Gaspar García, CFD portfolio

Caveated

Updated 2026-11-14

Windsor squareback: an extrapolation a fourth grid did not support

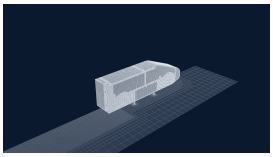
Objective. Measure the drag of the Windsor squareback (no wheels, 0° yaw) with steady RANS and establish how far it is from the wind-tunnel value once grid error is accounted for.

Parameters

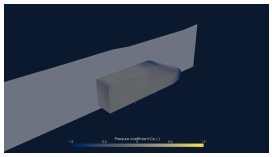
Free-stream speed	40 m/s
Reference length	1.044 m
Reference area	0.056 m^2 (half model)
Reynolds number	Not stated in the cited files
Fluid	Air, incompressible (Newtonian transport model)
Solver	OpenFOAM v2412, simpleFoam, steady
Turbulence model	k-omega SST
Wall treatment	Wall functions



1 Geometry



2 Mesh

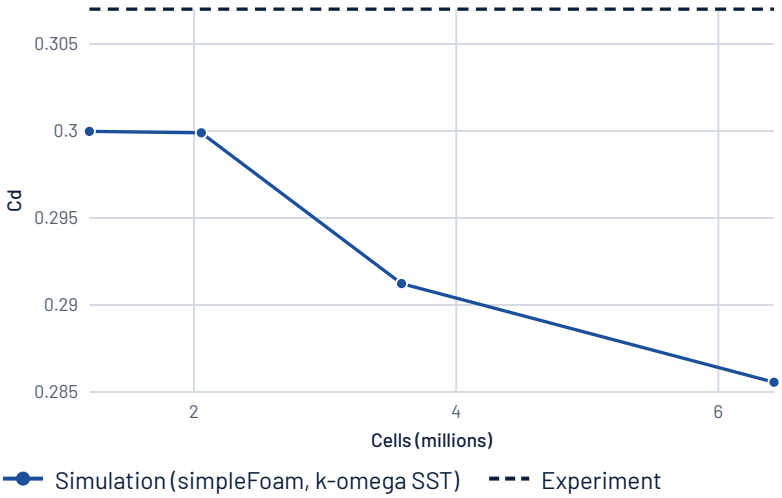


3 Results

Comparison with experiment

Quantity	Experiment	Simulation	Signed difference
Drag coefficient Cd, finest grid	0.3070	0.2856	−7.0 %
Lift coefficient Cl, finest grid	−0.030	−0.142	sign-magnitude failure
Drag, three-grid extrapolation (withdrawn)	0.3070	0.2765	−9.9 %

Cd against Cells (millions)



Verdict

On the finest grid steady k-omega SST under-predicts drag by −7.0 %. A fourth grid showed that the earlier three-grid extrapolation was not supported, so no grid-independent value is claimed.

Limits

- No positive observed order on four grids: no numerical uncertainty band.
- The tunnel's reference dynamic pressure convention is unresolved; the error's size depends on it.
- Lift is a sign-magnitude failure (−0.142 against −0.030).

1. AutoCFD workshops, Windsor squareback body (Loughborough University wind-tunnel model): experimental force coefficients, as quoted in the campaign closure memo of 2026-07-30.
2. Pavia et al. (2018, 2020): wake bi-stability on this model, cited in the closure memo for the base-pressure shape.
3. Celik et al. (2008), the ASME Journal of Fluids Engineering procedure for discretisation error; its refinement-ratio guidance is quoted in the ladder memo.
4. Eça and Hoekstra (2014), least-squares procedure for numerical uncertainty, as implemented in the shared GCI tool.

Full page with sources, mesh and numerical accuracy: /cases/windsor/. Every number is checked against its source file.