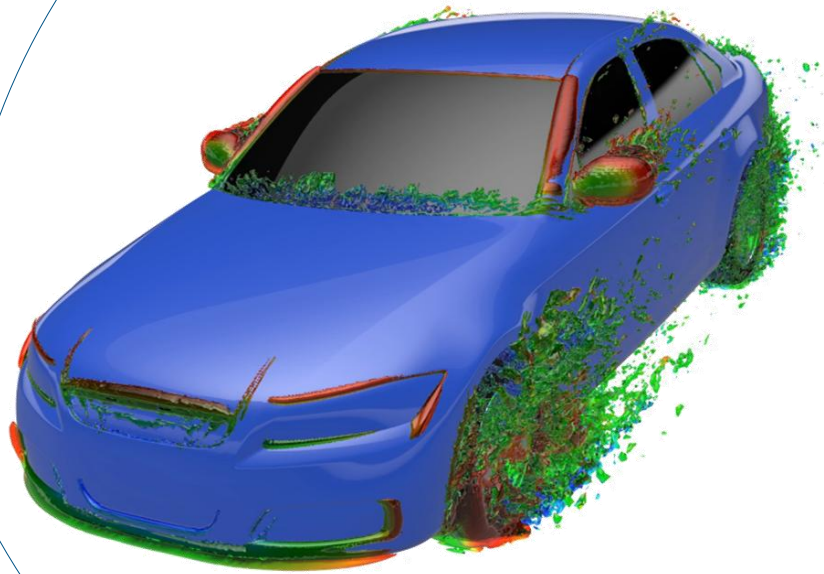
SIMULIA POWERFLOW®
Uncertainty Quantification from Surface Mesh on DrivAer

G. Parenti, A. Martinez

5th Automotive CFD Prediction Workshop

Bologna, 8–9 October 2026

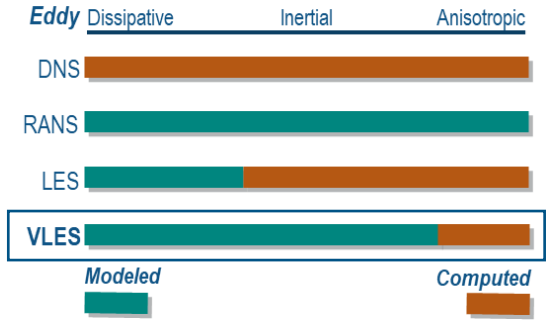


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POWERFLOW® TRANSIENT SOLVER



- **Lattice Boltzmann fluid dynamics solver**
  - Inherently transient
  - Low dissipation
  - Highly accurate timescale
- **VLES isotropic turbulence modelling with RNG k-ε equations**
  - No near-wall / bulk-flow blending function
  - No predefined length scale
- **Highly efficient HPC performance**
  - Excellent CPU scalability
  - Highly optimized GPU computation
  - Consistent results between GPU and CPU architecture



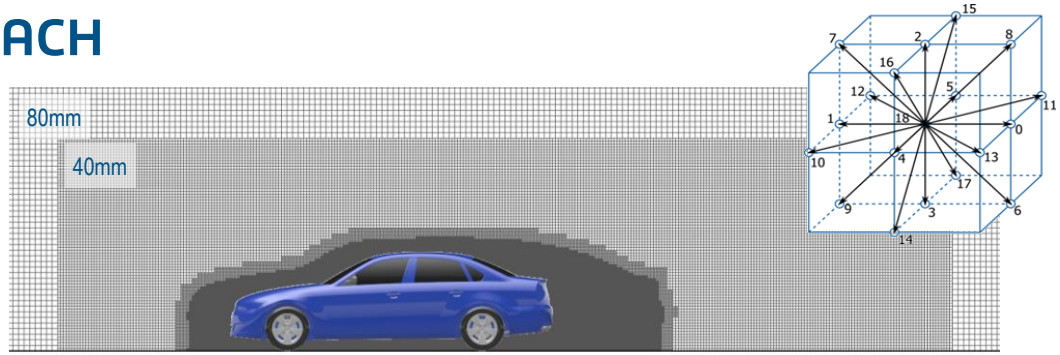
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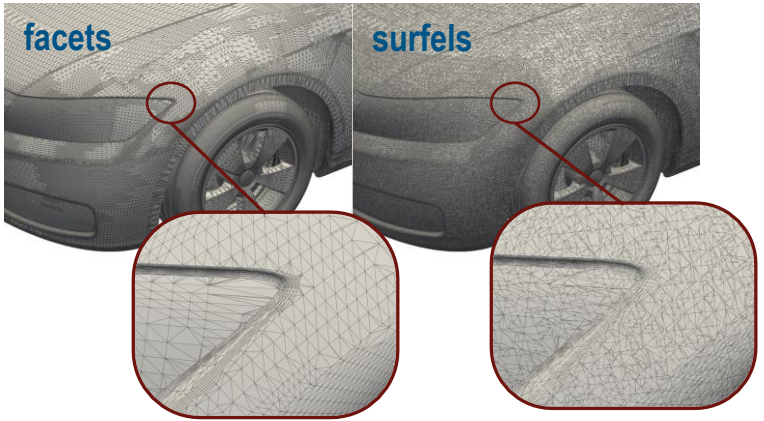
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POWERFLOW® MESHING APPROACH

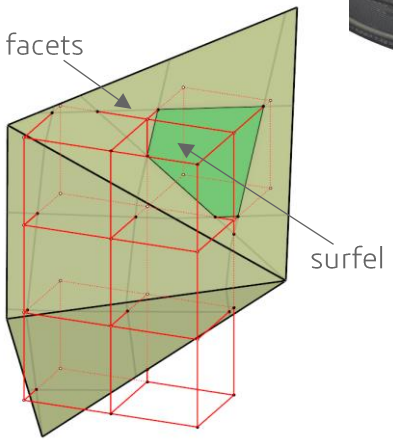
- **Mesh Topology**
  - **Cartesian D3Q19 voxel elements for the fluid domain**
  - **Surfel elements for solid boundaries**



- **Advantages**
  - Direct use of input mesh → better detail retention
  - Relaxed requirements → aspect ratio and skewness less relevant
  - Surfel–voxel advection → small details captured also on coarser fluid grid
  - No prism layer required → Volume and Surface meshes decoupled



- Surface mesh effects can be studied separately from the Fluid grid
- Surface meshing is a robust process but can introduce noise if left unchecked



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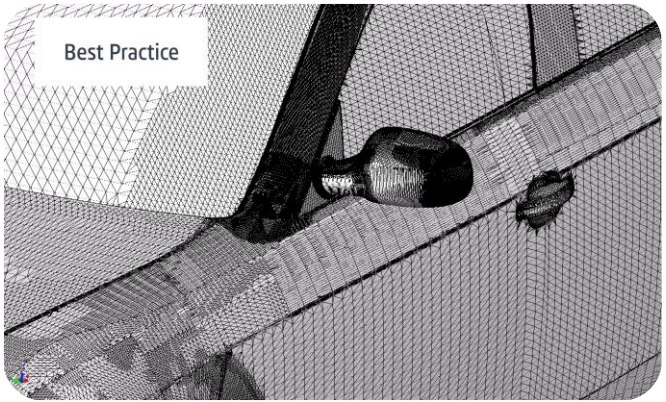
SURFACE MESH INVESTIGATION FRAMEWORK

- **PowerFLOW® dedicated meshes**
  - 3DEXPERIENCE Platform: CAD and Mesh in a single environment
  - PowerDELTA® preprocessing creates and validates the mesh from CAD
  - Three types of setup:
    - › **Best practice: accuracy with limited facet count**
    - › **Heavy settings: very fine tessellation**
    - › **Coarse settings: very coarse tessellation**

- **AutoCFD committee meshes**
  - More regular meshes,
    - › **AutoCFD3**
    - › **AutoCFD4**
    - › **AutoCFD5**

- Coarse settings comparable to AutoCFD3 mesh
- Heavy settings slightly finer than AutoCFD5 mesh
- **PowerFLOW® Best Practice gives a lighter mesh than committee**

Run	Facets	Surfels	Voxel
Best Practice	3.5 M	10.8 M	
Coarse Setting	0.9 M	7.1 M	73.6 M
Heavy Setting	15.8 M	21.5 M	
AutoCFD3	1.6 M	8.0 M	
AutoCFD4	17.2 M	16.4 M	73.6 M
AutoCFD5	9.0 M	16.0 M	



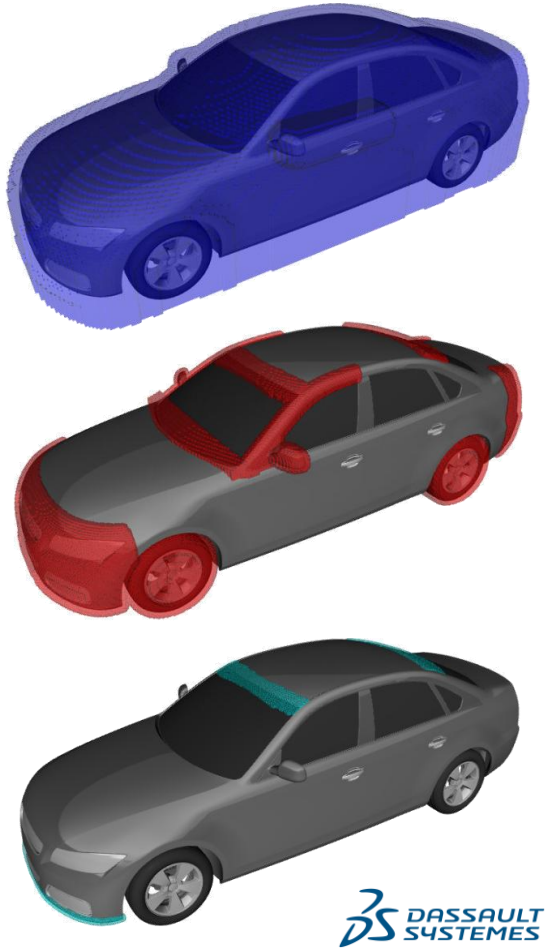
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SIMULATION SCENARIO SETUP

- **3DS SIMULIA standard Best Practice for external aerodynamic simulation**
  - PowerCASE templates simplify scenario setup
  - Geometry swap within the template
    - Consistency of all other settings maintained
  - Variable Resolution regions
    - Finest Cell Size: 1.25mm
  - Measurements with different time resolutions for storage efficiency



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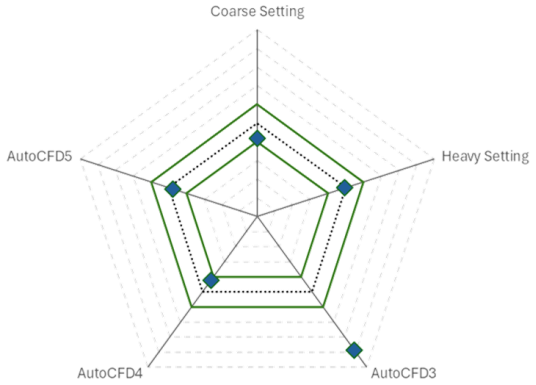
CASE 2 RESULTS – ACCURACY CRITERIA TIME

- Simulation time based on:
  - **Cd accuracy at ±0.0010 at 90% confidence level**
  - **Minimum simulation time set to 2.5 seconds (≈30 CFU)**

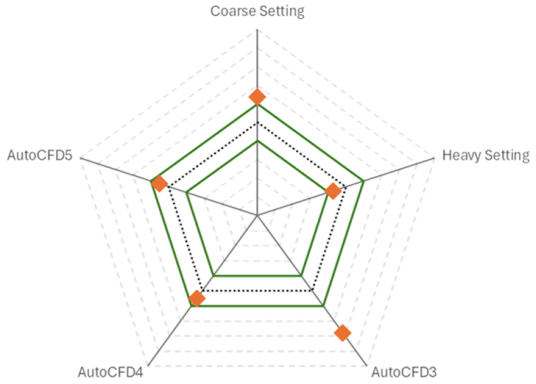
	Run	Simulated Time 2a	Simulated Time 2b	Cd 2a	Cd 2b	ΔCd 2b – 2a	Variability 2a	Variability 2b
	Experiment	-	-	0.2546	0.2424	**-0.0122**	-	-
PowerFLOW	Best Practice	3.2	2.6	**0.2711**	**0.2592**	**-0.0119**	**ref.**	**ref.**
PowerFLOW	Coarse Setting	**2.6**	**3.2**	0.2703	0.2606	**-0.0097**	-0.0008	0.0014
PowerFLOW	Heavy Setting	2.9	5.6	0.2711	0.2585	**-0.0125**	-0.0001	-0.0007
Committee	AutoCFD3	**2.6**	**5.4**	0.2750	0.2620	**-0.0129**	0.0038	0.0028
Committee	AutoCFD4	7.7	3.7	0.2703	0.2598	**-0.0106**	-0.0008	0.0005
Committee	AutoCFD5	2.6	4.6	0.2709	0.2598	**-0.0111**	-0.0002	0.0005

- **Results are very consistent**
  - Variability generally contained within ±0.0010 (except AutoCFD3)
  - Front Wheel Deflector variant (2b) shows slightly larger variations
- **Coarser meshes appear to introduce more noise**
  - AutoCFD3 mesh: absolute values shifted by +3 to 4 counts
  - PowerFLOW® Coarse: slightly shifted, front deflector delta underpredicted

Variability - Case 2a (ref Best Practice)



Variability - Case 2b (ref Best Practice)



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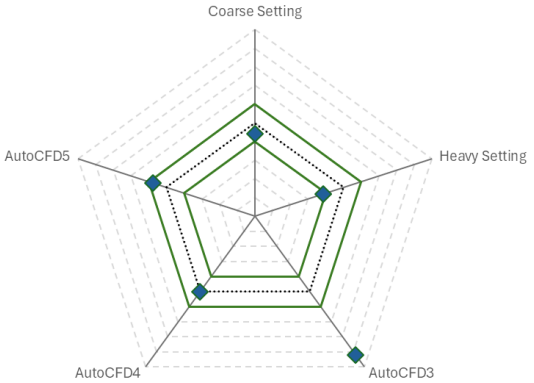
CASE 2 RESULTS – LONG SIMULATION TIME

- Simulation Time extended to **15 seconds**

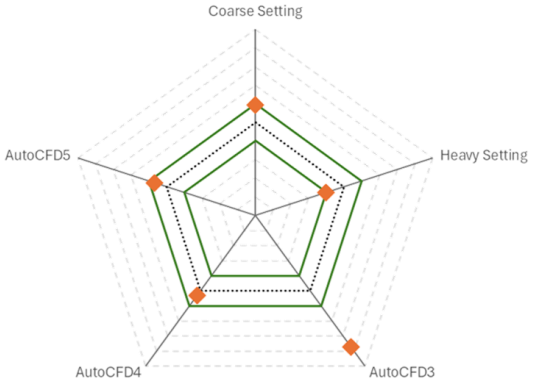
	Run	Simulated Time 2a	Simulated Time 2b	Cd 2a	Cd 2b	ΔCd 2b – 2a	Variability 2a	Variability 2b
	Experiment	-	-	**0.2546**	**0.2424**	**-0.0122**	-	-
PowerFLOW	Best Practice	15	15	0.2707	0.2586	-0.0121	**ref.**	**ref.**
PowerFLOW	Coarse Setting	**15**	**15**	0.2701	0.2595	-0.0106	-0.0006	0.0009
PowerFLOW	Heavy Setting	15	15	0.2695	0.2576	-0.0119	-0.0012	-0.0010
Committee	AutoCFD3	**15**	**15**	0.2749	0.2623	-0.0126	0.0042	0.0037
Committee	AutoCFD4	15	15	0.2707	0.2589	-0.0118	0.0000	0.0003
Committee	AutoCFD5	15	15	0.2714	0.2593	-0.0121	0.0007	0.0007

- **Results remain consistent over a long simulation**
  - Variability remains around ±0.001
  - AutoCFD3 and PowerFLOW® Coarse confirmed as the outliers
  - Only marginal improvement vs. accuracy-criterion simulation time
    - › The chosen accuracy criterion is a good approach

Variability - Case 2a (ref Best Practice)



Variability - Case 2b (ref Best Practice)

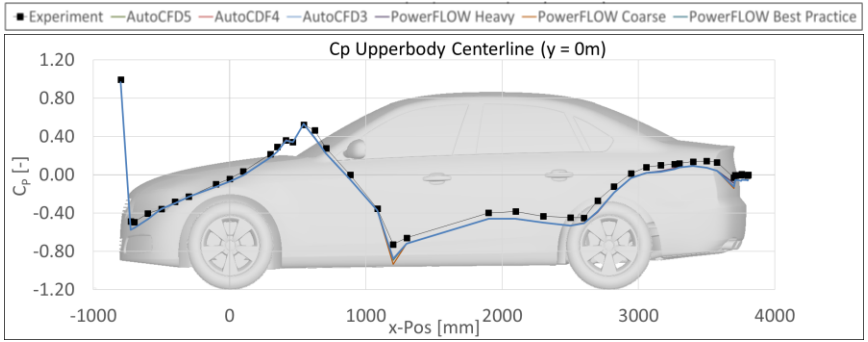


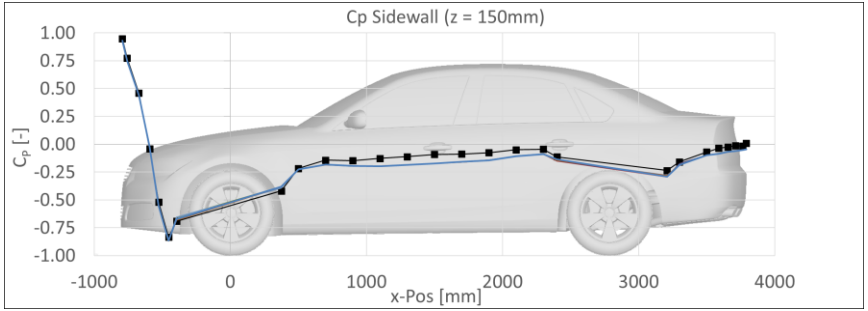
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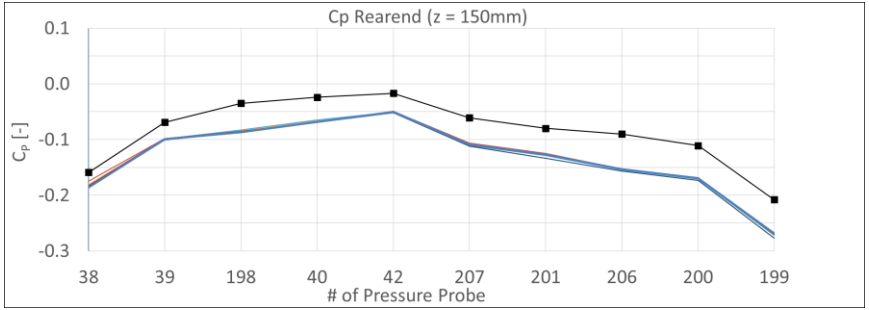
ACCURACY VS EXPERIMENTS – CASE 2A

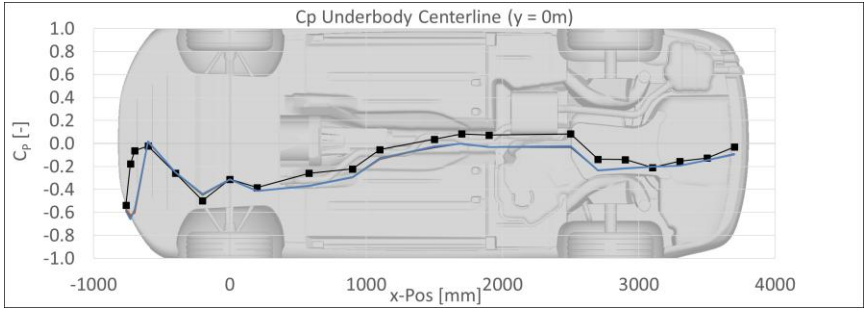
- **PowerFLOW® shows excellent correlation with experiment**
  - General trend of an higher rear-end suction
- **RMS of variations vs Best Practice mesh is small**
  - AutoCFD5, AutoCFD4 and Heavy meshes very close to Best Practice
  - AutoCFD3 also close to Best Practice
  - Coarse setting shows generally higher RMS

RMS	Best Practice	Coarse	Heavy	AutoCFD3	AutoCFD4	AutoCFD5
Upper	ref.	**0.0096**	0.0061	0.0038	0.0037	0.0035
Sidewall	ref.	**0.0045**	0.0038	0.0058	0.0037	0.0035
Underbody	ref.	**0.0092**	0.0062	0.0041	0.0129	0.0041
Rear End	ref.	**0.0014**	0.0039	0.0039	0.0021	0.0025





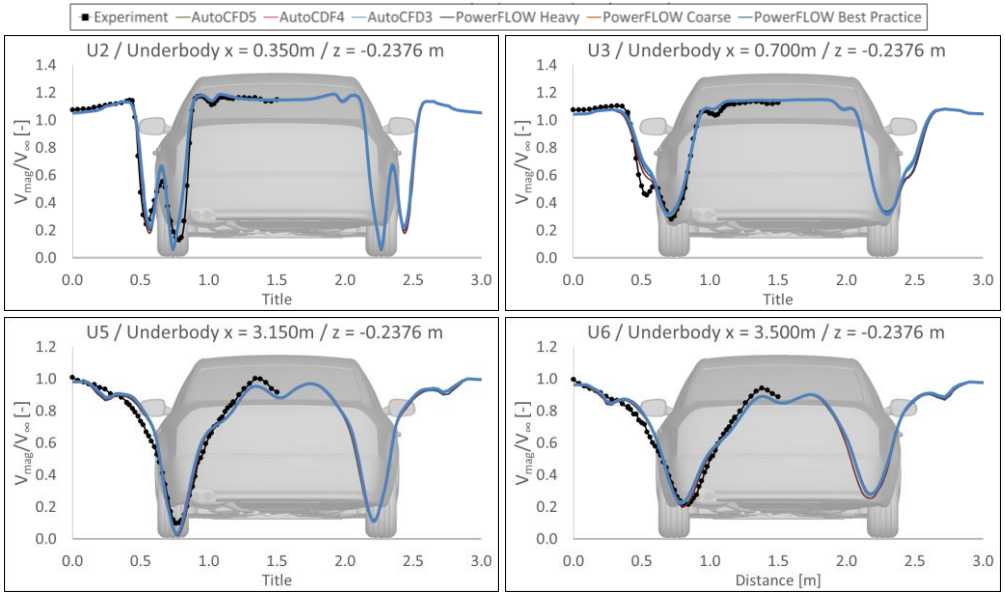




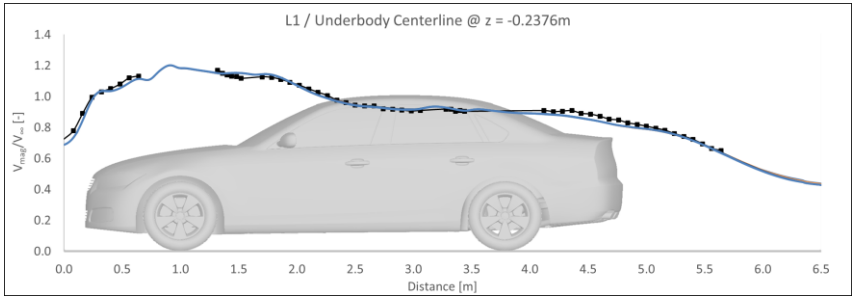
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ACCURACY VS EXPERIMENTS – CASE 2A

- **PowerFLOW® shows excellent correlation with experiment**
  - Tire wake profiles well replicated
  - Centerline underbody velocity well captured up to “far field”
- **RMS vs Best Practice still small**
  - Heavy, AutoCFD4 and AutoCFD5 meshes close to Best Practice
  - Coarse settings show higher RMS at the front wheel profile
  - AutoCFD3 shows much higher RMS
  - Centerline underbody RMS similar across all cases



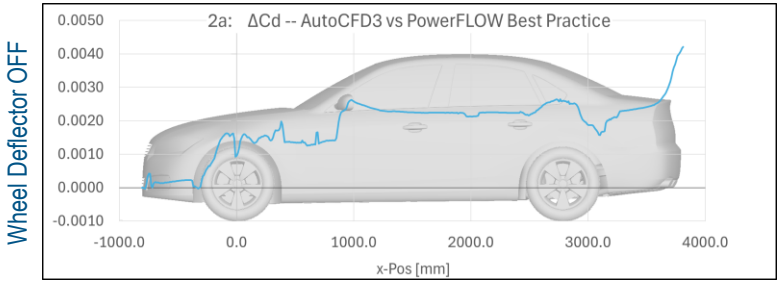
RMS	Best Practice	Coarse	Heavy	AutoCFD3	AutoCFD4	AutoCFD5
U2	ref.	**0.0139**	0.0055	**0.0260**	0.0055	0.0060
U3	ref.	**0.0155**	0.0068	**0.0235**	0.0053	0.0065
U5	ref.	**0.0087**	0.0042	**0.0184**	0.0037	0.0056
U6	ref.	**0.0067**	0.0049	**0.0205**	0.0042	0.0045
L1	ref.	**0.0033**	0.0036	**0.0018**	0.0045	0.0020

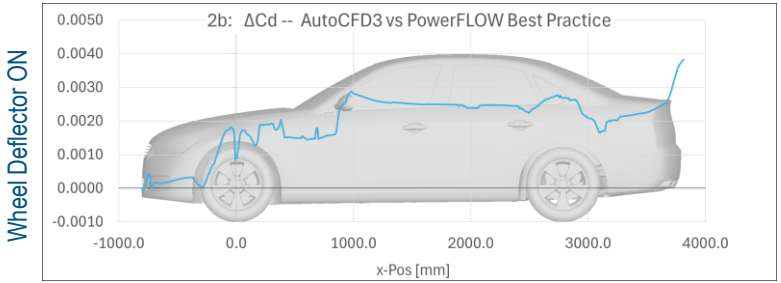


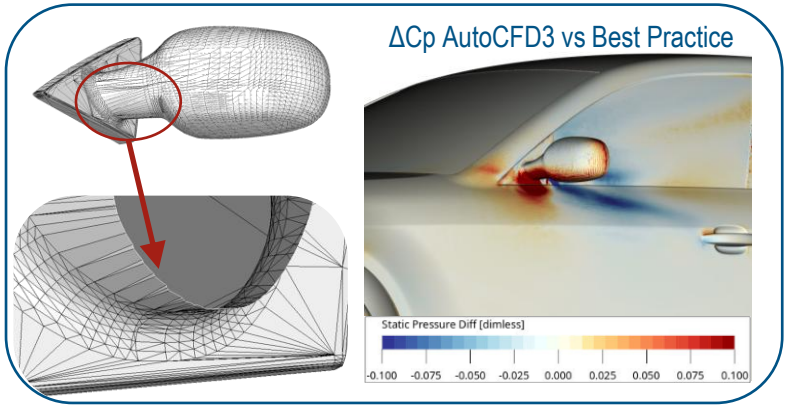
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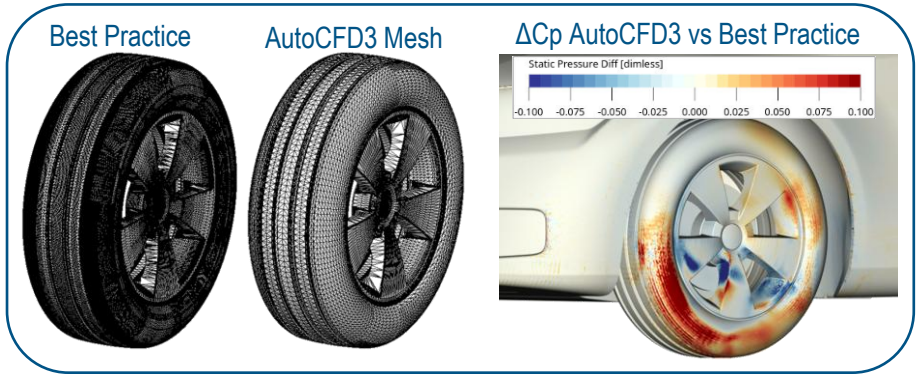
SURFACE MESH IMPACT - AUTOCFD 3

- **Drag development shows two suspect areas**
  - Mirror region
  - Front wheels
- **Similar effects on drag for both 2a and 2b**
  - Front Wheel deflector correlates with experiments
  - Pressure and velocity profiles appear correct
- **Two mesh details trigger the drag differences**
  - A mesh defect on the mirror arm
  - A poor mesh resolution on the front tires
- **Local effects propagate downstream and affect the rear end**





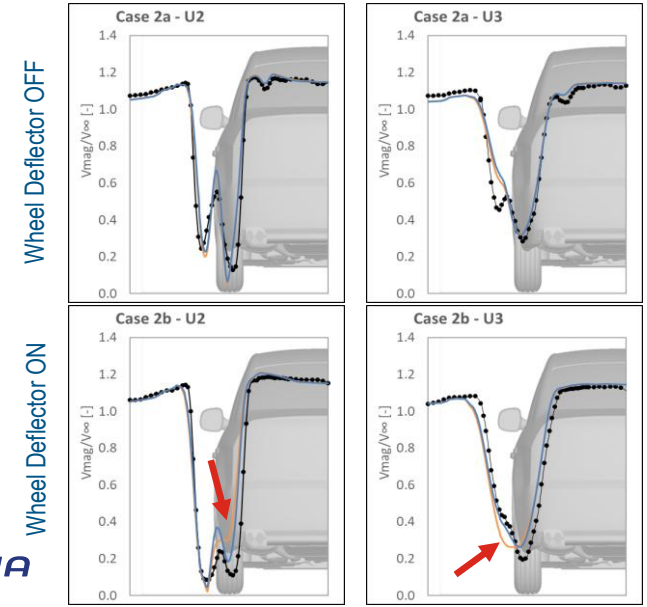


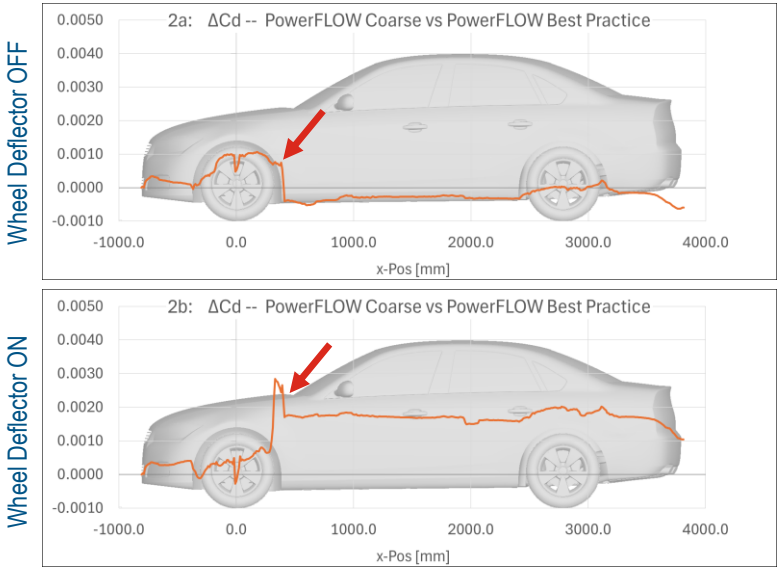


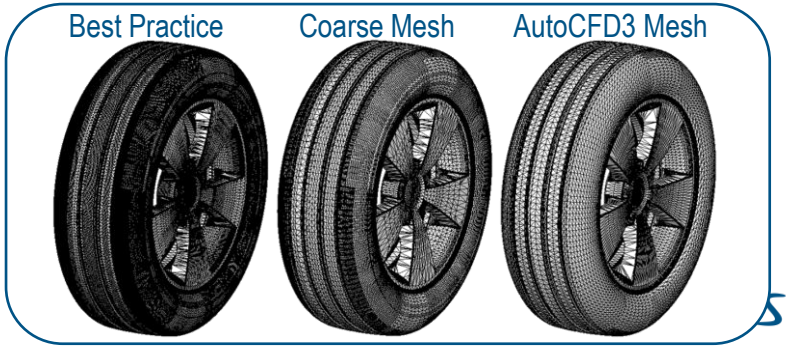
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SURFACE MESH IMPACT – POWERFLOW® COARSE

- **Drag development shows one critical area**
  - Front Wheels region
  - Mesh quality similar to AutoCFD3
- **Impact visible on the wheel wake velocity**
  - Stronger in Case 2b
- **Negligible effect on the rest of the vehicle**



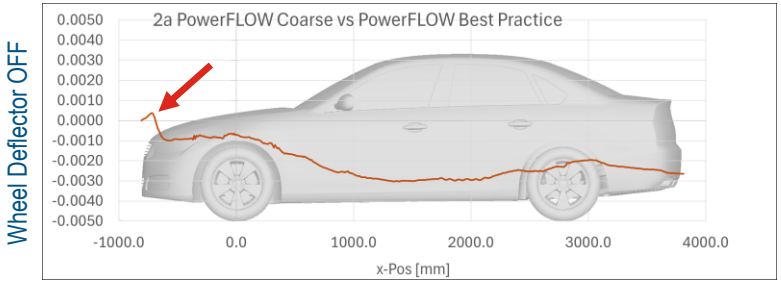


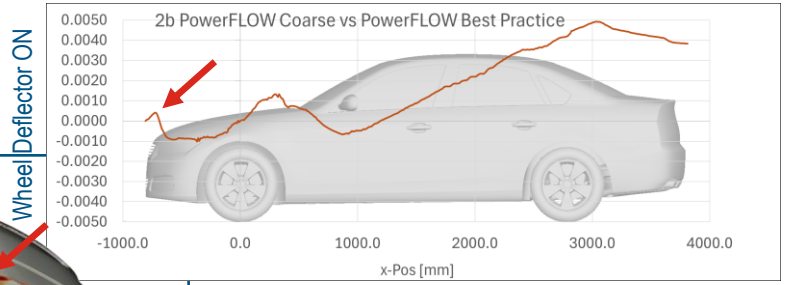


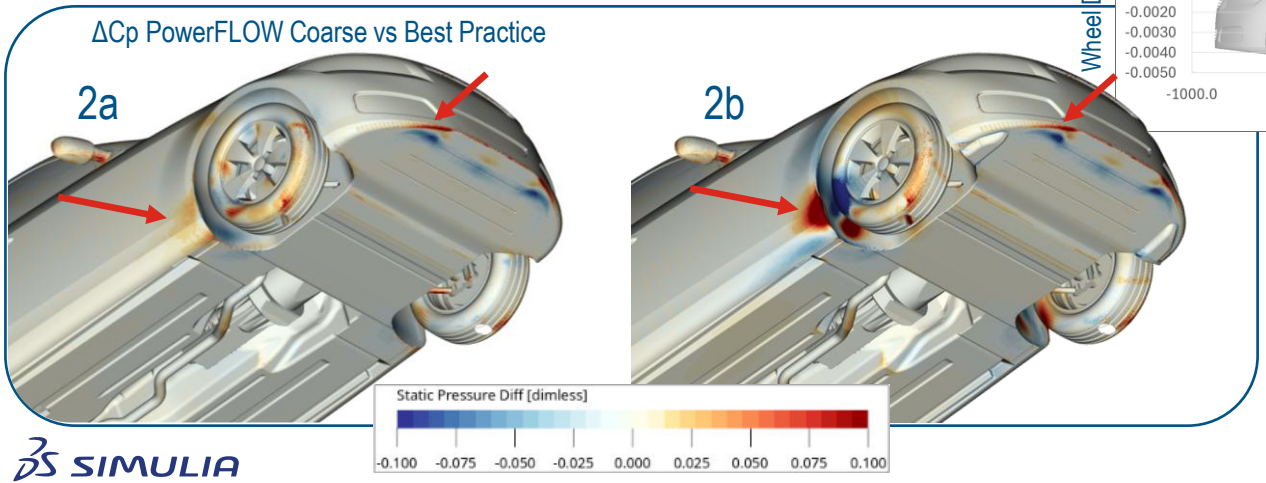
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SURFACE MESH IMPACT – POWERFLOW® COARSE

- **Impact on the Front Wheel shoulder**
  - Pressure change reflected in wheel arch pressure
- **Front chin shows a local change**
  - Surface mesh resolution on leading-edges is critical
- **Effects are stronger with the wheel deflector (2b)**
  - Configurations can respond differently with poor mesh resolution
- **Small effects on mirror arms, negligible impact on drag**







Coarse mesh is still a valid approach if critical areas are properly meshed

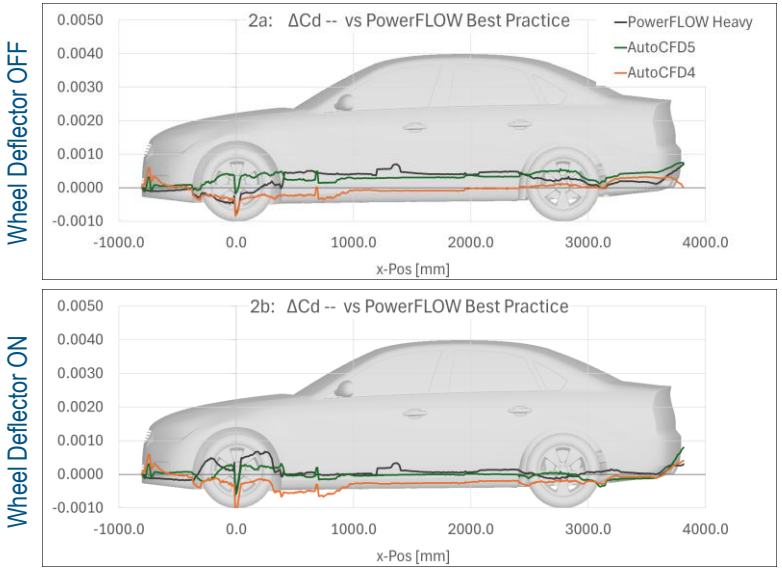
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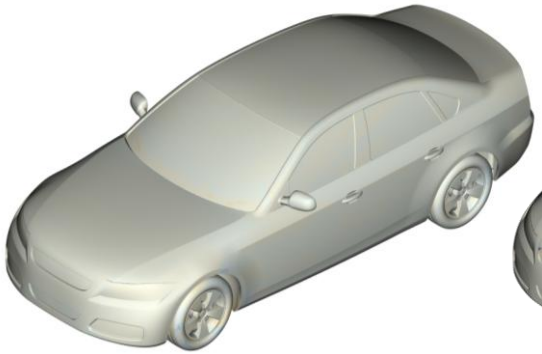
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SURFACE MESH IMPACT – FINER MESHES

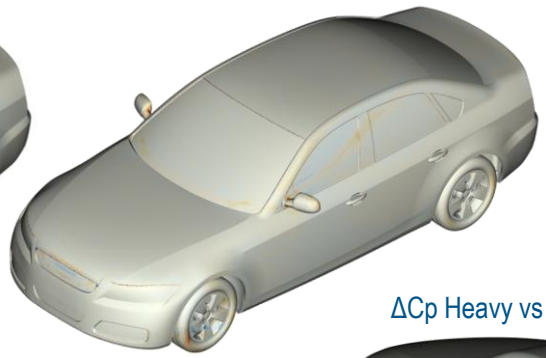
- **Finer surface meshes are comparable to PowerFLOW® Best Practice**
  - Variation over the whole drag development within ±0.001
  - Most of the effect concentrate at the front wheels

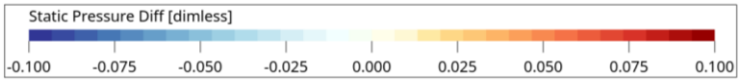


ΔCp Heavy vs Best Practice



ΔCp AutoCFD5 vs Best Practice





ΔCp Heavy vs Best Practice



ΔCp AutoCFD5 vs Best Practice



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SURFACE MESH IMPACT – FINER MESHES

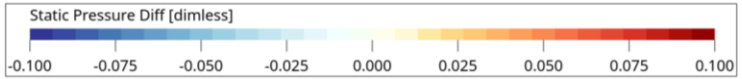
- **Finer surface meshes are comparable to PowerFLOW® Best Practice**
  - Lift variation remains within ±0.003

ΔCp Heavy vs Best Practice

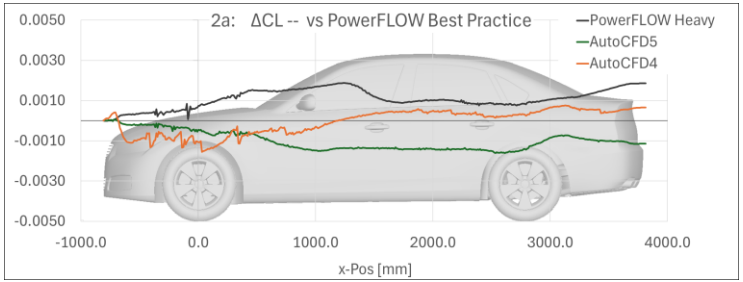


ΔCp AutoCFD5 vs Best Practice

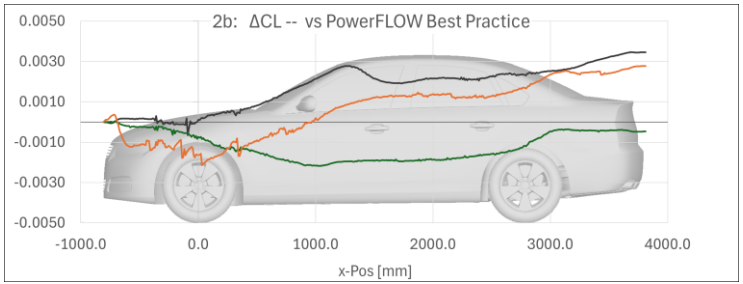




Wheel Deflector OFF



Wheel Deflector ON



ΔCp Heavy vs Best Practice



ΔCp AutoCFD5 vs Best Practice



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POWERFLOW® GPU SOLVER - IMPLEMENTATION ROADMAP

- **PowerFLOW® 6-2022:**
  - Support Single GPU
  - No Sliding Mesh / Porous Media
- **PowerFLOW® 6-2024:**
  - Support Sliding Mesh / Porous Media

Concept Aerodynamics

- **PowerFLOW® 6-2024-R1:**
  - Support Multi-GPU without Sliding Mesh
- **PowerFLOW® 6-2025:**
  - Support Sliding Mesh with Multi-GPU
- **PowerFLOW® 6-2025-R2:**
  - Performance enhancement
- **PowerFLOW® 6-2026-R2/R3:**
  - Scalability improvement

Vehicle Aerodynamics
Vehicle Aeroacoustics



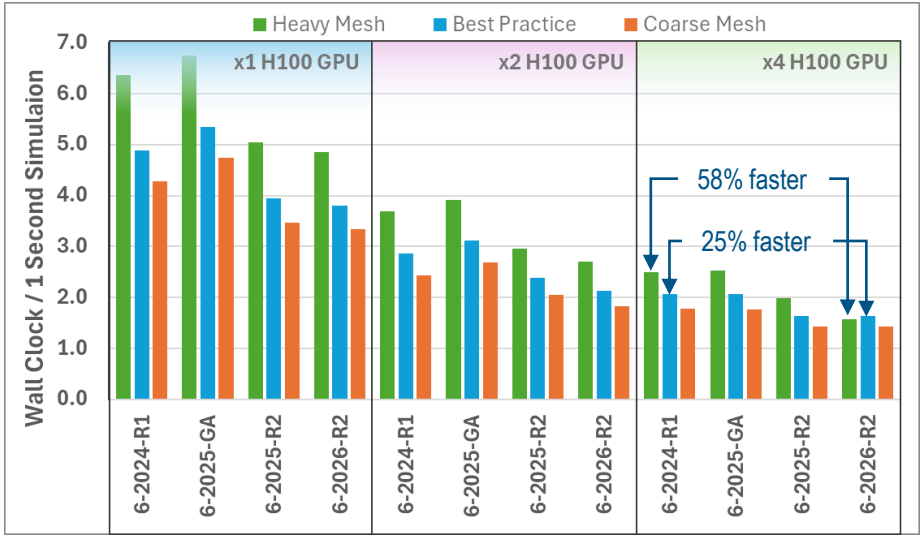
Note: not all features are supported on GPU. Active development in progress.
Future releases are expected to include: rotating treated tires, high subsonic solver, heat transfer

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SURFACE MESH IMPACT – PERFORMANCE EVOLUTION

- **PowerFLOW® GPU solver is under continuous development**
  - Improved both Performance and scalability

- **Performance: PowerFLOW® 6-2026-R2/R3 vs 6-2024-R1:**
  - **Single GPU: 28–30% faster**
  - **Multi-GPU: 24–58% faster**

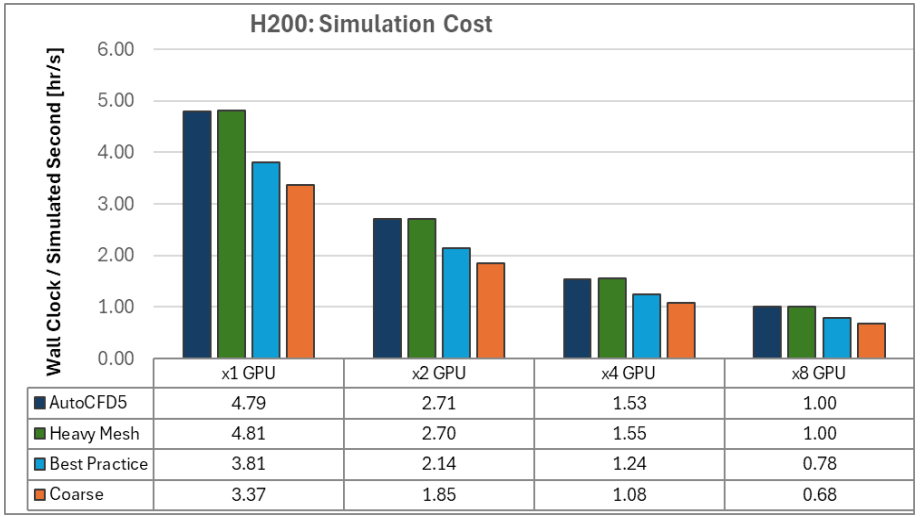


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SURFACE MESH IMPACT - PERFORMANCE

- **Performance assessed on H200 GPU**

		Simulated Time	Cd	Turn Around Time x1 H200	Turn Around Time x4 L40s	Turn Around Time x8 H200
2a	Best Practice	3.2	0.2711	**12.02**	**4.71**	**2.47**
	Coarse Setting	2.6	0.2703	**8.85**	**4.45**	**1.79**
	Heavy Setting	2.9	0.2711	**14.06**	**6.34**	**2.91**
	AutoCFD5	2.6	0.2709	**12.29**	**5.18**	**2.58**
2b	Best Practice	2.6	0.2592	**9.93**	**3.89**	**2.04**
	Coarse Setting	3.2	0.2606	**11.06**	**5.56**	**2.24**
	Heavy Setting	5.6	0.2585	**27.24**	**12.28**	**5.64**
	AutoCFD5	5.4	0.2598	**22.27**	**9.39**	**4.67**



	x1 GPU	x2 GPU	x4 GPU	x8 GPU
AutoCFD5	4.79	2.71	1.53	1.00
Heavy Mesh	4.81	2.70	1.55	1.00
Best Practice	3.81	2.14	1.24	0.78
Coarse	3.37	1.85	1.08	0.68

- **On 8x H200, one simulation runs in 2–5 hours (depending on the total sim time)**
- **Compared to Best Practice:**
  - Finer mesh: ≈25% higher cost
  - Coarse mesh: ≈12.5% lower cost

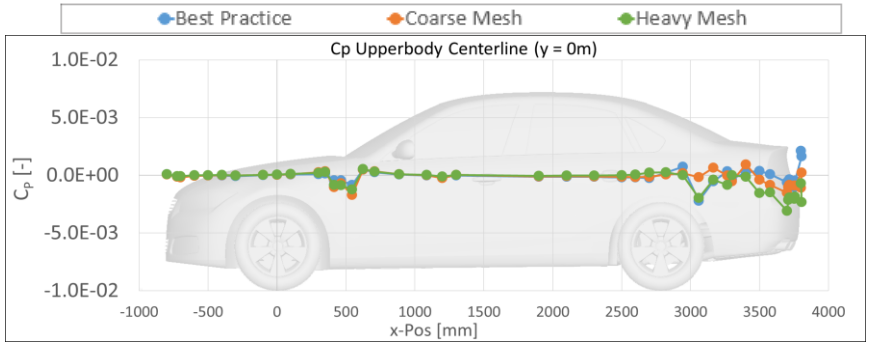
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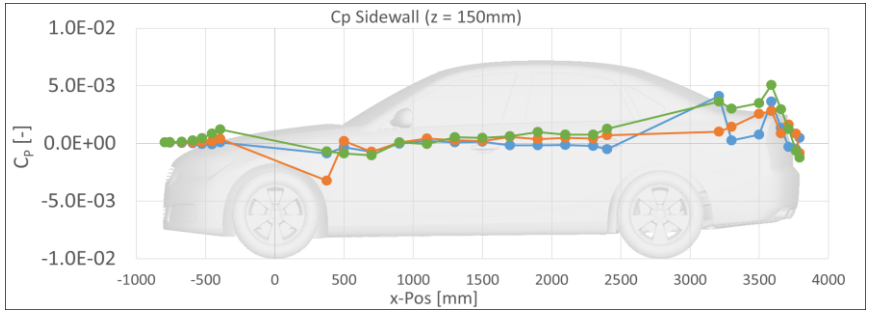
SURFACE MESH IMPACT – GPU / CPU COHERENCE

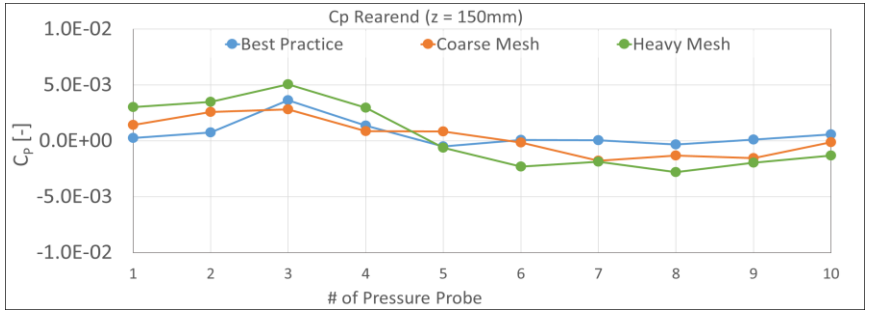
- **PowerFLOW® results are consistent between GPU and CPU**
- Extended simulation time: 15 s

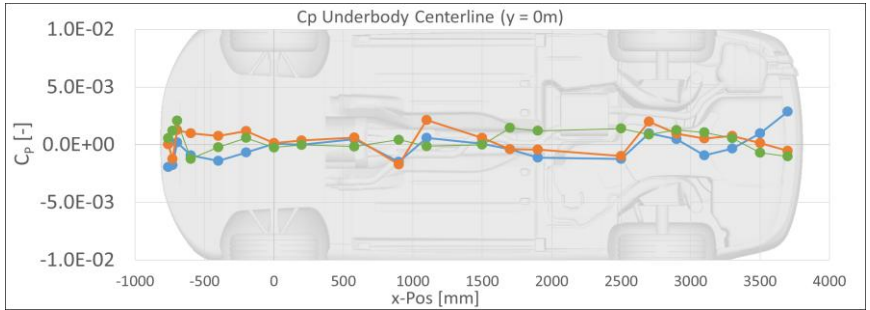
	Run 2a	Simulated Time GPU	Simulated Time CPU	Cd GPU	Cd CPU
PowerFLOW	**Best Practice**	**15**	**15**	**0.2707**	**0.2709**
	Coarse Setting	**15**	**15**	0.2701	0.2702
	Heavy Setting	15	15	0.2695	0.2706

- **Drag values within ±0.001**
- **Pressure profile differences within ±5.0E-3 Cp**









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CONCLUSION

- **PowerFLOW® proves to be robust and poorly sensitive to surface mesh**
  - **Results are coherent even with significant changes in resolution**
  - **Surfel approach reduces dependency on surface tessellation**
  - Measurable effects are limited to local areas
    - › Critical: high curvature and high flow velocity
    - › Front bumper, front wheels, mirrors
  - Small local changes in mesh quality do not affect global results
    - › Using the surface mesh setting will give consistent and comparable results

- **PowerFLOW® Best Practice Surface Mesh: provides good balance between cost and accuracy**
  - Finer surface meshes add little value
    - › Best Practice results in line with AutoCFD5 committee mesh
  - **Best Practice surface mesh: 3 second simulation in 2.5 hours on 8x H200**
    - › Finer : ≈+25% cost
  - Coarser surface mesh reduces simulation time further
    - › It requires more care in mesh preparation

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