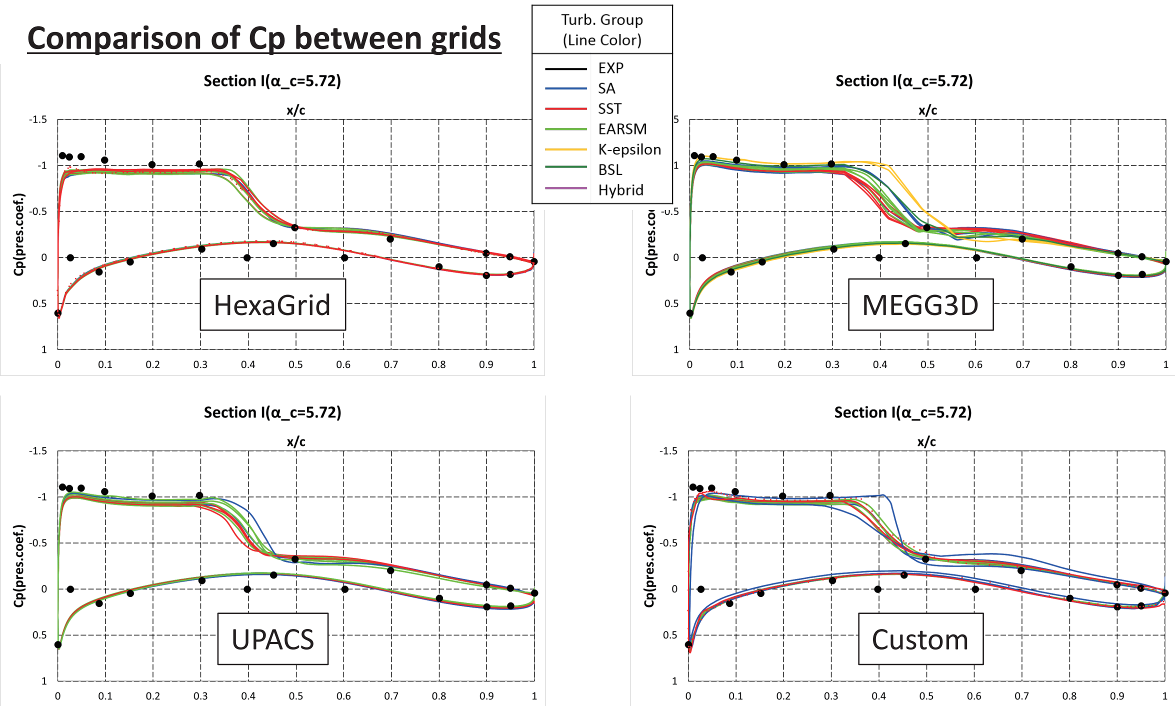
Case 1: Cp at high AoA

Comparison of Cp between grids



The peak of negative pressure is small for HexaGrid

77

Case 1: Summary

- We have collected total 53 submitted data with different grids and turbulence models (SA, SST, EARSM, and etc.).
- Turbulence model effects
  - The trend is similar for the alpha-sweep. The CL and Cm move up and down due to the turbulence model, but the slopes are same between the models.
  - CL is large in the order of SA, SST, EARSM. Cm is large in the order of EARSM, SST, SA. This is related with the shock location.
  - The Cp distributions agree with the experiment under the cruise condition. EARSM predicts the shock wave location well.
  - The idealized profile drag is higher than the experiment. The CL is lower than the experiment. (The shock locations are predicted well, but the lift is small.)
  - EARSM predicts the Cp well for the high angle of attack.
- Grid effects
  - There is no separation at the wing root for HexaGrid. This is same as the other coarse Cartesian grid.
  - The negative pressure is small for HexaGrid. The Cm is large for HexaGrid.
  - The nonlinear models (QCR, EARSM) have to be used for UPACS and MEGG3D grids to suppress the side-of-body separation.

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Case 2: Follow-up discussion

- Model : NASA-CRM (arbitrary configurations)
- Grid: arbitrary grids
- Conditions : arbitrary conditions
- Angles : arbitrary angles
- Data to be submitted : None
- Recommendations :
  - Discussion on the difference observed in APC-I and APC-II
  - Aeroelasticity
  - Wall interference
  - Transition
  - No tails
  - High Re
  - Subsonic

79

Case 2: Follow-up discussion

- Wall interference (JAXA)
  - The wall interference is small
  - Correction is almost same as the experiment
- Flow conditions (Toyama Univ.)
  - The lift curve slope is affected by Mach number.
- ETW (KHI)
  - The lift curve slope agrees with ETW.

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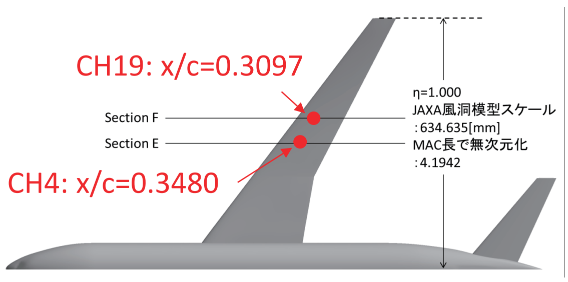
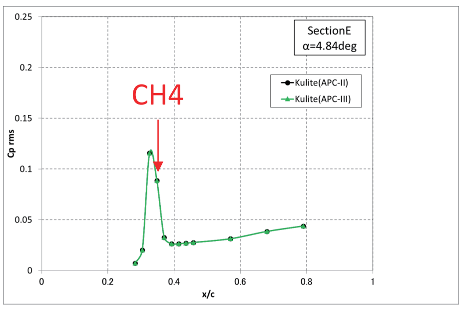
Case 3: Buffet

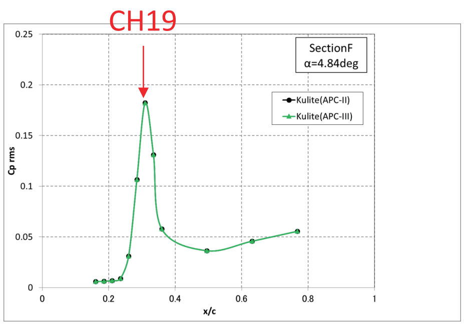
- Model : NASA-CRM(i_H=0deg) with deformation
- Grid: Arbitrary grids
- Conditions : M = 0.85, $Re_c = 1.5 \times 10^6$, T_{ref} = 282K
- Angles : 4.87deg, 5.92deg
- Data to be submitted :
  - Aerodynamic coefficients(C_D,C_L,C_m)
  - Surface C_p distributions
    - Average, RMS
  - Frequency spectra
  - Flow field contours (Pressure, Mach number, eddy viscosity)

Case 3: Comparison locations

- Unsteady pressure is compared at Section E(η=0.50) and Section F (η=0.60).
- Time histories and frequency spectra are compared at CH4 and CH19







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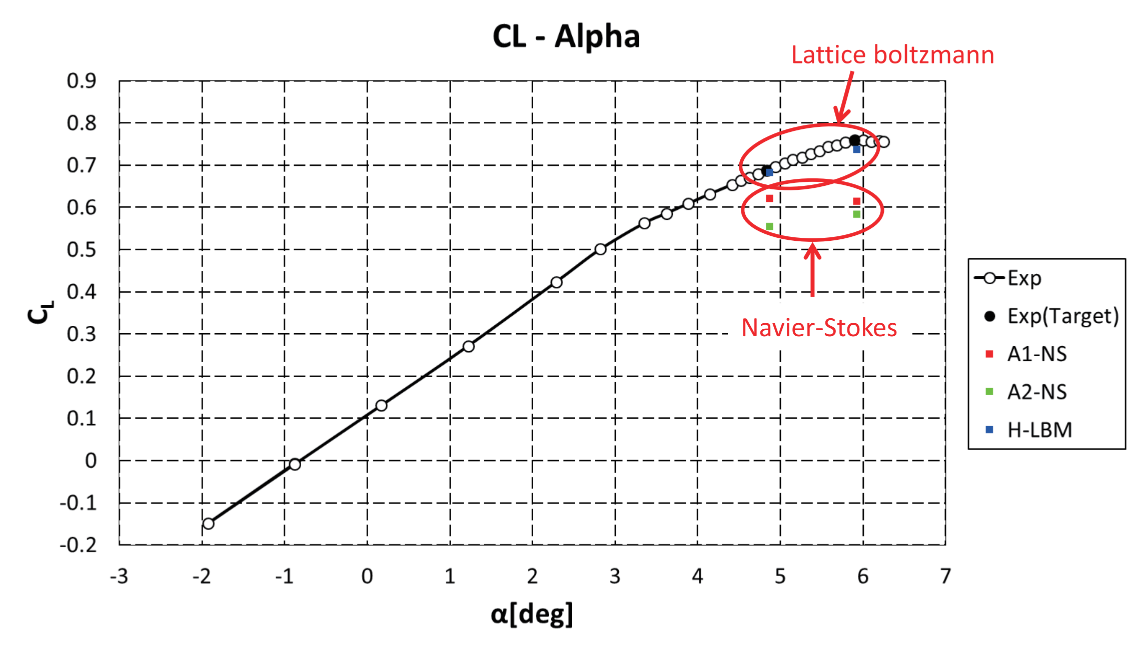
Case 3: List of data

- Aerodynamic coefficient(CL)
- Results of 4.87deg
  - Cp average and RMS(Section E, F)
  - Cp time histories and PSD (CH4, CH19)
  - Wing surface Cp(Average/RMS), Streamline(Average)
  - Cross sectional Cp(Average/RMS)
  - Cross sectional Mach number(Average/RMS)
  - Cross sectional eddy viscosity(Average)
- Results of 5.92deg
  - Cp average and RMS(Section E, F)
  - Cp time histories and PSD (CH4, CH19)
  - Wing surface Cp(Average/RMS), Streamline(Average)
  - Cross sectional Cp(Average/RMS)
  - Cross sectional Mach number(Average/RMS)
  - Cross sectional eddy viscosity(Average)

83

Case 3 : Aerodynamic coefficient



Dependency on the employed method

84

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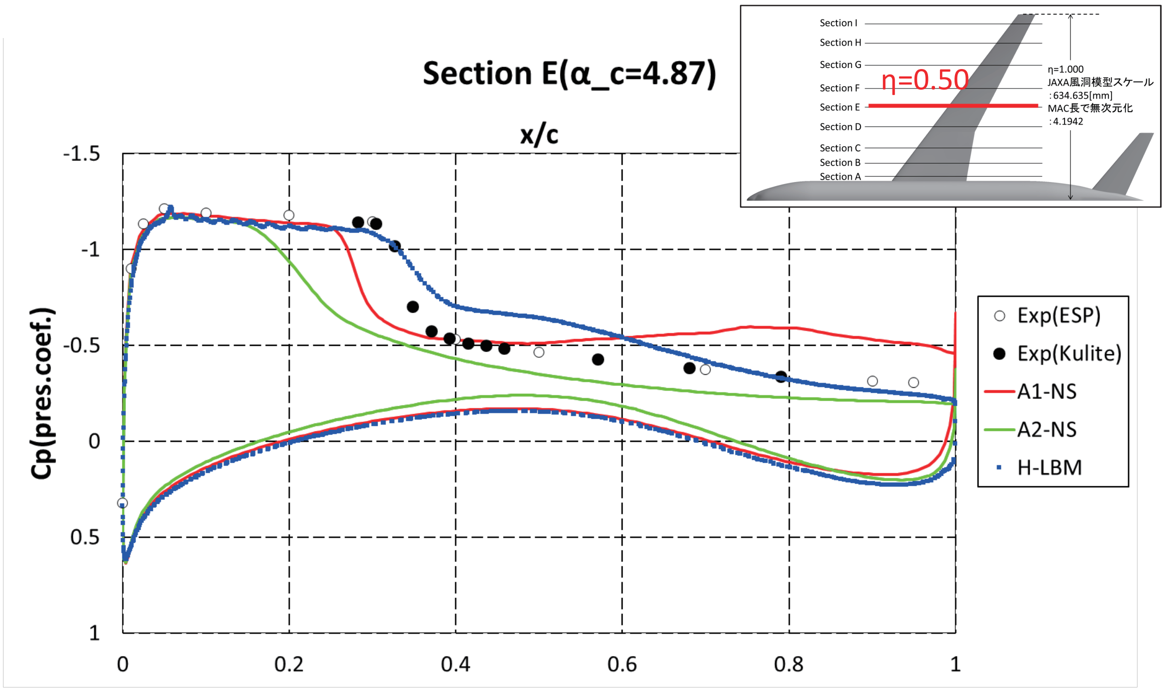
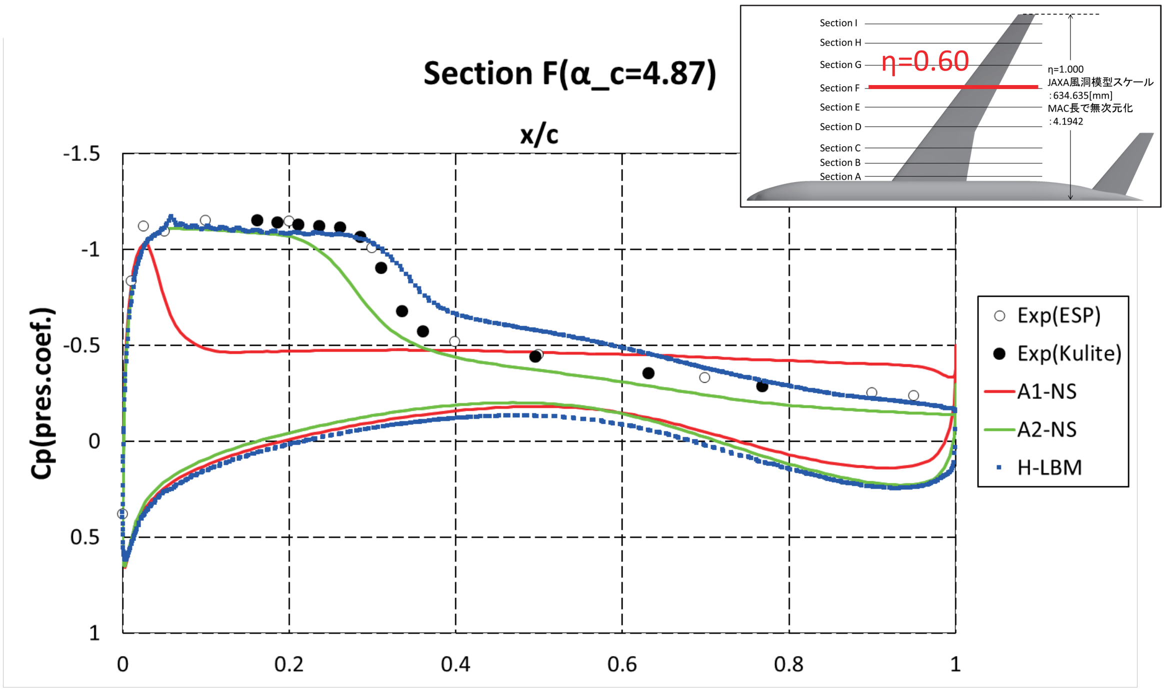
Case 3 : Cp average (4.87deg)



Variation of the shock wave location is large

85

Case 3 : Cp average (4.87deg)



Variation of the shock wave location is large

86

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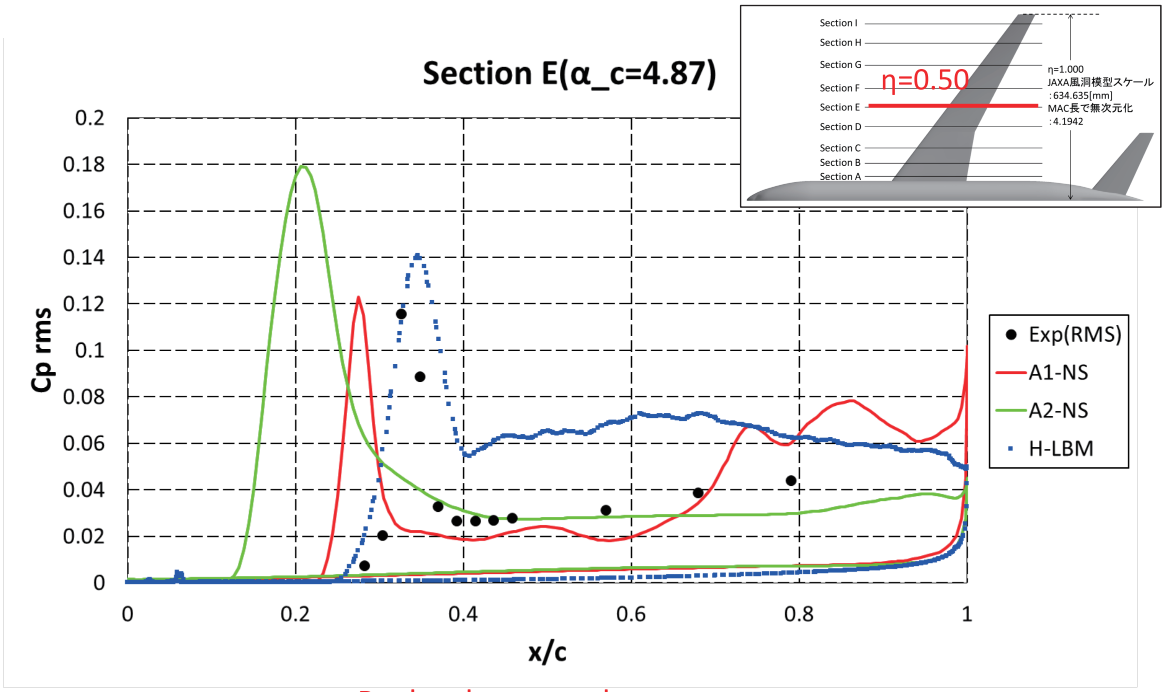
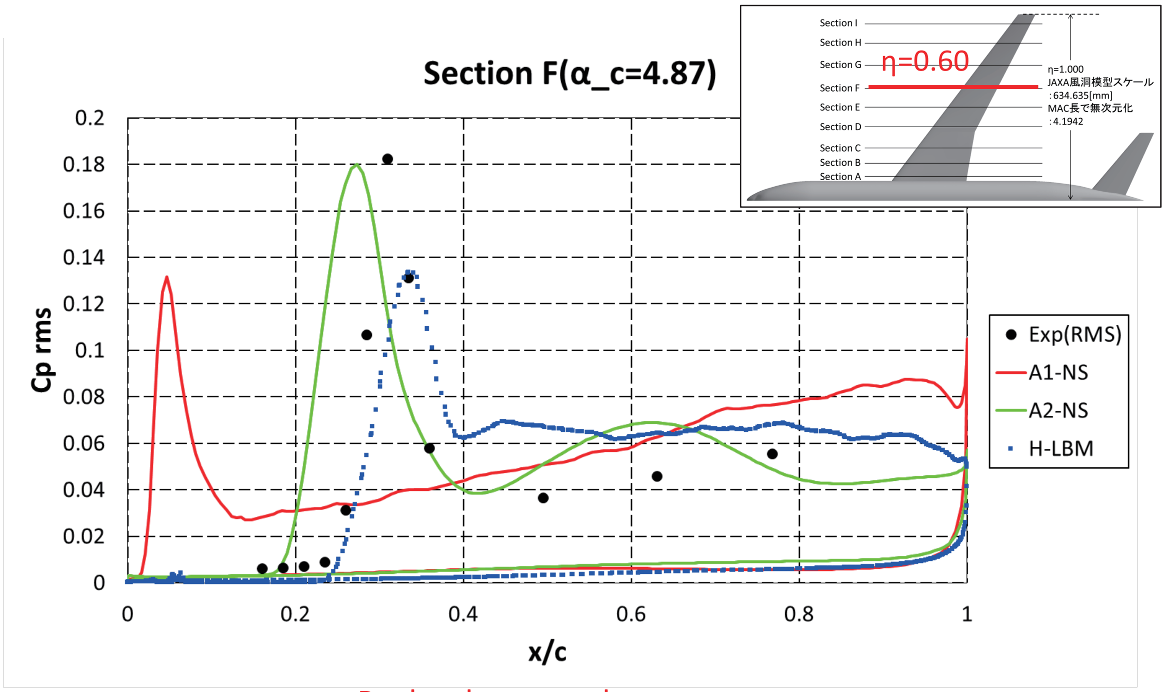
Case 3 : Cp RMS (4.87deg)



Peak values are almost same

87

Case 3 : Cp RMS (4.87deg)



Peak values are almost same

88

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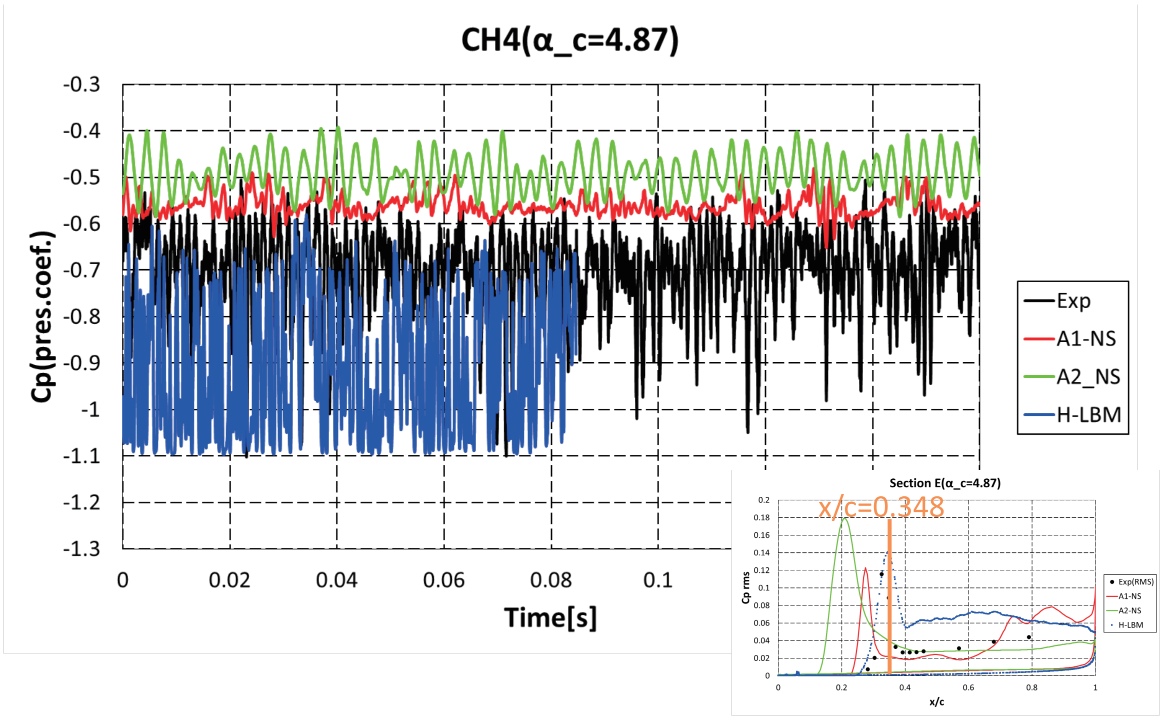
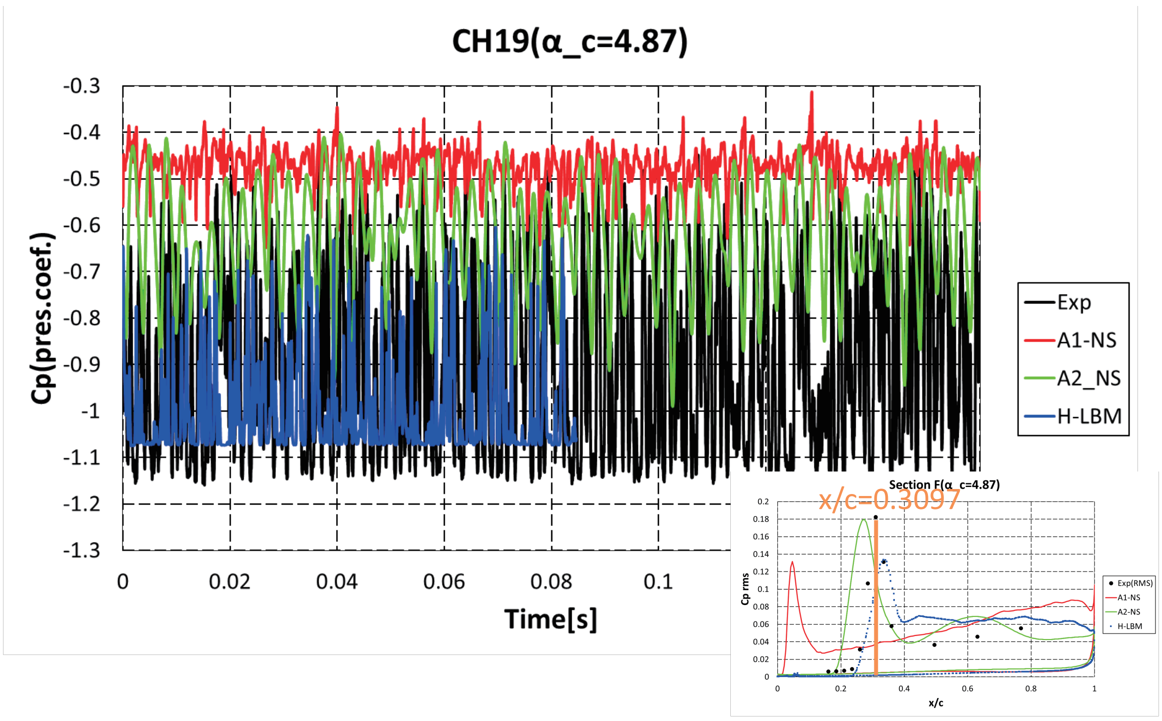
Case 3 : Cp time history (4.87deg)



89

Case 3 : Cp time history (4.87deg)



90

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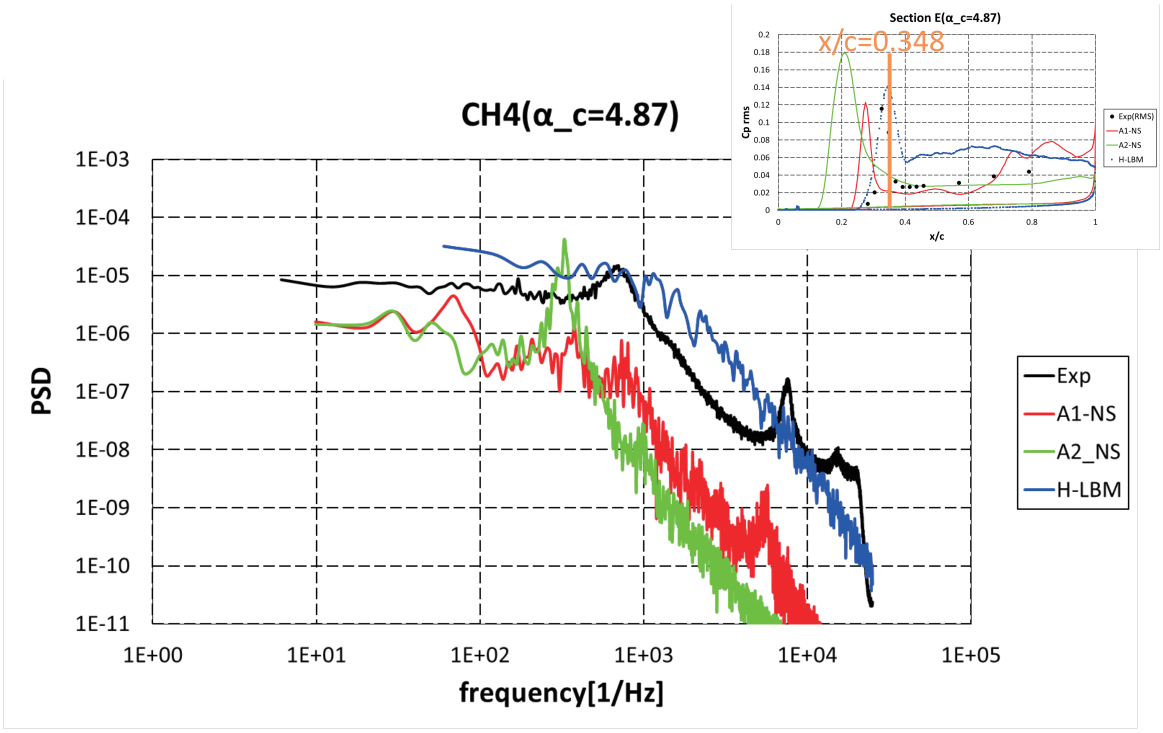
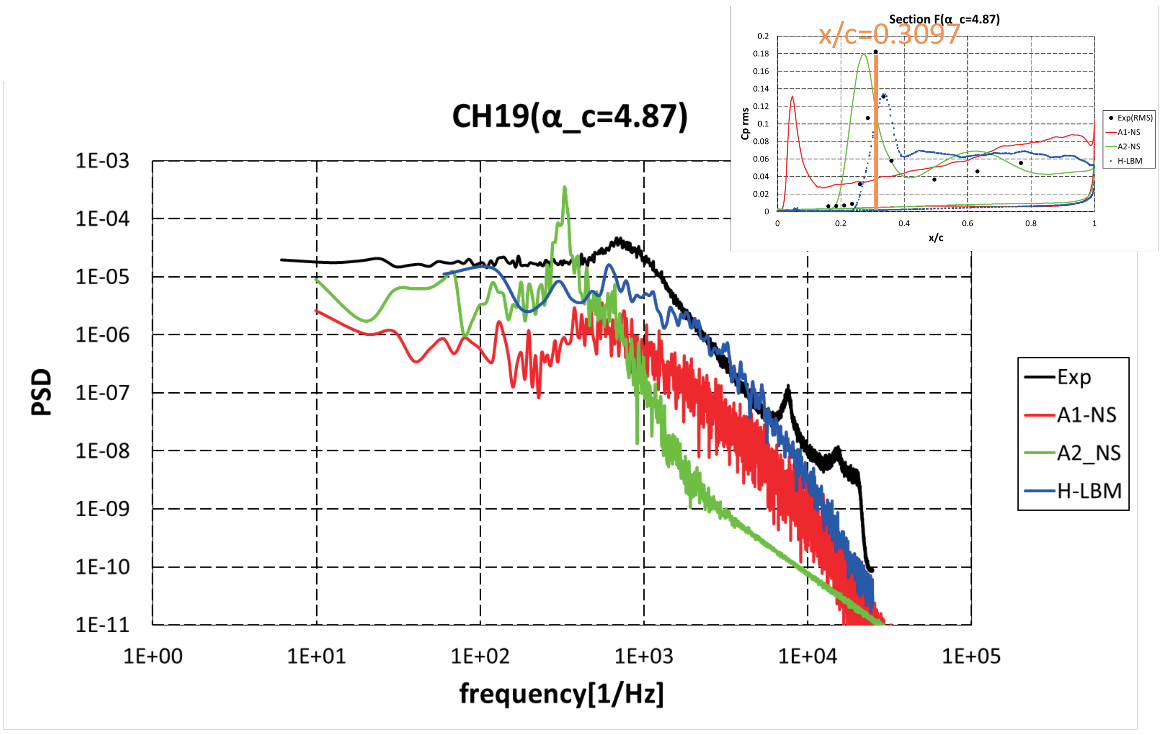
Case 3：Cp PSD (4.87deg)



91

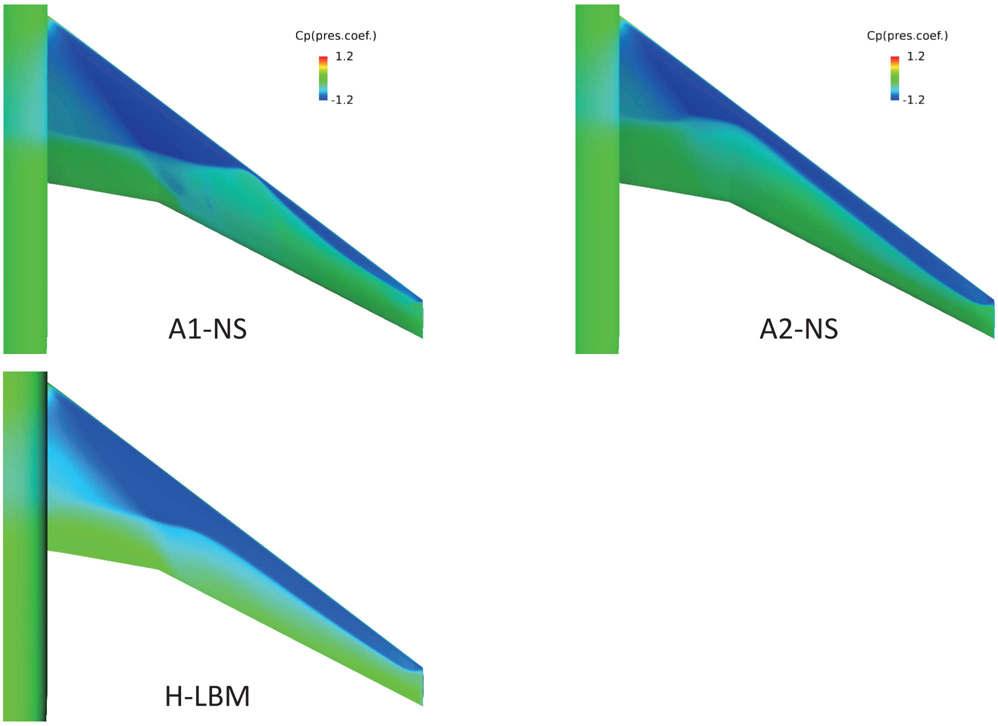
Case 3：Cp PSD (4.87deg)



92

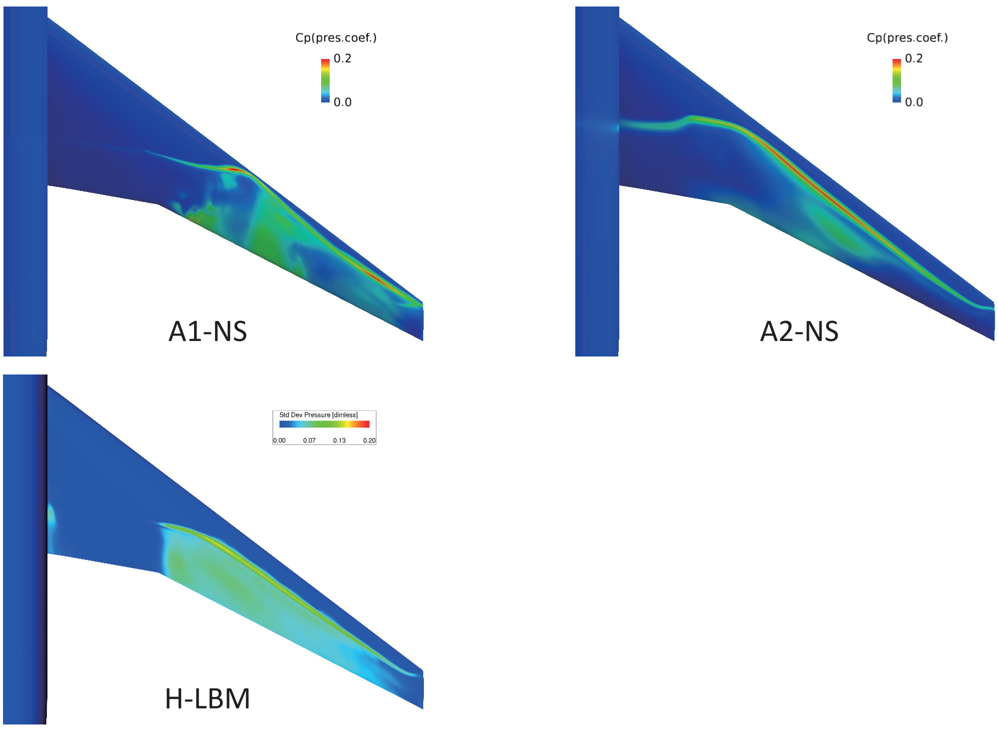
This document is provided by JAXA.

Case 3: Cp average (α=4.87deg)



93

Case 3: Cp RMS (α=4.87deg)



94

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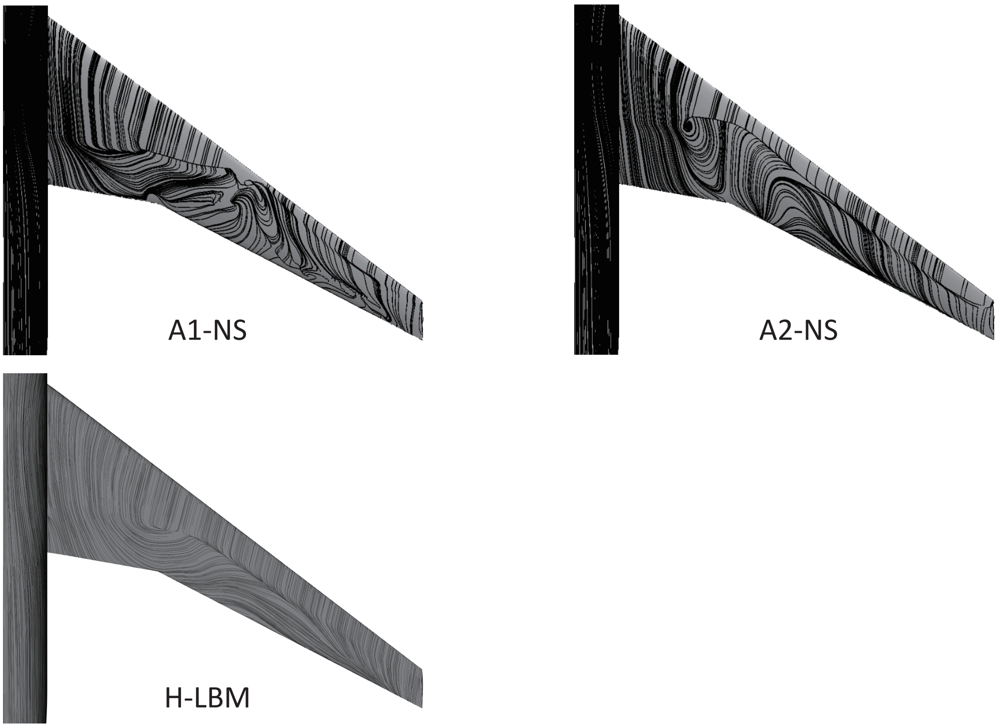
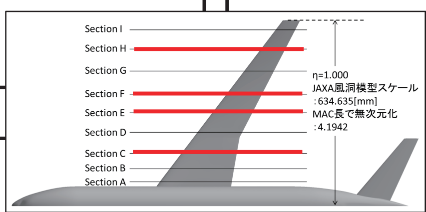
Case 3: Streamline (α=4.87deg)



Case 3: Cross sectional contours

We show the cross-sectional contours as follows,

Section C (η=0.28)	Section E (η=0.50)
Section F (η=0.60)	Section H (η=0.85)



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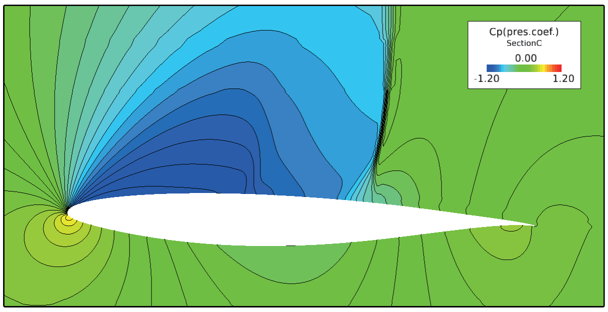
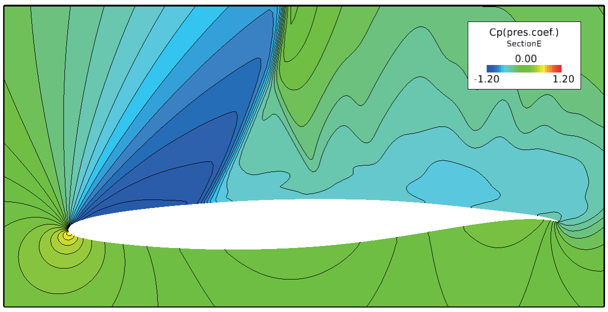
Case 3: Cp average (α=4.87deg)

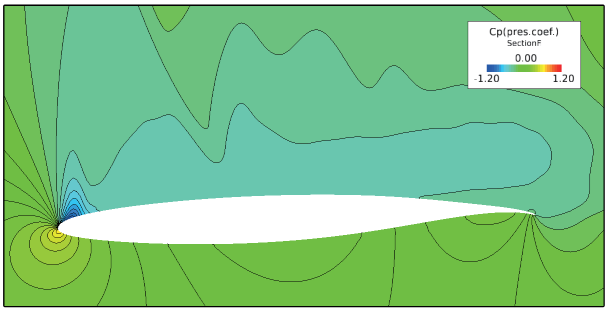
ID : A1



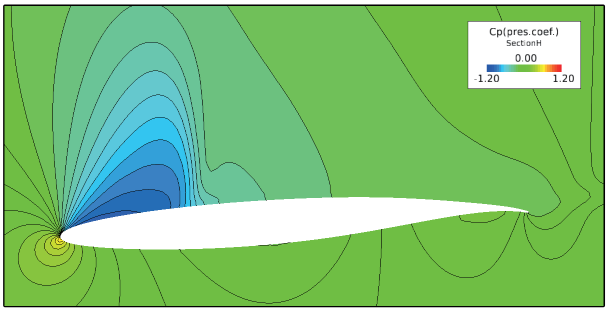
Section C (η=0.28)



Section E (η=0.50)



Section F (η=0.60)

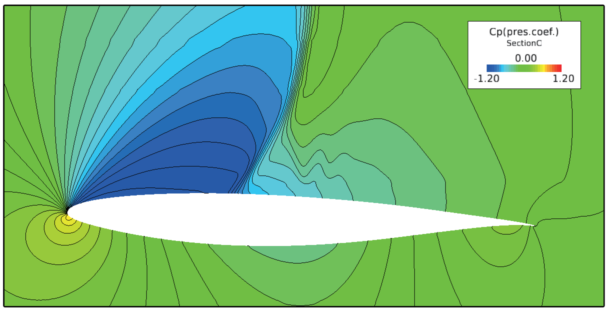


Section H (η=0.85)

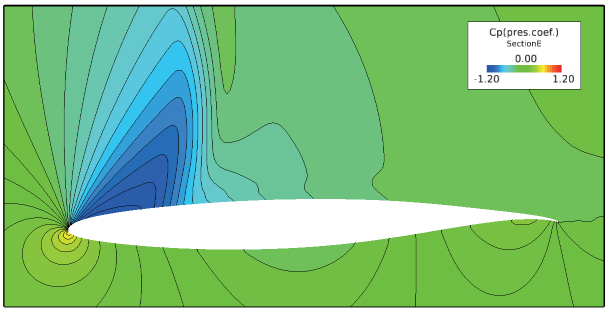
97

Case 3: Cp average (α=4.87deg)

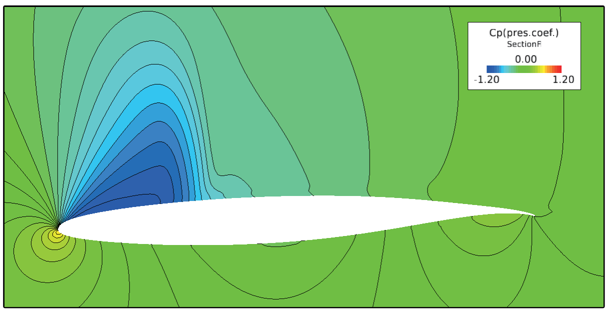
ID : A2



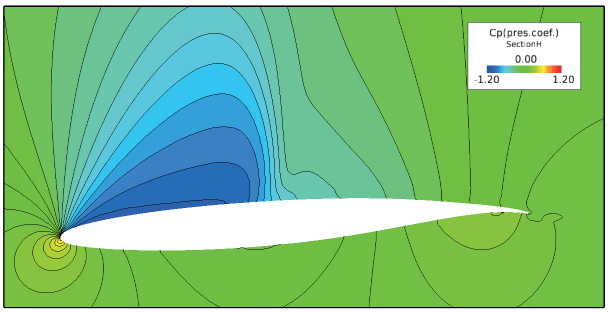
Section C (η=0.28)



Section E (η=0.50)



Section F (η=0.60)



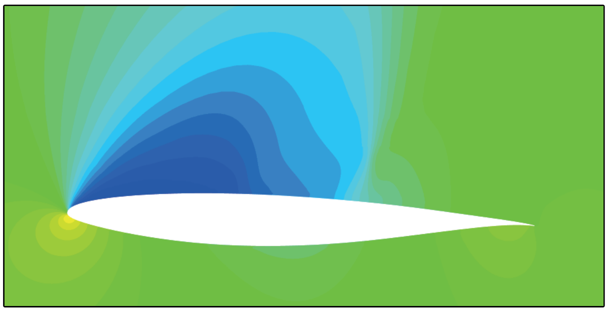
Section H (η=0.85)

98

This document is provided by JAXA.

Case 3: Cp average (α=4.87deg)

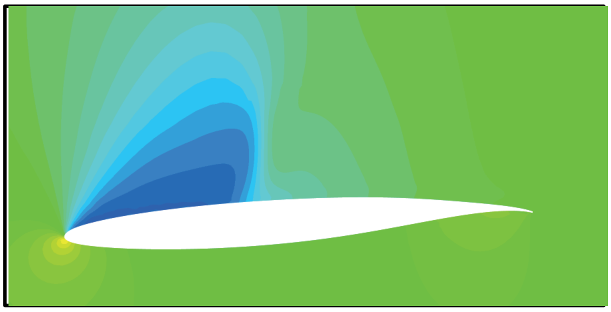
ID : H



Section C (η=0.28)

Section E (η=0.50)

Section F (η=0.60)

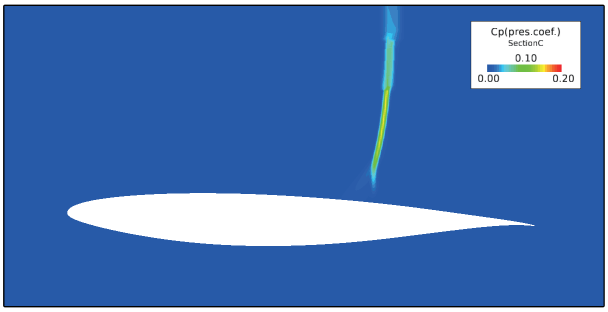


Section H (η=0.85)

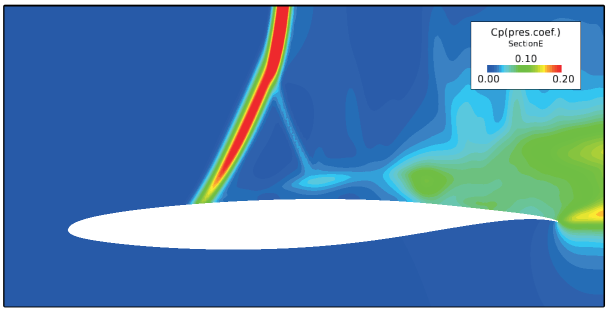
99

Case 3: Cp RMS (α=4.87deg)

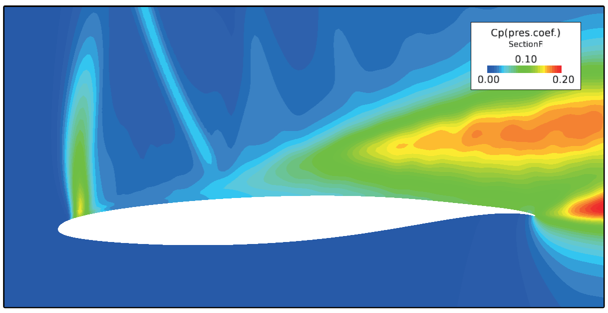
ID : A1



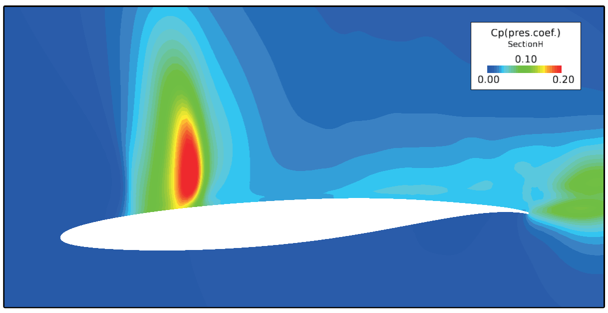
Section C (η=0.28)



Section E (η=0.50)



Section F (η=0.60)



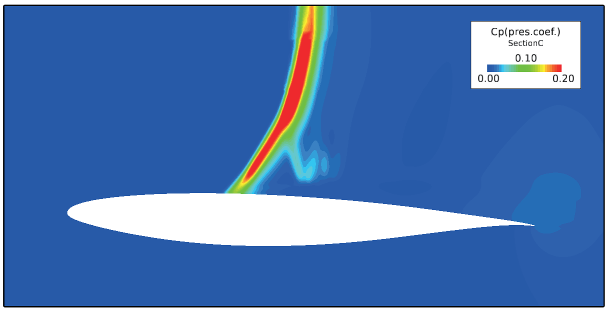
Section H (η=0.85)

100

This document is provided by JAXA.

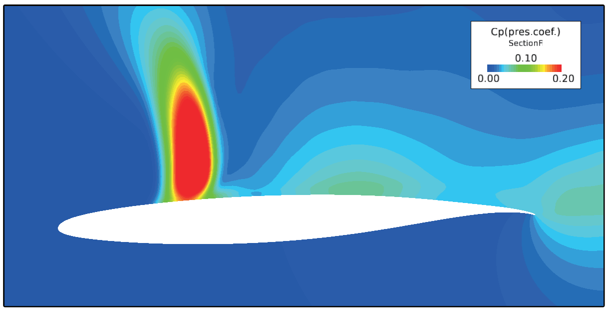
Case 3: Cp RMS (α=4.87deg)

ID : A2

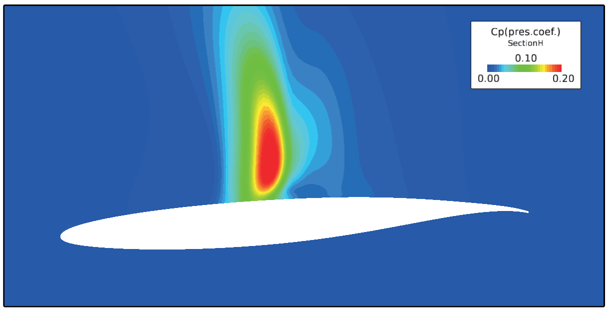


Section C (η=0.28)

Section E (η=0.50)



Section F (η=0.60)



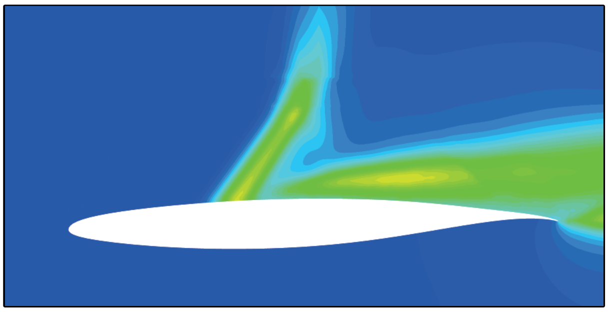
Section H (η=0.85)

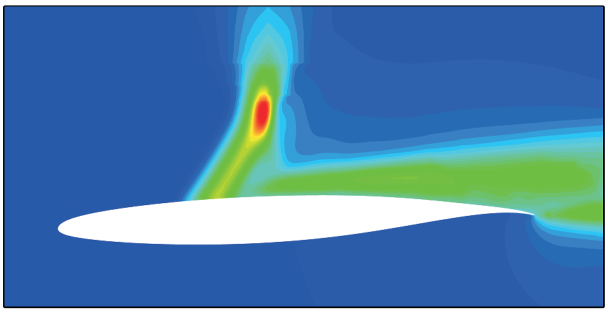
101

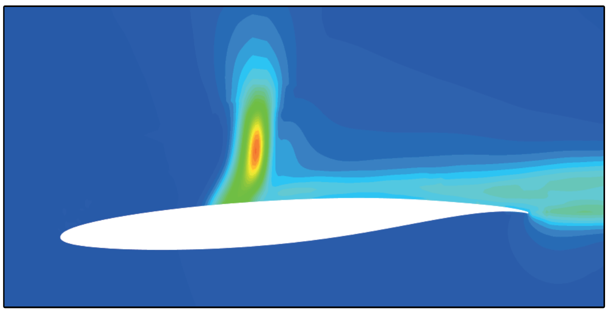
Case 3: Cp RMS (α=4.87deg)

ID : H


Section C (η=0.28)


Section E (η=0.50)


Section F (η=0.60)

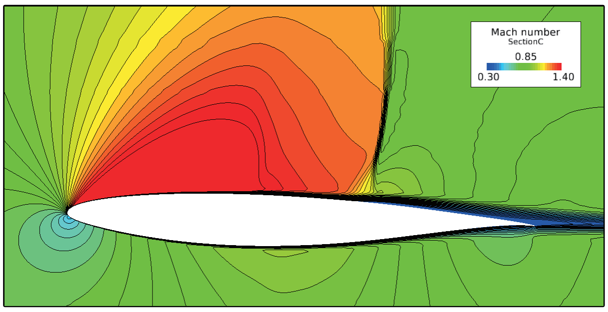

Section H (η=0.85)

102

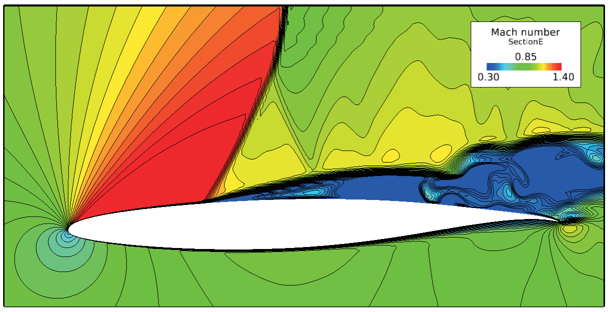
This document is provided by JAXA.

Case 3: Mach number (α=4.87deg)

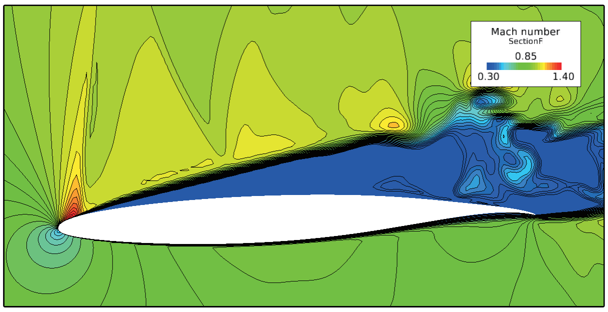
ID : A1



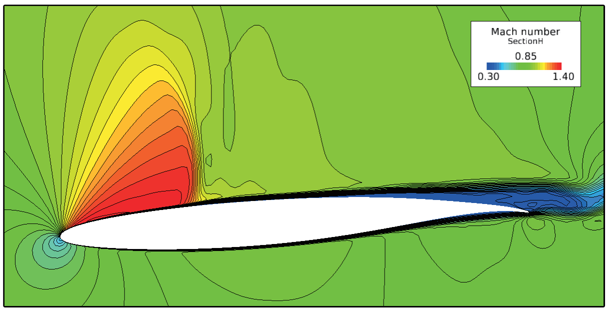
Section C (η=0.28)



Section E (η=0.50)



Section F (η=0.60)

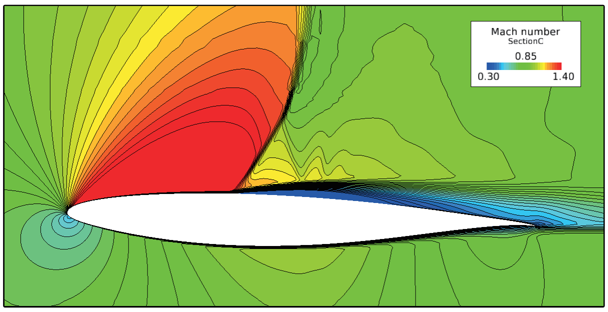


Section H (η=0.85)

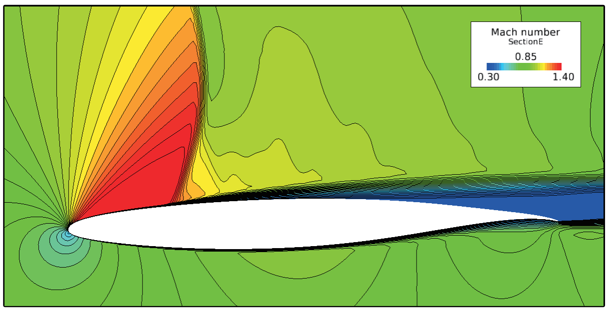
103

Case 3: Mach number (α=4.87deg)

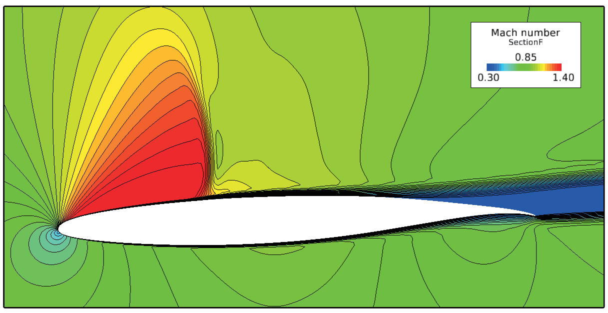
ID : A2



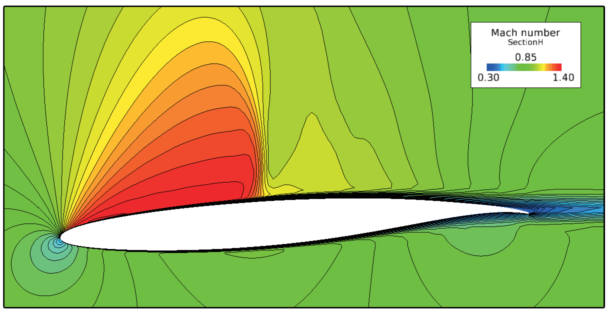
Section C (η=0.28)



Section E (η=0.50)



Section F (η=0.60)



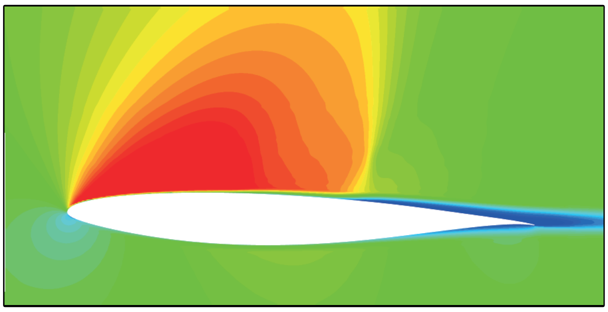
Section H (η=0.85)

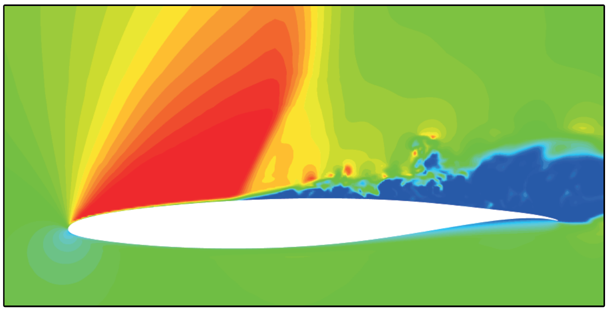
104

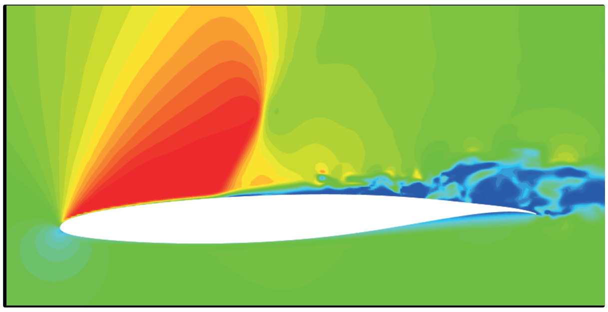
This document is provided by JAXA.

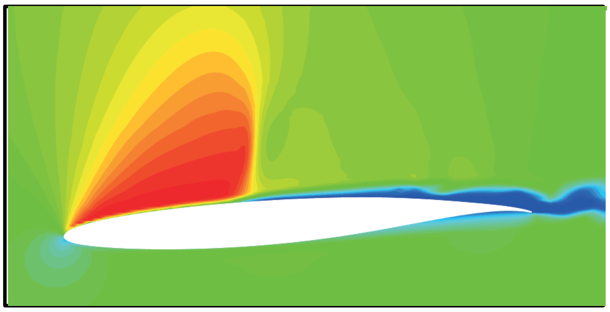
Case 3: Mach number (α=4.87deg)

ID：H


Section C (η=0.28)


Section E (η=0.50)

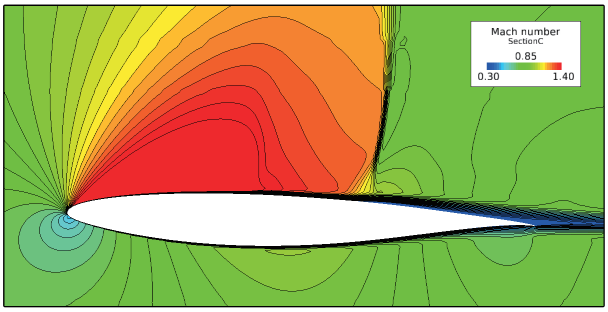

Section F (η=0.60)


Section H (η=0.85)

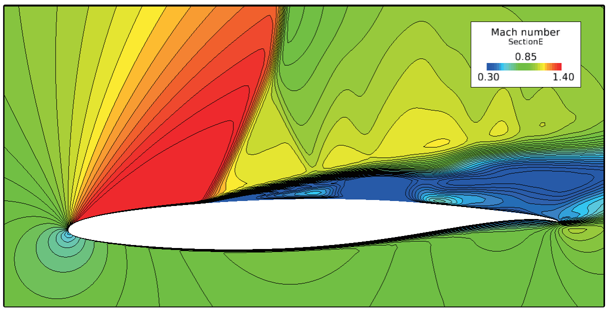
105

Case 3: Mach number average (α=4.87deg)

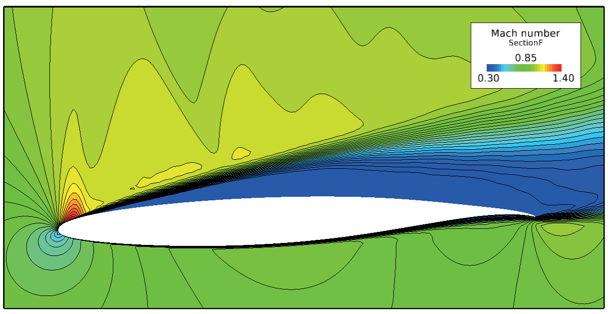
ID：A1



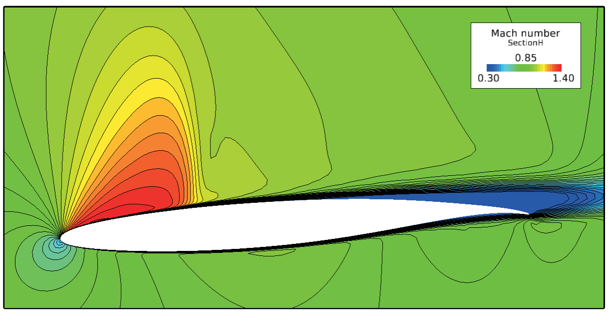
Section C (η=0.28)



Section E (η=0.50)



Section F (η=0.60)



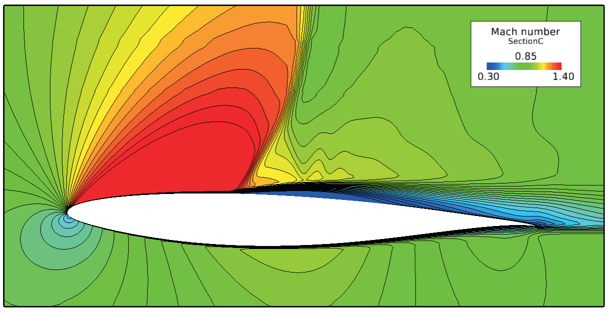
Section H (η=0.85)

106

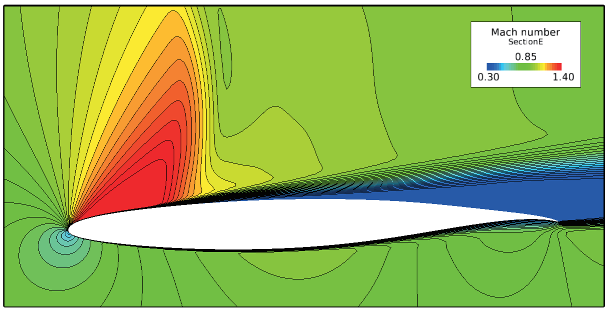
This document is provided by JAXA.

Case 3: Mach number average (α=4.87deg)

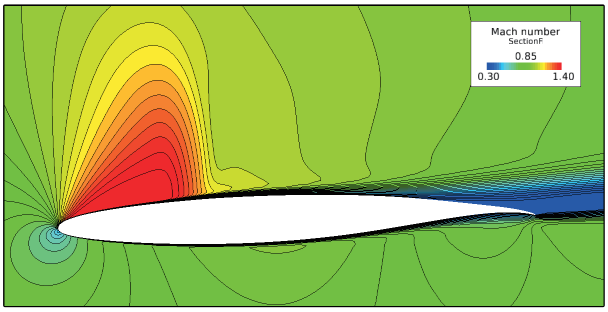
ID : A2



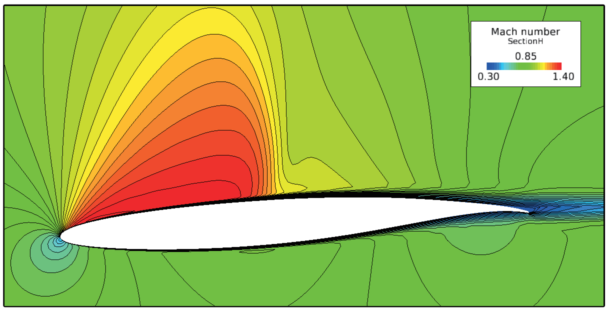
Section C (η=0.28)



Section E (η=0.50)



Section F (η=0.60)



Section H (η=0.85)

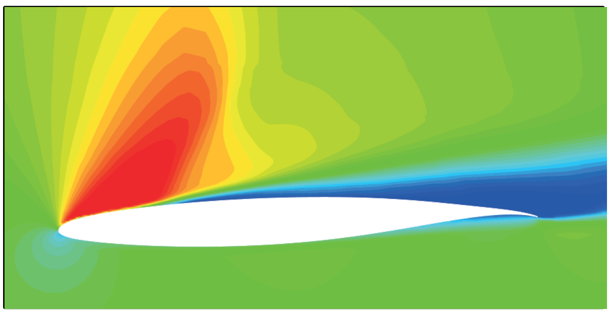
107

Case 3: Mach number average (α=4.87deg)

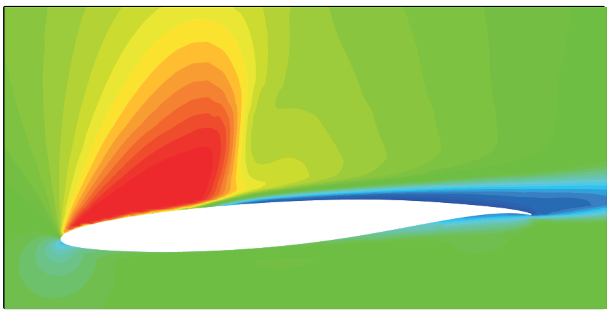
ID : H

Section C (η=0.28)

Section E (η=0.50)



Section F (η=0.60)



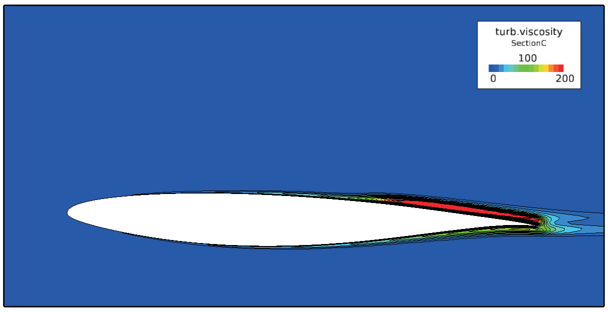
Section H (η=0.85)

108

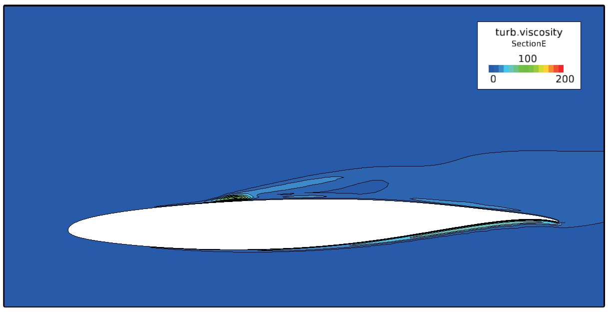
This document is provided by JAXA.

Case 3: Eddy viscosity average (α=4.87deg)

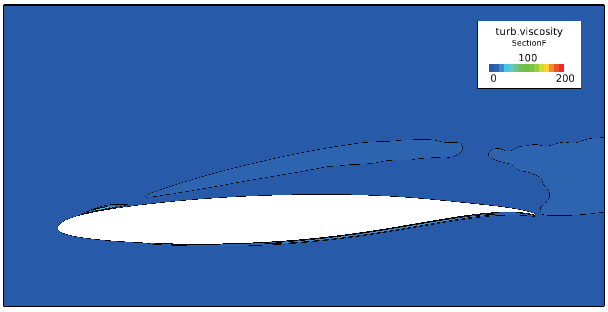
ID : A1



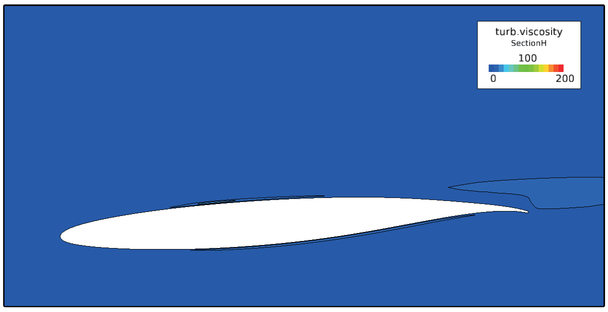
Section C (η=0.28)



Section E (η=0.50)



Section F (η=0.60)

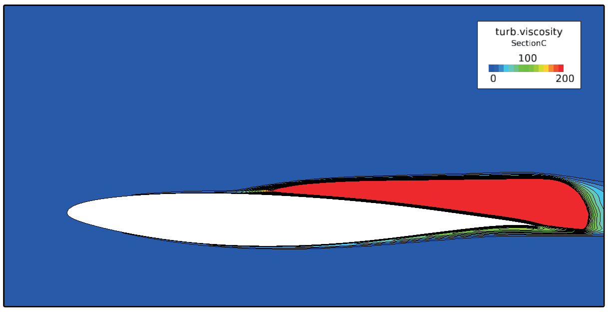


Section H (η=0.85)

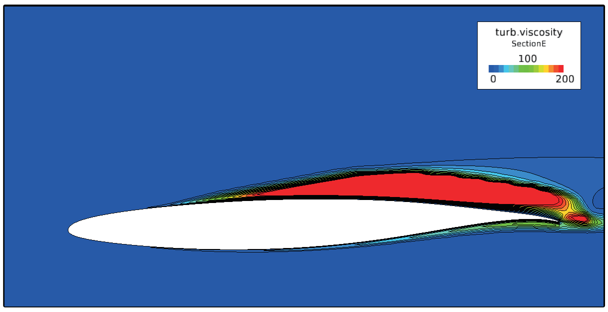
109

Case 3: Eddy viscosity average (α=4.87deg)

ID : A2

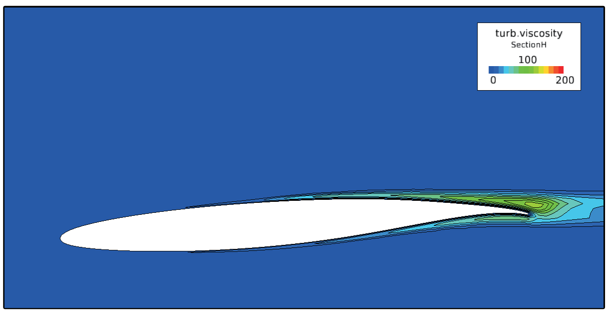


Section C (η=0.28)



Section E (η=0.50)

Section F (η=0.60)



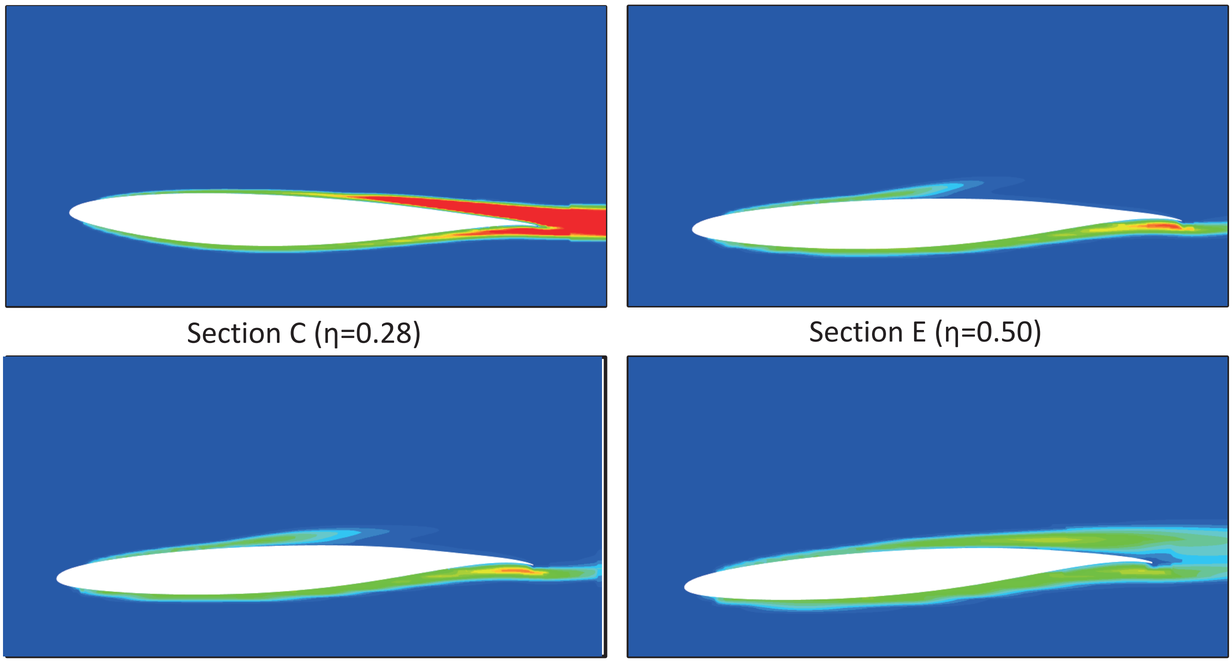
Section H (η=0.85)

110

This document is provided by JAXA.

Case 3: Eddy viscosity average (α=4.87deg)

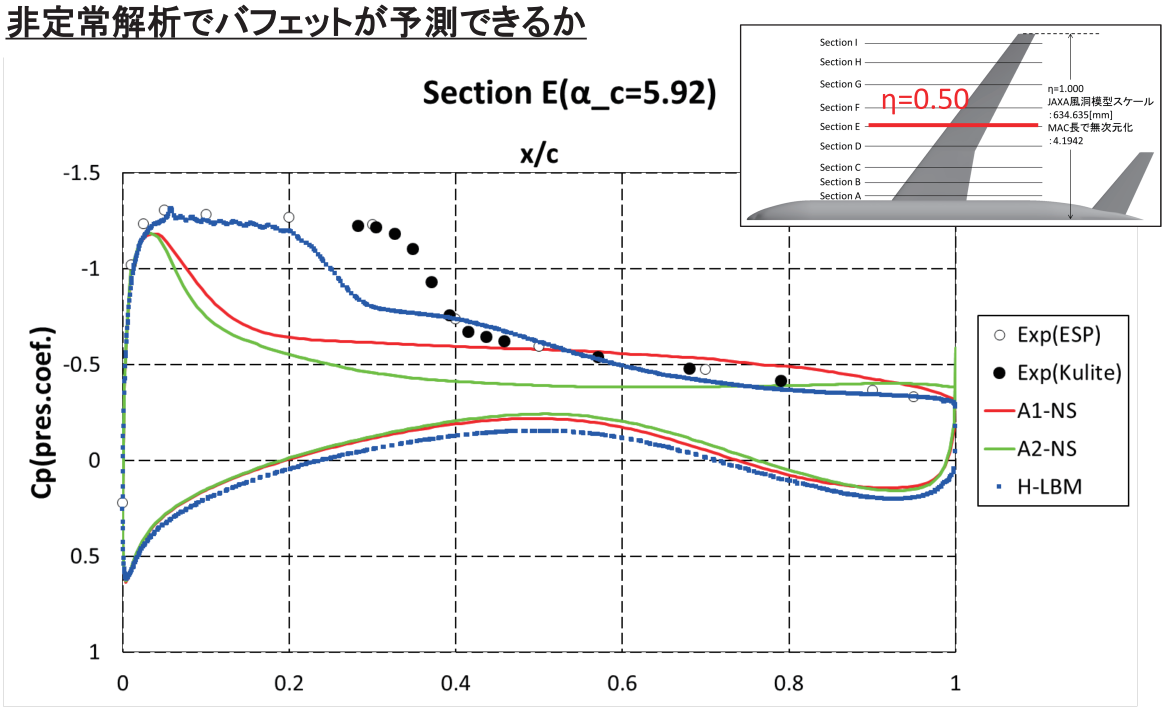
ID : H



111

Case 3 : Cp average (5.92deg)

非定常解析でバフェットが予測できるか

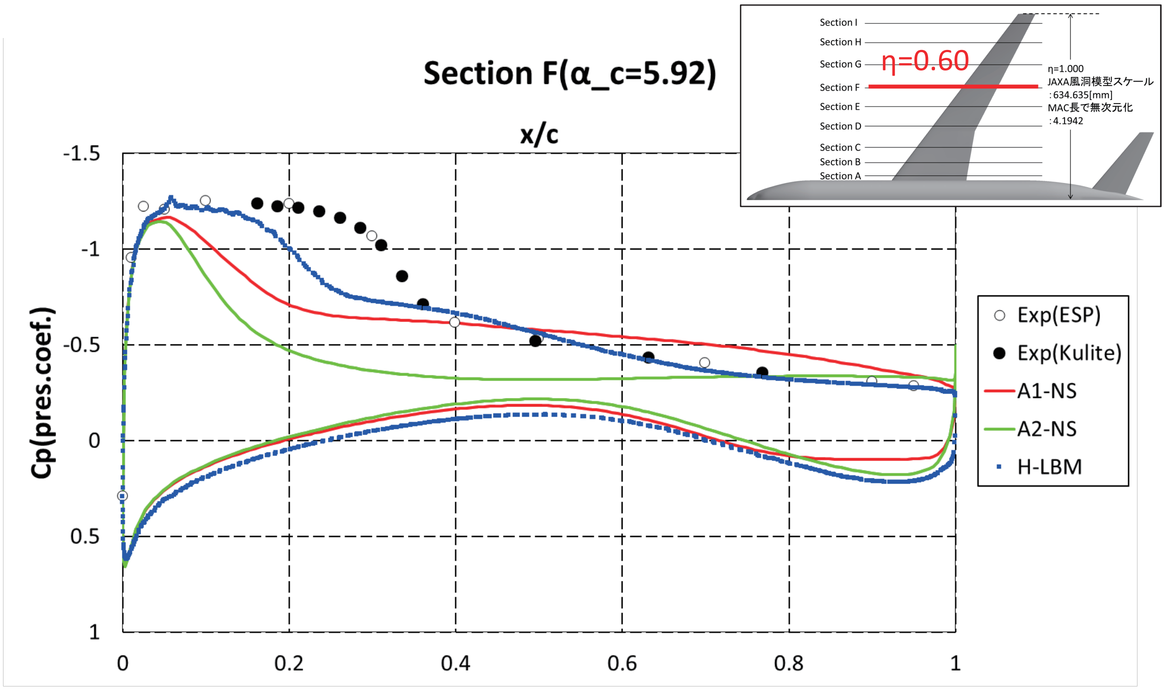


The shock wave moves forward for 5.92deg.

112

This document is provided by JAXA.

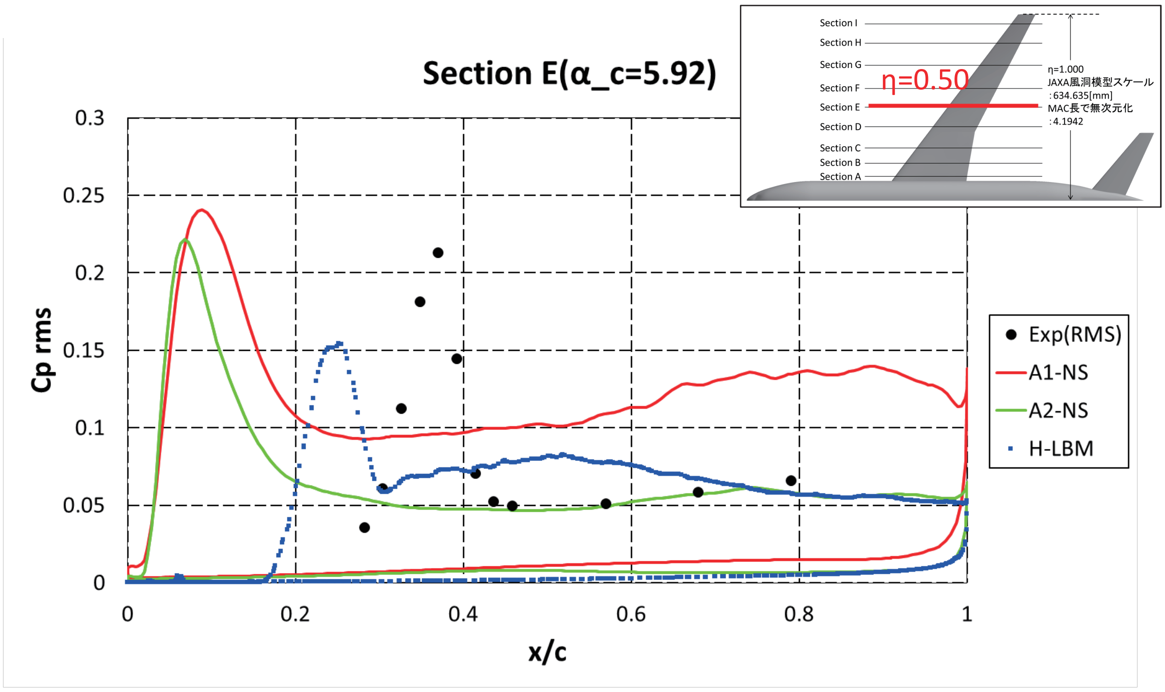
Case 3 : Cp average (5.92deg)



The shock wave moves forward for 5.92deg.

113

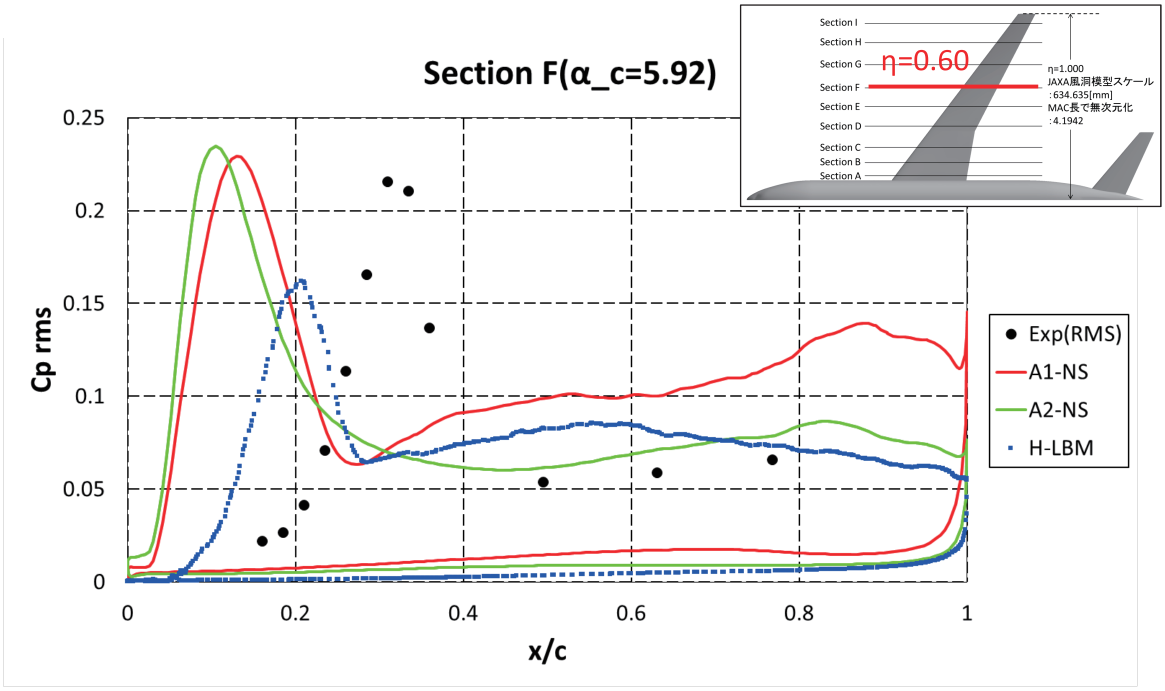
Case 3 : Cp RMS (5.92deg)



114

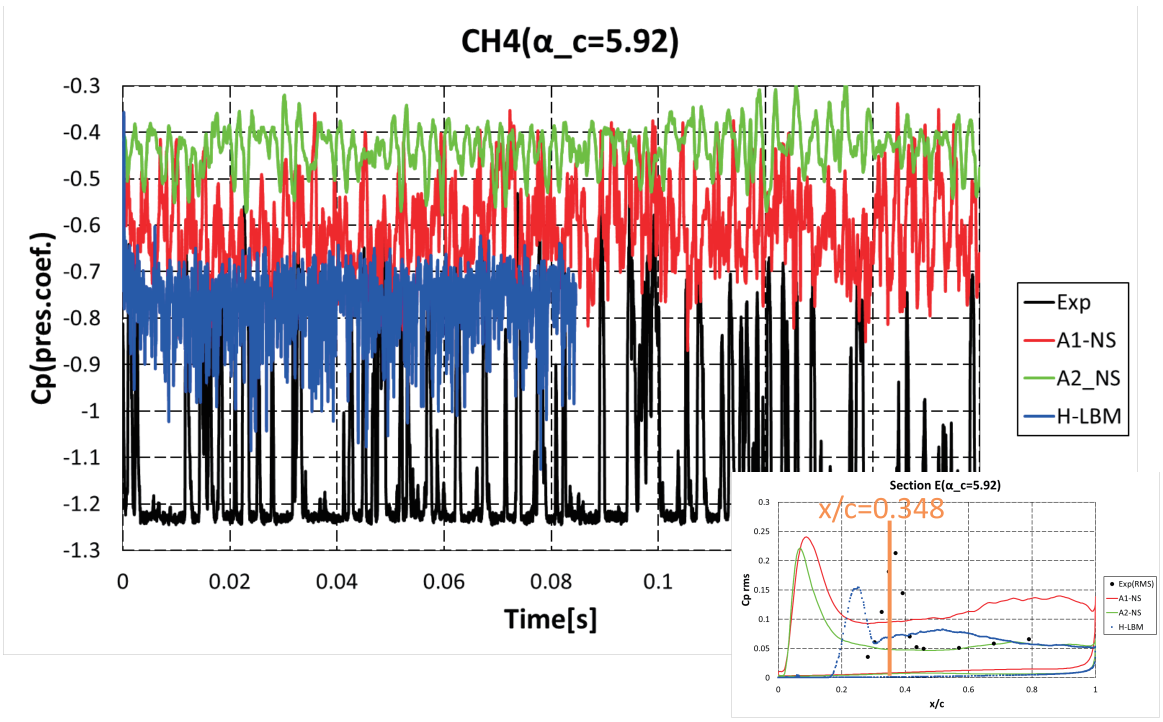
This document is provided by JAXA.

Case 3 : Cp RMS (5.92deg)



115

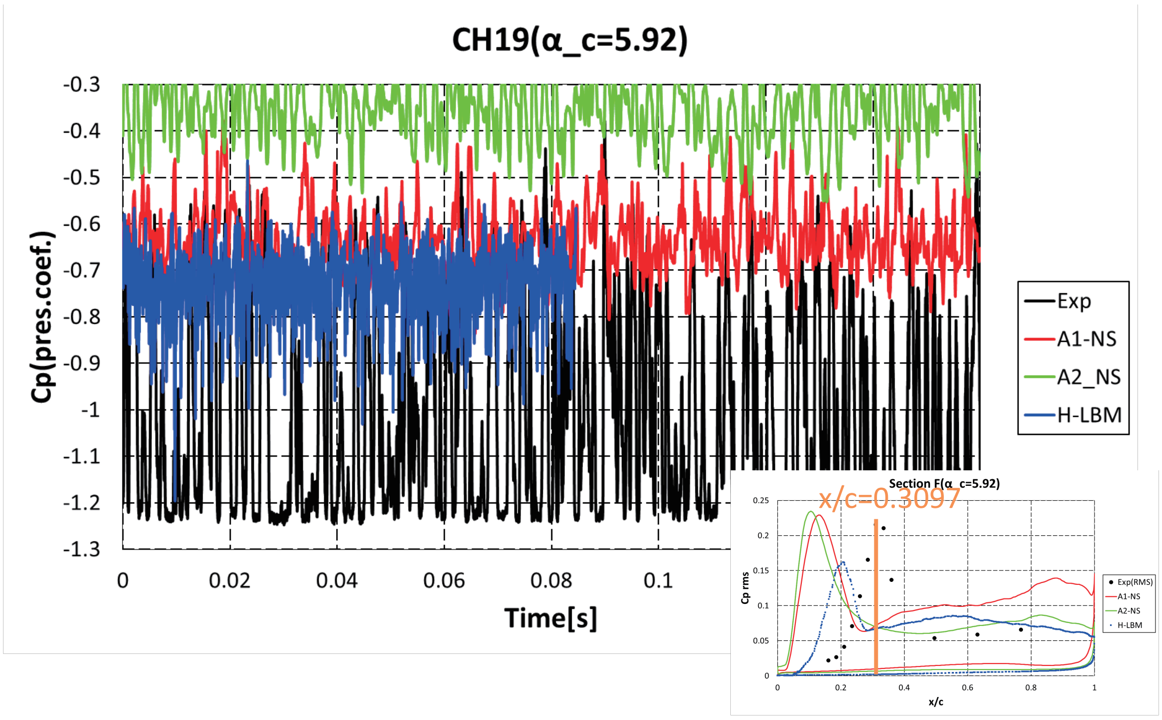
Case 3 : Cp time history (5.92deg)



116

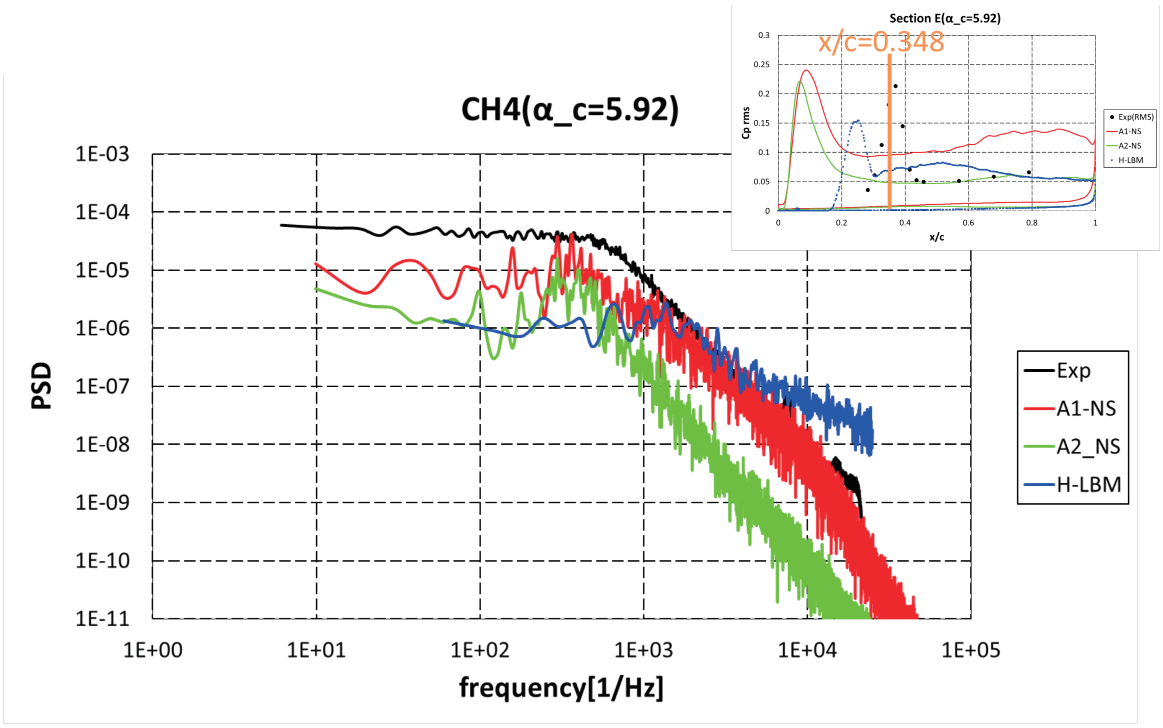
This document is provided by JAXA.

Case 3 : Cp time history (5.92deg)



117

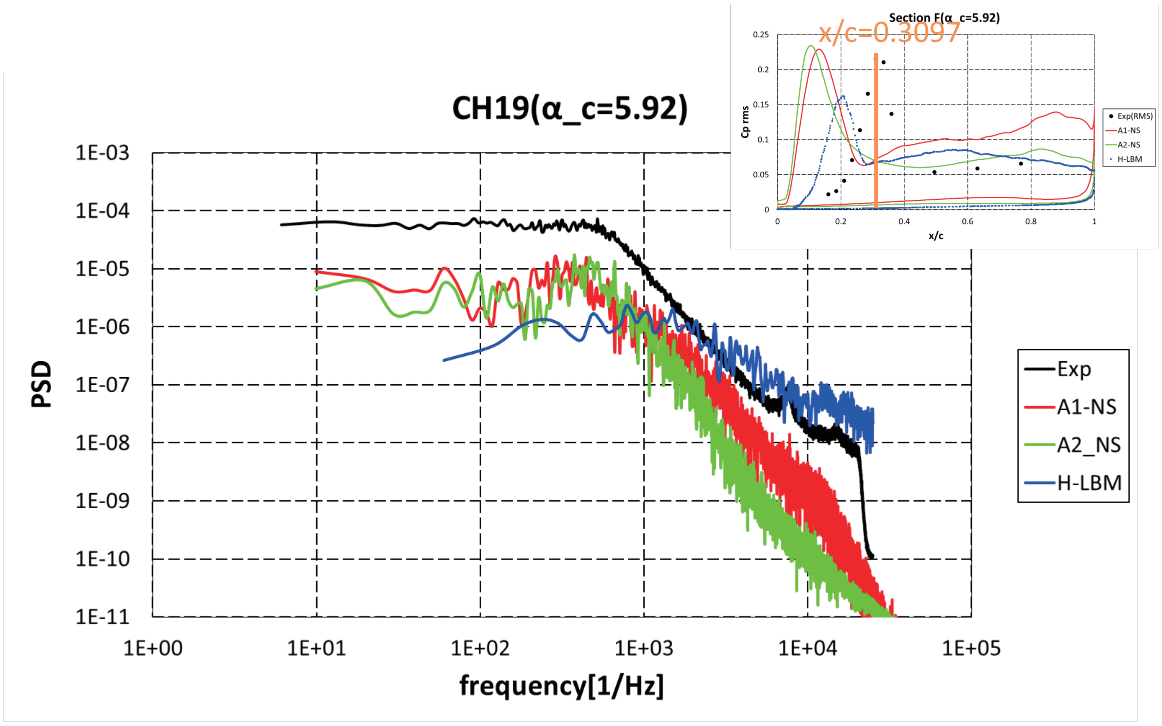
Case 3 : Cp PSD (5.92deg)



118

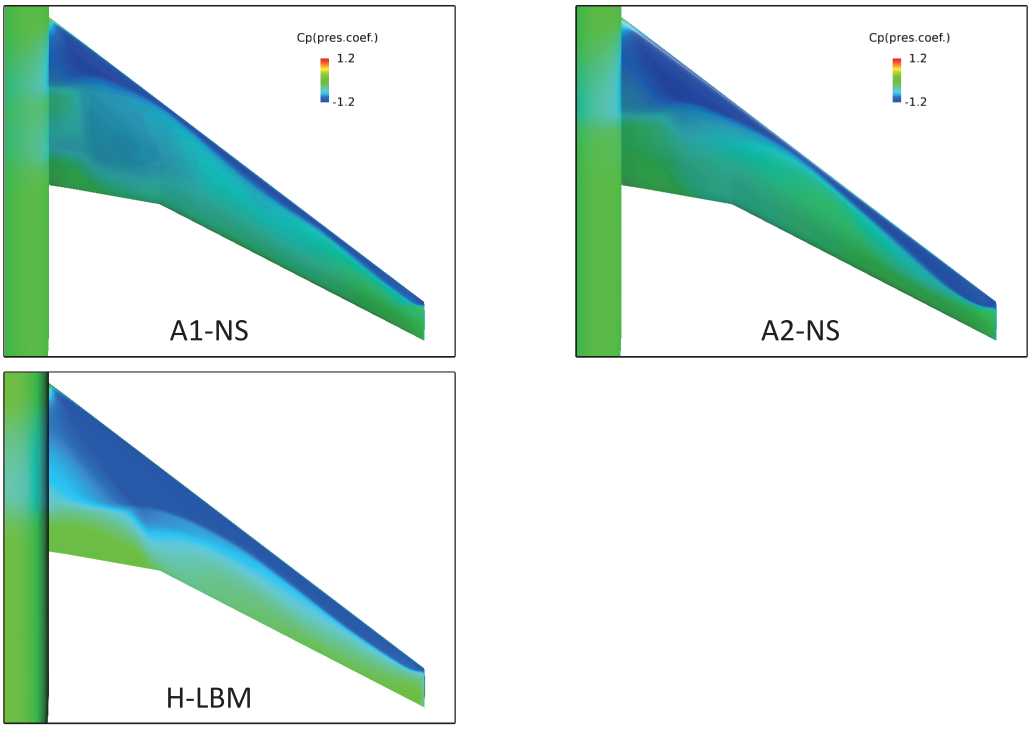
This document is provided by JAXA.

Case 3 : Cp PSD (5.92deg)



119

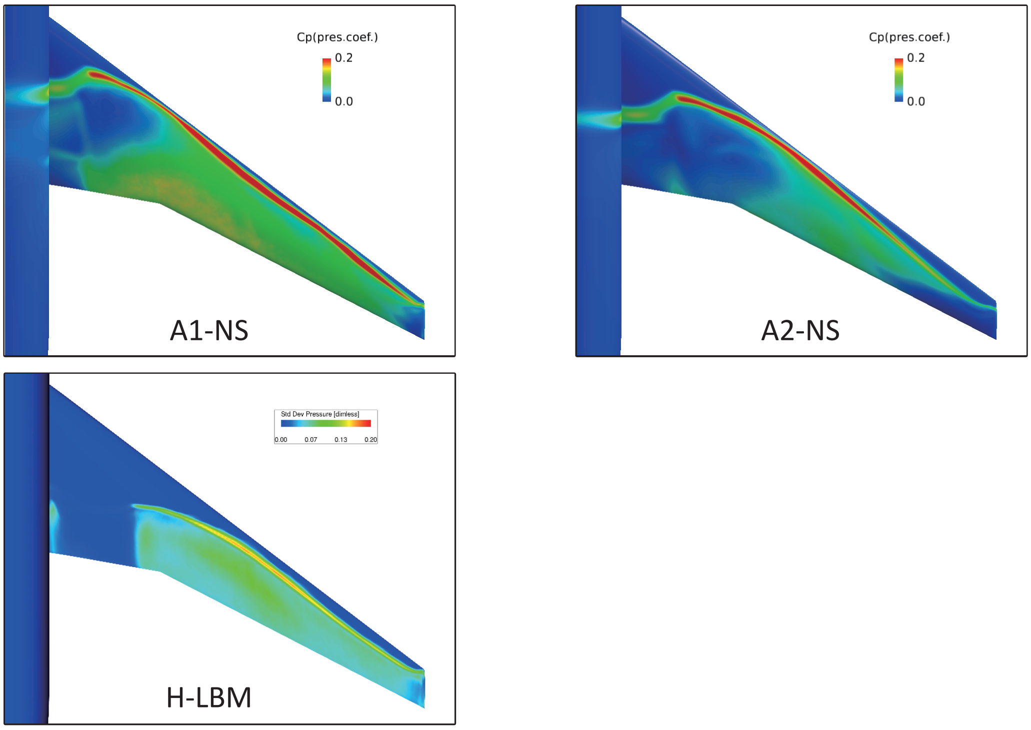
Case 3 : Cp average (α=5.92deg)



120

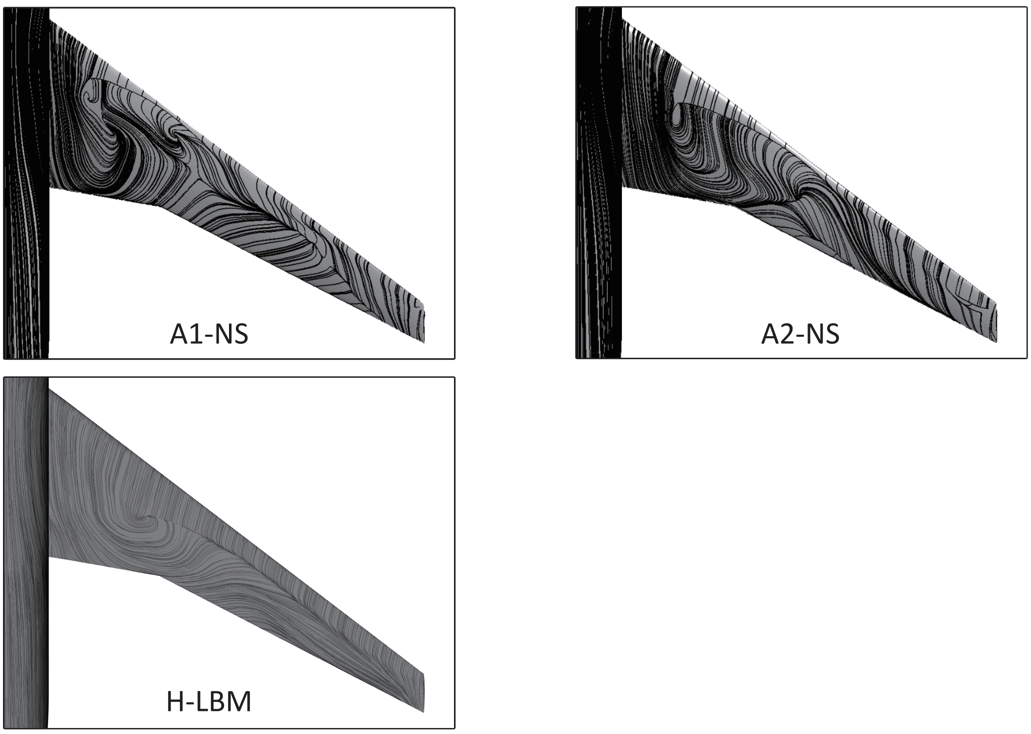
This document is provided by JAXA.

Case 3 : Cp RMS (α=5.92deg)



121

Case 3 : Streamline (α=5.92deg)



122

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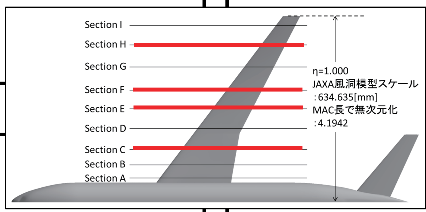
Case 3: Cross sectional contours

We show the cross-sectional contours as follows,

Section C (η=0.28)

Section E (η=0.50)

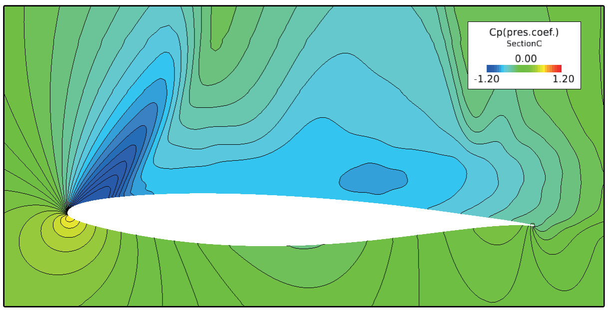


Section F (η=0.60)

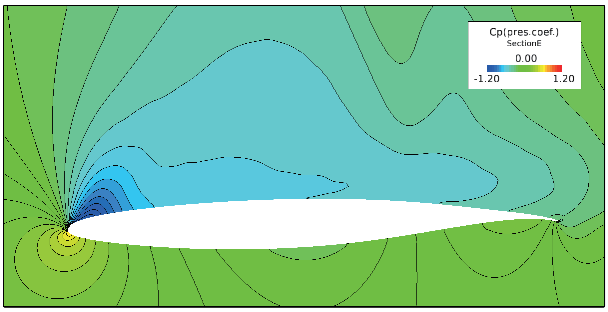
Section H (η=0.85)

Case 3: Cp average (α=5.92deg)

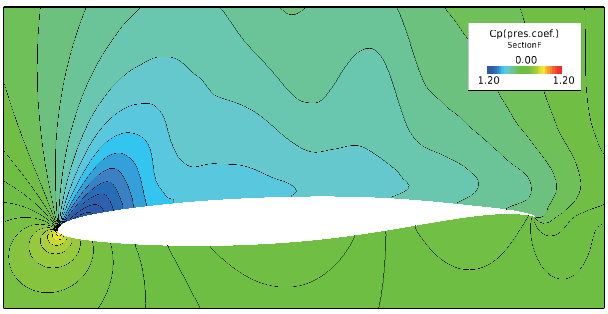
ID : A1



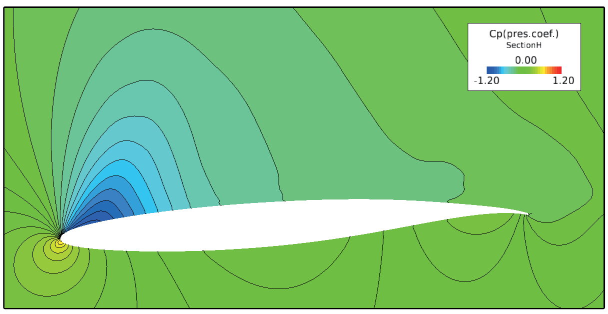
Section C (η=0.28)



Section E (η=0.50)



Section F (η=0.60)

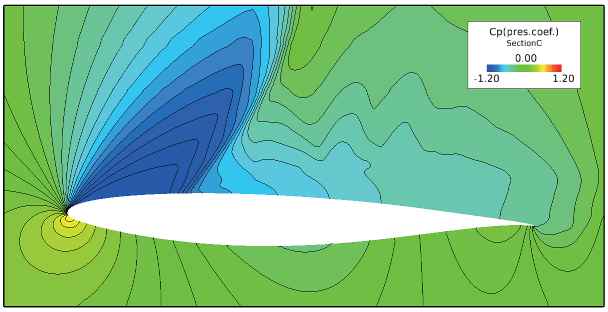


Section H (η=0.85)

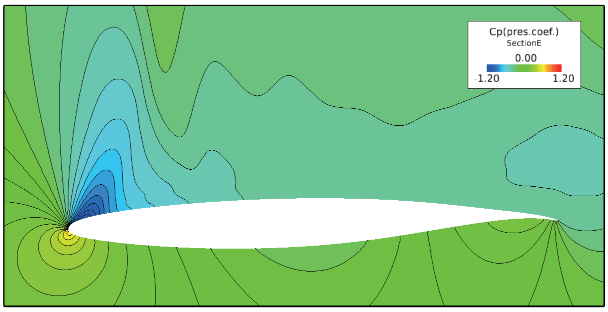
This document is provided by JAXA.

Case 3: Cp average (α=5.92deg)

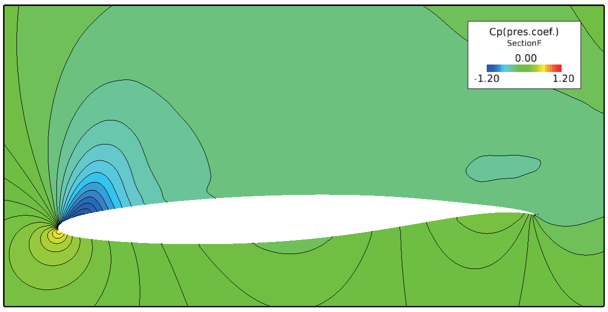
ID : A2



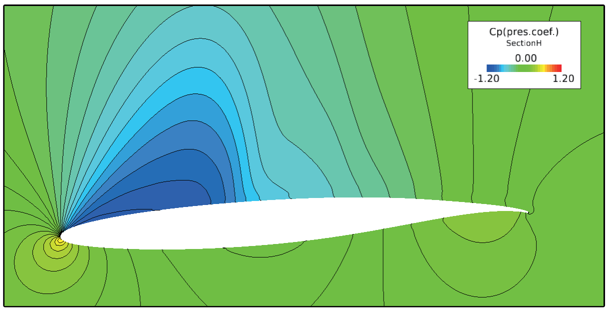
Section C (η=0.28)



Section E (η=0.50)



Section F (η=0.60)



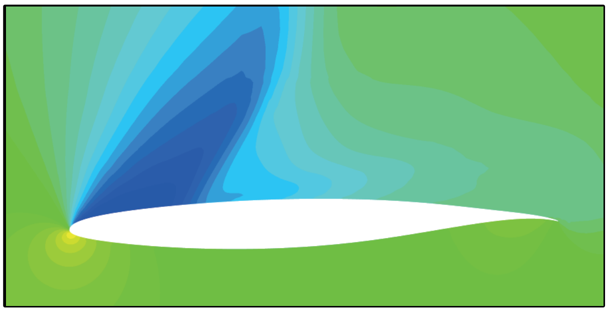
Section H (η=0.85)

125

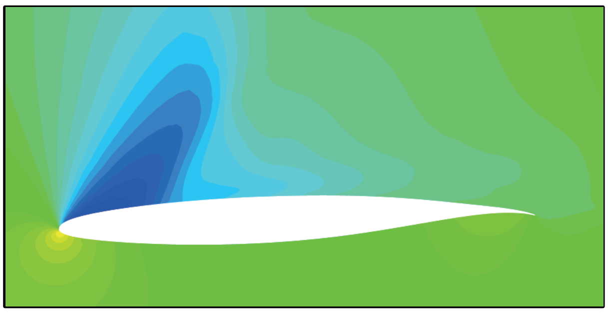
Case 3: Cp average (α=5.92deg)

ID : H

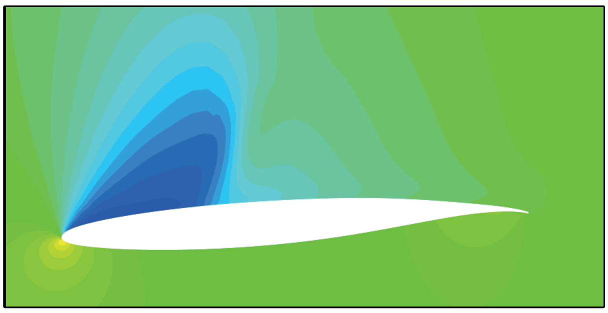
Section C (η=0.28)



Section E (η=0.50)



Section F (η=0.60)



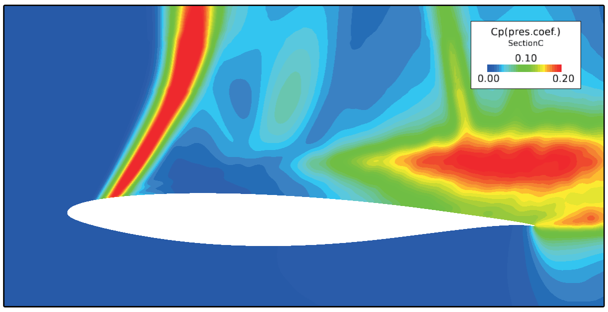
Section H (η=0.85)

126

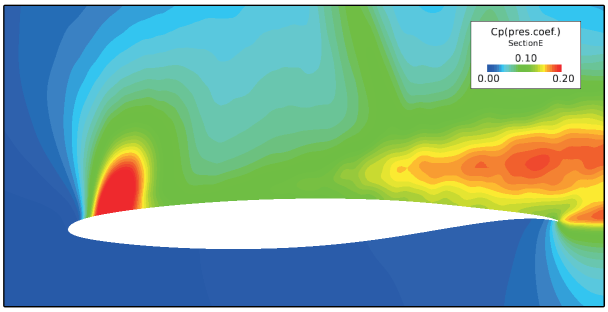
This document is provided by JAXA.

Case 3: Cp RMS (α=5.92deg)

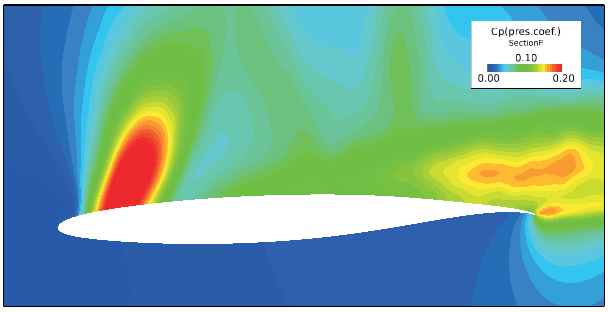
ID : A1



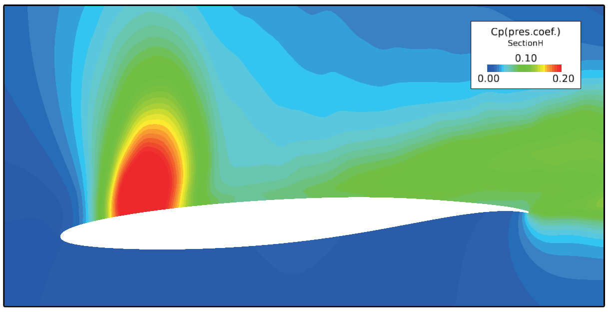
Section C (η=0.28)



Section E (η=0.50)



Section F (η=0.60)

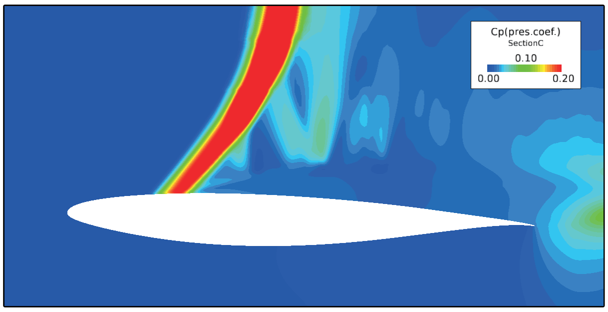


Section H (η=0.85)

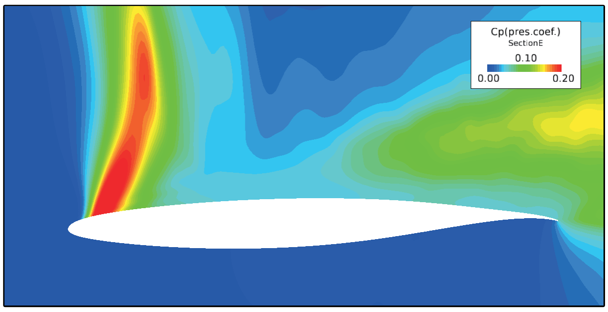
127

Case 3: Cp RMS (α=5.92deg)

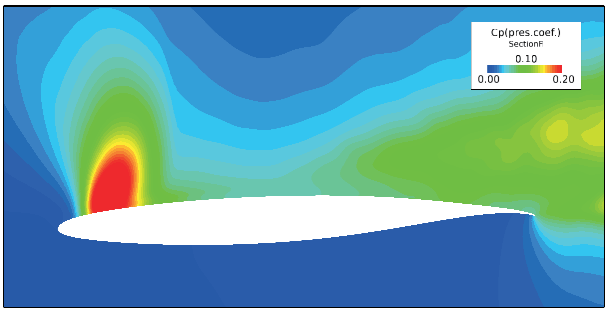
ID : A2



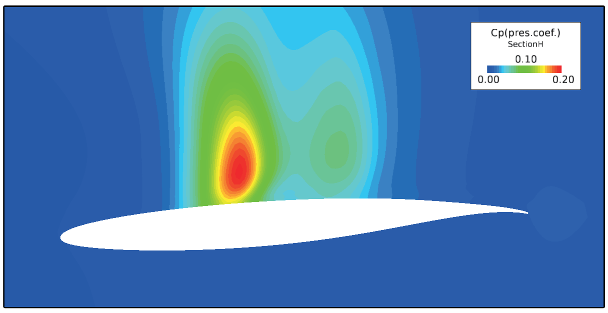
Section C (η=0.28)



Section E (η=0.50)



Section F (η=0.60)



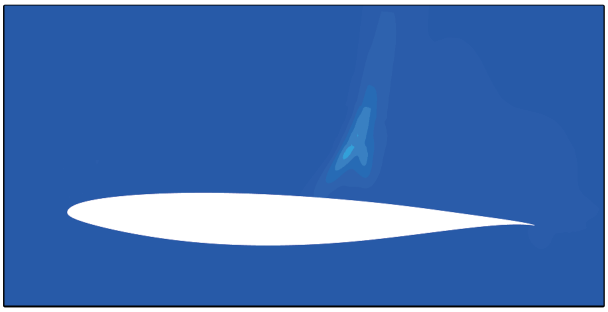
Section H (η=0.85)

128

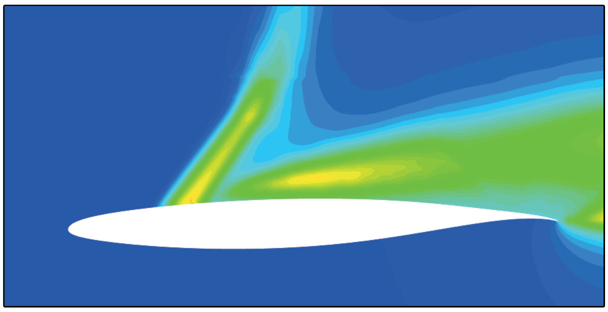
This document is provided by JAXA.

Case 3: Cp RMS (α=5.92deg)

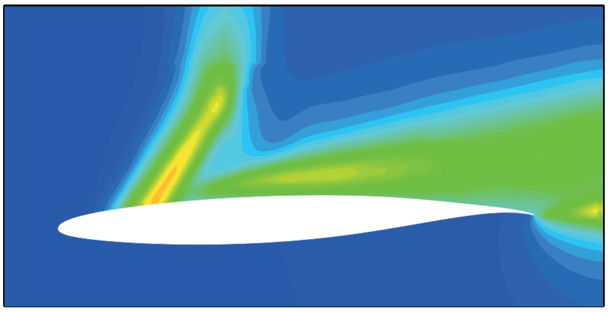
ID : H



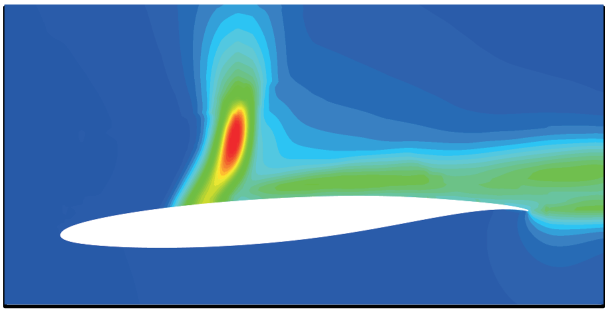
Section C (η=0.28)



Section E (η=0.50)



Section F (η=0.60)

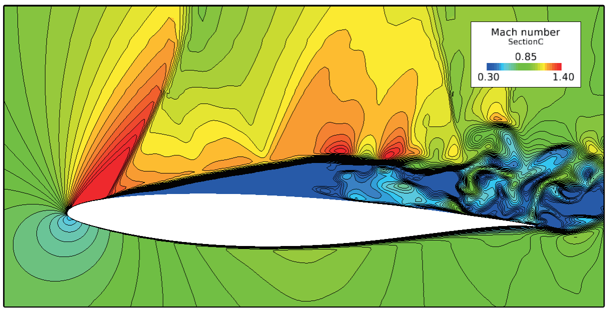


Section H (η=0.85)

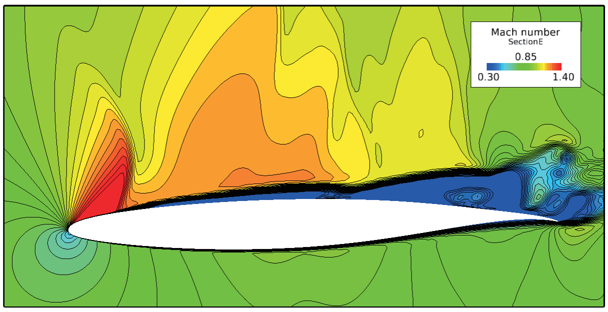
129

Case 3: Mach number (α=5.92deg)

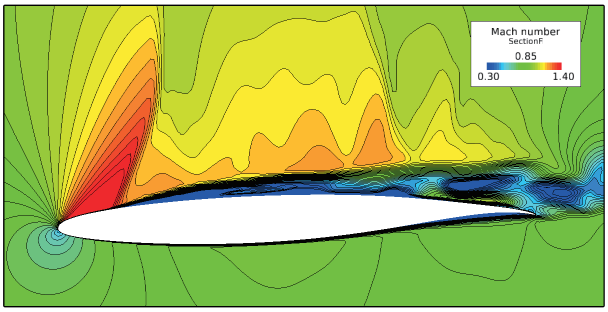
ID : A1



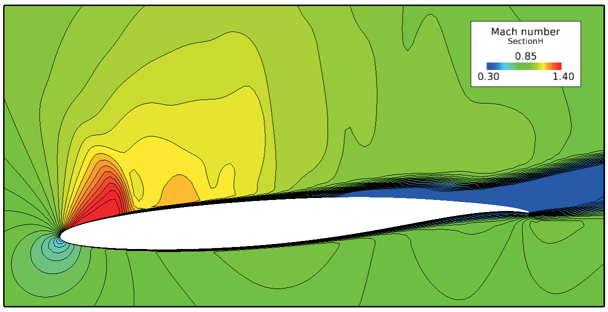
Section C (η=0.28)



Section E (η=0.50)



Section F (η=0.60)



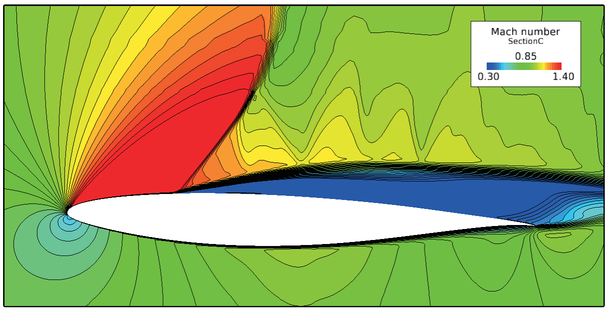
Section H (η=0.85)

130

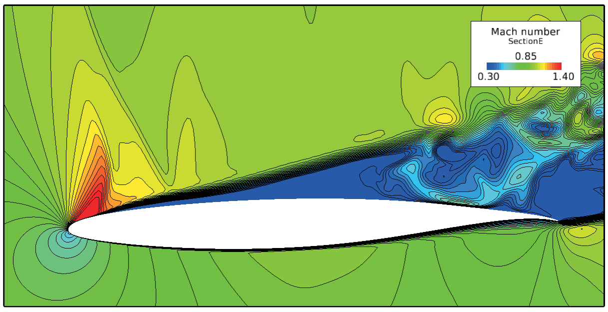
This document is provided by JAXA.

Case 3: Mach number (α=5.92deg)

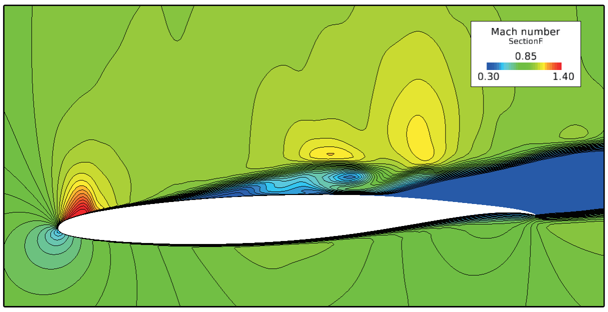
ID : A2



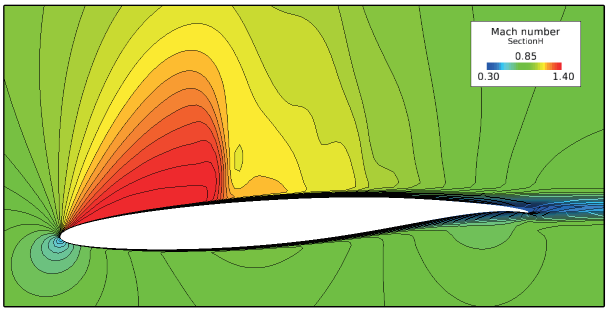
Section C (η=0.28)



Section E (η=0.50)



Section F (η=0.60)

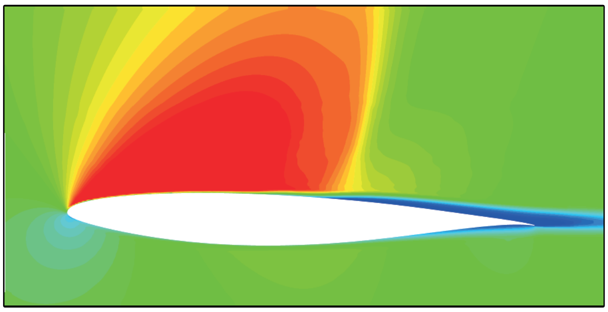


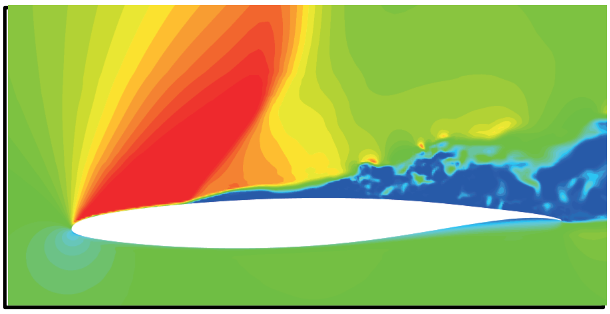
Section H (η=0.85)

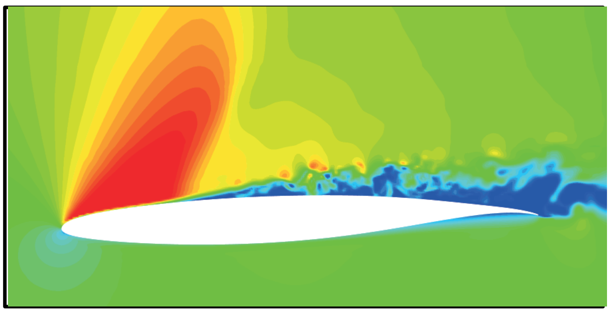
131

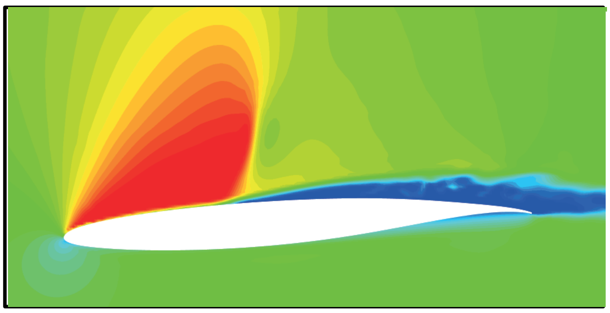
Case 3: Mach number (α=5.92deg)

ID : H


Section C (η=0.28)


Section E (η=0.50)


Section F (η=0.60)

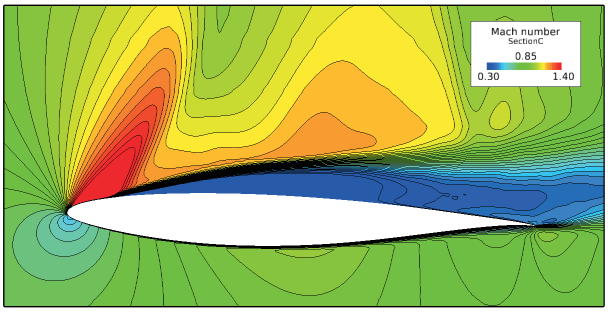

Section H (η=0.85)

132

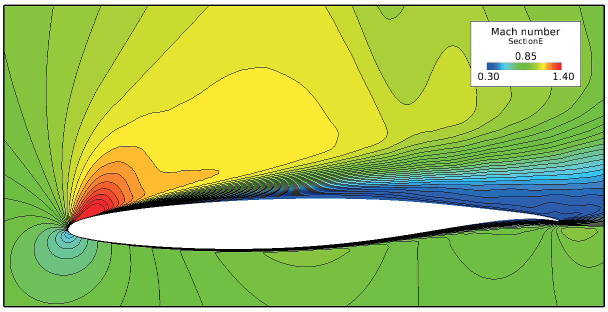
This document is provided by JAXA.

Case 3: Mach number average (α=5.92deg)

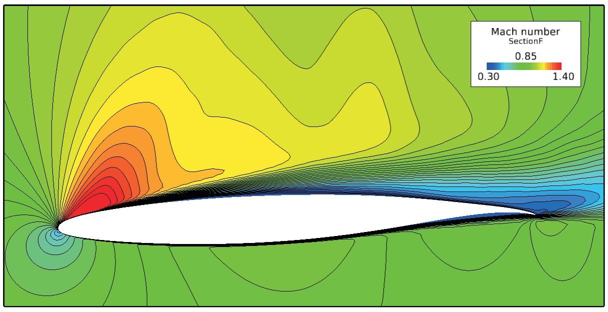
ID : A1



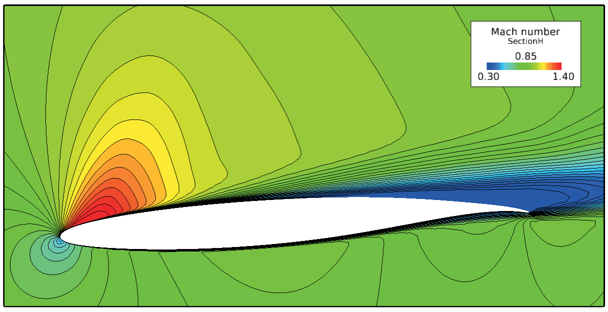
Section C (η=0.28)



Section E (η=0.50)



Section F (η=0.60)

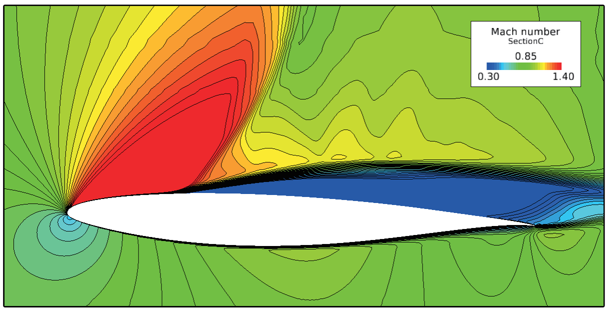


Section H (η=0.85)

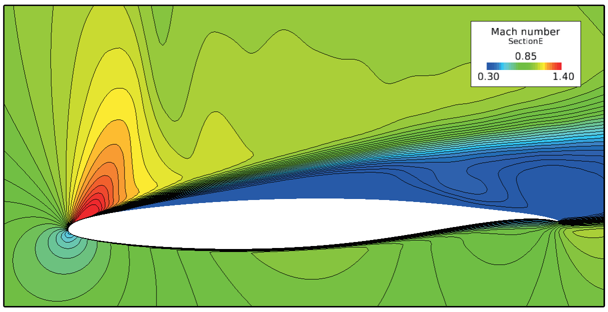
133

Case 3: Mach number average (α=5.92deg)

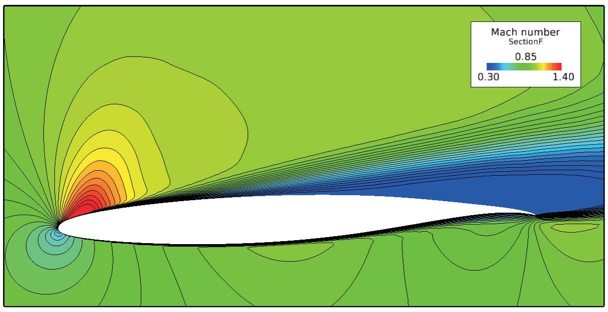
ID : A2



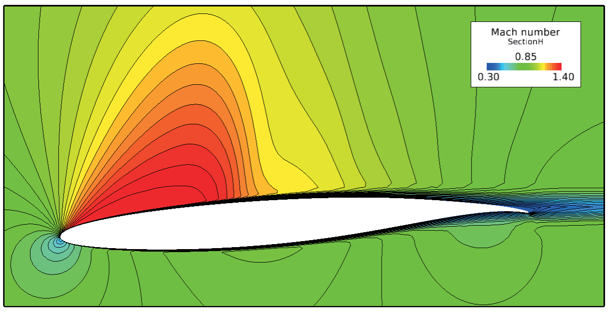
Section C (η=0.28)



Section E (η=0.50)



Section F (η=0.60)



Section H (η=0.85)

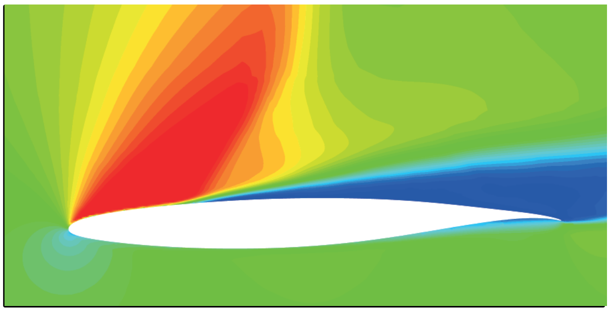
134

This document is provided by JAXA.

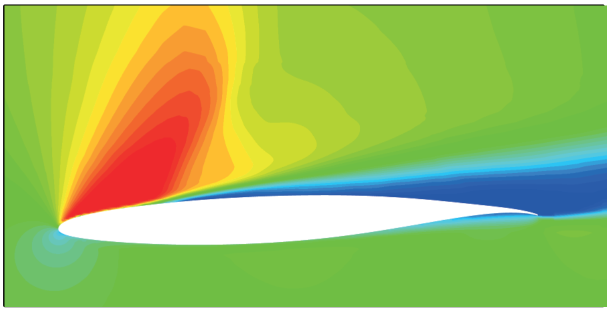
Case 3: Mach number average (α=5.92deg)

ID : H

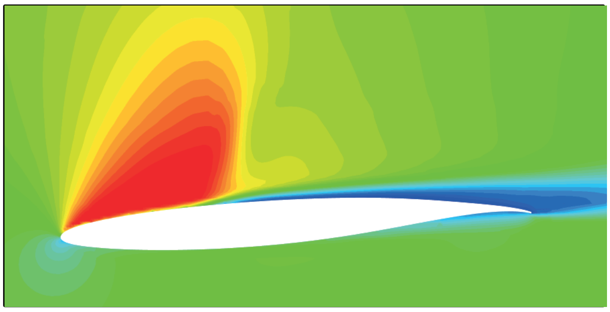
Section C (η=0.28)



Section E (η=0.50)



Section F (η=0.60)

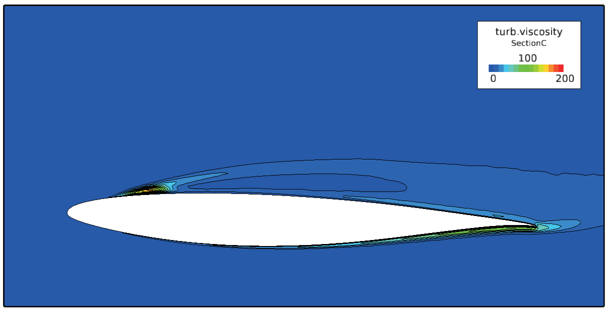


Section H (η=0.85)

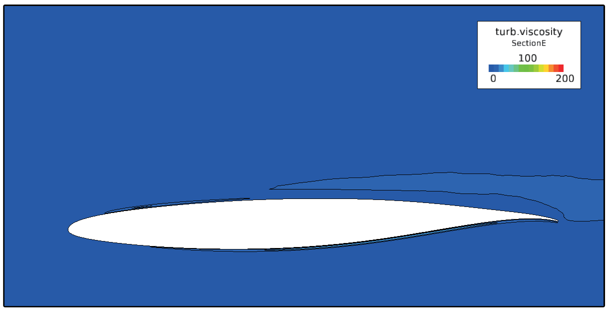
135

Case 3: Eddy viscosity average (α=5.92deg)

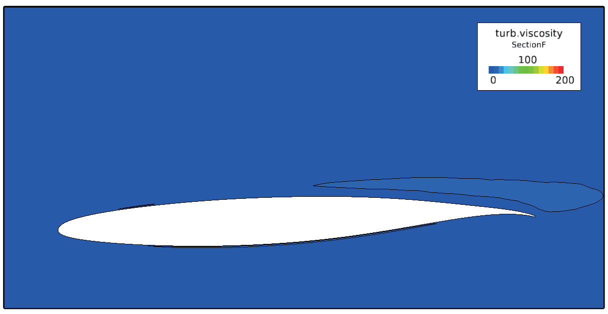
ID : A1



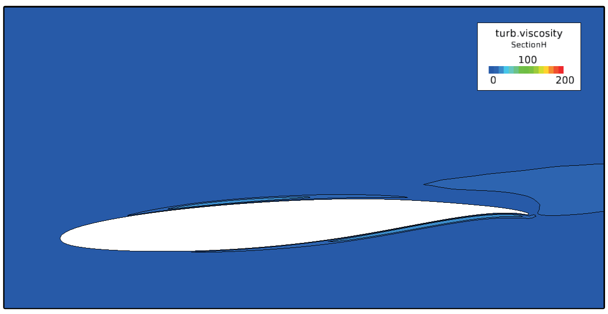
Section C (η=0.28)



Section E (η=0.50)



Section F (η=0.60)



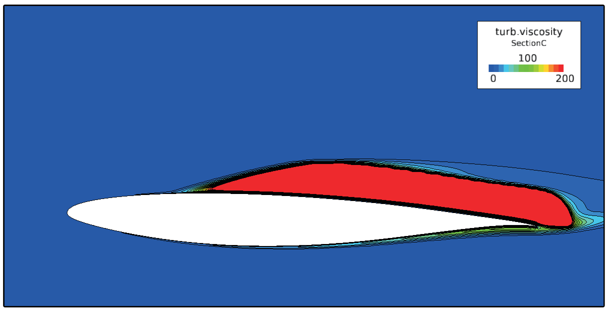
Section H (η=0.85)

136

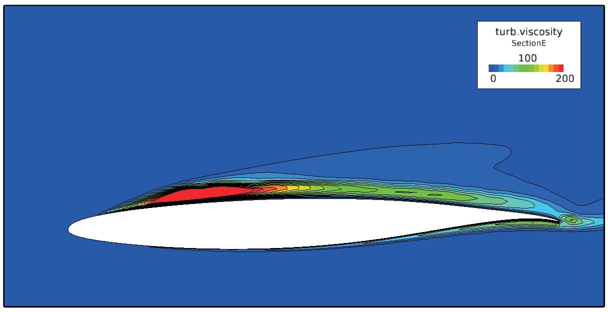
This document is provided by JAXA.

Case 3: Eddy viscosity average (α=5.92deg)

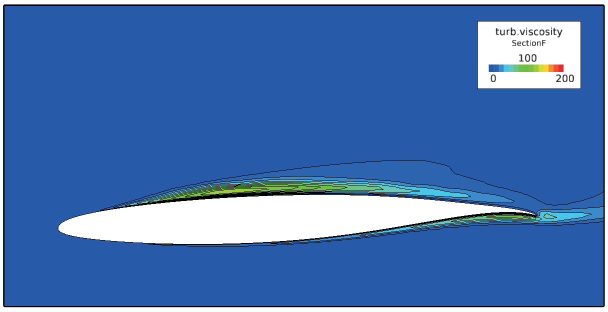
ID : A2



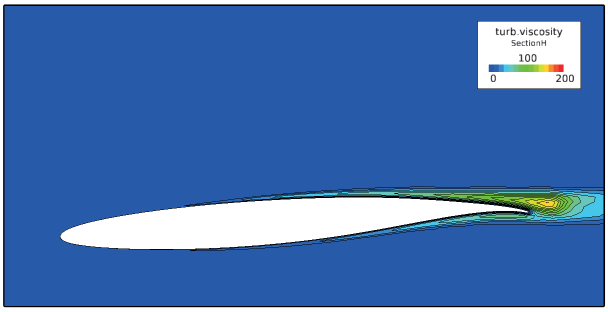
Section C (η=0.28)



Section E (η=0.50)



Section F (η=0.60)

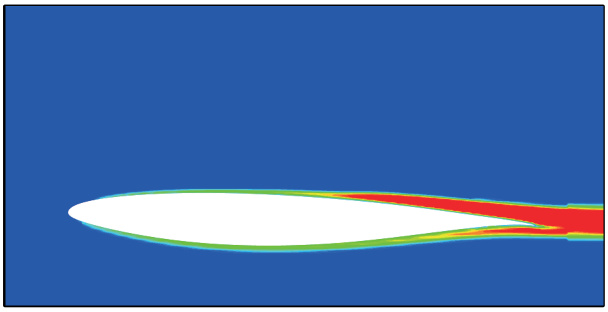


Section H (η=0.85)

137

Case 3: Eddy viscosity average (α=5.92deg)

ID : H



Section C (η=0.28)

Section E (η=0.50)

Section F (η=0.60)

Section H (η=0.85)

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Case 3: Summary

- We collected three submitted data from two groups.
- The prediction of shock wave location is still difficult. (The results are almost same as those of APC-II)
- The PSD is similar to the experiment.
- The resolution of separated flow behind the shock wave is different between the data.
- The eddy viscosity development is different between the data.

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Important days

- Submission of PowerPoint files
  - Deadline: 14 July
  - The slides are published as JAXA-SP
  - Please submit a PowerPoint file (Do not submit a PD). Read-only PowerPoint is also acceptable.

- The 53rd Aircraft Symposium (20-22 November)
  - Organized session "APC-III"

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Acknowledgements

- We would like to thank all participants for submitting data.
- We also would like to thank for the following corporations,
  - Grid generation : Dr. Kazuomi Yamamoto, Dr. Mitsuhiro Murayama, Dr. Yasushi Ito (JAXA), Mr. Kentaro Tanaka (Ryoyu Sysmtems)
  - Grid deformation : Dr. Kanako Yasue (JAXA)
  - Web, Pre/Post processing: Kenji Hayashi, Keiji Ueshima, Takahiro Yamamoto (Ryoyu Systems)
  - Experimental data: Shunsuke Koike (JAXA), Yosuke Sugioka, Taku Nonomura, Keisuke Asai (Tohoku University)

Computational Information

ID	Grid	Turbulence Model	Spec	Core	Time	Memory
A	HexaGrid	SA-noft2-R-QCR2000	SPARC64XIfx(2GHz) (JAXA Supercomputer System generation 2 SORA-MA)	96	3h6m	21.4G
		SST-2003			3h24m	29.7G
		SST-2003-sust			3h36m	29.7G
		SST-2003-sust-QCR2000			4h6m	29.7G
		EARSM			4h48m	29.4G
		EARSM(w/o nonlinear)			3h54m	29.4G
		EARSM-QCR2000 (w/o nonlinear)			4h12m	29.4G
	MEGG3D	SA-noft2-R-QCR2000			2h20m	26.1G
		SST-2003			8h56m	27.4G
		SST-2003-sust			8h56m	27.4G
		SST-2003-sust-QCR2000			11h48m	27.4G
		EARSM			14h6m	27.2G
		EARSM(w/o nonlinear)			13h30m	27.2G
		EARSM-QCR2000 (w/o nonlinear)			15h	27.2G

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Computational Information

ID	Grid	Turbulence Model	Spec	Core	Time	Memory
A	UPACS	SA-noft2-R-QCR2000	SPARC64XIfx(2GHz) (JAXA Supercomputer System generation 2 SORA-MA)	96	1h26m	21.4G
		SST-2003			1h42m	22.4G
		SST-2003-sust			1h54m	22.4G
		SST-2003-sust-QCR2000			2h6m	22.4G
		EARSM			2h24m	22.2G
		EARSM(w/o nonlinear)			2h	22.2G
		EARSM-QCR2000 (w/o nonlinear)			2h6m	22.2G
	Custom (Cartesian based)	SA-noft2-R-QCR2000			3h29m	26.8G
		SST-2003			10h42m	28.3G
		SST-2003-sust			13h6m	28.3G
		SST-2003-sust-QCR2000			13h30m	28.3G
		EARSM			16h18m	28G
		EARSM(w/o nonlinear)			13h	28G
		EARSM-QCR2000 (w/o nonlinear)			14h6m	28G

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Computational Information

ID	Grid	Turbulence Model	Spec	Core	Time	Memory
C	Custom (MEGG3D+BCM)	SA	SGI UV2000	160	168h	18G
D	Custom (Octree Cartesian)	SA-noft2-R-QCR2000	Xeon E5-2695 v4	144	5h20m	60G
E	HexaGrid	SST-2003	Intel Xeon CPU E5-2697 v4 @ 2.30GHz	36	18h30m	27.3G
F	HexaGrid	SST-2003	Intel Xeon E5-2697 v2 (2.7 GHz) (九州大学hakozaki)	384	50h	613G
		SS/SST-2003 Hybrid			50h	613G
I	Custom (polyhedra)	SST	Intel(R) Xeon(R) CPU E5-2697 v3 @ 2.60GHz	28	19h30m	85G
J	HexaGrid	SST	Intel Xeon E5-2695 v4 2.10GHz	144	54m	65.4G
	Custom (polyhedra)				1h12m	76.3G

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Computational Information

ID	Grid	Turbulence Model	Spec	Core	Time	Memory
K ●	UPACS	SA-fv3(Cmat)	Intel E5 - 2697 V2 - 2.60 GHz	96	1h50m	
		SST-2003(Cmat)			39m	
		SSC-EARSM(Cmat)			2h38m	
	MEGG3D	SA-fv3(Cscal)		72	15h28m	
		SA-fv3(Cmat)			4h28m	
		SST-2003(Cscal)			13h18m	
		SST-2003(Cmat)			4h47m	
		SSC-EARSM(Cscal)			15h17m	
		SSC-EARSM(Cmat)			11h38m	
		KE-YS-1993(Cscal)			13h17m	
		KE-YS-1993(Cmat)			11h37m	
		S-BSL-EARSM(Cscal)			11h29m	
L ○	HexaGrid	SST	XEON E5-2650 v4 @ 2.20GHz	24	48h	120G

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