2nd AUTOMOTIVE CFD PREDICTION WORKSHOP
26th – 27th AUGUST 2021
HYBRID (IN-PERSON + VIRTUAL)

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Overview

• Case 2: Closed cooling DrivAerNotchback with static wheels and static floor.
• Feedback on workshop supplied mesh
• Modeling setup
• Turbulence model
• Results
• Summary & Outlook
Feedback on workshop supplied Low-Re (y+~1): ~244M mesh

Mesh Quality:
• Minimum Orthogonal Quality = 0.00000e+00 cell 485254 on zone 74 (ID: 244624321 on partition: 479) at location (3.56448e+00, 8.63244e-01, 1.00462e+00) **Warning: minimum Orthogonal Quality below 0.01.**

• Maximum Aspect Ratio = 6.54998e+03 cell 31157 on zone 74 (ID: 175650867 on partition: 248) at location (3.03844e+00, -7.05605e-01, -1.96018e-01)

• Cells marked with orthogonal quality < 0.01 (# 730 cells)
• Bad orthogonal cells quality, where CAD surface depicts ~90deg step change.
• ANSYS Fluent acceptable mesh orthogonal quality ranges from 0.05 to 1.

Cell volume jump:
• **Prism stair stepping.**

• Recommend to avoid cell volume jumps closed to the walls, where flow exhibits high gradient changes.
Modeling setup

- **Mesh:** Octree, Low-Re ~244million cells, workshop provided ANSA
- **Turbulence models**
  - RANS: GEKO
  - SRS: Hybrid RANS-LES Stress Blending Eddy Simulation (SBES) + GEKO
- **Boundary conditions**
  - Inlet: uniform $V_\infty = 38.89 \text{ m/s}$, experimental turbulent intensity ~0.26%.
  - Outlet: pressure outlet conditions with ambient pressure 101325Pa.
  - No-slip wall condition on car body and stationary ground.
  - Slip Side-wall condition on virtual tunnel walls.
- **Software:** ANSYS Fluent 2021 R2
- **Numerics**
  - PV-Coupling scheme: Coupled/SIMPLeC-1(skewness correction)
  - Flux type: Rhie-Chow
  - Gradient re-construction: GGNB/LSQ
  - Spatial discretization:
    - Pressure – standard
    - Momentum – Bounded central differencing
    - Turbulence – 2nd order
- **Transient parameters**
  - Transient formulation: Bounded second order implicit.
  - $\Delta t = 1.25e^{-4} \text{ sec}$
  - Initial transient: 0.5sec -> ~4 CTUs*
  - Averaging time: 1.9sec -> ~16 CTUs
- **Simulation time**
  - RANS: 5hrs, 480CPU, 1000iterations
  - SRS: 75.35hrs, 704CPU, 2.4sec

* CTUs = Convective time units
Turbulence models

❖ **RANS - Generalized k-ω (GEKO)**
  - Consolidate various two-equation RANS models into a single RANS model and provide user a flexibility to tune using **free parameters** *(based on near-wall influence, flow separation, mixing, and jet spreading)* that can be adjusted for specific types of flows.

\[
\frac{\partial (\rho k)}{\partial t} + \frac{\partial (\rho U_j k)}{\partial x_j} = P_k - C_{\mu k} \rho k \omega + \frac{\partial}{\partial x_j} \left( \mu + \frac{\mu_t}{\sigma_k} \frac{\partial k}{\partial x_j} \right)
\]

\[
\frac{\partial (\rho \omega)}{\partial t} + \frac{\partial (\rho U_j \omega)}{\partial x_j} = C_{\omega 1} F_{\omega 1} P_k - C_{\omega 2} F_{\omega 2} \rho \omega^2 + \rho F_3 CD + \frac{\partial}{\partial x_j} \left( \mu + \frac{\mu_t}{\sigma_\omega} \frac{\partial \omega}{\partial x_j} \right)
\]

where \( \mu_t = \rho \nu_t = \frac{k}{\max(\omega, C_{\text{realize}})} \), \( P_k = -\tau_{ij} \frac{\partial U_i}{\partial x_j} \), \( CD = \frac{2}{\sigma_\omega} \frac{1}{\omega} \frac{\partial k}{\partial x_j} \frac{\partial \omega}{\partial x_j} \), \( C_{\text{realize}} = \frac{1}{\sqrt{3}} \)


❖ **SBES - Stress Blending Eddy Simulation (SBES)**
  - Developed on the same principle as the DES model, which uses a **RANS model for near wall flows** and **LES for the bulk flows**.
  - Faster transition to LES from RANS, based on the **stronger blending function** \( f_{SBES} \).

Turbulence stress tensor blending

\[
\tau_{ij}^{SBES} = \tau_{ij}^{RANS} f_{SBES} + \tau_{ij}^{LES} (1 - f_{SBES})
\]

Turbulent eddy-viscosity

\[
\mu_t^{SBES} = \mu_t^{RANS} f_{SBES} + \mu_t^{LES} (1 - f_{SBES})
\]

[https://doi.org/10.3390/app11062459](https://doi.org/10.3390/app11062459)

These **free parameters** are implemented through the functions F1, F2 and F3 in the omega equations.

- **C_{SEP}** - Parameter to optimize flow separation from smooth surfaces \(-0.75 < C_{SEP} < 2.5\) (default \( C_{SEP} = 1.75 \))
- **C_{NW}** - Parameter to optimize flow in non-equilibrium near wall regions (such as heat transfer or shear stress) \(-2 < C_{NW} < 2\) (default \( C_{NW} = 0.5 \))
- **C_{MIX}** - Parameter to optimize strength of mixing in free shear flows \( 0 < C_{MIX} < 1 \) (default \( C_{MIX} = 0.35 \text{sgn}(C_{SEP} - 1)\sqrt{C_{SEP} - 1} \))
- **C_{JET}** - Parameter to optimize free shear layer mixing \( 0 < C_{JET} < 1 \) (default \( C_{JET} = 0.9 \)).
Results: Aerodynamic Coefficients

<table>
<thead>
<tr>
<th>Method</th>
<th>CD</th>
<th>CL</th>
<th>CFL</th>
<th>CRL</th>
</tr>
</thead>
<tbody>
<tr>
<td>RANS: GEKO</td>
<td>0.251</td>
<td>0.084</td>
<td>-0.034</td>
<td>0.118</td>
</tr>
<tr>
<td>SRS: SBES+GEKO</td>
<td>0.279</td>
<td>0.037</td>
<td>-0.059</td>
<td>0.096</td>
</tr>
</tbody>
</table>
Results: Pressure Coefficient

Top Surface

Bottom Surface
Results: Normalized velocity profiles, $Y=0m$
Results: Normalized velocity profiles, $z=-0.2376m$
Results: Normalized velocity profiles, L1 $Z=-0.2376m$. 

- RANS-GEKO
- SRS-SBES+GEKO
Results: Normalized velocity profiles, R1, R2 & R3.
Results: Iso-surface X-velocity=0

RANS-GEKO

SRS-SBES+GEKO

C-pillar separation
Results: Pressure coefficient contours

RANS-GEKO

SRS-SBES+GEKO
Results: Q-criterion turbulent structures (17000 1/s)
Summary

- Simulations performed using ANSA Low-Re (y+~1) ~244M cells mesh.
- SRS-SBES predicts more mixed flow under and behind the car.
- Pressure coefficient on the top surface centerline do not show any significant differences between SRS-SBES and RANS.
- C-pillar shows more separated flow using SRS-SBES.

Outlook

- Compare against experimental data.
- Tune GEKO and SRS-SBES for further improvements.
- Prepare good quality mesh.
Thank you!

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