Racecar Rear Wing Setup Optimization via 2D CFD Simulations

Simulating Systems
Ground Transportation – Motorsport

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Graduate Engineer – Test & Development
Lotus Cars

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Acknowledgements

CD-adapco

- Romuald Bavarin
  - Academic Manager France

ART Grand Prix – AOTech

- Guillaume Capietto
  - Technical Director
- Christophe Perrin
  - Aerodynamics Manager & GP3 Race Engineer
- Pierre-Alain Michot
  - GP3 Chief Engineer
- Romain Peretmere
  - CFD Engineer
ART Grand Prix – French motorsport company, created in 1996 (as ASM)
Activities organized in two entities:

- Composite lab
- Racing simulator
- CFD facilities

Race engineering
R&D

Permanent connection
Achievements

- 11 titles in F3 Euroseries
- 8 titles in GP2 Series
- 4 titles in GP3 Series
- 11 out of 22 current F1 drivers drove for ART/ASM in the past
Project origin

Request from the GP3 engineers

New GP3 car from 2013 onwards (Dallara GP3/13)
Project origin

Request from the GP3 engineers

Key figures:

<table>
<thead>
<tr>
<th>Spec</th>
<th>GP3/10</th>
<th>GP3/13</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine type</td>
<td>2.0L inline-4</td>
<td>3.4L V6</td>
</tr>
<tr>
<td>Aspiration</td>
<td>Turbocharged</td>
<td>Naturally aspirated</td>
</tr>
<tr>
<td>Power output</td>
<td>280 bhp</td>
<td>400 bhp</td>
</tr>
<tr>
<td>Weight (incl. driver)</td>
<td>630 kg</td>
<td>630 kg</td>
</tr>
<tr>
<td>Aerodynamics</td>
<td></td>
<td>New aerodynamic package</td>
</tr>
</tbody>
</table>

- Increase in power output
- Improved power-to-weight ratio
Rear wing terminology

- Endplate
- Gurney
- Flap
- Mainplane

Rear wing
Study targets

- Need to refine the aerodynamic balance
- Benefits of gurney on this new rear wing?
- Aerodynamic data collection for the AOTech simulator

- Determination of rear wing drag polars for several angles of attack (AOA), with and without gurney
Drag polar?
Relation between drag & lift coefficient

Simulation required to gather these data
Development process

Bases

- CD-adapco STAR-CCM+ 7.04
- 2D CFD simulation – saving of computational performance
- Simulations performed on a laptop

<table>
<thead>
<tr>
<th>Processor</th>
<th>Intel Core i5 - Ivy Bridge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clock rate</td>
<td>2.50 GHz</td>
</tr>
<tr>
<td>Cores / Threads</td>
<td>2 / 4</td>
</tr>
<tr>
<td>RAM</td>
<td>6 GB</td>
</tr>
<tr>
<td>Iteration time</td>
<td>1 iteration per sec</td>
</tr>
<tr>
<td>Meshing time</td>
<td>15 min</td>
</tr>
</tbody>
</table>
Development process

Geometry

- 3D surface geometry done in CATIA V5, according to Dallara’s data
- Regions made to ensure refined meshing setup
- 2D conversion done through STAR-CCM+
Development process

Meshing

- Hexahedral meshes for the domain
- Prism layers for the boundary layer
- Surface wrapper & remesher
- Volumetric controls for wake management
- Meshing size & parameters optimized to:
  - Provide a satisfactory resolution of the flow
  - Ensure the validity of the rear wing wake

Cell count

- **4 millions** fluid cells in 3D
- **220 000** fluid cells in 2D
Development process

Meshing
Development process

Meshing

13L  22L  44L  66L
Physics & boundary conditions

- 2D
- Steady state
- Incompressible flow
- Turbulence model: realizable K-Epsilon

- Air velocity = 50 m/s
- AOA without gurney = [7;10;12;14;16;18] °
- AOA with gurney = [7;10;12;14;16] °
Development process

Automated process

- **JAVA** powered batch tests
- Rotation performed automatically at given angles
- Iterations follow angle setup

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Tests results

Deliverables

- Absolute values of $SC_z$ & $SC_x$
- Rear wing stalling point
- Gurney impact
Results interpretation & stalling point determination

- Raw values of $SC_z$ & $SC_x$ averaged on the 500 or 1000 last iterations
- Indicators of stall occurrence:
  - Increase of $SC_x$ with constant $SC_z$
  - Standard deviation above 3% => result deemed not reliable
  - Sudden & incoherent increase in the $SC_z$ and/or $SC_x$ value
  - Flow separation on velocity visualization

Tests results

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Tests results

Stall occurrence

No stall

Stall
Tests results

Rear wing assembly – Without gurney

<table>
<thead>
<tr>
<th>AOA (°)</th>
<th>7</th>
<th>10</th>
<th>12</th>
<th>14</th>
<th>16</th>
<th>18</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCx</td>
<td>0.0114</td>
<td>0.0137</td>
<td>0.0165</td>
<td>0.0301</td>
<td>0.0483</td>
<td>0.0590</td>
</tr>
<tr>
<td>SCz</td>
<td>-0.6425</td>
<td>-0.6965</td>
<td>-0.7161</td>
<td>-0.6402</td>
<td>-0.5510</td>
<td>-0.6217</td>
</tr>
<tr>
<td>Stand dev SCx</td>
<td>0.0000</td>
<td>0.0001</td>
<td>0.0004</td>
<td>0.0011</td>
<td>0.0031</td>
<td>0.0128</td>
</tr>
<tr>
<td>Stand dev SCz</td>
<td>0.0000</td>
<td>0.0002</td>
<td>0.0022</td>
<td>0.0026</td>
<td>0.0027</td>
<td>0.0330</td>
</tr>
</tbody>
</table>

SCz vs SCx

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Tests results

Rear wing assembly – Without gurney

➢ Stalling point: 12°
Tests results

Rear wing assembly – Without gurney (12°)

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Tests results

Rear wing assembly – With gurney

<table>
<thead>
<tr>
<th>AOA (°)</th>
<th>7</th>
<th>10</th>
<th>12</th>
<th>14</th>
<th>16</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCx</td>
<td>0.0135</td>
<td>0.0162</td>
<td>0.0217</td>
<td>0.0397</td>
<td>0.0578</td>
</tr>
<tr>
<td>SCz</td>
<td>-0.7236</td>
<td>-0.7677</td>
<td>-0.7676</td>
<td>-0.6761</td>
<td>-0.4886</td>
</tr>
<tr>
<td>Efficiency</td>
<td>-53.6925</td>
<td>-47.3068</td>
<td>-35.4232</td>
<td>-17.0101</td>
<td>-8.4588</td>
</tr>
<tr>
<td>Stand dev SCx</td>
<td>0.0000</td>
<td>0.0001</td>
<td>0.0006</td>
<td>0.0013</td>
<td>0.0009</td>
</tr>
<tr>
<td>Stand dev SCz</td>
<td>0.0000</td>
<td>0.0006</td>
<td>0.0040</td>
<td>0.0032</td>
<td>0.0085</td>
</tr>
</tbody>
</table>

SCz vs SCx

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Tests results

Rear wing assembly – With gurney

- Stalling point: 10°
Tests results

Rear wing assembly – With gurney (10°)
Tests results

Data analysis

At iso-AOA

- **+7.12 points** of extra downforce
- **+0.25 points** of extra drag
- **+28.5 points** of efficiency

<table>
<thead>
<tr>
<th>10° AOA</th>
<th>Without gurney</th>
<th>With gurney</th>
<th>Δ</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCx</td>
<td>0.0137</td>
<td>0.0162</td>
<td>0.0025</td>
</tr>
<tr>
<td>SCz</td>
<td>-0.6965</td>
<td>-0.7677</td>
<td>-0.0712</td>
</tr>
</tbody>
</table>
# Tests results

## Data analysis

<table>
<thead>
<tr>
<th></th>
<th>12° AOA without gurney</th>
<th>10° AOA with gurney</th>
<th>Δ</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCx</td>
<td>0.0165</td>
<td>0.0162</td>
<td>-0.0003</td>
</tr>
<tr>
<td>SCz</td>
<td>-0.7161</td>
<td>-0.7677</td>
<td>-0.0516</td>
</tr>
</tbody>
</table>

At iso-drag

➢ **+5.16 points** of extra downforce
Conclusion

Action items

➢ Systematic usage of gurney for all cars
➢ Data incorporated into AOTech simulator
➢ New rear wing data used for setup refinement

Further developments

➢ Refine the study via 3D simulations (impact of endplates)
Overview

- Racing state of mind, attention to details
- Not compulsory, yet beneficial for success
- Competitive business: Gain of 21% in development time thanks to automated process

2013 season review

- Teams’ champion (1st/9)
- Drivers P2, P3 & P5 (/31)
- 4/16 wins, 2/8 poles, 4/16 fastest laps
Thank you for your attention

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