DLR Contribution to the first High Lift Prediction Workshop
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• Motivation

• DLR Grid Generation Contributions
  - SOLAR hybrid unstructured grid family
  - CENTAUR hybrid unstructured grid family (incomplete)

• CFD solutions for the Trap Wing configuration, case 1
  - Grid convergence study - SOLAR/TAU and CENTAUR/TAU
  - Turbulence model variation - CENTAUR/TAU

• CFD solutions for the Trap Wing configuration, case 2 - SOLAR/TAU

• CFD solutions for the Trap Wing configuration, case 3 - SOLAR/TAU

• Conclusion and outlook
DLR Motivation for Workshop Participation

- Extend validation and verification of the DLR TAU-code’s predictive capabilities for a ‘new’ 3D high lift test case

- Benchmark hybrid unstructured grid generation approaches, namely CENTAUR/TAU vs. SOLAR/TAU for a 3D high lift configuration
  - consideration of gridding guidelines for high lift cases
  - check prism-dominant vs. hex-dominant near wall grid topologies
  - grid refinement study for 3D configuration

- Check/improve best practice approaches for complex high lift configurations
  - turbulence model performance
  - convergence and start-up procedures
  - efficiency aspects, simplifications (e.g. b.t.e. resolution)
SOLAR Grid Family
• Grid family approach with 3 levels for configuration 1
• Medium grids for configuration 8 (case 2) and configuration 1 with brackets (case 3)
• Grid level characteristics (volume grid scaling factor = 3)

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• Grid generation and adaptation approach
  ➢ surface resolution quad-based (about 0.3 % of total surface elements triangle based)
  ➢ constant first cell height according to overall $y^+$-adaptation
  ➢ hex-layer thickness driven by variable expansion ratio
  ➢ semi-automated source distribution
Grid Generation - SOLAR

- Solar coarse grid - configuration 1

- cut at $\eta = 0.50$
- cut at wing tip
• Surface grid – expansion ratio distribution
CENTAUR Grid Family
Grid family approach with 3 levels (initially 4) for configuration 1

Grid level characteristics (no grid family, but grid resolution variation)

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Grid generation and adaptation approach

- surface resolution triangle-based
- $y^+$ -adaptation sectionwise and spanwise
- spanwise adaptation of streamwise surface resolution at l.e. and t.e.
- additional refinement by local cylinder sources along trim curves at root and tip
- semi-automated source distribution
• Surface grid - configuration - rear view
Grid Generation - CENTAUR Grid Family

- Surface grid – wing t.e., flap gap - upper side view
• grid cut for coarse grids at $\eta = 50$
Gridding guidelines compliance/deviations:

- **Solar:**
  - 1st cell height lower than recommended value ($y^+ > 1$)
  - initial no. of layers with constant height scaled to grid levels to improve similarity
  - target no. of pts at grid levels achieved with accuracy of about 1.5 percent
  - nearfield value of growth rate of 1.25 only partially met

- **CENTAUR:**
  - initial no. of layers with constant height could not be met (inherent to approach)
  - No of wall-normal layers not consistenly varied
  - target no. of pts at grid levels not consistently achieved – no grid family, more sequence of grid
CASE 1

SOLAR/TAU, CENTAUR/TAU

Baseline CFD Results - Medium grid
Grid Refinement
• Code Version: DLR TAU code 2010.1.0

• Spatial Discretization:
  ➢ Main equations: Jameson central, 2\textsuperscript{nd} order;
  Blend scalar (80%) – matrix (20%) dissipation
  ➢ Turb. Equations: Roe upwind, 2\textsuperscript{nd} order

• Turbulence Models: - Spalart-Allmaras, original formul. (SAO)
  - Menter k-ω SST (SST)
  - SSG/LRR-ω diff. Re-stress model (RSM)

• Temp. Integration: - LU-SGS Backward Euler
  - Multigrid, 3V cycle
TAU-Computations - Case 1

- TAU-SA0, SOLAR grid-family; $\eta = 0.50$

pressure distribution at

$\alpha = 13^\circ$

$\alpha = 28^\circ$
• TAU-SAO, SOLAR vs. CENTAUR grid-families; $\eta = 0.98$ pressure distribution at $\alpha = 13^\circ$
• TAU-SA0, SOLAR vs. CENTAUR grid-families; $\eta = 0.98$ pressure distribution at $\alpha = 28^\circ$
- TAU-SA0, SOLAR vs. CENTAUR grid-families lift (left) and pitching moment at

$\alpha = 13^o$

$\alpha = 28^o$
• TAU-SA0, grid-n; $\alpha = 13^\circ$: turb.-model-var.

pressure distribution at $\eta = 0.50$ and $0.98$
• TAU-SA0, grid-n; $\alpha = 28^\circ$: turb.-model-var.

pressure distribution at

$\eta = 0.50$

and 0.98
• TAU-SAO, grid-family; $\alpha = 13,\ 28^\circ$: turb.-model var.

![](chart.png)
- TAU-SA0/SST/RSM, grid-m; $\alpha = 13, 28^\circ$: isobars and surface streamlines
• TAU-SA0, grid-m; $\alpha = 13, 28^\circ$: start-up procedure: scratch
- TAU-SA0, grid-m; \( \alpha = 13, 28^\circ \): start-up procedure stepwise restart (\( \Delta \alpha = 2^\circ \))
CASE 2

SOLAR/TAU, CENTAUR/TAU

Configuration 1 and 8 - Medium Grid
• TAU-SA0, grid-m; polar computations for config. 1
- TAU-SAO, SOLAR grid; polar computations for config. 1 and 8
CASE 3

SOLAR/TAU

Configuration 1 with brackets - Medium Grid
TAU-Computations - Case 3

- TAU-SA0, SOLAR grid; bracket influence

Flap pressure distribution at

\[ \alpha = 13^\circ \]
\[ \eta = 0.50 \]

and 0.98
 Validation and verification of the DLR TAU-code extended for NASA Trap Wing test case for two flap settings and configuration with support brackets
- in general good agreement obtained w.r.t. forces, moments, cp-distributions
- effect of flap setting variation and brackets consistently captured
- wingtip area most critical part of the configuration with significant deviations between CFD and w/t test results

 Benchmark of hybrid unstructured grid generation package SOLAR
- generation of grid family (widely) considering gridding guidelines achieved
- grid convergence not reached at higher AoA’s

 Benchmark of hybrid unstructured grid generation packages CENTAUR/TAU
- consistent grid family could not be successfully completed on fine grid level
- high input effort to resolve bte.’s due to patchwise grid generation approach
- grid resolution variation carried out on three grid levels with moderate impact

 Moderate influence of grid resolution on forces, moments and cp-distributions; most pronounced at wing tip area and in extend of side-of-body separation
Turbulence model variation carried out based on 1-, 2-equation eddy viscosity models and a differential RSM model on CENTAUR medium level grid

- in general moderate influence on pressure distribution except at wingtip area
- SST model predicts strongest side-of-body separation
- RSM model shows strongest trend for tip separation at high AoA’S
- based on current evidence higher fidelity approaches don’t offer superior agreement to experimental evidence, but
- slat vortex interaction with rear part of the wing and flap currently not properly resolved – seen as a requirement for reliable assessment of model performance (in outer wing area)

Sensitivity of convergence start-up procedure requires best practice guidelines and investigation of possible means to alleviate it

Outlook for DLR activities:
- detailed study of slat edge vortex and interaction with downstream elements
- extend validation on Trap wing for field data and transition effects
Thank You