

Case 1: 1st Automotive CFD Prediction Workshop: SAE Reference Notchback Model

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Introduction

This case requires the simulation of a simplified vehicle like shape in wind tunnel conditions and is intended to capture the important flow-field structures without needing to model complex geometrical detail. The case is based on the SAE 20-degree backlight angle notchback reference model at 1/5 scale (Cogotti 1988) with an experimental campaign undertaken at Loughborough University (Wood, Passmore and Perry 2014). The Loughborough institutional repository contains the underpinning PhD thesis (Wood 2015) and a 'green' open access version of the paper. This test-case description, geometry, meshes and example post-processing are available on the website transfer section (autocfd-transfer.eng.ox.ac.uk).

Geometry and Domain

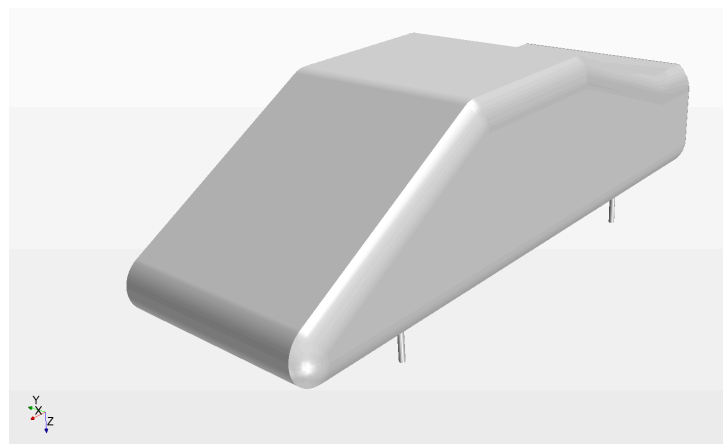


Figure 1 SAE Reference Model Geometry

This is a 1/5 scale model with a length of 840mm, a width of 320mm and a height (excluding pins) of 240mm. The reference frontal area is defined as 0.076m^2 and the car length L and height H are used to non-dimensionalise distances. Note that Cogotti (1988) documents the full scale variant has a frontal area of 1.896m^2 , so that a 1/5 scale should be 0.7584m^2 , however the paper rounds this to **0.076m^2 and is the reference value that should be used.** The front of the model has a 30 degree slant and at the rear there is a 20 degree backlight leading to the notchback. The underside is flat until reaching a small 6 degree diffuser starting at the nominal location of the rear axle.

The model is mounted in the wind tunnel with four pins at a ground clearance of 40mm and zero pitch.

The CAD geometry of the model has its origin at the centre of the vehicle with the x-direction forward (nose +420mm, rear -420mm), y-direction to the right (left side -160mm, right side +160mm) and z-direction downwards (bottom -40mm, top -280mm).

The supplied CAD geometry differs from that on the Loughborough University repository: the gap between the pins and the recessed holes in the model has been faired over and the pins extended to ensure that they reach down to the ground. Geometry is supplied as IGES, STEP, STL and Siemens NX part files. The Modified geometry should be used.

The experimental wind tunnel has a 3.2m long working section with a 1.92m wide x 1.32m high cross section expanding to 1.94m wide x 1.32m high at the end of the section. There is no moving ground plane and so boundary layers grow along the walls and the experimentalists estimate a δ^{99} boundary layer thickness of 40-60mm, with a momentum thickness of 9-10mm at the model location (note the ground clearance is 40mm).

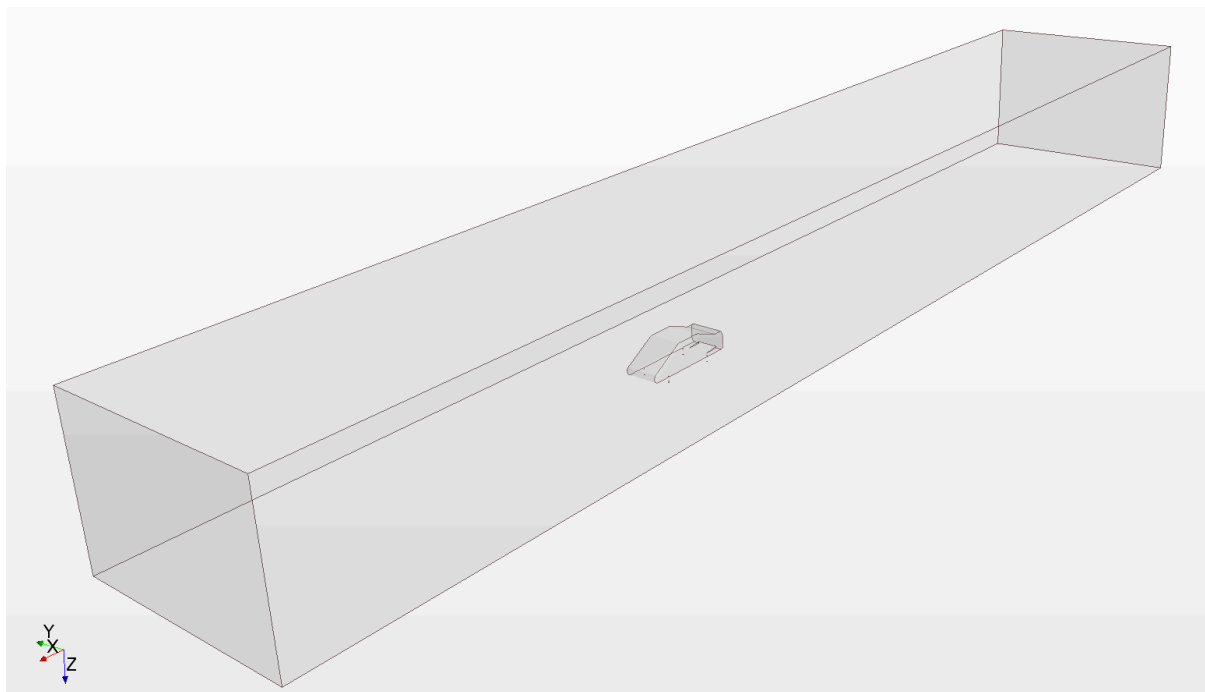


Figure 2: Computational wind tunnel domain

The domain required for this case represents the wind tunnel confinement but with the following modifications:

1. Parallel walls
2. Only the ground plane has a no slip condition and hence has a boundary layer growth
3. A long parallel inlet run is used in order to grow a boundary layer on the ground plane of approximately the correct thickness.
4. A parallel exit run is added downstream to avoid interactions with the wake.

The recommended domain has five car lengths (4.2m) forward of the nose and eight car lengths (6.72m) downstream giving a total length of 14L (11.76m). The working section is

1.94m wide and 1.32m high. Of the wind tunnel walls, only the ground plane should be treated as a no-slip wall.

Grids

Two grids are supplied: a medium grid suitable for (Unsteady) RANS with resolved boundary layers and a fine grid suitable for Detached Eddy Simulation. The first exploits symmetry so only half the model and domain is gridded, whilst the DES grid is of the full geometry.

The grids are generated using a Cartesian trimmer mesh with prism layers on no-slip walls. A single refinement zone extending 4L downstream is used to capture the wake for RANS grid. Additional refinement zones are added in the notch and close to the base for the DES grid. Table 1 summarises key parameters that defines these meshes – note that % refer to the vehicle height of 240mm as a reference.

Table 1: Grid Definitions

Parameter	RANS		DES	
	Largest Cell	32%	76.8mm	32%
Smallest Cartesian Cell	1 %	2.4mm	1%	2.4mm
Wake refinement minimum size	2%	4.8mm	0.5%	1.2mm
Prism layer wall				
thickness	19%	4.8mm	19%	4.8mm
number	19		19	
stretching	1.15X		1.15X	
near wall cell size		0.52mm		0.52mm
Prism layer body				
thickness	5%	12mm	5%	12mm
number	23		23	
stretching	1.2X		1.15X	
near wall cell size		0.037mm		0.075mm
Total cells	4,115,762		29,145,776	

Grids are supplied in CGNS, OpenFOAM (v2.4, 3.0, 4.0), ANSYS Fluent .msh and Siemens Star-CCM+ .csm formats.

Experimental Data

A large amount of experimental data is available in the SAE paper, online repository and Daniel Wood PhD thesis. For the purposes of the workshop we will be interested in:

1. Drag and lift coefficients.
2. Mean pressure coefficient over the surface of the model, this will be compared to top surface centreline and backlight, boot-deck and base pressure distributions.
3. Slices of mean velocity for comparison with PIV data ($x=-380\text{mm}$, $x=-290\text{mm}$, $y=0\text{mm}$, $y=-60\text{mm}$, $y=-90\text{mm}$). See Figure 3.

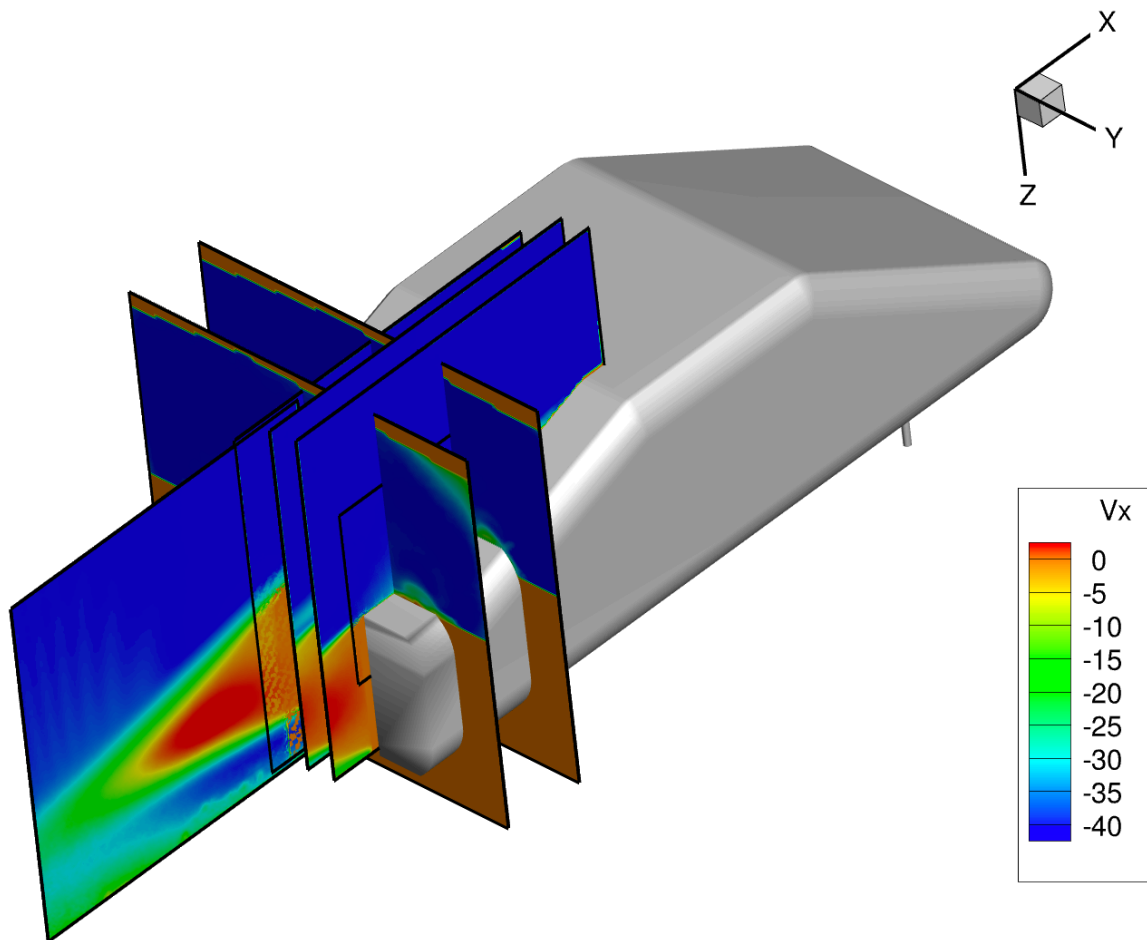


Figure 3: Experimental PIV locations of interest

Test Cases

A zero yaw case at an inlet condition of 40 m/s, with a Reynolds number of 2.3M based on the vehicle length, should be run. A low turbulence intensity of 0.2% is reported in the experiment and should be used as a boundary condition for RANS inlet conditions alongside a sensible length scale. At this speed there is a characteristic time scale t^* (vehicle length/freestream speed) of 0.021s.

When presenting pressure and force coefficients, the experimental data uses a free stream probe approximately 2m forward of the origin mounted near the roof of the tunnel to determine total and static pressure. The same procedure should be used when presenting CFD data, the local static pressure and velocity magnitude at [2,-0.002, -0.92]m should be used for normalisation of force and pressure coefficients. Note that no other forms of wind tunnel correction should be used for the data supplied to the workshop. As the mounting pins are connected to the balance, these need to be included when computing force coefficients. To be clear, positive lift would lift the vehicle from the surface of the road.

As the PIV system directly measures velocity, no corrections are applied by the experimentalists, and in the SAE paper it is normalised by the assumed freestream velocity of 40 m/s.

For RANS solutions you should assume that the model is fully turbulent, and for DES cases no inflow turbulence is required.

Data Submission

All the requested data should be sent to g.j.page@lboro.ac.uk by November 25th with the subject line being "AUTO CFD: XXX_Lastname" – where XXX is your submission ID (provided once you complete the intention to participate form on the website) and the Lastname of the lead investigator.

The data should be zipped up with the following convention:

XXX_Lastname_Code_Model__Case1_v1.tar.gz

Where XXX is the submission ID, Lastname is the lead investigator last name, Code is the CFD code used and Model is the turbulence model i.e

001_Page_STARCCM+_SSTDDES_Case1_v1.tar.gz

Please contact g.j.page@lboro.ac.uk prior to submission if you believe the data will be too large and access to a FTP site can be arranged.

---- (exact data requirements will be confirmed shortly but will include the following)---

Mean Drag and lift coefficients. For unsteady simulations a time history of lift and drag coefficient for at least one characteristic time scale t^* . (tecplot template provided)

Mean pressure coefficient over the body surface. (VTK format or tecplot format **TBC**)

Mean components of velocity at the experimental planes $x=-380\text{mm}$, $x=-290\text{mm}$, $y=0\text{mm}$, $y=-60\text{mm}$, $y=-90\text{mm}$. (tecplot template provided)

For unsteady simulations: computational time step, length of time used to compute means.

Note that although we are defining lengths in mm, the velocity data should be provided in metres for position and metres per second for velocity.

Cogotti, A. "A Parametric Study on the Ground Effect of a Simplified Car Model," SAE 980031, 1998.

Wood, D., Passmore, M., and Perry, A., "Experimental Data for the Validation of Numerical Methods - SAE Reference Notchback Model," *SAE Int. J. Passeng. Cars - Mech. Syst.* 7(1):2014, doi:10.4271/2014-01-0590. <https://dspace.lboro.ac.uk/2134/15978>

SAE reference model: 20 degree notchback validation dataset (reference SAE paper 2014-01-0590). <https://dspace.lboro.ac.uk/2134/13886>

Wood, D., "The effect of rear geometry changes on the notchback flow field," PhD Thesis, Loughborough University, 2015. <https://dspace.lboro.ac.uk/2134/18889>