Validation of AcuSolve for Automotive External Aerodynamics

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Introduction

Automotive aerodynamics is a field where increasingly CFD is being used as the primary design tool, with wind tunnel use decreasing, and CO₂ targets becoming increasingly stringent. This presents an number of challenges:

- Aerodynamic solutions need to fit in within the styling direction
- Increasing need for smaller drag deltas to be resolved, and time to market decreasing
- Complex CAD assemblies – GBs of CAD data per complete assembly
- Often the same model needs to be used for cooling & aerodynamic studies
- Complex physics including rotating wheels

A number of projects are underway to validate AcuSolve for automotive external aerodynamic applications, and develop best practice for modelling such flows

This presentation will give an overview of two of these projects - DrivAer & Fackrell’s isolated rotating wheel
DrivAer

DrivAer is a collaboration between Technische Universität München (TUM), Audi & BMW to produce a generic geometry for the study of automotive aerodynamics:

- Aim is to close the gap in complexity between previous reference models e.g. Ahmed body, and the extremely complex production geometries
- Composite geometry of styling features from the A4 & 3-Series models
- Multiple geometric configurations available

Many of the OEMs now have their own physical models of DrivAer
- Ford has 3 full scale models to compare their global wind tunnel facilities

Geometry available for download from tum.de website

Experimental data from TUM available in SAE 2012-01-0168
  Heft, Indinger, & Adams, *Introduction of a New Realistic Generic Car Model for Aerodynamic Investigations*
Experimental Configuration

- Wind Tunnel A @ TUM
- 40% Scale Model
- Wheels off Configuration
- Experimental Data:
  - Force Balance Measurements
  - Surface Pressure Data
  - Fixed & Moving Groundplane
Downloaded Geometry

- 3 Rear End Configurations
- Smooth & Detailed Underbodies
- Closed Front Grills
CFD Process

Is there enough information available for the CFD validation model to replicate the conditions of the test data?

- If not, would it make a significant difference?

- Different wheel & rim geometry
  - Is it significant - wheels can contribute 15-25% of total drag

- No wind tunnel geometry
  - Compared to a CFD simulation run in a large box domain both the blockage ratios and longitudinal pressure gradients will be different
Baseline model: Fastback, Smooth Underbody, With Mirrors, Moving Ground / Rotating Wheels:

- Geometry preparation & surface meshing in HyperMesh v14 (pre-release)
  - New mesh controls process for v14
  - Single environment for CFD meshing
  - Meshing parameters are assigned to groups of entities
    - Includes metadata / names / colours imported from CAD & PLM systems
  - Allows mesh optimization through mixed mesh topologies
  - Single click for surface & then volume mesh creation

- Volume meshing via AcuConsole
  - Volume mesh size ~28 million nodes, all tets, target $y^+ = 1$

- Solve in AcuSolve
  - Steady state analysis, Spalart-Allmaras turbulence model
  - Flowfield averaging enabled
  - Large box domain

- Scripted post-processing in AcuFieldview
Surface Mesh

Mixed meshing algorithms allow efficient meshing of tight radii

Refined mesh for wheels & front corner of the bodywork

Initial conservative approach
Comparison to Experiment

Surface Pressures - Centreline, Upper Surface
Comparison to Experiment

Surface Pressures - LHS, Z60mm
Comparison to Experiment

Surface Pressures - Centreline, Lower Surface

Largest discrepancy at start of underbody
Centreline Velocities

Separation Bubble at Underbody LE
Integrated Loads

In the wind tunnel drag is measured by an internal 6 component balance within the body & single component load cells at the end of each wheel arm. Only a total drag is published.

Comparison of the drag coefficients:

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<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>Experiment</td>
<td>0.243</td>
</tr>
<tr>
<td>CFD</td>
<td>0.244</td>
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For the CFD body drag equates to 74% of total drag.
Next Steps

Future numerical work with DrivAer will include:

• Investigate the separation bubble of the leading edge of the underbody
  • Correct the geometry for the central grill recesses
• Further data analysis & comparison, e.g. off-centerline on windscreen & rear window
• Optimisation of the solution process
  • Stopping criterion
  • Mesh setup – y+ values, mesh size & growth rates
  • Turbulence models – revised 2 equation models in AcuSolve v14
  • Transient simulations
• Geometric deltas
  • Comparisons of the 3 rear end configurations, and smooth & detailed underbodies
  • Fixed and moving ground delta
• Combined surface & volume meshing with mesh controls in HyperMesh v14
Fackrell – Isolated Wheel
Experimental Data

The 1974 PhD of Fackrell entitled ‘The Aerodynamics of an Isolated Wheel Rotating in Contact with the Ground’ remains one of the reference works for understanding wheel flows. This is one of the most important aspects of automotive aerodynamics as wheel drag can contribute up to 25% of total drag for a passenger car.

Using custom machined metal wheels (i.e. a revolved body with no attempt to resolve tyre squash) Fackrell managed to measure surface pressures when the wheel was rotating on a moving belt.

The key finding was that the rotating wheel generated less lift and drag than the equivalent stationary wheel.
Separation Points

CFD, especially steady state, often predicts the separation from the top of the rotating wheel too late resulting in a shorter wake – surface roughness is used to open the wake up. AcuSolve predicted well the flow over the top of the wheel without surface roughness.
Surface Pressures

Comparison of the surface pressures to Fackrell’s data on the tyre centerline shows only a slight over-prediction in peak suction on top of the wheel. Pressure coefficients greater than unity at the front of the contact patch are successfully predicted.
Next Steps

Future numerical work will include:

- Optimisation of the solution process
  - Mesh setup – y+ values, mesh size & growth rates
  - Transient simulations
- The influence of how the contact patch is resolved
Summary

Preliminary results from two projects related to automotive external aerodynamics have been presented:

- AcuSolve has been shown to give very encouraging correlation in both, even when running in steady state mode
- The importance of considering the test environment in which validation data was gathered has been shown
- HyperMesh v14 is a significant step forward in functionality for CFD meshing
Celebrating 30 Years of Innovation