CFD & Aerodynamics at Volvo Car Corporation

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Outline

• Introduction
• Why work with CFD
• What kind of problems we look at
• Hands on the CFD process
• How we work in projects
• Exemples
CFD groups at VCC

Fluid Dynamics Centre, Computational Fluid Dynamics

Powertrain, Thermodynamics analysis

Powertrain, Combustions systems
VCC Fluid Dynamics Centre

Research and Development

Chassis and Vehicle Dynamics

Fluid Dynamics Centre
  Magnus Blomstrand

Thermodynamics
  Mats Löfman

Aerodynamics
  Alexander Broniewicz

CFD
  Hans Enwald

System Attributes
  Göran Karlsson
## VCC Fluid Dynamics Centre

<table>
<thead>
<tr>
<th>Thermodynamics</th>
<th>Aerodynamics</th>
<th>CFD</th>
<th>System Attrib.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooling Performance</td>
<td>Drag</td>
<td>Aerodynamics</td>
<td>Aerodynamics</td>
</tr>
<tr>
<td>Thermal Environment:</td>
<td>Stability</td>
<td>Climatic Comfort</td>
<td>Thermodynamics</td>
</tr>
<tr>
<td>Engine bay</td>
<td>Dirt Deposition</td>
<td>Thermodynamics</td>
<td>Dirt Deposition</td>
</tr>
<tr>
<td>Floor</td>
<td>Water Tightness</td>
<td>Water Tightness</td>
<td></td>
</tr>
<tr>
<td>Air Intake / Intercooler</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13 People:</td>
<td>11 People:</td>
<td>15 People:</td>
<td></td>
</tr>
<tr>
<td>3 Mechanics</td>
<td>1 Mechanics</td>
<td>5 M.Sc.</td>
<td></td>
</tr>
<tr>
<td>2 B.Sc.</td>
<td>7 M.Sc.</td>
<td>1 Lic.</td>
<td></td>
</tr>
<tr>
<td>7 M.Sc.</td>
<td>1 Lic.</td>
<td>8 Ph.D</td>
<td></td>
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<tr>
<td>1 Lic.</td>
<td>2 Ph.D</td>
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<td></td>
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</tbody>
</table>

- Requirement specification, Customer requirements, Project management
- Testing / System simulations, R&D / method development
- Plus 1 Aerodynamicist resident at the Design Studio
CFD Aerodynamics:

Magnus Ahl, Ms.C.
Jonas Ask, Ph.D. student
Andreas Borg, Ph.D.
Olga Roditcheva, Ph.D.
Simone Sebben, Ph.D.
Why work with CFD?

- UNDERSTANDING: complete picture of the flow field at any time
- COMPLEMENTS physical testing
- Show CONSEQUENCES of choices early on in project, balancing of requirements
- Meets the need for REDUCED LEAD TIME

Successful factors of our CFD group:

- Competent staff
- Computer environment
- Working process
Connection to Academic Research

Universities

- Fundamental fluid mechanics & CFD research

VCC Ph.D. projects

- CFD research work for future automotive applications

Method dev. projects

- Development of computational procedures according to technology
  Strategies (help of ex-job work)

R&D and Vehicle projects

Approximate resource allocation:

- Universities: 10%
- VCC Ph.D. projects: 20%
- R&D and Vehicle projects: 70%

Computational Fluid Dynamics Group, 96630
Aerodynamic issues

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

45%

25%

30%
What we do:

• Flat underbody simulations

• Detailed underbody simulations

• Dirt deposition / underbody contamination
• Snow ingress analysis based on models from thermal analysis

• Aeroacoustic analysis based on modelled acoustic source terms

• Comfort in convertibles
Hands on CFD process

VPM: Data base of VS

VPM/CATIA
ANSA
Icem-CFD/TGrid
Star-CD
Ensight
Hands on CFD process

Clean up CAD and generate surface mesh
Hands on CFD process

Generate volume mesh

VPM/CATIA

ANSA

Icem-CFD/TGrid

Star-CD

Ensight
Hands on CFD process

Set-up case & solver

- VPM/CATIA
- ANSA
- Icem-CFD/TGrid
- Star-CD
- Ensiteh
Hands on CFD process

- VPM/CATIA
- ANSA
- Icem-CFD/TGrid
- Star -CD
- Ensight

Aerodynamics - CFD
<table>
<thead>
<tr>
<th>Workstations</th>
<th>Servers</th>
</tr>
</thead>
<tbody>
<tr>
<td>15 HP FX6-10 Graphics, 3 –8 GB</td>
<td>2 IBM Linux cluster:</td>
</tr>
<tr>
<td>3 SGI Octane, 4 GB</td>
<td>3x12 CPU: Intel 3.06GHz</td>
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<tr>
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<td>Xeon</td>
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<td>2x8 CPU: Intel 2.2GHz</td>
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<td>Pentium 4</td>
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</tbody>
</table>
Project work

• Requirements specification
• Tests / Computations
• Analyses
• Recommendations & design guidelines
• Information and implementation
Product development phases

- **Concept study**
  - Generic shape studies
  - Evaluate styling proposals
  - Define underfloor concepts

- **Prestudy**
  - Develop frozen design
  - Develop underfloor solutions

- **Project**
  - Detail optimization
  - Verification
Exemples:

- Flat underbody simulations
  - Detailed and quick analysis of the flow field
  - Recommendations on exterior body shape
  - Used at very early stages of the project
  - Used for Cd/dCd comparisons among models
  - Lead-time: 1 to 2 weeks

Surface restricted streamlines
Visualization of the wake

Pressure distribution on the car
Effect of tailgate spoiler on base pressure

Without spoiler

With spoiler
Side wind simulations

- Detailed and quick analysis of the flow field
- Recommendations on exterior body shape
- Used for analysing effects of side forces
- Effect on handling
- Lead-time: 1 to 2 weeks

Representation of the wake with yaw = 10 degrees

Representation of the wake with yaw = 30 degrees
Cylindrical wind tunnel
One mesh for different angles
BC control the wind angle

Good results on squarish shapes.
Detailed underbody simulations

• Detailed analysis of the flow field
• Recommendations on underbody parts (deflectors, pannels)
• Used at any stage of the project
• Used for Cd / dCd comparisons among configurations / models
• Large models, hybrid meshes of 7 - 10 million cells
• Lead-time: 5 to 7 weeks for a completely new model
  3 days for configurations
Velocity planes and pressure distribution
Contribution of the individual parts of the underbody to Cd*A. Easy to identify problematic areas or zones of improvement due to additional parts (ex. deflectors, rear pannel)
Underbody contamination

- Water mist contaminated with dirt particles is entering the rear rims causing unbalance.

- The water mist is generated from the front wheels.

- The biggest factor to affect the dirt deposition in the rims is the underbody airflow.
The effect of underbody deflectors and body plates to reduce dirt deposition in rear rims.

Dirt deposition in rear rim
**hits on rear-susp. parts and wheels**

No deflector 79 of 1045, 7.5 %

Deflector 38 of 1045, 3.6 %

No deflector, 6 % of released nr

Deflector 4.3 % of released nr
• SNOW DUST, ENGINE AIR FILTER INSTALLATION

CFD: Method to approximately predict the intake of snow into the air filter

(understanding mechanisms)
Geometry of the air intake

New ideas
Number of particles entering the air intake

Total no of particles = 40,000
Dirt deposition on the rear screen

Without rear tailgate spoiler
- Counterclockwise flow

With rear tailgate spoiler
- Clockwise flow
Aerodynamics - CFD

Without wing

Smoke visualisation

With wing
Comfort in convertibles - C70

• Driving a convertible roof-down at high-way speeds is by no means comfortable.
  • The recirculating air entering the compartment reaches ~15 m/s when driving 90 km/h.

• Introducing a windblocker keeps the recirculation bubble above the rear seat.
  • Flow speed is kept below 2 m/s in the front seat when driving 90 km/h.
  • The windblocker is modelled as a permeable surface with a prescribed pressure drop.

• A windblocker is sold as an accessory to C70.
Ph.D. project & RD project on Aeroacoustics

- Increase knowledge about aeroacoustics
- Develop engineering tool for analysis

- Initial focus - rearview mirror and A-pillar
- Later on - underbody and climate system noise

Want coupled analysis - e.g. drag, dirt, noise
Aero Concept Car

\[ C_d = 0.20 \]
ACC Final Design 1999
Important parameters - drag of basic shape

• Stationwagon
  Sweeping of roof
  Boat-tailing

• Sportswagon
  Angle of rear tailgate
  Boat-tailing

• Sedan
  Angle of rear window
  Length, height and angle of boot-lid

• Hatchback
  Angle of tailgate
  Radius where roof meets tailgate
  C-post

• Front end (common for all variants above)
  Orientation and size of stagnation region surface.
  Radius from front to hood
  Incline of hood
  Rake of windscreen
Aerodynamics, CFD and Volvo

- Heading for different areas of interest
  - Aeroacoustics
  - Dirt-deposition (water, sand, snow)
  - Handling