Impact of STAR-CCM+ v7.0 in the Automotive Industry
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Vehicle Simulation Components

Vehicle Aerodynamics
- Design Studies
- Aeroacoustics
- Water/Dirt Management

Vehicle Thermal Management
- Front End Cooling
- Component Temperature Prediction

Cabin Simulations
- HVAC
- Deice/Defog
- Passenger Thermal Comfort

Manufacturing Simulations
- Paint Dipping
- E-coat
Vehicle Simulation Components

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Vehicle Aerodynamics News
- Unsteady Aerodynamics
  - When to use?
- Reducing Turn-around Time
  - Taking Advantage of Coupled Solver for reducing
  - Automation
- Water/Dirt Management
  - New wall film model in STAR-CCM+ being used for water management
Should we use steady or unsteady simulation?

- Statement: Vehicle Aerodynamics is Unsteady
  
  *True Statement*
  
  • Use turbulence model to capture the unsteady nature
  • Model the Unsteady structures using LES type model

- Statement: Need to have the right physics to get the correct solution
  
  • LES Models physics more accurately
    
    – Flow structure capture depends upon:
      » Grid Size/Time Step Size
    – Wall interaction: 2 Layer
      » 20-25 layers
    – Drag value is based upon a time average
      » Time length really depends on vehicle
      Example: Class 8 trucks: 10-30 seconds
S-Class Sedan

- Model
  - A-pillar noise generation: target size 1mm
  - Side Window, Tire Wakes: Resolve to 2mm
  - Boundary layer on exterior: 2-Layer on wall. 20 layers
    Model Size: 500,000 million cells

- Computer Resource
  - High Performance Computing Center Stuttgart (HLRS)
Direct Eddy Simulation (DES) allows large structures with LES while small, under-resolve regions with RANS

Positive Features

• Capture large wake structures on typically able to be replicated with pure RANS solution
• Reduces the need for fine grid to capture small structures
  – RANS can be used in regions of coarse grid
• Can run with larger time step

Negative Features

• Still require long transients to get time averaged solution
Running pure steady reduces run time

Positive Features

• Reduced Run Time
• Accurately models flow approach to the vehicle
• Accurately captures separation points
  – Still recommended 2-Layer grid for boundary layer development and prediction of separation.
• Do not need to run long for averaging of results.
• Not as sensitive to grid density

Drawbacks

• Not time accurate
• Wake structures not correctly produce
  – Not ideal for multi-vehicle drag prediction
  – Looking at curvature correction to improve wake structures, but there is a limit to how far these will take us.
Detail: Experimental data was taken for a generic truck. Purpose was to help test and validate CFD.

- Ran case with full Yaw Sweep:
  - 0,1,2,3,4,5,7,9,7,5,4,3,2,1,0
- Between 2-3 degrees, solution is not stable

Example 2: GCM Truck Benchmark
Detail Experimental data was taken for a generic truck. Purpose was to help test and validate CFD

- RANS matches fairly well to Yaw study
  - Results are not symmetric, and only half yaw sweep completed
- Averaged RANS fits reasonably on Yaw sweep
  - In location of high instability with RANS, running unsteady solver may provide higher time accurate result
  - Alternative: can look at case using DES
Unsteady Simulations

Where DES is being used:
- Aeroacoustic Studies
- Examining Rotating Wake Interactions
  - Fans, Blowers, Wheels
- Vehicle Handling
More complex passing requires more complex grid motion.

- Studies have used rotating regions to aid in simulation of overtaking.
- Mesh morphing has been used to change ride height.
- Overlapping grids can simplify grid motion in the future.
Where Steady RANS solutions are being used?

Vehicle Design Tool
- Formula 1 Design
  - High accuracy
    - Daily comparison to wind tunnel tests available
  - Fast Turn-around
    - Need to minimize CPU usage

DOE Studies
- Optimizing multiple variables
- Running 100’s of studies to look at drag reduction
- Being used today for Trains, Trucks, Passenger Cars and Performance Vehicles

Recent Workshop:
- “STAR-CCM+ has proven to be as accurate as our other in-house tools and easy to setup while providing a much faster overall turn-around time”
- “CD-adapco idea of DOE license scheme very appreciated for design optimization studies”
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Couple solver has really been pushed hard over the past year by our F1 teams

- Latest testing shows significant gains for all vehicles

STAR-CCM+ has some features to help make running complex cases easier with couple solver

- Expert initialization: Grid sequencing
  - CFL value should be similar to target CFL (120-200)
- Expert Driver: Intelligent system which makes it easier to run with high CFL value
- AMG Acceleration: Bi Conjugate Gradient Stabilized
  - Improves rate of convergence.

In 2012, we are investigating improvements to extend coupled solver to the vehicle thermal management
Vehicle Simulation Components

Vehicle Aerodynamics
• Design Studies
• Aeroacoustics
• Water/Dirt Management

Vehicle Aerodynamics News
• Water/Dirt Management
  • Rain management and soiling affect the safety, handling and aesthetics of passenger vehicles.
Modeling Rain Water/Mist:

- Lagrangian droplet model, active or frozen gas field
  - Low computational costs
  - Generally Freeze flow field
  - Define mass/particle size
- Eulerian Multi-Phase
  - Can seed flow field with range of particle sizes

Courtesy M. Islam, Audi AG
Capturing full affects of water management:

- Aerodynamics field for vehicle,
- Lagrangian-Eulerian two-phase and coupled particle tracking of discrete particles in an airflow continuum,
- liquid-film formation due to impingement of droplets on the surface, resulting liquid-film transportation,
- and droplet stripping (re-entrainment) back into the continuum airflow due to edge effects of film instability.
Sample: Side Window Soiling
Add two scalar displayers:

- For the droplets select as “Part” the “Water” Lagrangian Phase and “Velocity Magnitude” as the scalar.
- For the Fluid Film select as “Part” the desired shells and “Fluid Film Thickness” as scalar.
Simulating Wiper Motion

Wall Film Influence by windshield wiper

- Part of the design of the A-Pillar is influenced by flow pushed by the windshield wiper blades.

Note: v7.04, expanding wall film for multi-component evaporation and condensation. This is a needed feature for SRC (Selective Reduction Catalyst) simulations for users to migrate applications from Star-Cd.
Vehicle Simulation Components

Vehicle Thermal Management
Front End Cooling
Component Temperature Prediction

Vehicle Thermal Management News
- Reducing Turn-around Time
  - Handling Complex Assemblies
  - Indirect Mapped Interfaces
  - Automation: Customizing STAR-CCM+ for seamless integration to PLM
Component Temperatures

- **Surface-2-Surface Radiation**
  - Parallel View Factor Calculation
  - Using from 300,000 to over 1 million radiation patches

- **Tools for modeling large CHT models**
  - PMLXML import to maintain CAD structure
  - Tools/Procedures for building part contacts
  - Thin mesher for sheet metal
  - Co-Simulation
    - Allows separate model of solid and fluid to be joined together during analysis.

Vehicle Aerodynamics
Surface Remesher

Geometry retention (patch perimeter, cad face perimeter)
Curvature aligned meshes (if cad data is available)
Indirect Mapped Interfaces

- Interface type for CHT analyses
  - Allows for quick and reliable generation of non-conformal interfaces
  - Saves time at the surface preparation stage
  - Designs may be easily changed and analyzed

- Leverages proven CAE mapping technology

- Robust, high quality results for non-conformal meshes
New element type for modeling thin solids using “shell” elements
- Simulation of in plane thermal conduction
- Single or multiple layers of shells

Shell regions automatically created on surface parts
- New shell region and interfaces generated
Solids Model – Automatic Polyhedral Meshing
Solids Model – Heavy use of Thin Mesher
Co-Simulation: Coupled Vehicle Thermal Analysis

Thermal Solution
STAR-CCM+
Conduction + Radiation

Air Side BC
HTC, Air Temp

Metal Temps

Underhood Flow Solution
STAR-CCM+

Solid Model
10-20 Million cells
2000-3000 Parts

Airstream Model
30-50 Million cells
Global Temperature – Underbody

Full Vehicle Thermal Management
Really used as a predictive tool.
30-40 Cases examined last year by our service group.
Alternatively, can study local region for none problem.
Peak Temperatures
Min/Max Temperatures are reported on all components
Temperature Monitor – Turbocharger Heat Shield

Heat Source
Conduction/convection and radiation are all broken out for each component
Vehicle Thermal Management: Custom Tools

Designed to build simple/quick front end cooling studies.
Targeting users of UH3D.
STAR-CCM+ is continuing to grow in the automotive industry

- Increase usage has pushed our development team to grow, and address new challenging issues
- We are seeing improvements in speed, and reduction in turn-around time thru features such as the coupled solver
- Wall film model is being used today to investigate vehicle soiling
  - In 2012, added multi-phase will help with SRC simulations
- Thermal Heat Protection growing strong
  - Producing highest quality models in the industry
  - Continue to improved productivity of the engineers

Wednesday morning presentations:
8:30  Fast simulation of body-in-white dipping
9:45 Customizing STAR-CCM+ for seamless Integration to PLM