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Ingenuity for life

STAR-CCM+を用いたNASA CRMの空力特性予測
Aerodynamic Prediction of NASA CRM with STAR-CCM+
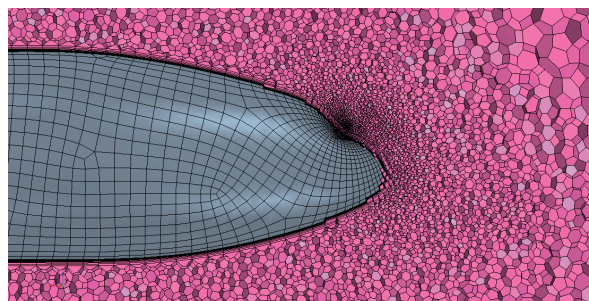
曽我匡統、鈴木竜太、大関昌平、山西伸宏
シーメンスPLMソフトウェア(旧：株式会社CD-adapco)

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Mesh / Solver information

- Case 1

- Solver : STAR-CCM+
  - Mesh type：Polyhedral Mesh
  - Finite Volume Method : Cell centered
  - Inviscid flux : 2nd-order
  - Viscous flux : 2nd-order
  - Turbulence Model : SST k-ω
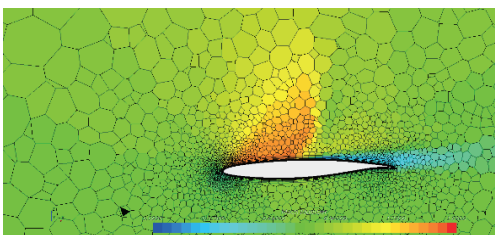
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Solver setting

- CFL : 50

- Grid sequencing initialization technique
  - Maximum grid levels : 5
  - Maximum iterations per level : 250
  - Convergence tolerance per level : 1.0e-4

- Continuity convergence accelerator technique to improve mass conservation
  - Convergence accelerator update frequency : 1
  - Under-relaxation factor : 0.05

- k-ω Turbulence
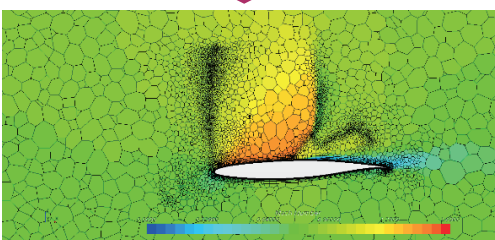 - Under-relaxation factor : 0.8

Page 3　　　　　June. 28. 2017　　　　　　　　　　　　　　　　　　　　　Siemens PLM Software

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Adaptive mesh refinement with polyhedral mesh

Refinement

Table-based mesh refinement implemented in STAR-CCM+ is used for AMR
We carried out the refinement twice to obtain the convergent solutions

Residual history

1st　　　2nd　　　Converged solution

Page 4　　　　　June. 28. 2017　　　　　　　　　　　　　　　　　　　　　Siemens PLM Software

Adaptive mesh refinement with polyhedral mesh

Variables used for mesh refinement criteria in
a custom field function are:

- Gradient of pressure coefficient
- Range of Mach number

Defined field function

If {WD} > 0.2 then   x = 2.5/14*{WD} + c0
Else if |grad(Cp)| > 100 or (M > 0.99 and M < 1.01) and {WD} < 0.1 then   x = c1
Else if |grad(Cp)| > 50 or (M > 0.97 and M < 1.03) and {WD} < 0.1 then   x = c2
Else if |grad(Cp)| > 20 or (M > 0.95 and M < 1.05) and {WD} < 0.1 then   x = c3
Else if |grad(Cp)| > 15 or (M > 0.93 and M < 1.1) and {WD} < 0.1 then   x = c4
Else if |grad(Cp)| > 10 or (M > 0.91 and M < 1.2) and {WD} < 0.1 then   x = c5
x: Cell size, Cp: Pressure coefficient, WD: Wall distance
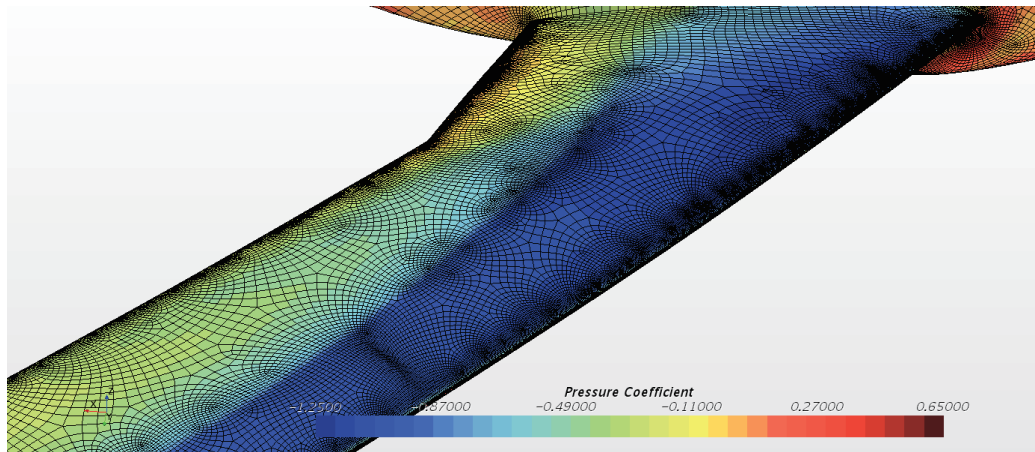c0 = 0.012, c1 = 5.0e-4, c2 = 0.001, c3 = 0.002, c4 = 0.004, c5 = 0.008
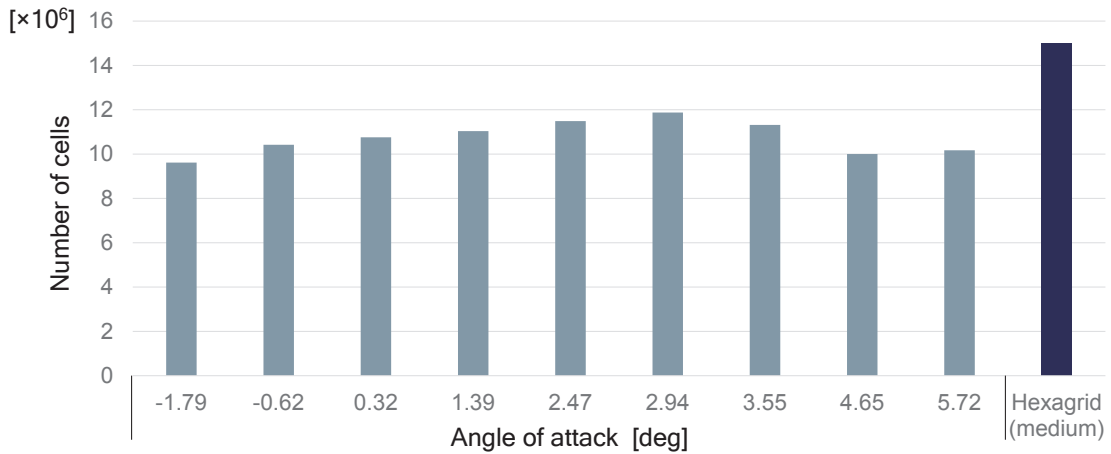
Cell size distribution at Section E

Cell size [m]

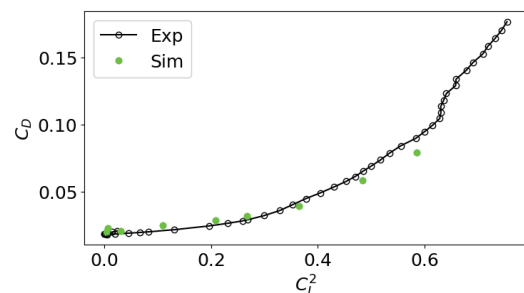0   0.015
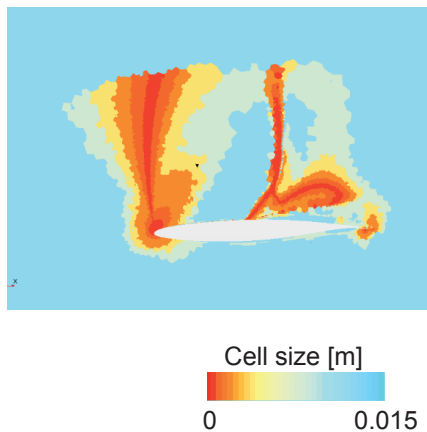
Surface mesh adequately resolved to capture shock

C_p distribution and mesh on the wing

Pressure Coefficient
-1.2500   -0.87000   -0.49000   -0.11000   0.27000   0.65000

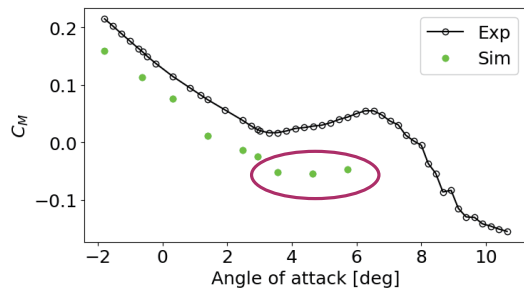## The numbers of cells used for calculation are approximately 10 million

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AoA sweeps
C_M prediction deviates at high angle of attack

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M Software

Pressure coefficient distributions on the wings

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AoA = -1.79 deg

AoA = 3.55 deg

AoA = 0.32 deg

AoA = 5.72 deg

AoA = 2.47 deg

Pressure Coefficient

-1.4   1.2

Page 9   June. 28. 2017   Siemens PLM Software
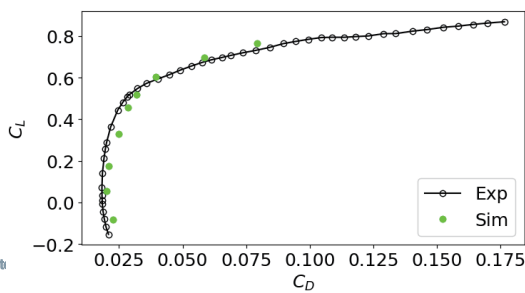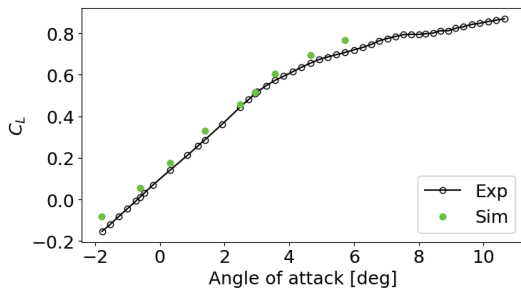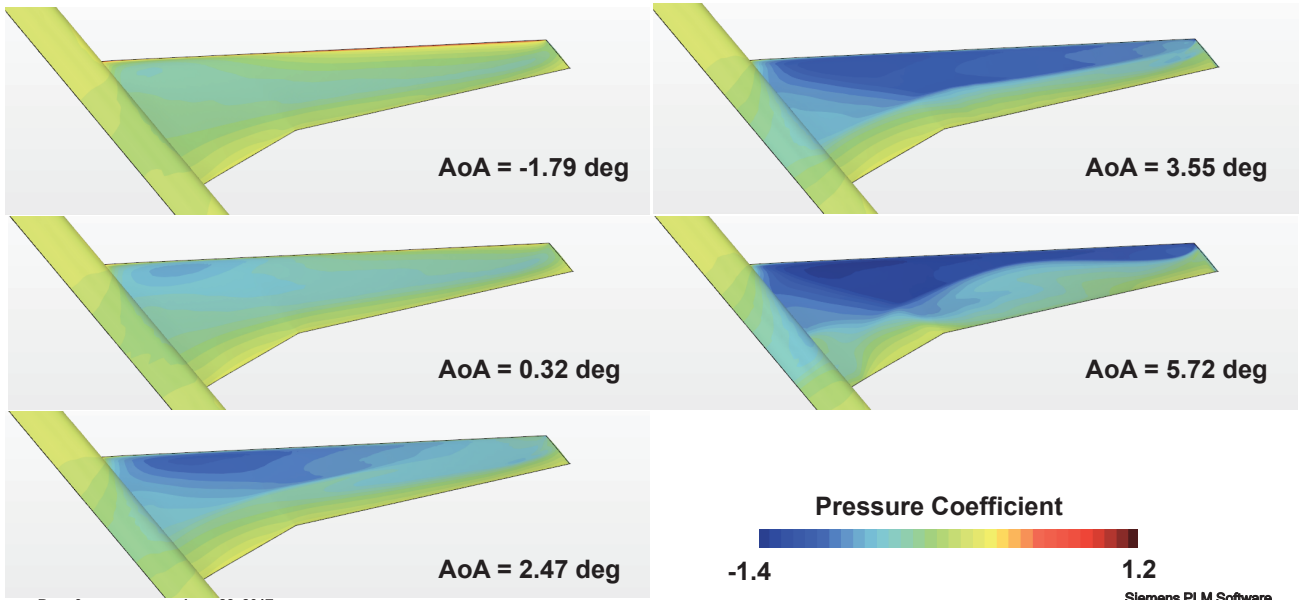
The location of the shock wave does not match with the experiment at Section D, E, and G

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C_p distributions (AoA = 5.72 deg)

C_p

-1.25   0.65

x/c

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Page 10   June. 28. 2017   Siemens PLM Software
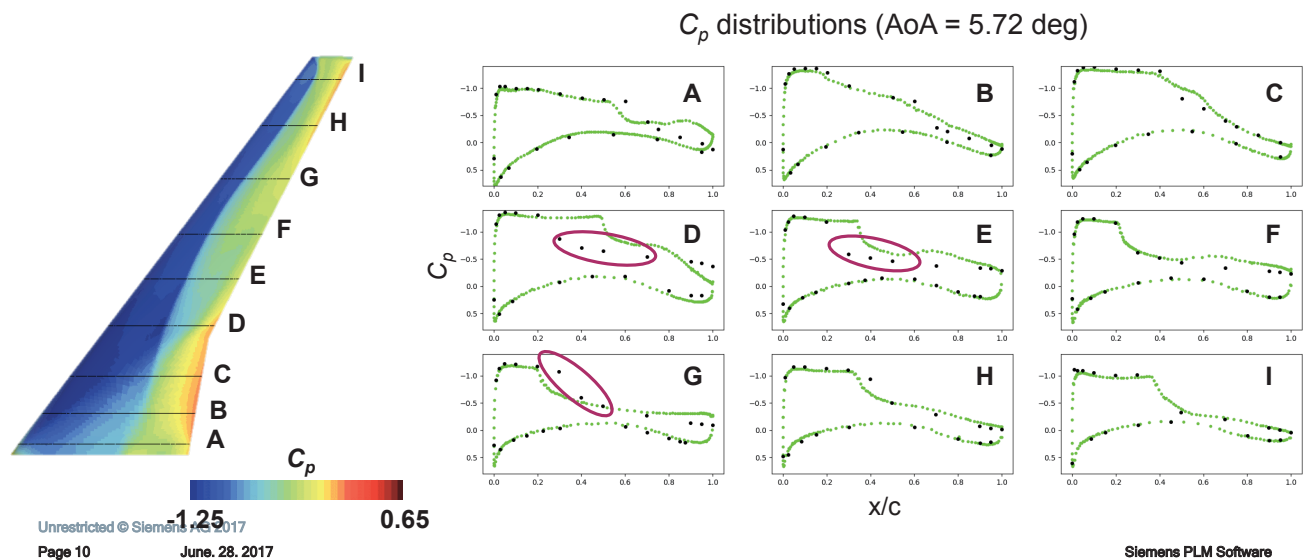
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Points of improvement

- Modify the mesh refinement criterion

- Refine the leading edge

- Switch from polyhedral mesh to trimmed mesh

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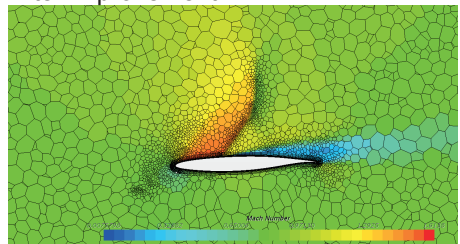## Reduction of number of cells by modifying the mesh refinement criterion

The variables for the refinement has been changed to

- Gradient of pressure coefficient

- **Gradient of Mach number**

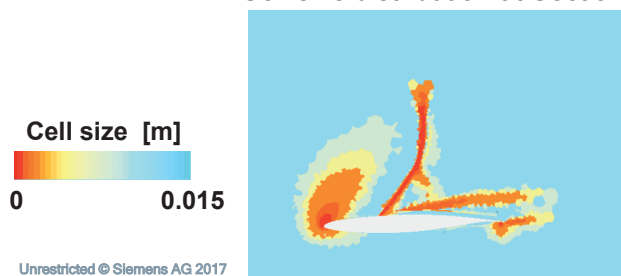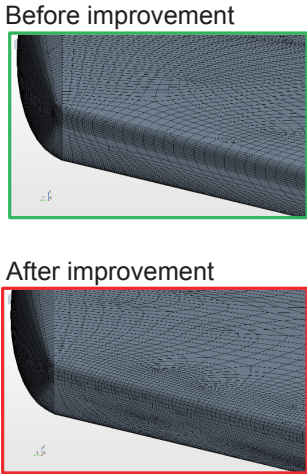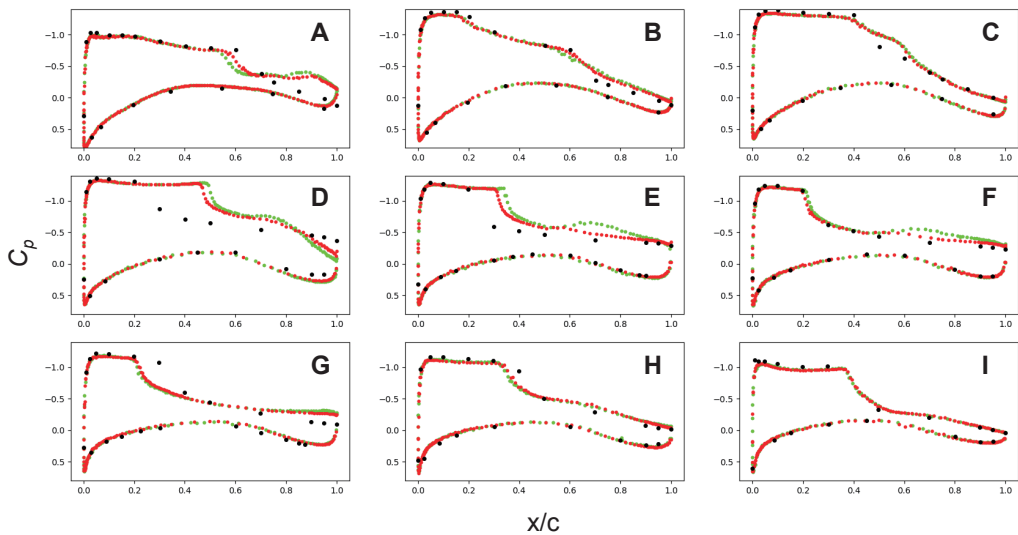Before improvement

Cell size distribution at Section E

Cell size [m]

0   0.015
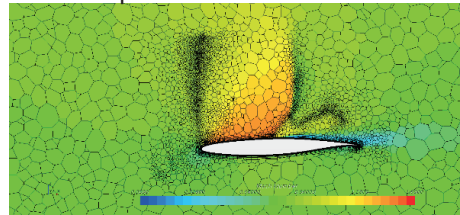
After improvement

C_p distribution improved by refining the leading edge (AoA = 5.72 deg)

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Before improvement

After improvement

Trimmed mesh with AMR

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Polyhedral mesh with AMR　　　　　　Trimmed mesh with AMR
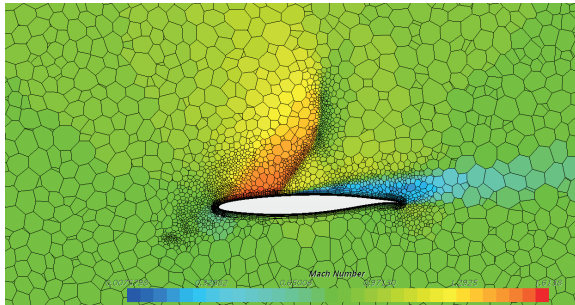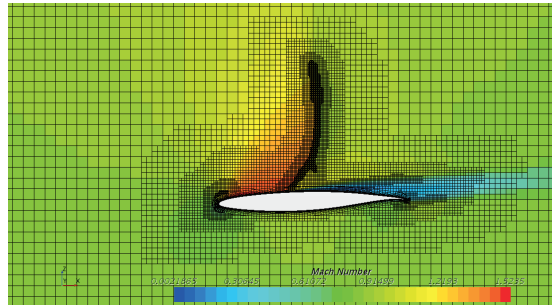
AoA sweep improved by using trimmed mesh
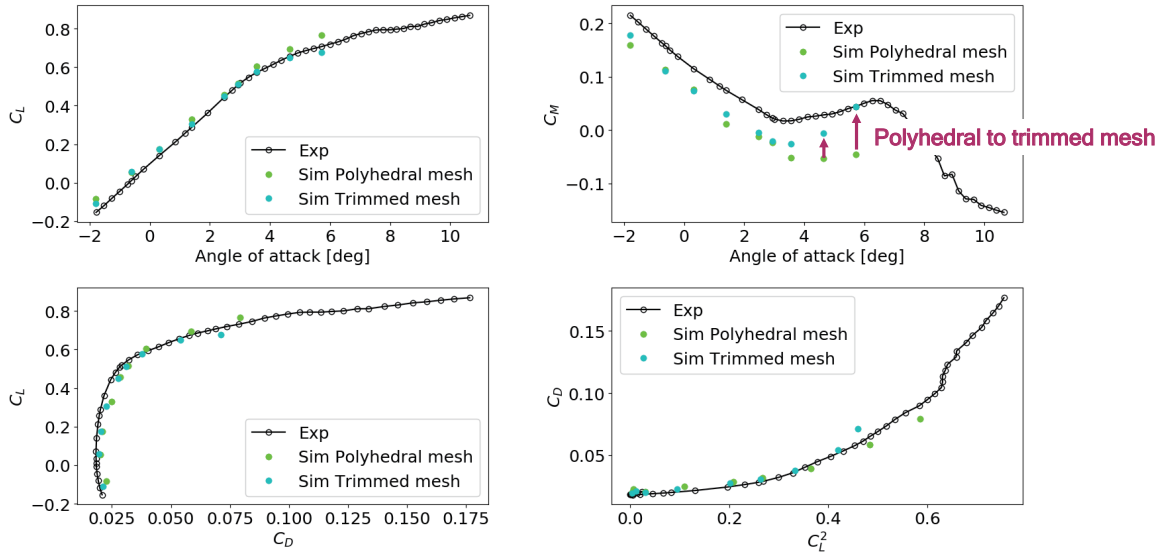
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Significantly improved predictions of C_p profiles on trimmed mesh (AoA = 5.72 deg)
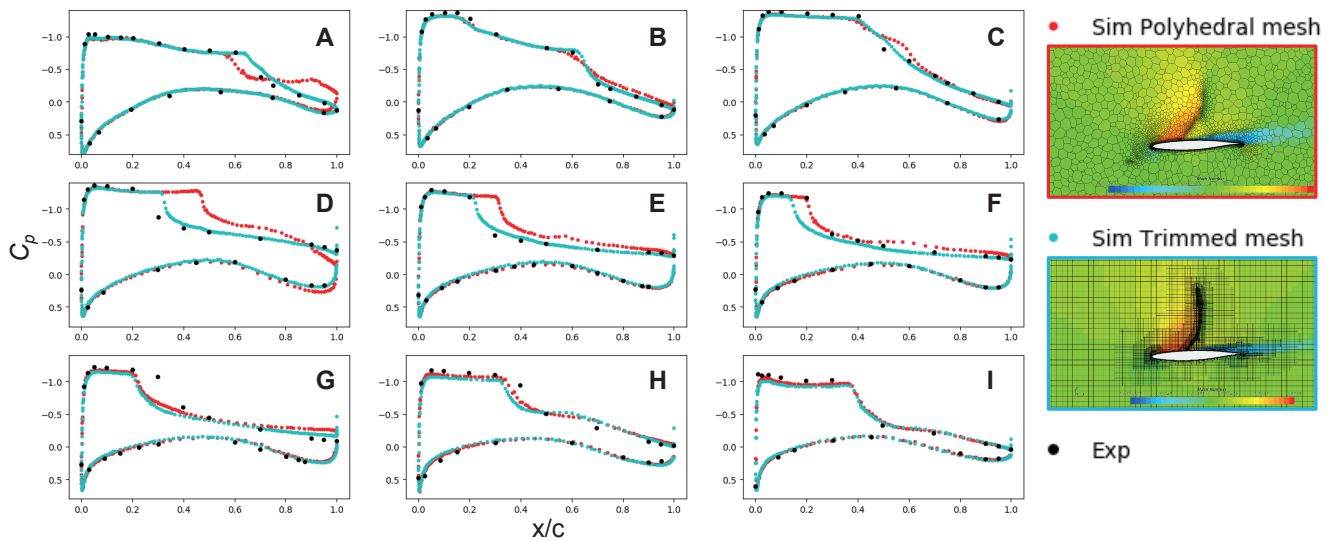
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Comparison of turbulence models (AoA = 5.72deg)
Good agreement of SST k-ω result with the experiment

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Trimmed Mesh
- Sim Spalart-Allmaras
- Sim Standard $k - \varepsilon$
- Sim SST $k - \omega$
- Exp
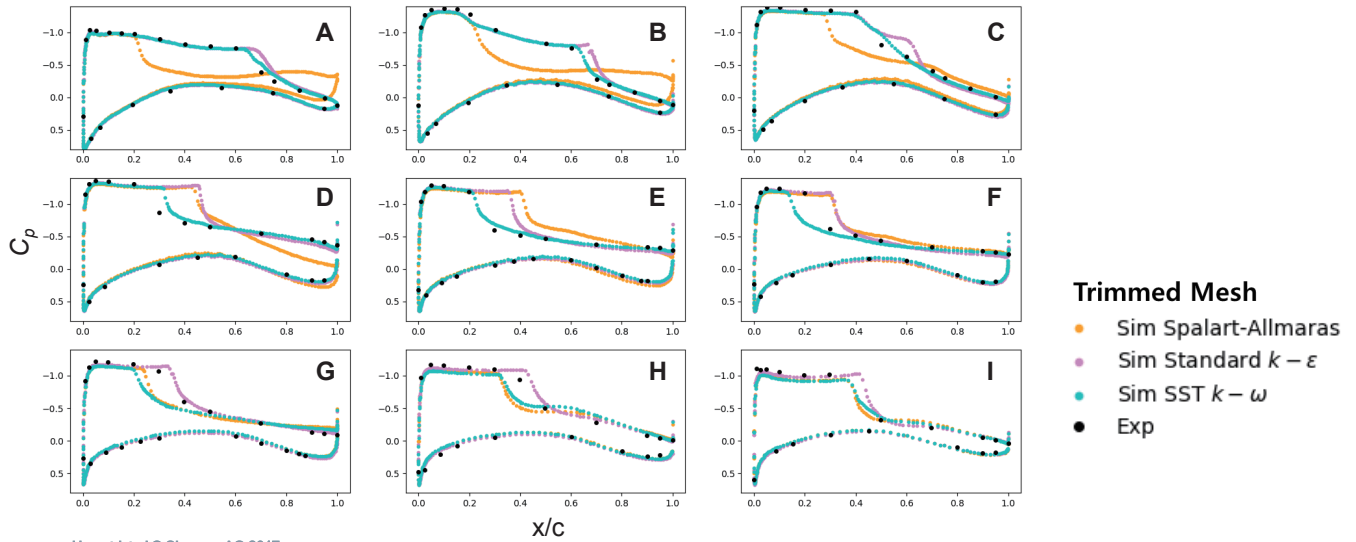
- We carried out the calculations with polyhedral mesh and AMR

- C_D and C_L predictions agreed with the experimental results

- C_M prediction deviates at high angle of attack

- Resolving the leading edges provided better results

- Prediction significantly improved with trimmed mesh

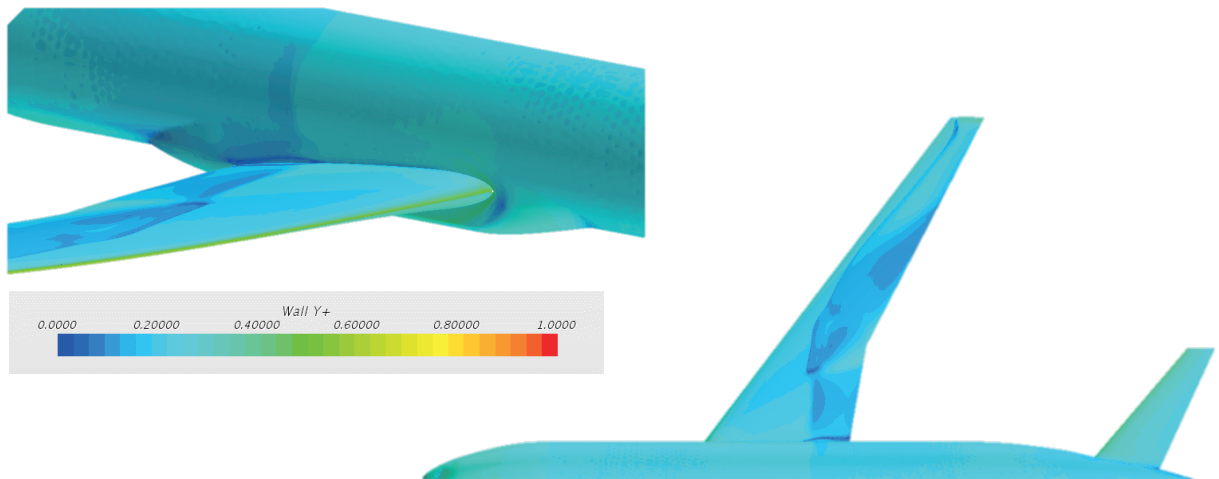- SST k-ω turbulence model provided better results than other models
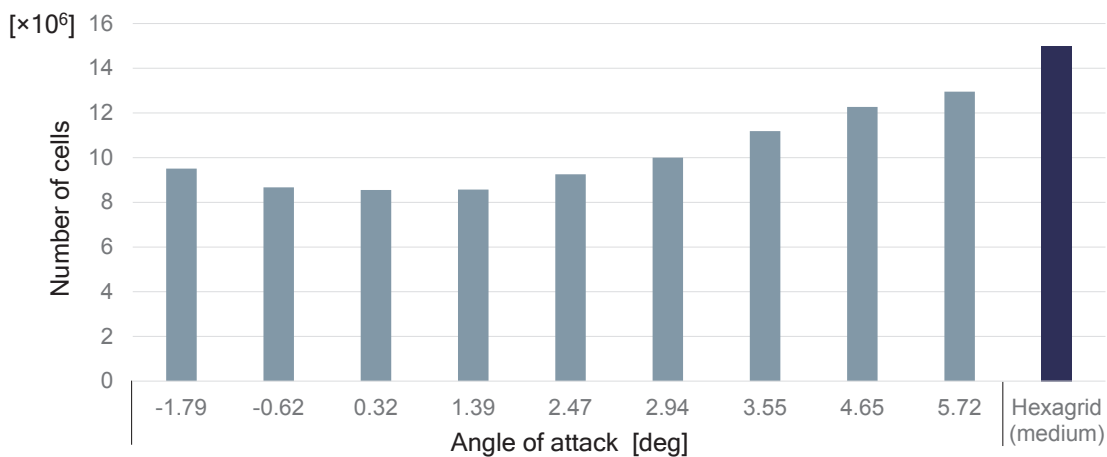
Appendix

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Realize innovation.

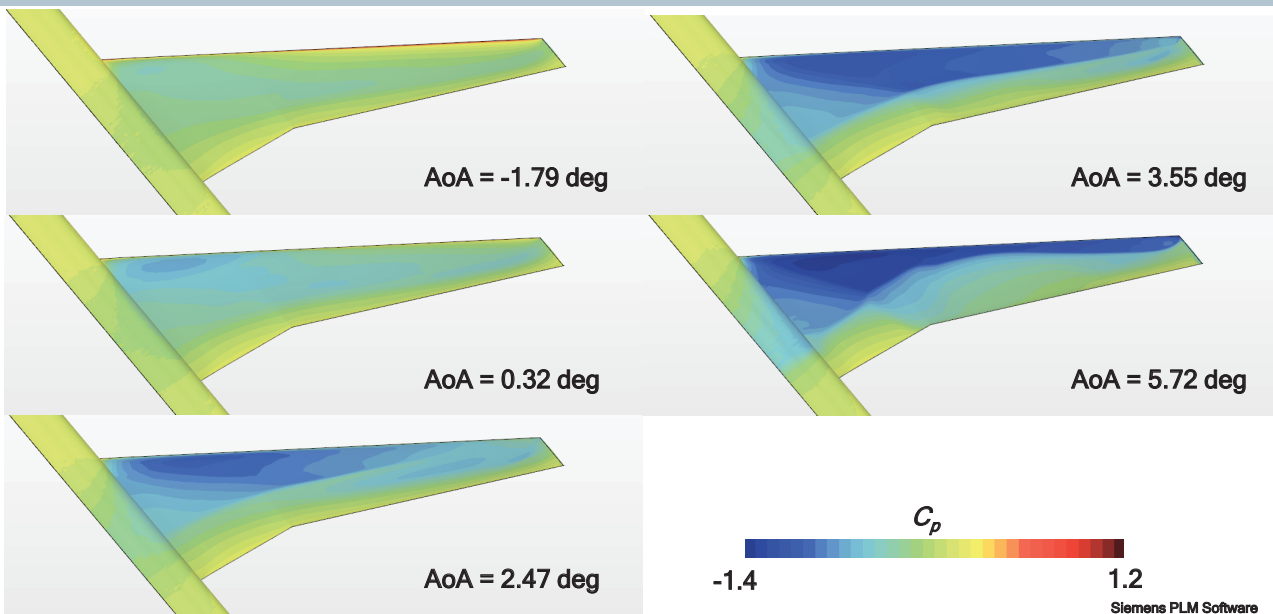**Wall Y+ distribution calculated with trimmed mesh (AoA = 5.72 deg)**

Number of cells generated with trimmed mesh and AMR
Cell counts increases as the angle of attack gets higher

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Page 21   June. 28. 2017   Siemens PLM Software
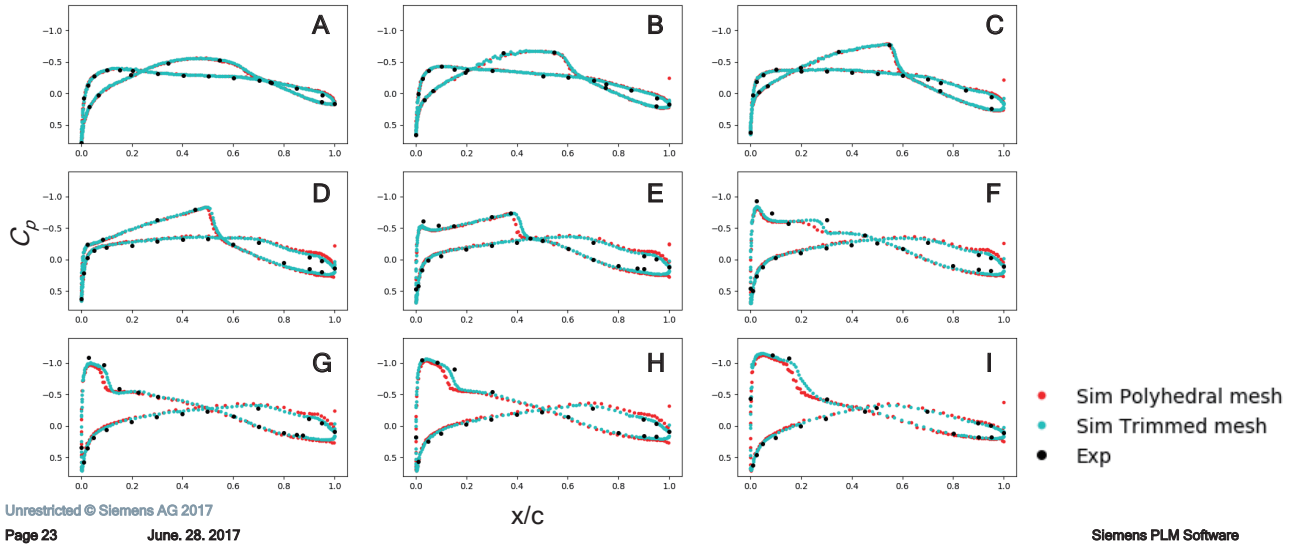
Pressure coefficient distributions on the wings
trimmed mesh

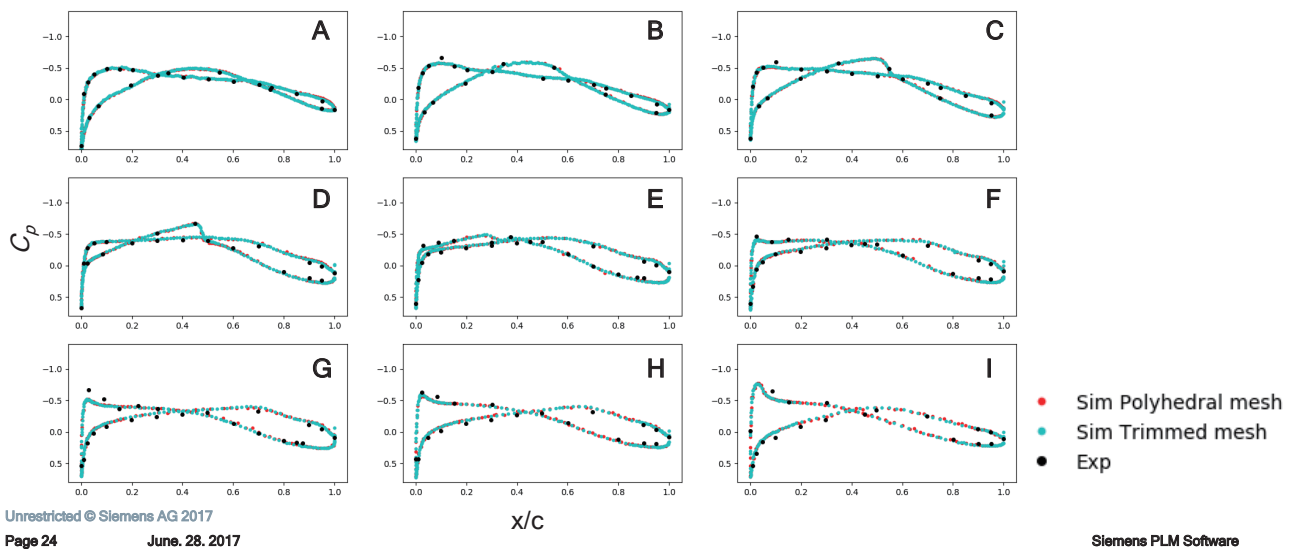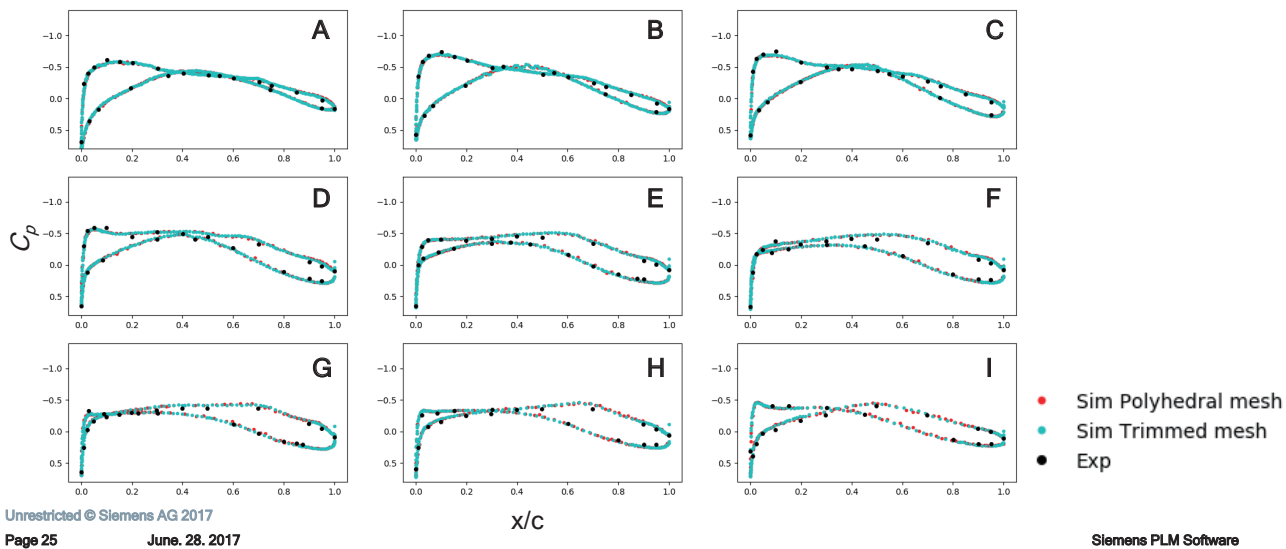**SIEMENS**

AoA = -1.79 deg

AoA = 3.55 deg

AoA = 0.32 deg

AoA = 5.72 deg

AoA = 2.47 deg

C_p

-1.4   1.2

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Comparison of C_p calculated with polyhedral / trimmed mesh at each section (AoA = -1.79 deg)

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- Sim Polyhedral mesh
- Sim Trimmed mesh
- Exp

Page 23　　　　June. 28. 2017　　　　　　　　　　　　　　　　　　　　Siemens PLM Software

Comparison of C_p calculated with polyhedral / trimmed mesh at each section (AoA = -0.62 deg)

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- Sim Polyhedral mesh
- Sim Trimmed mesh
- Exp

Page 24　　　　June. 28. 2017　　　　　　　　　　　　　　　　　　　　Siemens PLM Software

Comparison of C_p calculated with polyhedral / trimmed mesh at each section (AoA = 0.32 deg)

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Sim Polyhedral mesh
Sim Trimmed mesh
Exp

Comparison of C_p calculated with polyhedral / trimmed mesh at each section (AoA = 1.39 deg)

SIEMENS

Sim Polyhedral mesh
Sim Trimmed mesh
Exp

Comparison of C_p calculated with polyhedral / trimmed mesh at each section (AoA = 2.47 deg)

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Sim Polyhedral mesh
Sim Trimmed mesh
Exp

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Page 27　　　June. 28. 2017

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Comparison of C_p calculated with polyhedral / trimmed mesh at each section (AoA = 2.94 deg)

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Sim Polyhedral mesh
Sim Trimmed mesh
Exp

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Page 28　　　June. 28. 2017

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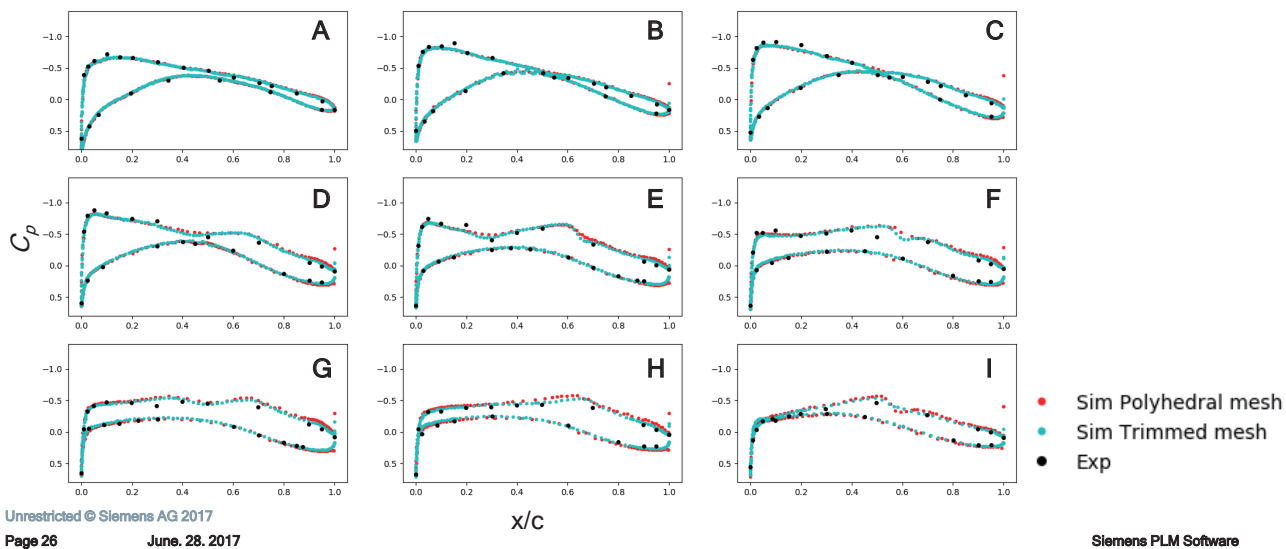
Comparison of C_p calculated with polyhedral / trimmed mesh at each section (AoA = 3.55 deg)
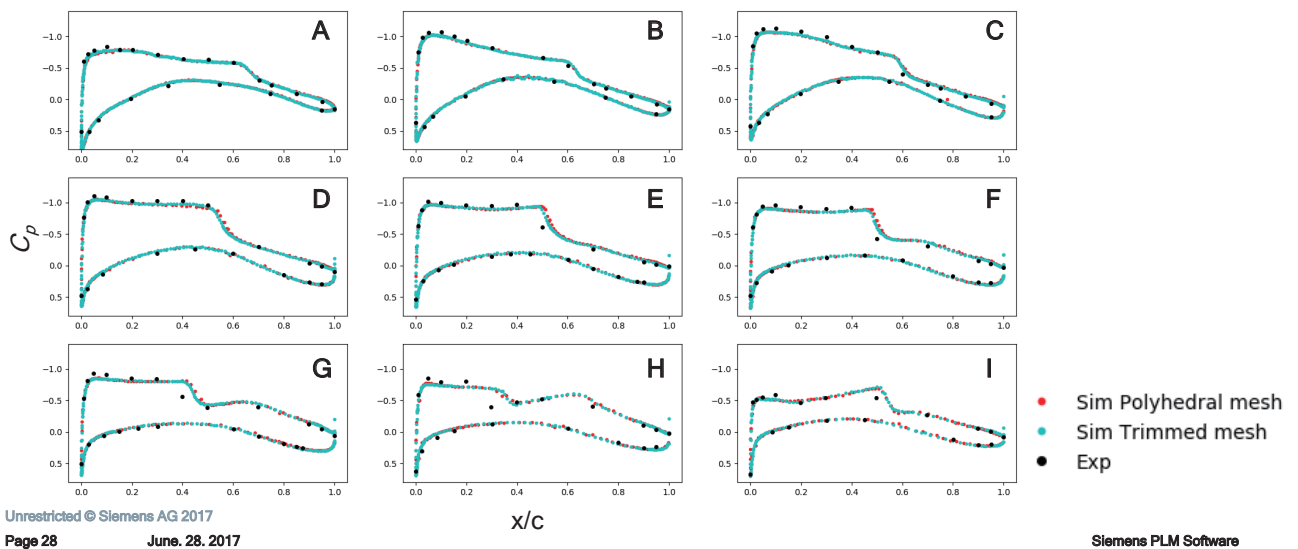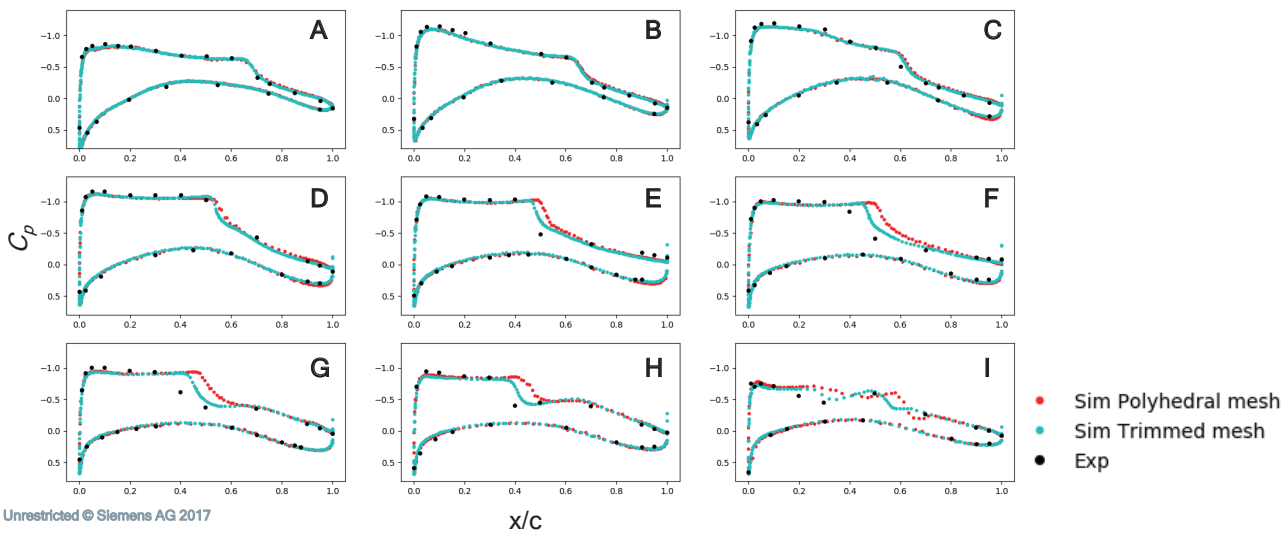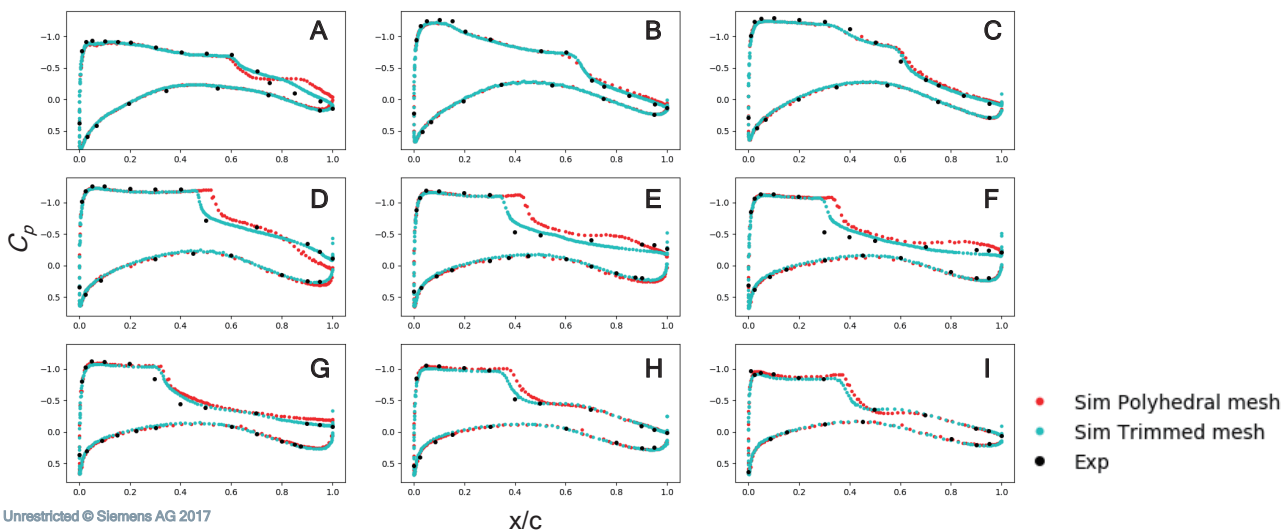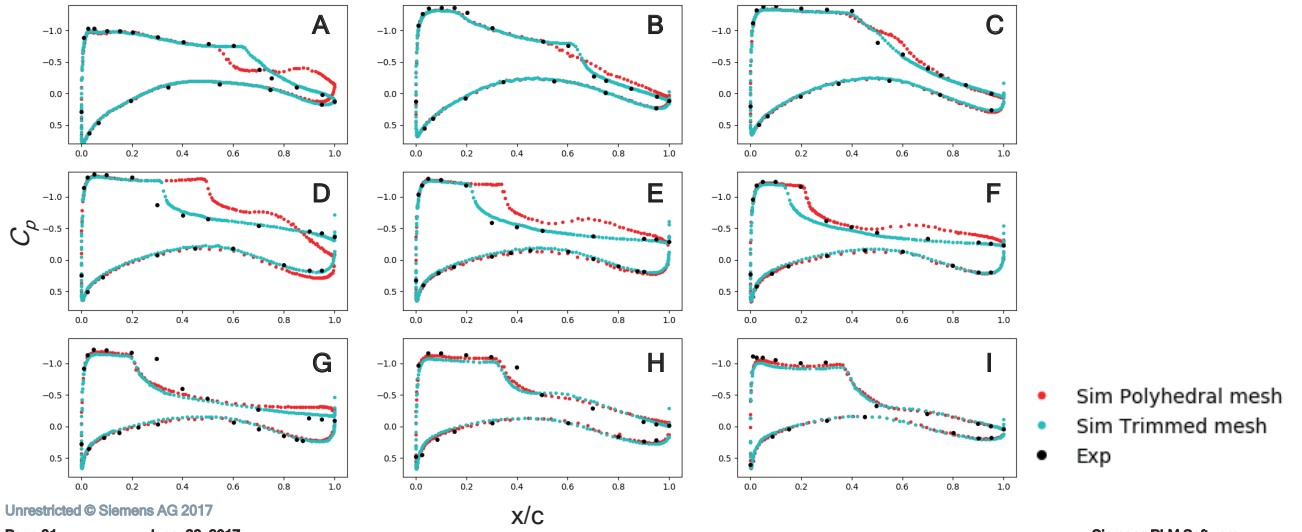
Comparison of C_p calculated with polyhedral / trimmed mesh at each section (AoA = 4.65 deg)

Comparison of C_p calculated with polyhedral / trimmed mesh at each section (AoA = 5.72 deg)

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Sim Polyhedral mesh
Sim Trimmed mesh
Exp

C_p

x/c

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