Aerodynamics and CFD at Volvo Car Corporation

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Volvo Car Corporation

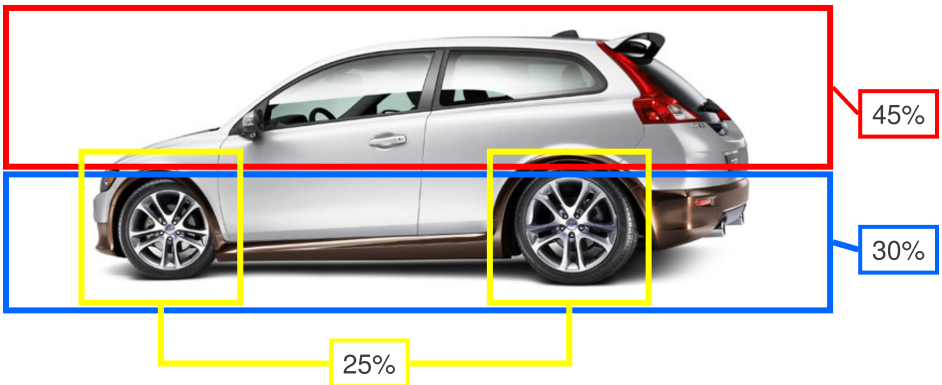
Overview

- Background
- Influence of Aerodynamics
  - Why is aerodynamics important
- Development
- Facilities
  - Test Techniques
  - Moving Ground

Influence of Aerodynamics

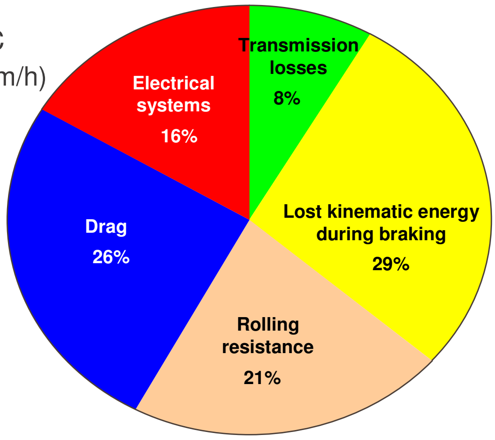
- Drag (fuel consumption, top speed, acceleration)
- High-speed stability (lift)
- Cross-wind stability (side force and yawing moment)
- Passenger comfort (cabriolets)
- Cooling Performance
- Dirt deposition (visibility)
- Aero acoustics (limiting the strength of sources)
- Body deformation (Door frames etc)

Sources of drag on a modern car



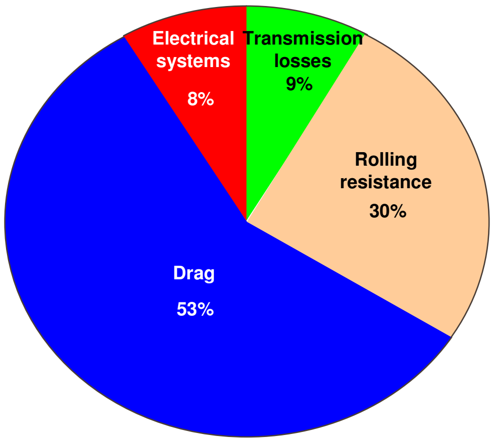
Aerodynamics part of total fuel consumption

"EU Combined cycle" NEDC
(Note! Average speed ≈33km/h)



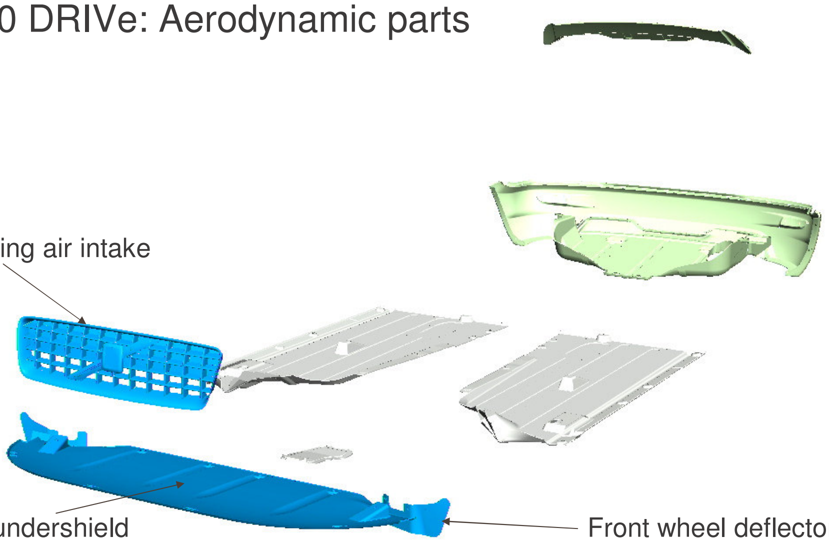
Aerodynamics part of total fuel consumption

Constant speed 90km/h

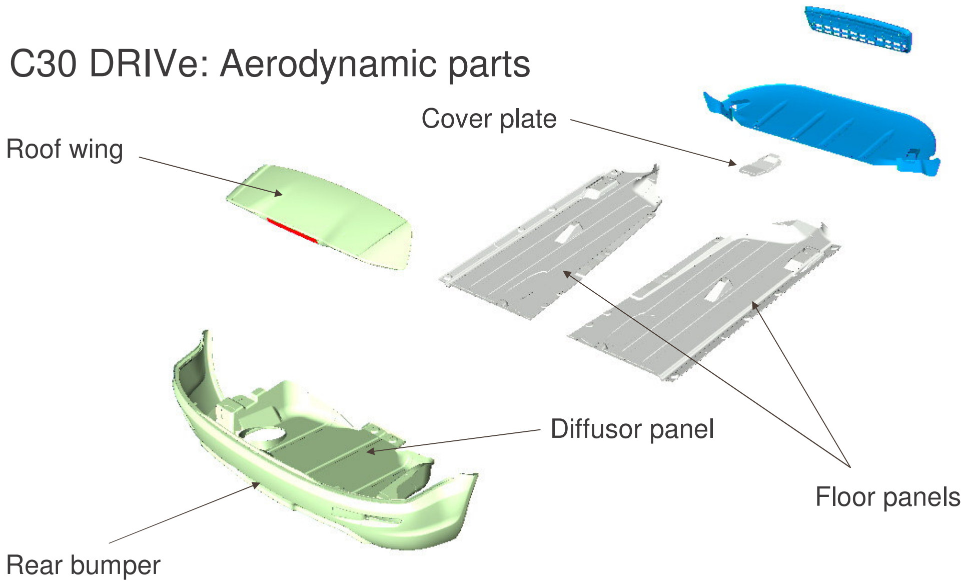


Aerodynamics On the C30 DRIVe

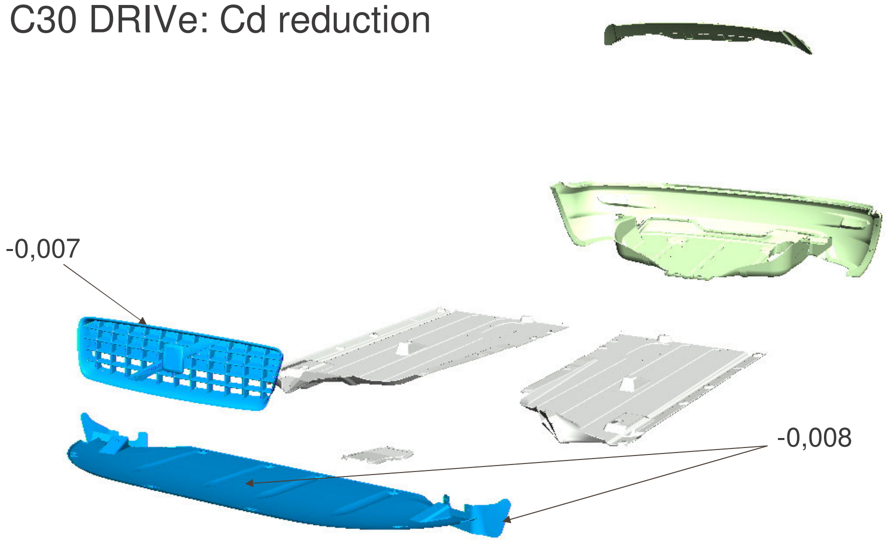
C30 DRIVe: Aerodynamic parts



C30 DRIVe: Aerodynamic parts



C30 DRIVe: Cd reduction



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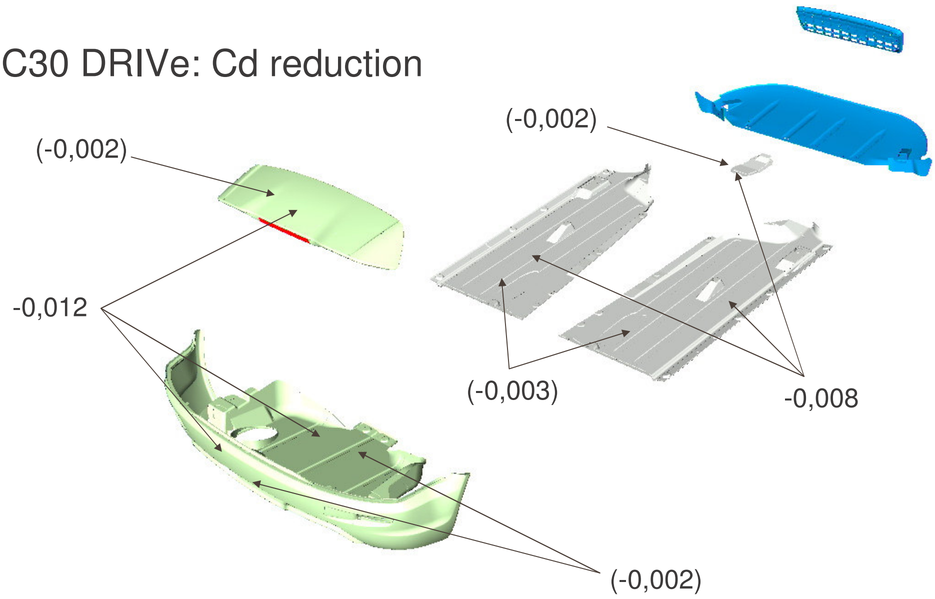


C30 DRIVe: Aerodynamic parts

Special wheels (Libra)

delta Cd (compared to steel rims)
-0,005 (rotating)

Lowered chassis
delta Cd -0,005

Aerodynamic drag reduced more than 10% compared to standard car

Fuel consumption reduced by:

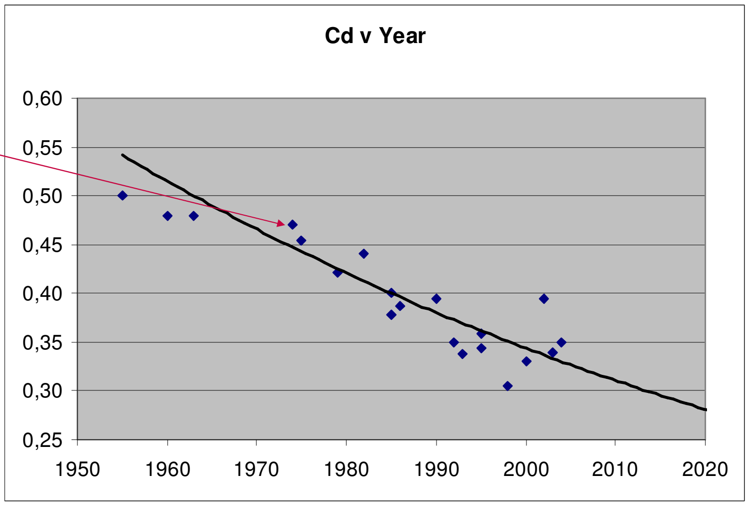
- 0,12 l/100km or 3g CO_2/km (EU Combined)
  - (this corresponds to an equivalent weight reduction of approx. 80kg)
- 0,3 l/100km @ constant 90km/h

Challenges facing Aerodynamicists

- Styling
- Manufacturing
  - Parts
  - Assembly
- Packaging
- Visbility
- Other attributes (eg Thermo, dirt, handling ……)
- ”Carry-over” content
- Cost!!!

Aerodynamics through the ages

	Year	Cd
PV 544	1955	0,50
Amazon	1960	0,48
P1800	1963	0,48
P1800ES	1968	0,61
240	1974	0,47
245	1975	0,45
343	1979	0,42
760	1982	0,44
765	1985	0,40
960	1990	0,40
854	1992	0,35
855	1993	0,34
S80	1998	0,31
V70	2000	0,33
XC90	2002	0,40
V50	2004	0,35
S40N	2003	0,34
460	1986	0,39
480ES	1985	0,38
S40	1995	0,34
V40	1995	0,36



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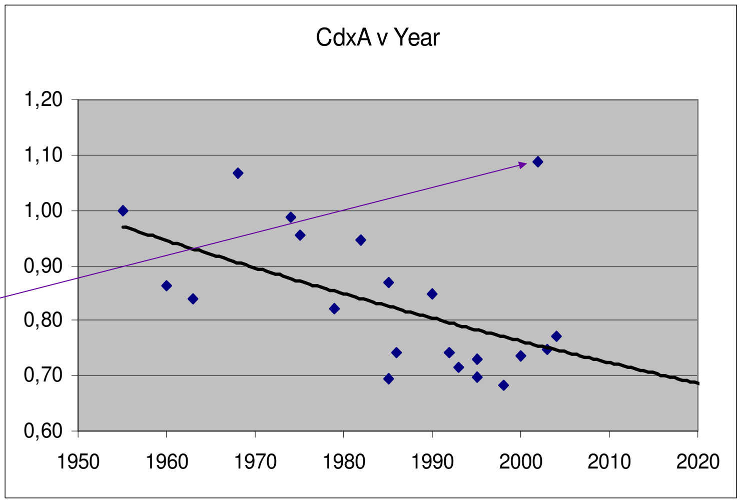

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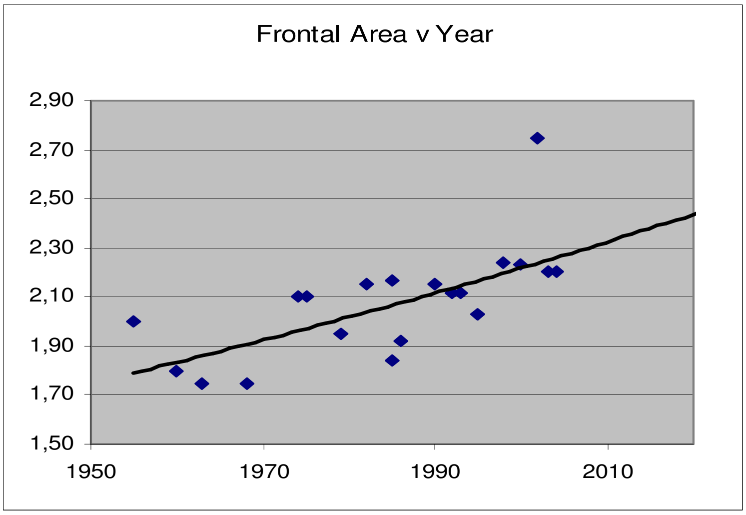


Development process

Concept study

- Generic shape studies
- Evaluate styling proposals
- Define underfloor concepts

•Analysis and research of previous models and competitors
•Simple scale model tests (parameter studies)
•Semi-detailed CFD (parmeter studies)
•Create guidlines to design and engineering
•Create aerodynamic ”hard points”

Development process

Prestudy

- Develop frozen design
- Develop underfloor solutions

•Analyse and suggest improvements to many designs (CFD and models)
•Give recommendations when choosing design
•Develop and improve chosen design using full-scale clay model and fully detailed CFD modelling
•Confirm and approve the chosen design's predicted characteristics

Development process

•Fine tuning of pre-production prototypes
•Confirm and approve all characteristics
•Follow up any late design changes
•Confirm production car

Project

- Detail optimization
- Verification

36-48 months

Concept study

- Generic shape studies
- Evaluate styling proposals
- Define underfloor concepts

Prestudy

- Develop frozen design
- Develop underfloor solutions

Project

- Detail optimization
- Verification

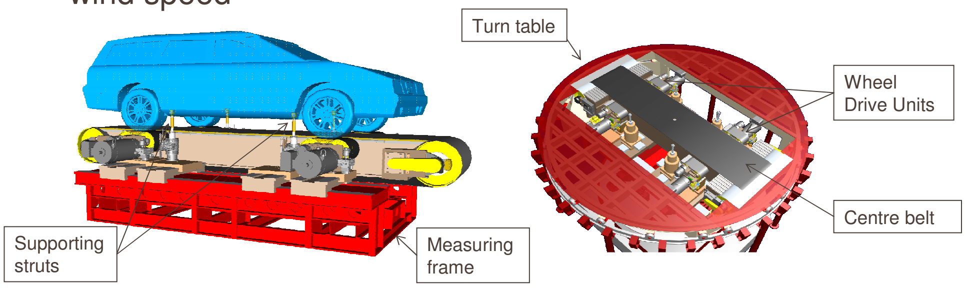
Wind tunnel facilities at Volvo

In-house testing in three wind tunnels, Gothenburg

PVT	MWT	Climatic
Test section 27m^2 (6.6mx4.1m , length 15.8m) Max speed 250 kph Temp. +20 to 60° C Chassi dyn. load 150 kW Sun sim. max 1200 W/m^2	1:5 scale of PVT Test section 1.1m^2 Max. speed 200 kph	Test section/nozzle 11.2m^2 Max. speed 200 kph Temp range -40 to +50° C Chassi dyn. load 280 kW Sun sim. max 1200 W/m^2

Conventional aerodynamic testing

- Balance measurements
  - Effect of configuration changes on aero coefficients
  - Investigate sensitivity to flow angle, vehicle attitude and wind speed



Why Moving Ground is Neccessary

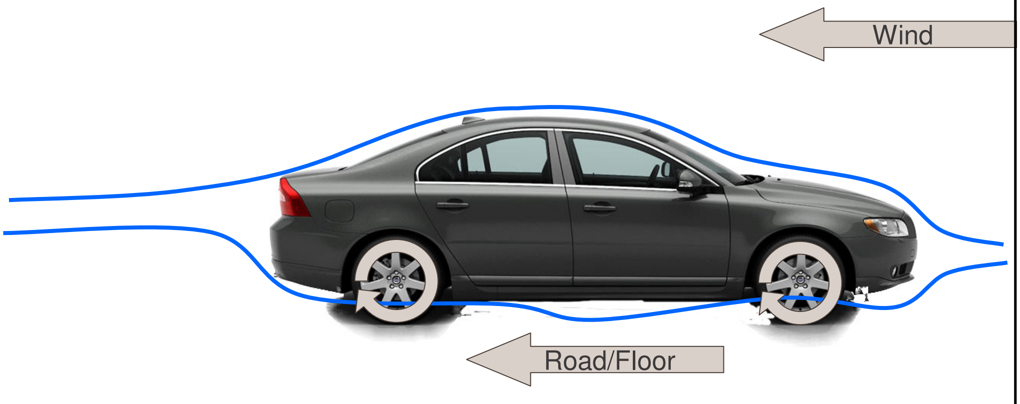
Provides correct relative movement between the car body and tunnel floor

Provides correct relative movement between the car body and wheels

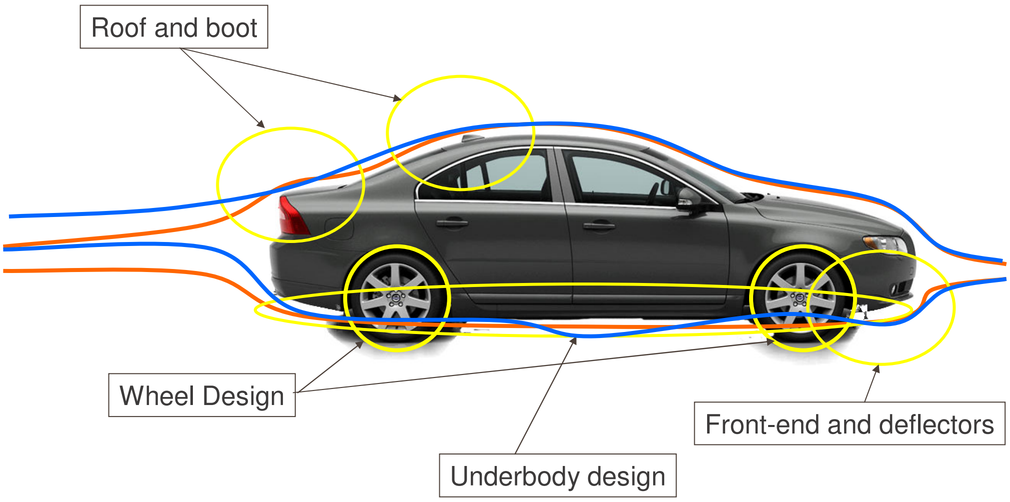
} Influences flow under and around car

How: Stationary Floor and Wheels

How: Moving Ground and Rotating Wheels

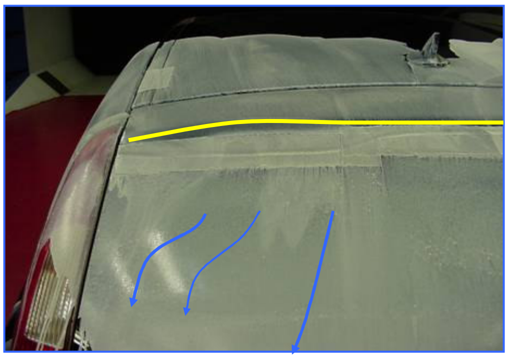


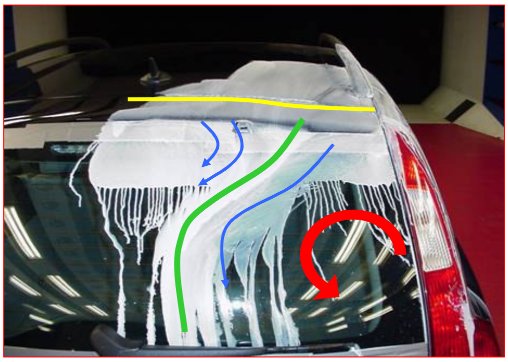
Optimisation affected



Methods to increase the knowledge gained from aerodynamic testing

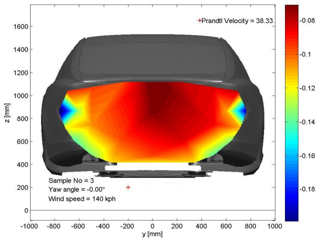
- Flow visualization (smoke, surface paint, tufts)





Methods to increase the knowledge gained from aerodynamic testing

- Pressure Measurements



Methods to increase the knowledge gained from aerodynamic testing

- Wake measurements

$$D = \iint (P_1 + \rho U_1^2 - P_2 - \rho U_2^2)\,dydz$$

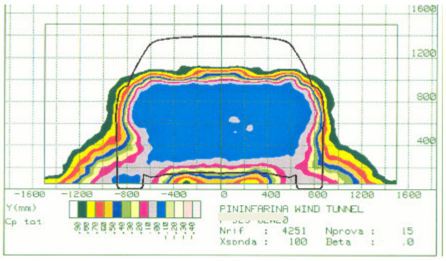
Seven-hole probe rake

Floor traverse

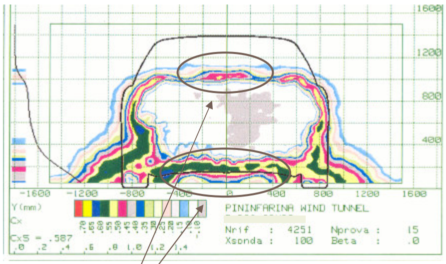
Wake analysis

- Wake measurements 100 mm downstream of a notchback

Total pressure



Microdrag



Identify regions that can be improved