Vehicle Simulation with STAR-CCM+

Vehicle Aerodynamics

Aero Acoustics

Front End Cooling

Component Temperatures

Passenger Thermal Comfort
Prism Layer Growth Rate: Slow

- Typical we use dual template growth rate settings. On the exterior, we want slow growth, to resolve the flow around the vehicle. For small cells, we want a fast growth, to reduce cell count.

Size: 100% base
Dist: ~ 100mm
Generalize Wake Refinement
Automatically refine in wake of a boundary

Boundaries: All Surfaces
Size: 100 % base size
Distance in X: 2 Meters

Boundaries: Tires
Size: 50 %
Distance: .4 Meters
Near Wall Refinement: Low Yplus Grid

- Robust procedure for including prism layer around the vehicle
  - External aerodynamics cases typically use Low Reynolds wall modeling to improve prediction of separation.
  - Underbody/Engine compartment typically use a high Reynolds' approximation.

**Prism Layer**
- Height: 8-20mm
- Yplus: 1-5 (~0.03mm)
- Number Layers: 10-21
Prediction of Separation

Sensitivity Studies on Separation

- Coarse mesh may predict early separation.
- K-epsilon is known to separate late.
  » As grid is refined, separation gets later, and wake shape is mis-predicted.
- RNG turbulence variance can drive early separation.
  » Many clients have found this prediction to be better due to early separation, typically while using coarse grids. But it does not provide consistent results and is sensitive to the mesh density.

Best results have been obtained using k-omega SST, with 2-Layer grid by wall.
Aerodynamics Process Automation

STAR-CCM+ reading setup information directly from excel

- Fully Automated from CAD to Report
  - STAR-CCM+ is single environment with all tools needed
  - Java helps control process for clients needs
  - Input Information from Spreadsheet
    » Spreadsheet can be used to define load cases

Input: Cad/Excel
Run: Mesh/Solve/Post
Output: PowerPoint

STAR Transportation Forum, December 8-9, 2009
Spreadsheet Defines Analysis

- First worksheet used to describe analysis.
  - Set inlet boundary conditions
  - Toggle on/off moving ground
  - Call out heat exchangers
  - etc
Organizing the data: Group Worksheet Sample

- Group Worksheet helps organize the data
  - Looks at patterns in the name, and generates groups to set local properties.
CAD -> STAR-CCM+

Group of CAD parts get assigned to a boundary type for mesh refinement settings

Imported CAD

Organized CFD Model
Local Mesh Size/Prism Layer Set Per Group Definition

- Worksheet can be use to set local cell size per group.
- Groups are defined on previous worksheet.
Process is easy!
Place CAD in folder, run scripts
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Industrial Applications of Aeroacoustics

Aviation industry
- Jet noise
- Engine noise (combustion, turbomachinery)
- Airframe noise (wings, landing gears)

Vehicle industry
- Car sunroof
- Wind noise
- Climate system noise
Aeroacoustics Overview: v4.06 and beyond

Steady state
- Broadband Correlations
- Synthesized Fluctuations SNGR
- CURLE surface
- PROUDMAN volume
- GOLDSTEIN 2D-axi
- Mesh Frequency Cut-off

Transient
- LES
- DES
- Transient RANS
- Point FFTs
- Surface FFTs
- FW-H
- Direct Export to ACTRAN / V.Lab.Acoustics

Export to Propagation codes
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Heat Exchanger Package

Heat Exchanger Simulation
- Fixed Heat Rejection
- Dual Stream (Top Tank Temperature)
  - New features (5.02):
    - Variable Cp (CAC)
    - Multi-pass heat exchangers
- Condenser/Evaporators
  - Use fixed heat rejection
  - 2010 looking at phase change

Fan Simulation
- Body Force
  - Including Fan Interfaces
  - Local Rotating Reference Frame (MRF)
- Rigid body motion

*Recommended Approach
Tested regularly against fan test rigs
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Thermal Component Temperature

- Surface-2-Surface Radiation
  - Over 600,000 radiation patches, solved in parallel, completed in minutes.
- Robust Conjugate-Heat-Transfer procedures
  - Passing of material properties
  - Interfaces between solids
  - Thin Wall Modeler
- Robust mapping routines
  - Pass data to codes such as ABAQUS, Radtherm
- Connection to 1D code
  - For example: KULI, wave, GT-Power
Geometry CAD Parts Structure

- For solid modeling, detail breakdown of solids is important for material property.

Mesh Settings/Post Processing Information are more general.

Material Property information typically comes from the leaflet.
Meshing – Thin Object Mesher Examples

CAD → Imprint → Imprinted CAD → Mesh → Conformal Thin Mesh

Conformal prismatic mesh automatically generated after merge/imprint operation
Closely Coupled Thermal Soak

**STAR-CCM+ Solid Model**
- 800-1200 Components
- 16 Million cells
- Thermal Heat Transfer
- Radiation: 900K Patches
- Processors: 1

**Star-CCM+ Fluid Model**
- 35 Million cells
- Heat Exchangers
- MRF Fan
- Processors: 32

Data Exchanged Each Time Step

Heat Transfer Coefficient Near Wall Temperature

Wall Temperature
Coupled Thermal Solution

Details Included:
- Cooling System
- Fan and Shroud
- Lubrication System
- Crank/Cam Shafts
- Cylinder Sleeves
- Engine/Transmission
- Valve Cover and Components

3D STAR-CCM+
1D Backbone (GT-SUITE)
Results: Coolant, Engine, Exhaust Temperatures

- Metal Temperature
- Coolant Flow
- Exhaust Air Flow
- Engine compartment/Underbody Thermal Environment
- Vehicle Aerodynamics
Coupled Thermal Solution
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Passenger Modeling Process

Similar process to exterior/underhood

- Import CAD
- Wrap/Resurface Mesh
- Generate Volume Mesh
Thermal comfort manikin + De-Ice/De-Fog

- Additional physics applied:
  - Thermal Comfort Manikin
  - De-Ice/De-Fog
  - Thermal/Solar Radiation

- Applications
  - Passenger Cars
  - Truck Cabs
  - Trains
  - Planes

Note: Plot annotation available in v5.02
Passenger Modeling Process

Vents Modeled Using CAD Modeler (STAR-CCM+ v5.02)

Cabin Surfaces Read in With Parts Tree
TCM: Manikin Thermal Comfort Modeling

Support for up to 99 passengers

Select boundaries from those defined in model

Specify TIM-required parameters
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Summary

• STAR-CCM+ is the primary tool from CD-adapco for vehicle simulation.
  - STAR-CCM+ is being used as a standard tool today
• For 2010, we expect strong growth usage to continue
  In particular:
    » Automation of process
      - Geared towards clients needs
    » Increase in demand for component temperature prediction
      - New parts based structure will make it even easier for working with 1000’s of components.
      - Improved tools for making interface between solids even easier.