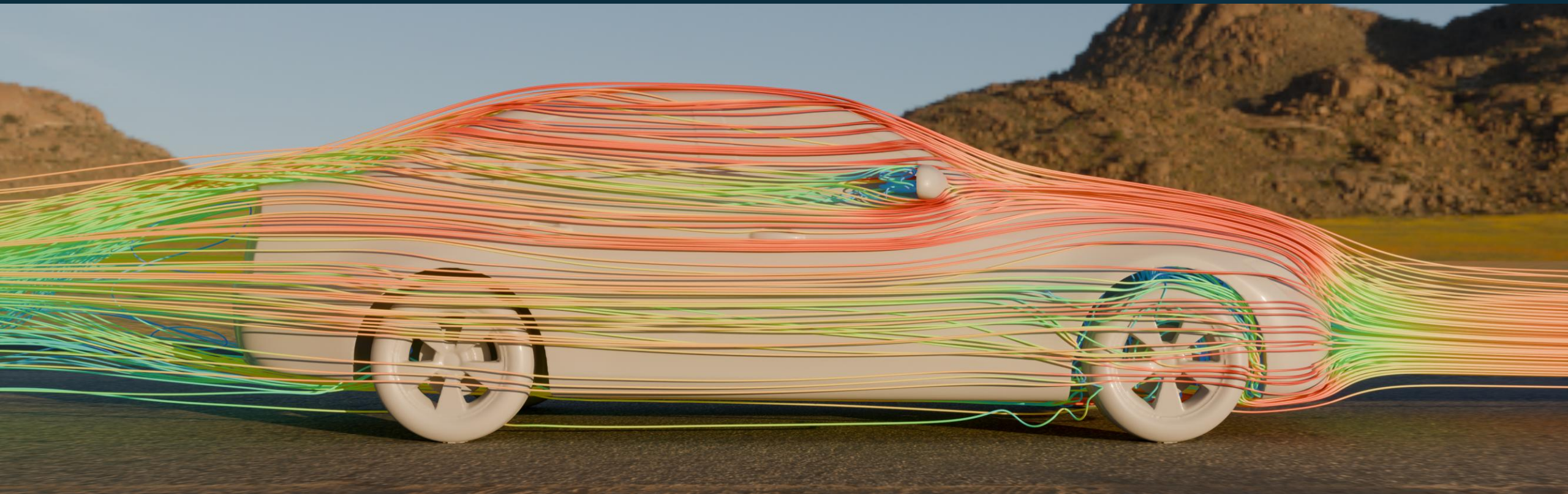
Voxshell

Automated Parallel Hex-Dominant Volume Mesh Generation for the DrivAer Notchback Using ChopMesh

Bryan Wiranata, Sahil Dey, Keren Tuv, Thomas Bainbridge, Leo Yang

5th Automotive CFD Prediction Workshop



01 Why automated meshing?

Geometry keeps getting more detailed

Realistic vehicles carry millions of CAD surfaces and fully detailed underbodies; manual clean-up does not scale.

Manual meshing is slow and skill-scarce

Hand-meshing is rarely part of the modern curriculum and is hard to reproduce consistently between engineers.

Meshes keep growing

High-fidelity cases run into hundreds of millions of cells and heavy to move and demanding on local workstations.

The goal: speed without losing quality

An automated mesher must stay fast at high density while holding element quality that solvers can trust.

The meshing bottleneck

70–80%

of pre-processing effort in a typical high-fidelity CFD or FE workflow is spent on mesh generation and clean-up.

ChopMesh targets exactly this step.

02 The ChopMesh approach

1 Straight from STL

Meshes the surface as supplied: the first Case 2a mesh came from a decimated STL with open and duplicate panels, with no manual repair.

2 Hex-dominant octree

Cubes refined towards the surface and cut at the wall: 64 % hexahedra, with 2:1 transitions between levels.

3 Inflation layers

Prism layers are grown out from the cut-cell wall: 4 layers on this car, the first 0.73 mm thick, growth rate 1.4.

4 Parallel meshing

The Pro edition meshes the domain in blocks on several cores.

03 Case 2a strategy

One automated mesh

32.2 M cells with 4 inflation layers, generated straight from the STL, then exported directly to OpenFOAM.

Clean car surface

The organisers' car surface re-triangulated (3.1 M triangles), with the tyres on the benchmark floor at z = −0.3176 m.

Laptop and HPC

Meshing and RANS on a laptop Intel Core Ultra X7 358H with 64 GB of memory; URANS on 80 cores of an HPC cluster, Intel Xeon E5-2620 v4 (2.1 GHz).

Steady RANS and URANS

OpenFOAM simpleFoam and pimpleFoam with k-ω SST on the same mesh, compared with the AutoCFD 5 reference.

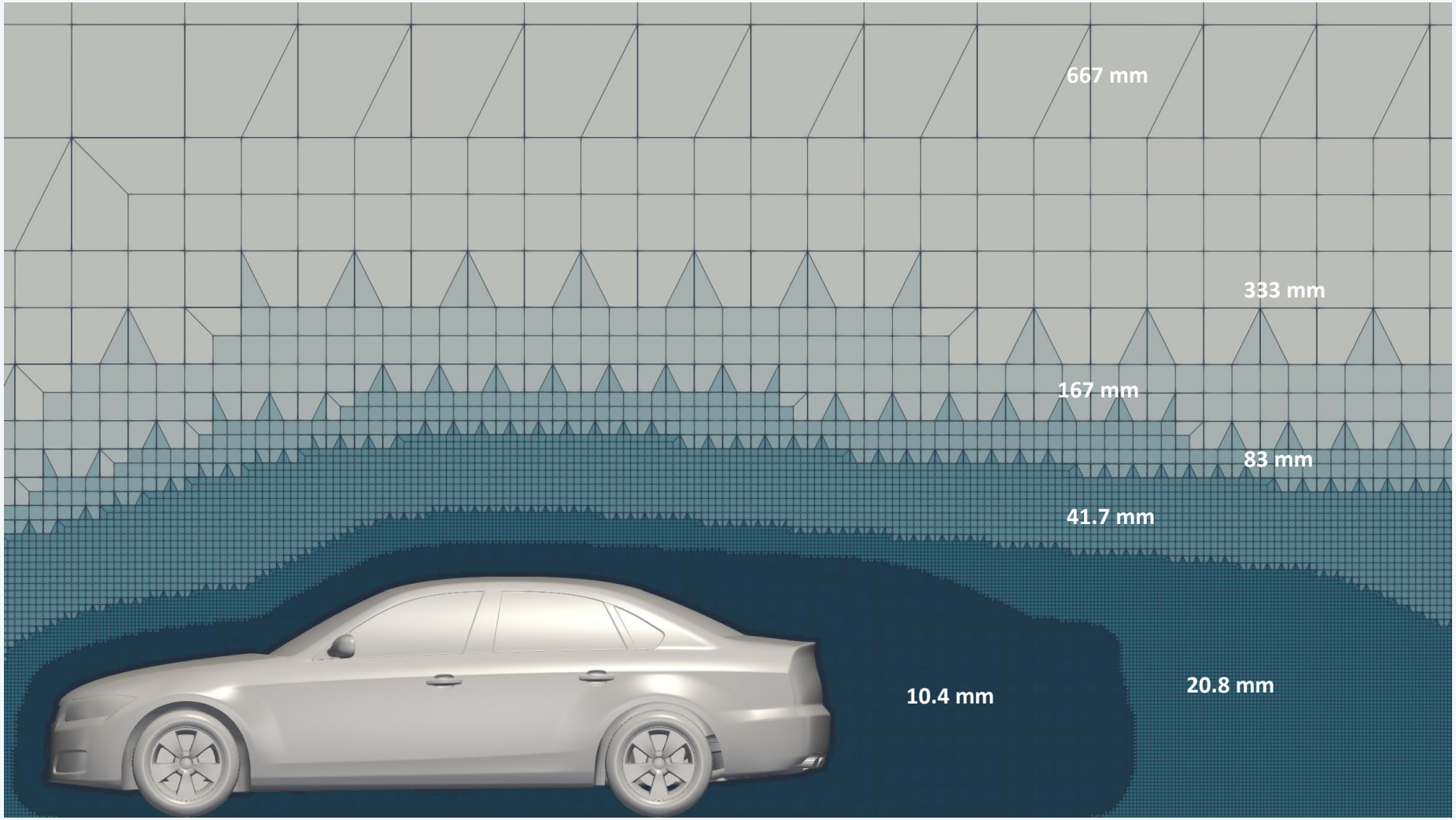
Solver set-up

k-ω SST

OpenFOAM v2412, Spalding wall function. RANS: 1st order to iteration 250, then 2nd order to 1,100. URANS (v2112): Δt = 1 ms to t = 1.2 s, averaged from 0.2 s. Inlet 38.89 m/s, I = 0.26 %; no-slip floor from x = −2.35 m.

RANS 9.4 h on 12 cores; URANS 11 h on 80 cores.

03 Refinement strategy

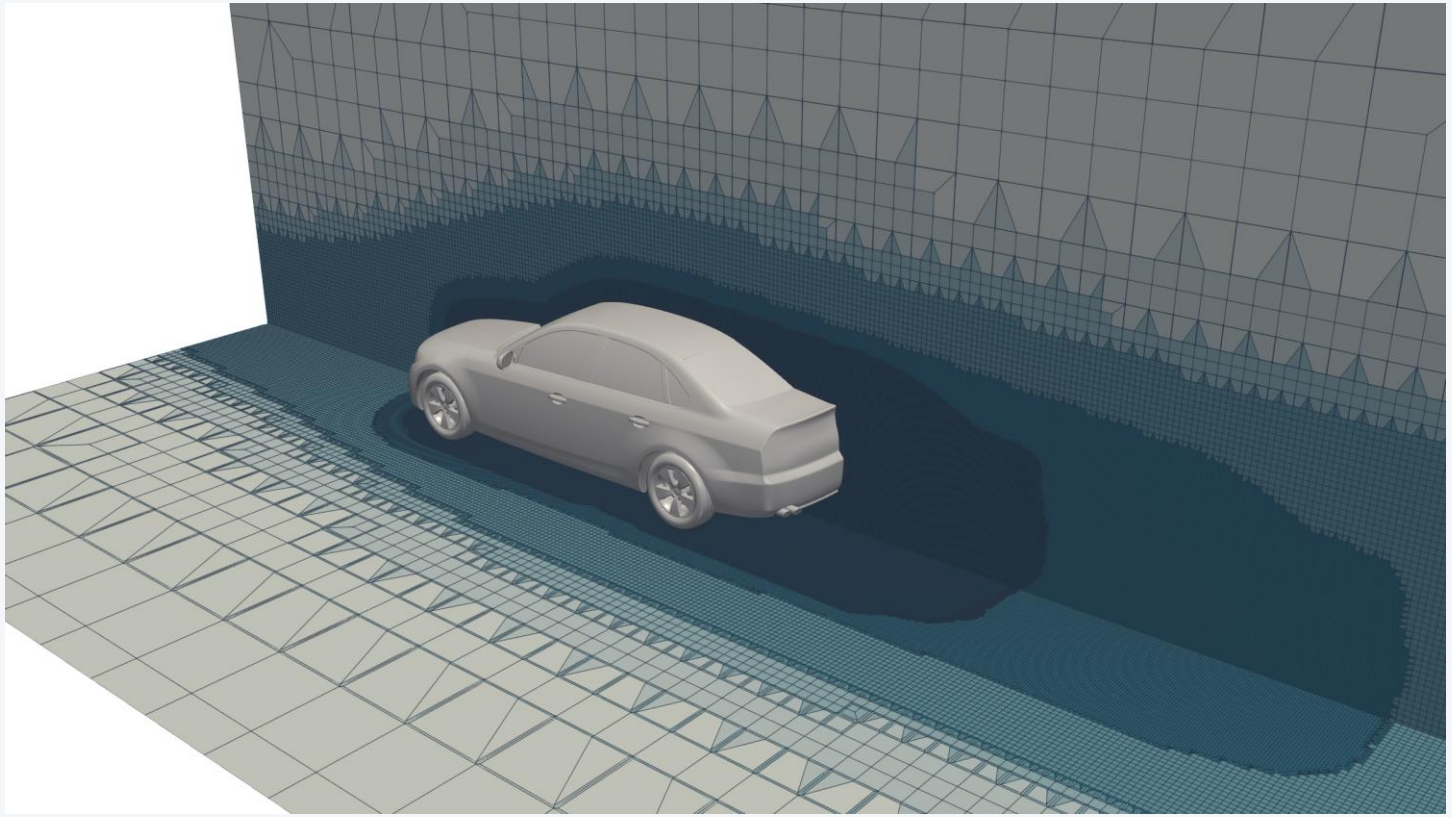


Cell size

5.2 mm on the car surface, with 4 prism layers at the wall (0.73 to 2.0 mm).

10.4 mm in the near-wake box; two outer boxes at 20.8 and 41.7 mm; 0.67 m background.

03 Mesh at a glance

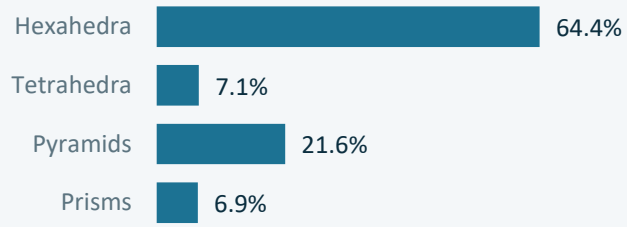


Centreline and floor-level (z = −0.30 m) cut planes: 0.67 m background cells down to 10.4 mm around the car and wake.

How it was built

Cells	32.15 million.
Base grid	NX 180 (0.67 m cells), octree level 7
Car surface	5.2 mm cells all over the car, including the underbody and wheels
Wall cells	4 prism layers, 0.73 to 2.0 mm thick; average y+ about 26

Cell types



OpenFOAM checkMesh

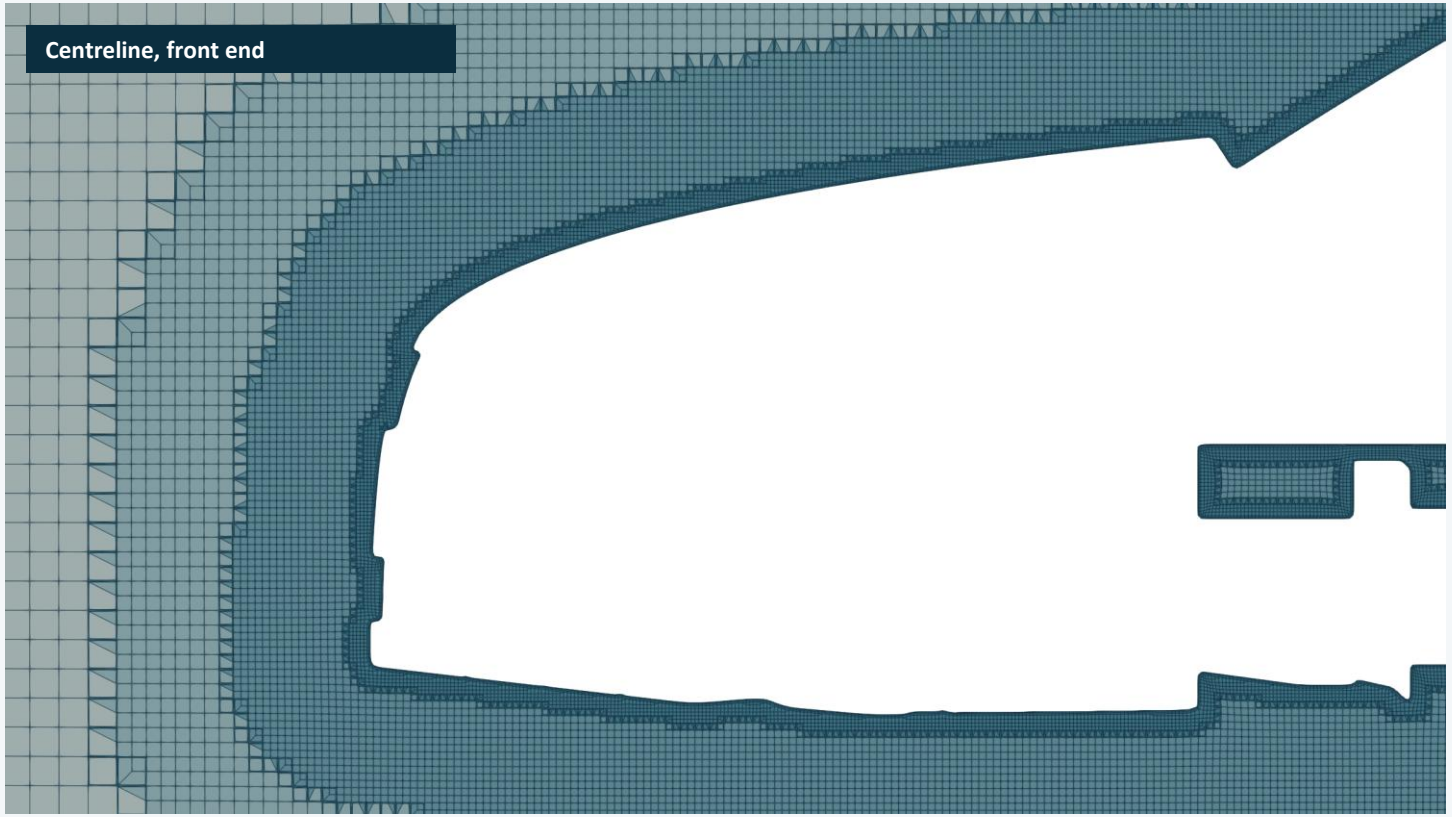
0 negative cells

69.8° max non-orthogonality

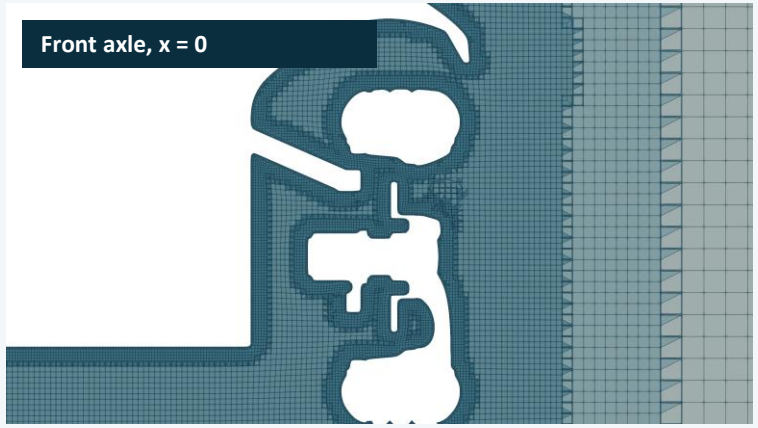
3.99 max skewness

76.5 max aspect ratio

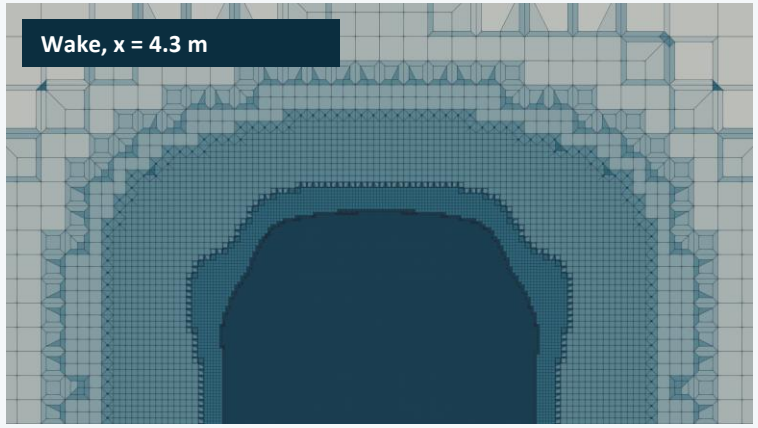
04 Volume mesh



5.2 mm cells wrap the body, with 4 thin prism layers at the wall, then 10.4 mm further out.

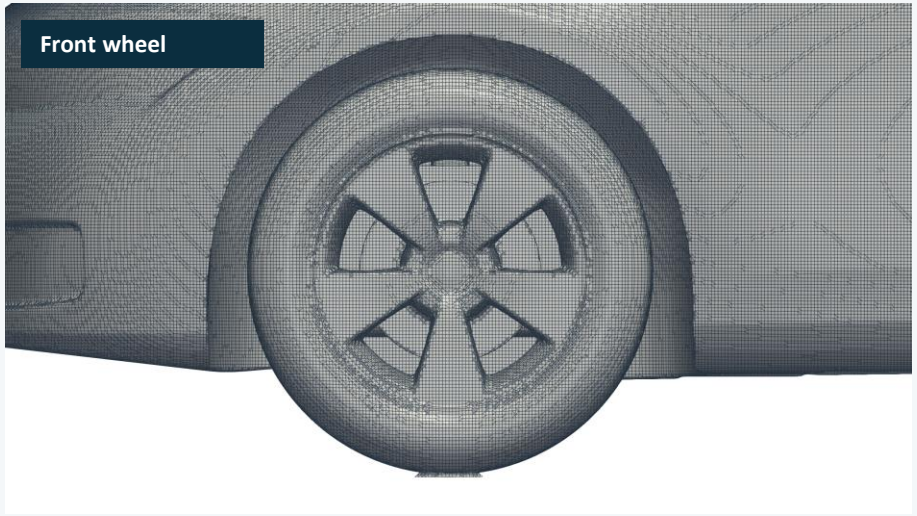


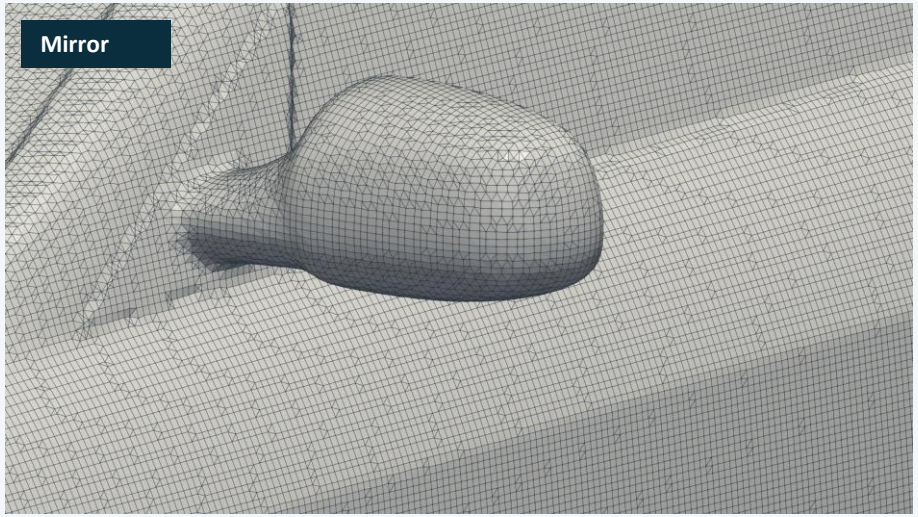
Tyre, rim and brake at the front axle, each wrapped in 5.2 mm cells and prism layers.

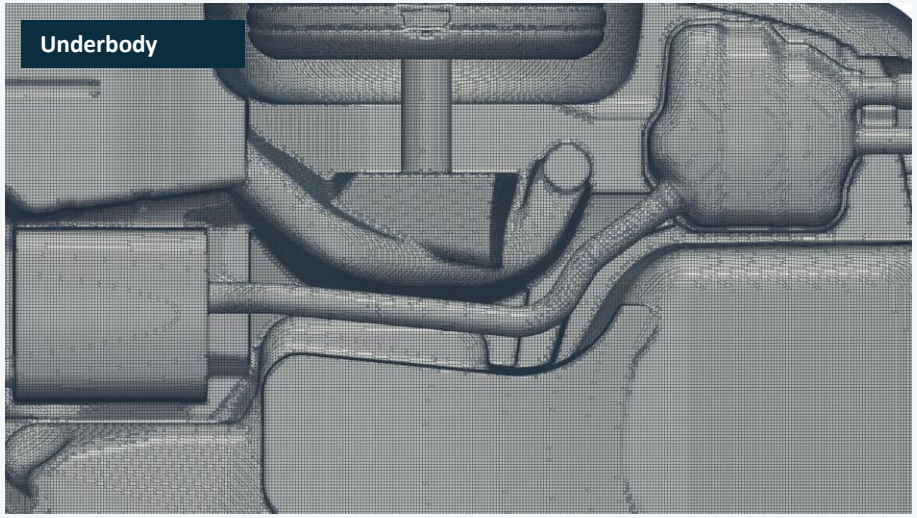


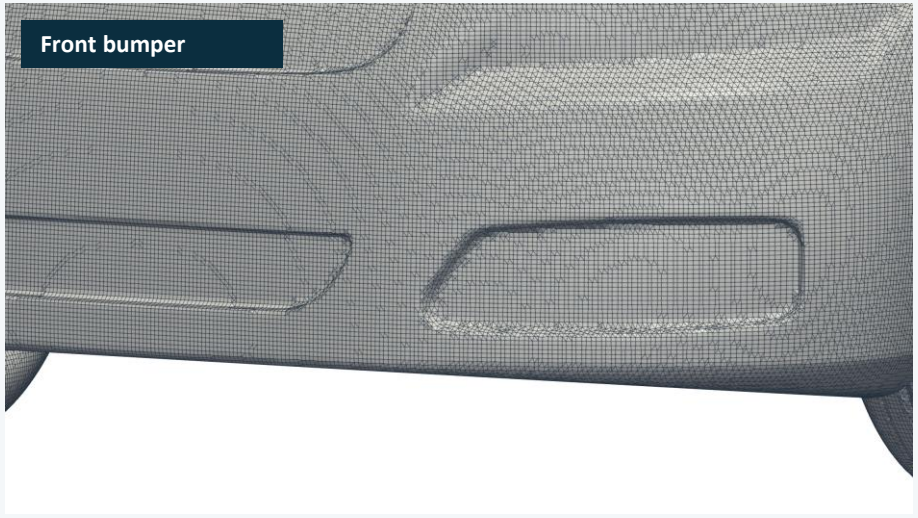
Nested refinement boxes 0.5 m behind the car.

04 Surface mesh









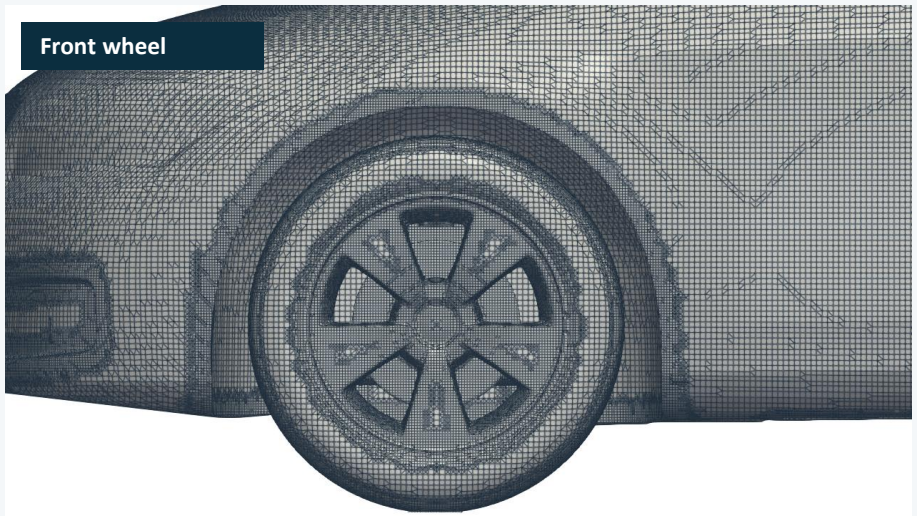
Cut-cell surface

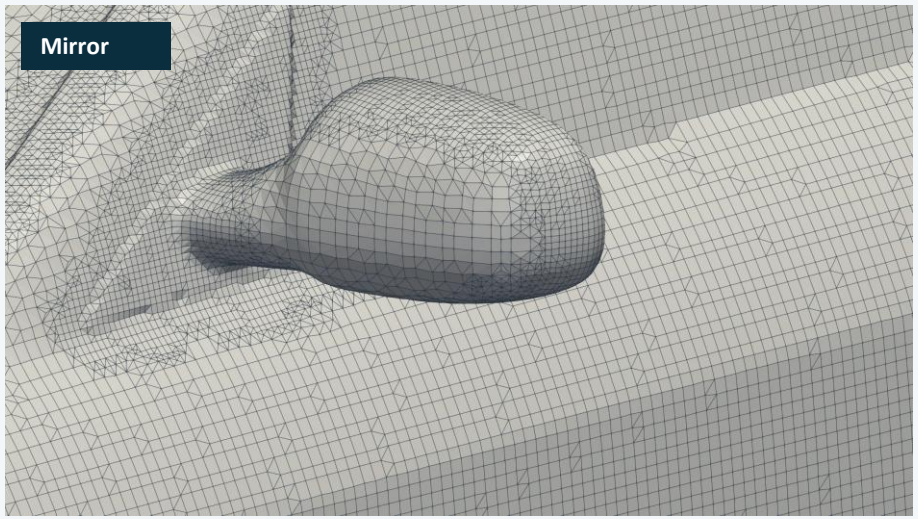
The wall is formed by the octree cells the car cuts through, at 5.2 mm all over the car; the 4 prism layers then grow out from this surface.

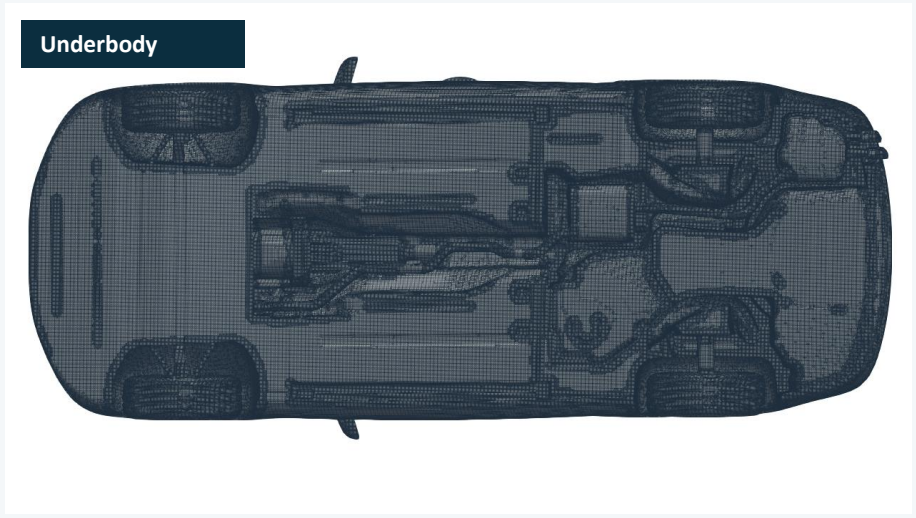
1,460,000

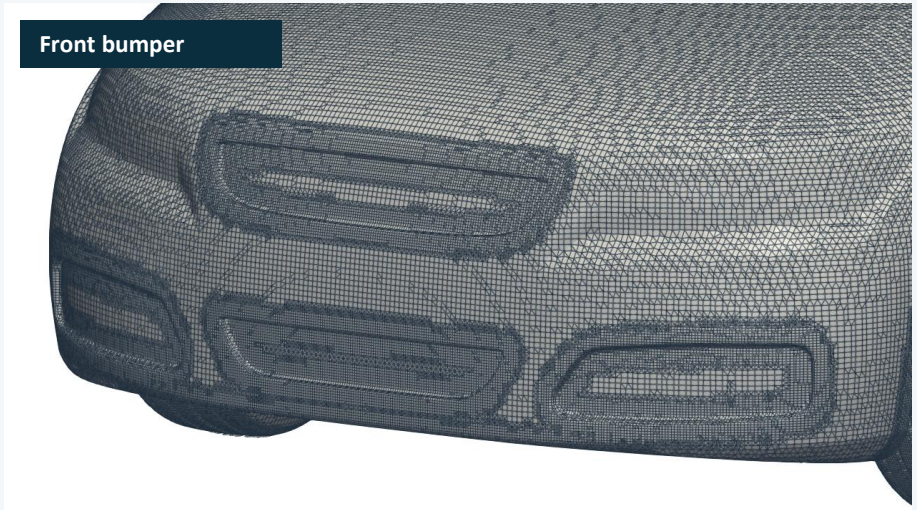
wall faces on the car and tyre plinths

04 Surface mesh: targeted refinement









Targeted refinement

ChopMesh has an option to refine specific parts of the car. With sharp-edge and thin-wall refinement switched on, edges, openings, wheel spokes and the exhaust get one finer level of cells automatically, while smooth panels keep the base size.

05 Results: forces

Drag, Cd

0.293 **0.269**

RANS · URANS · reference 0.272

Lift, Cl

0.040 **0.060**

RANS · URANS · reference 0.026

Front lift

−0.049 **−0.052**

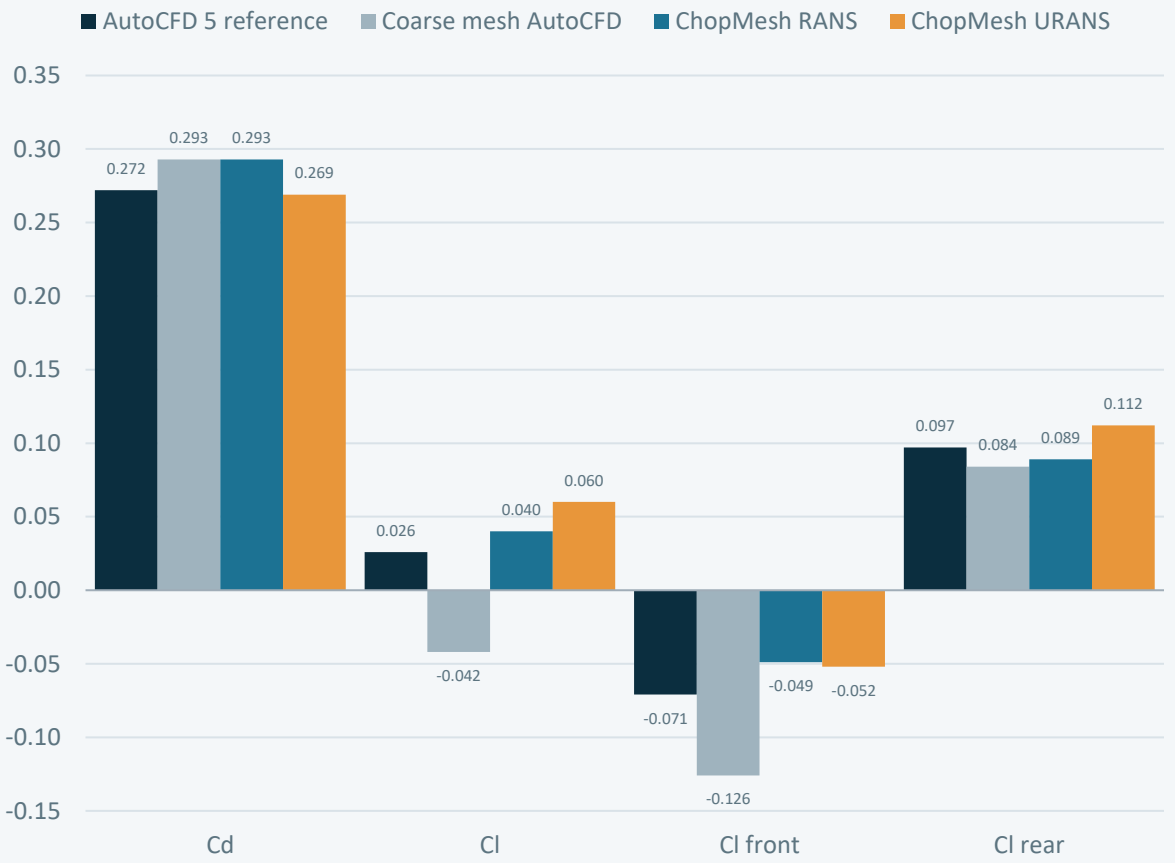
RANS · URANS · reference −0.071

Rear lift

0.089 **0.112**

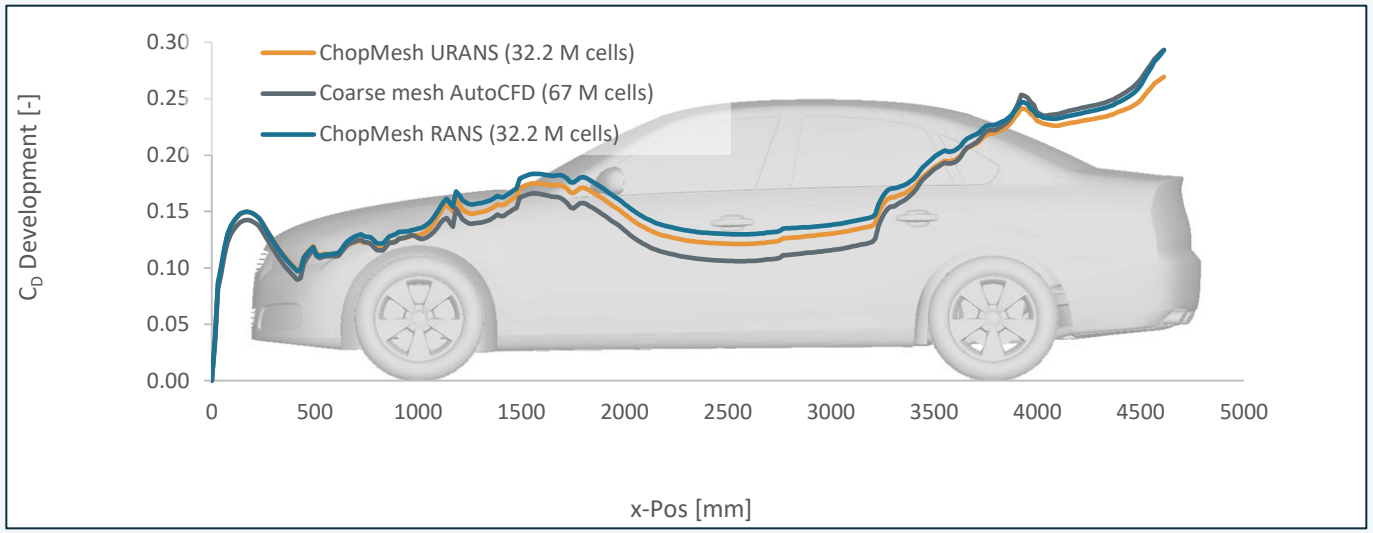
RANS · URANS · reference 0.097

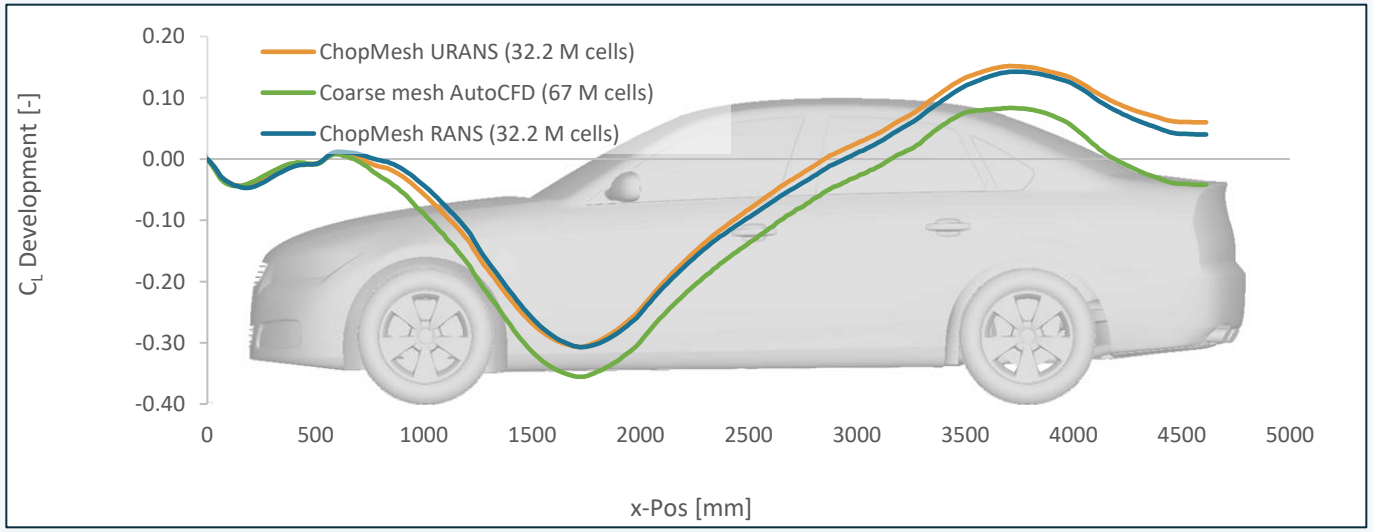
RANS: mean of iterations 801–1,100. URANS: time average over t = 0.2–1.2 s (about 8 flow passes). Forces on the car and tyre plinths. Reference: AutoCFD 5 committee CFD.



ChopMesh RANS and URANS on the inflation-layer mesh, the coarse-mesh AutoCFD case and the AutoCFD 5 reference. 1 count = 0.001.

05 Results: drag and lift build-up





Where the forces build up

Cumulative Cd and Cl along the car, measured from the front bumper. RANS averaged over iterations 801–1,100; URANS over t = 0.2–1.2 s.

Drag: RANS and URANS agree to ~0.5 m. RANS gains ~7 counts over the front wheels and ~19 at the rear and base, ending 24 above URANS. The coarse mesh is ~20 counts lower to ~3 m, then gains ~25 over the backlight and trunk.

Lift: the coarse mesh builds ~30–45 counts more downforce over the front wheels and bonnet and ~35 more towards the tail, which makes its total negative. URANS ends 20 counts above RANS: more downforce at the front wheels, but more lift over the windscreen and roof and less downforce at the tail.

05 Results: surface pressure





Surface pressure, Cp

What it shows: stagnation on the bumper and at the base of the windscreen, suction around the A-pillars, mirrors and roof edges. Colour range −1 to 1.

RANS vs URANS: almost identical over the front and sides, and both surfaces are smooth.

RANS: fields averaged over iterations 801–1,100. URANS: time-averaged over t = 0.2–1.2 s. Rendered in Blender.

05 Results: vortex structures





Vortex structures, Q = 5 000 s^{-2}

What it shows: the A-pillar and mirror vortices and the front-wheel wake.

RANS vs URANS: the same A-pillar, mirror and front-wheel structures; the RANS shows larger pieces in front of the front wheel.

Raw iso-surface, not cleaned: the thin sheet over much of the body is the boundary layer, resolved by the inflation layers, not a vortex.

05 Results: vortex structures, rear





Vortex structures, rear view

What it shows: the rear-pillar vortex pair trailing over the trunk, plus the mirror and wheel vortices.

RANS vs URANS: both show the structures trailing from the rear pillars over the trunk; the RANS has more separate pieces along the side, the URANS a slow (blue) sheet over the base. The drag and rear-lift differences come from the base pressure and wake.

Raw iso-surface, not cleaned: the thin sheet over much of the body is the boundary layer, resolved by the inflation layers, not a vortex.

05 Results: streamlines





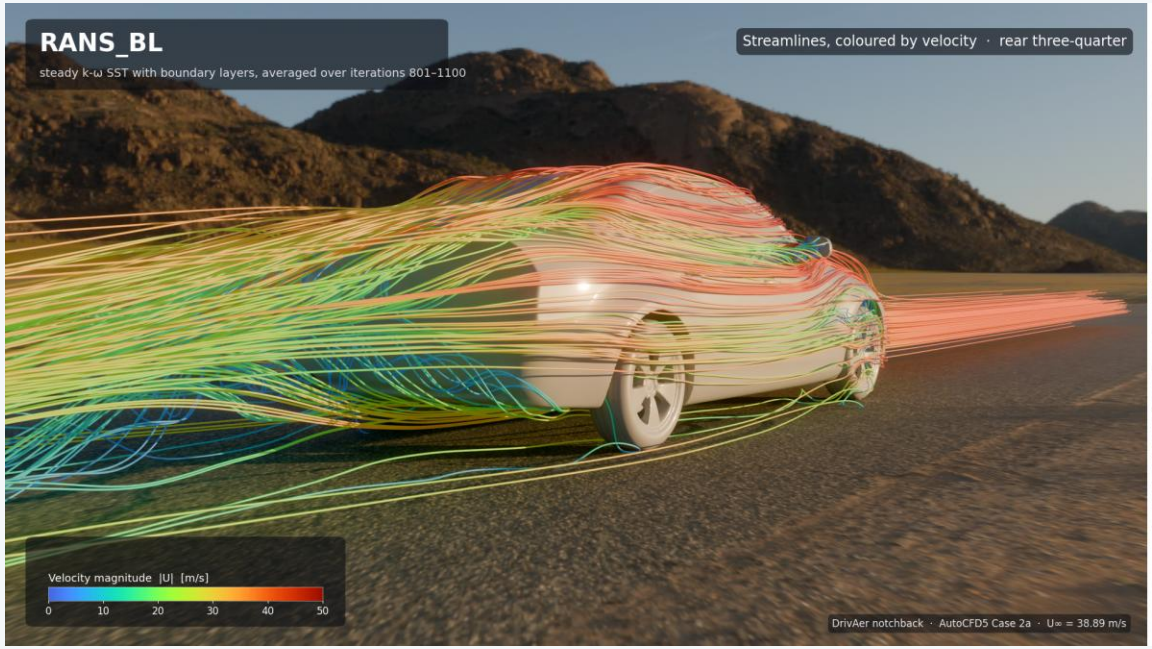
Streamlines around the car

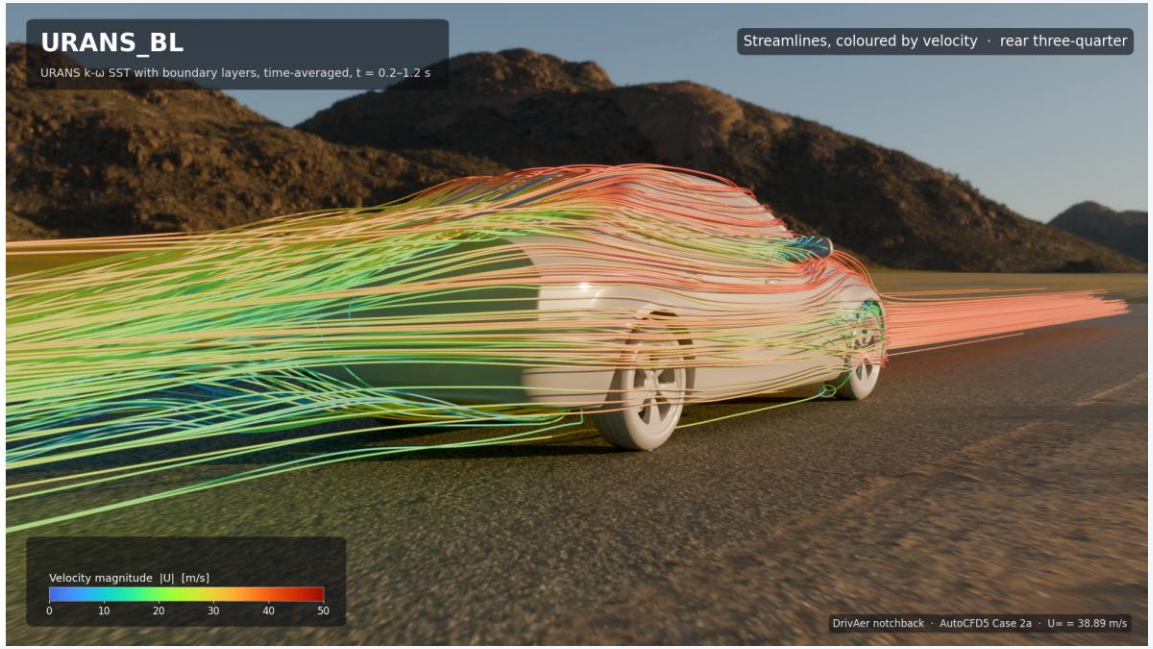
What it shows: streamlines seeded 3 cm off the nose, bumper, tyre fronts, A-pillars and side windows and traced both ways, so each line comes in from upstream and wraps the body, wheels and mirror.

RANS vs URANS: the paths around the body are almost identical; the RANS has more slow lines near the ground at the front wheel. The drag and rear-lift differences build up at the base and in the wake (slide 11).

RANS: fields averaged over iterations 801–1,100. URANS: time-averaged over t = 0.2–1.2 s. Rendered in Blender.

05 Results: streamlines, rear





Streamlines, rear three-quarter view

What it shows: the same streamlines from behind: flow over the roof and trunk, the side flow turning in behind the rear wheel, and the slow flow (green and blue) in the wake.

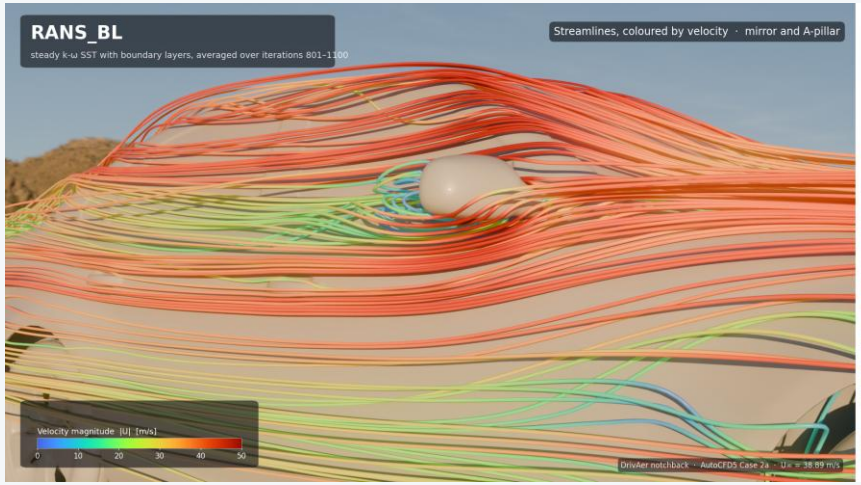
RANS vs URANS: the same paths over the body; behind the car the RANS has many more slow (blue) lines spreading low and wide, the URANS a narrower wake. This is where the RANS picks up its extra drag (slide 11).

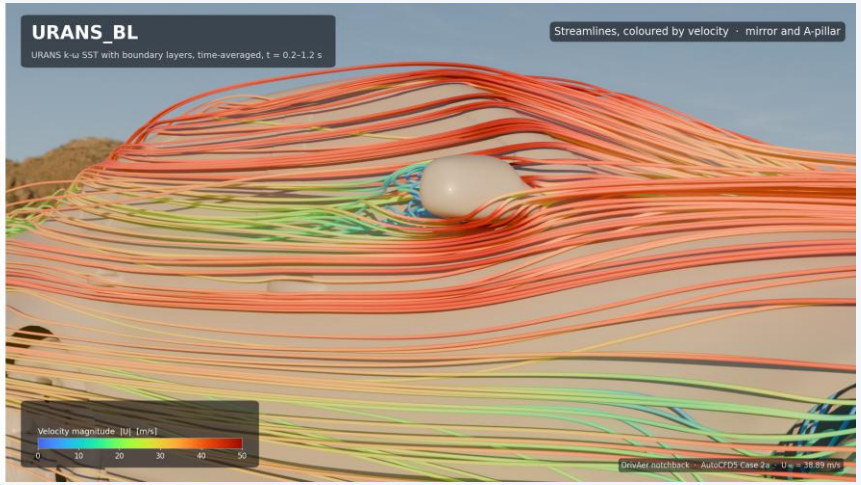
RANS: fields averaged over iterations 801–1,100. URANS: time-averaged over t = 0.2–1.2 s. Rendered in Blender.

05 Results: flow close-ups









Front wheel and mirror

Front wheel: the flow wraps the tyre and slows down (blue) inside the wheel arch; the RANS has more slow lines escaping low in front of the wheel.

Mirror and A-pillar: the flow speeds up (red) over the A-pillar and around the mirror; the extra lines behind the mirror show its slow wake, very similar in both.

RANS: fields averaged over iterations 801–1,100.

URANS: time-averaged over t = 0.2–1.2 s. Rendered in Blender.

Conclusions

1 Automated, straight from STL

One ChopMesh run from the car STL to a 32.2 M-cell mesh with 4 inflation layers, exported directly to OpenFOAM.

2 Solver-ready quality

OpenFOAM checkMesh: 0 negative cells, 69.8° max non-orthogonality, 3.99 max skewness; average y+ about 26 on the car.

3 Inflation layers at the wall

4 prism layers from 0.73 to 2.0 mm on 5.2 mm surface cells, and 64 % of the mesh is hexahedra.

4 Applied to DrivAer Case 2a

32.2 M cells: steady RANS Cd 0.293 on a 16-core laptop and URANS Cd 0.269 on 80 HPC cores, against 0.272 for the AutoCFD 5 reference.