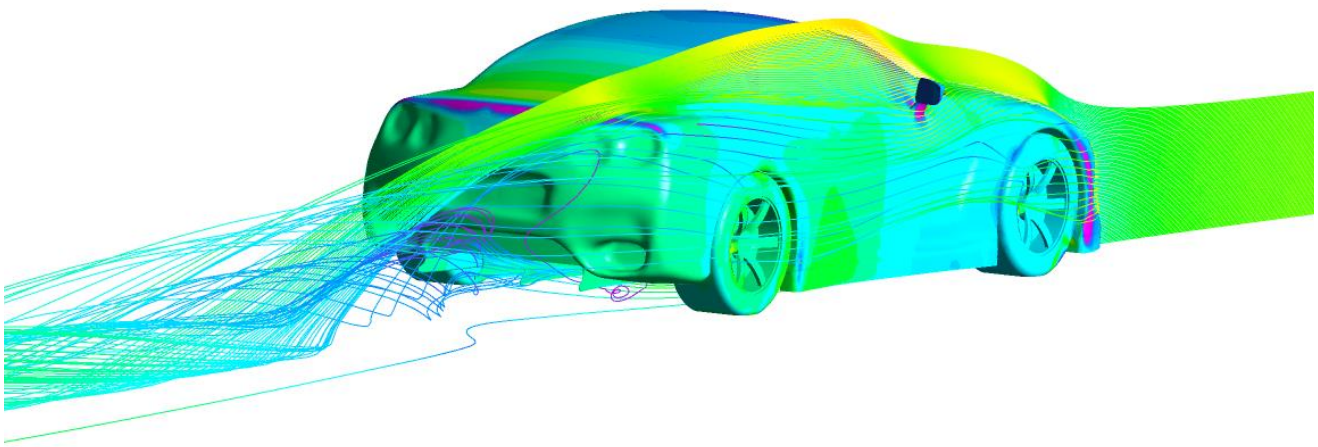
Nissan R35 GTR

Performance of Verus Engineering Rear Diffuser Strakes



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Rev	Date	Author	Description
1	2017/03/20	P. Lucas	Issued for Release
2	2017/08/07	P. Lucas	Company Name Change From Velox to Verus

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CONTENTS

Nissan R35 GTR – Performance of Verus Engineering Rear Diffuser Strakes

1. Executive Summary
    - Increased downforce
    - No change in drag
    - Improved aerodynamic efficiency

All work was done using ANSYS software: geometry preparation was completed using SpaceClaim, meshing was done with ANSYS Meshing, setup and solution was computed on ANSYS Fluent, and post-processing was completed in CFD-Post.

1.1. Coefficient Deltas

Cd	Cl	Aerodynamic Balance
0.00	-0.06	42/58

Figure 1.1.1: Coefficient Deltas

1.2. Aerodynamic Forces

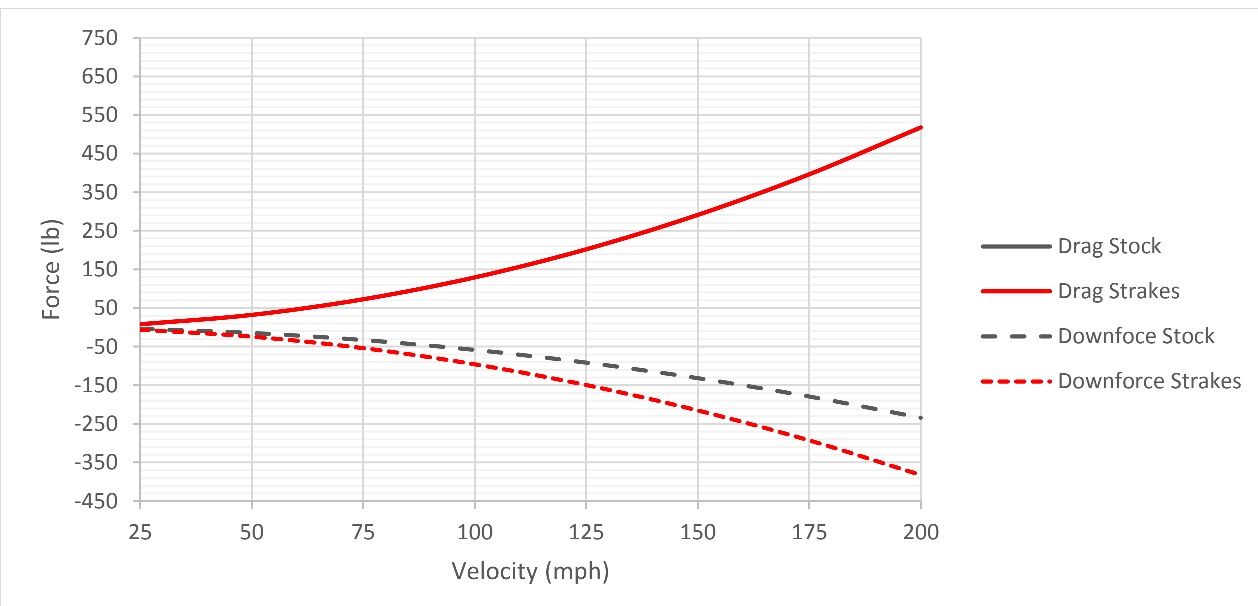

Figure 1.2.1: Aerodynamic Forces at Speed

Aerodynamic forces change with the square of velocity. This is why a single downforce number cannot be given unless it is at a specific speed. Most OEM road vehicles create lift from the factory, however the GTR is not in this category. Notice Figure 5.2.1, the factory GTR creates downforce from the factory. With our strakes attached, this downforce is increased quite substantially.

1.3. Summary Plots

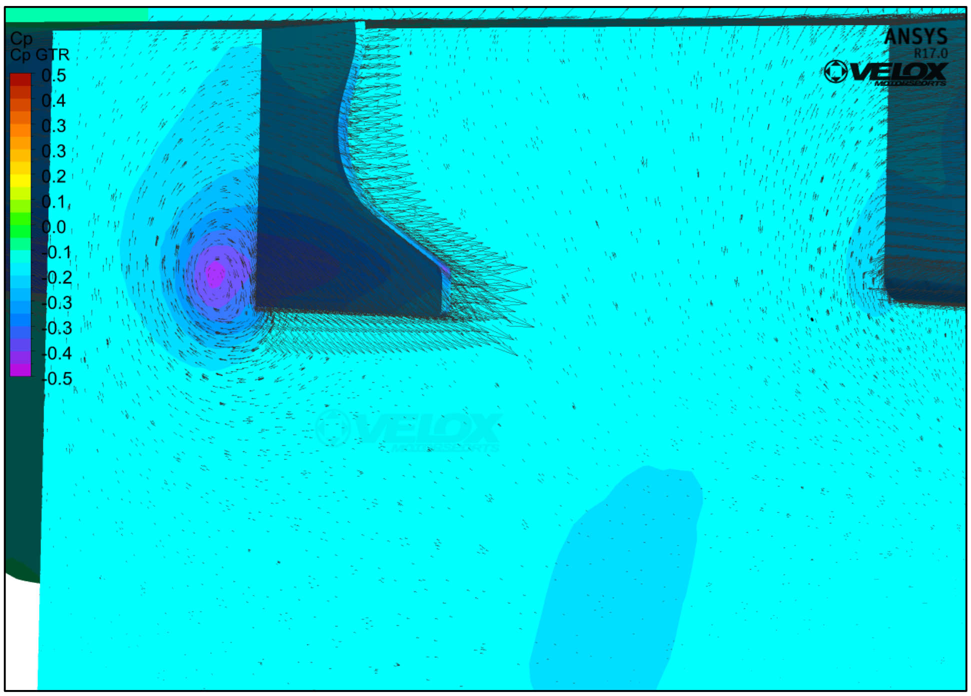

Figure 1.3.1: Strake Vortices

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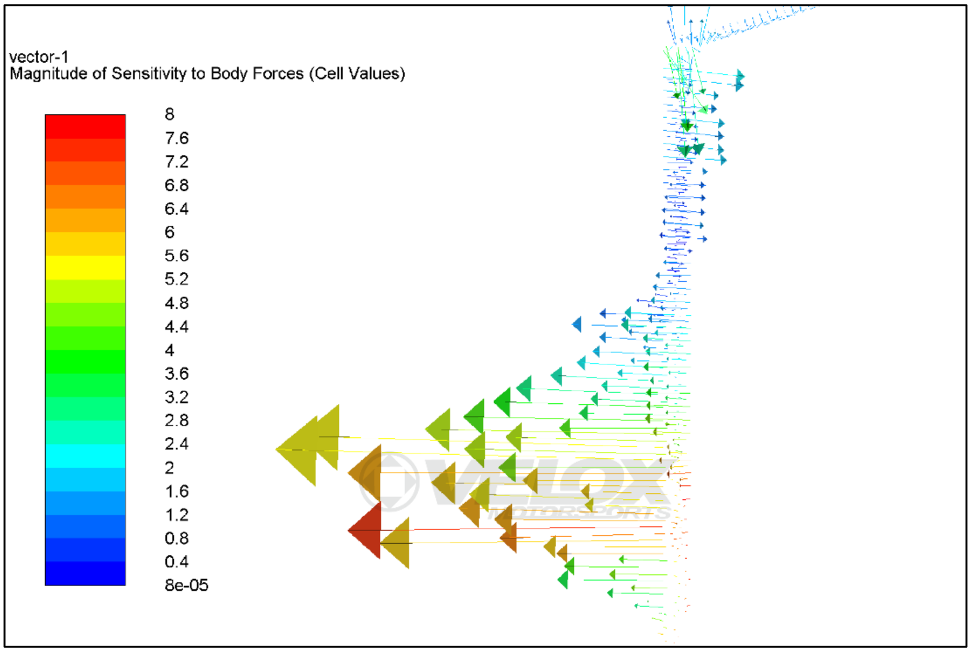

Figure 1.3.2: Shape Optimization of Strake

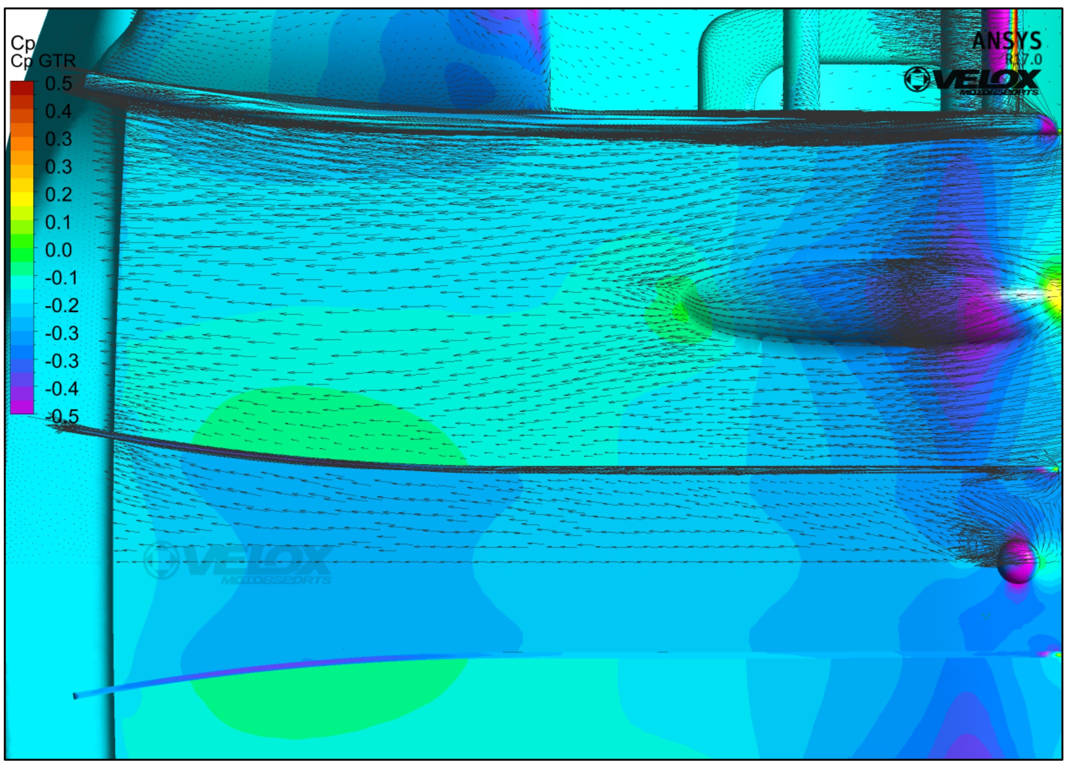

Figure 1.3.3: Diffuser Surface Cp (Coefficient of Pressure) with Surface Vectors

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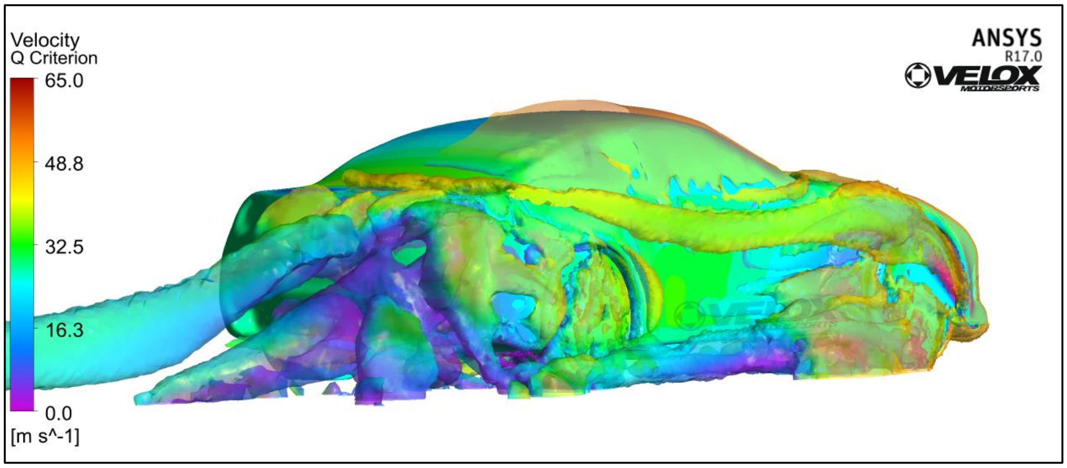

Figure 1.3.4: Q-Criterion (vorticity) with Velocity Plot

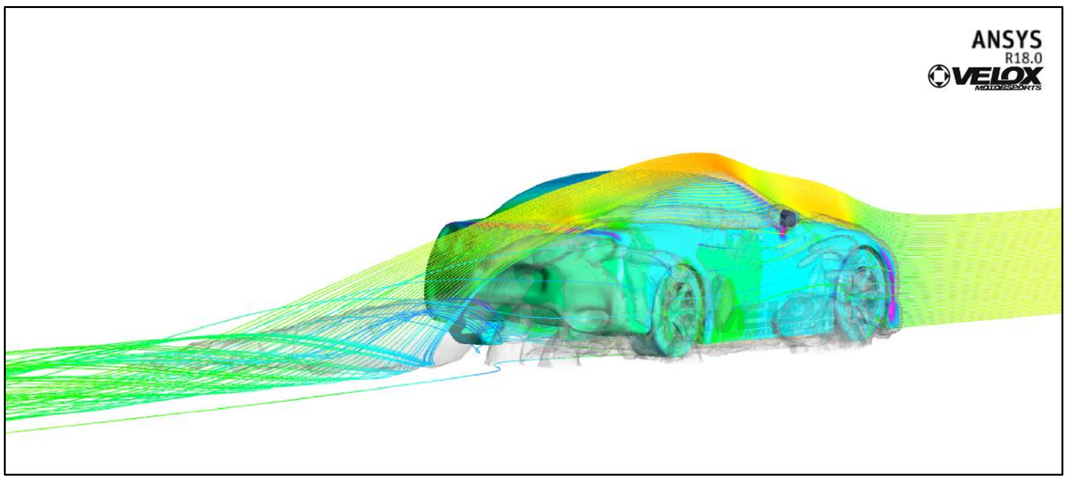

Figure 1.3.5: Streamlines and Transparent Q-Criterion

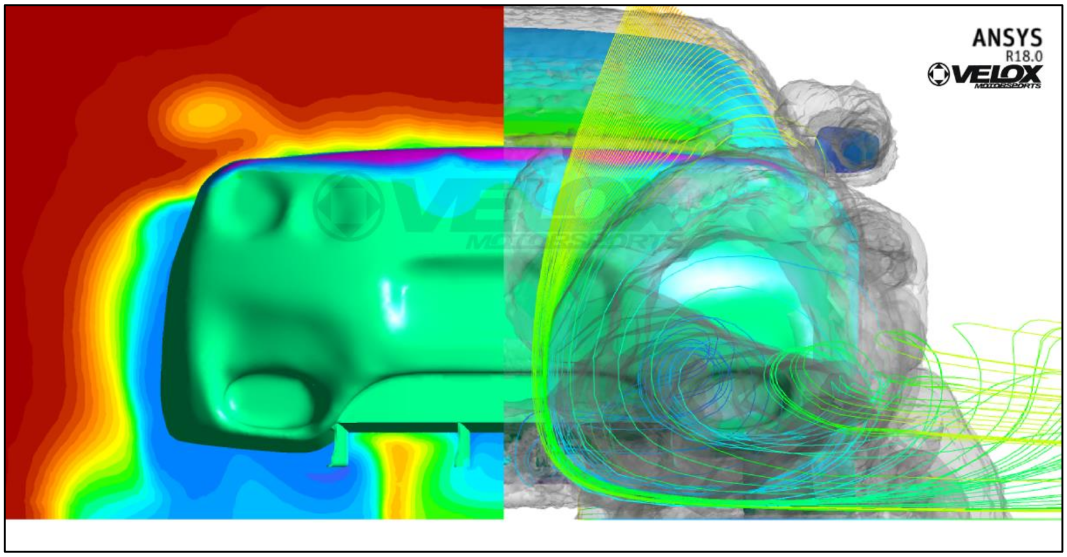

Figure 1.3.6: CpT Cut Plane Behind Rear Tire

Figure 1.3.1 allow visualization of the vortex coming off the rear diffuser strake. Vortices in these locations have a positive impact on diffuser performance and something we pay heavy attention to in our simulation and development. We use these vortices to optimize many aspects of our components.

Figure 1.3.2 shows optimization of the strake's trailing edge geometry. The optimization was done using ANSYS Adjoint Solver which optimizes geometry based on our design goals. Adjoint Solver is the same software that multiple F1 companies use to optimize various aspects of their aerodynamic components.

In Figure 1.3.3, we have a Cp plot (Coefficient of Pressure) which quickly and easily shows us the pressure on the bottom side of the diffuser. This low pressure is what causes downforce and is dramatically improved with the use of the Verus Engineering Strakes.

Figures 1.3.4 and 1.3.5 show Q-Criterion plots which highlights areas of vorticity and streamlines. Q-Criterion helps locate vortices and allows us to direct vortices to locations where they can be utilized efficiently and positively. Streamlines are another tool that can locate vortices and general flow field.

CpT (total pressure coefficient) locates free stream flow, which is shown in Figure 1.3.6. The red in the CPT plot is free stream flow and the other colors represent disruptions in free stream flow. One important design goal of strakes is to help decrease the effect of the horseshoe vortex coming off the rear tire. Figure 1.3.6 shows this is in fact happening.

2. <u>ASSUMPTIONS</u>

2.1. Geometry

In many automotive analysis cases, simplification of the geometry is required. Analyzing a fully detailed automotive case is not necessary, and much of the critical information we are after could get lost in the plethora of data. The proper approach to the analysis is to setup a simplified physical model. [1] In the automotive case, we isolate particular aspects of the system to capture and ensure we can set proper boundary conditions. In these cases, we are interested in the overall flow field around the Nissan GTR and how the Verus Engineering Diffuser Strakes improve the aerodynamic efficiency. The simplifications made were as follows:

- Simplified wheels and brakes
- Simplified underbody
- Simplified suspension
- Solid grill surface
- Removed door handles
- Removed all car panel gaps

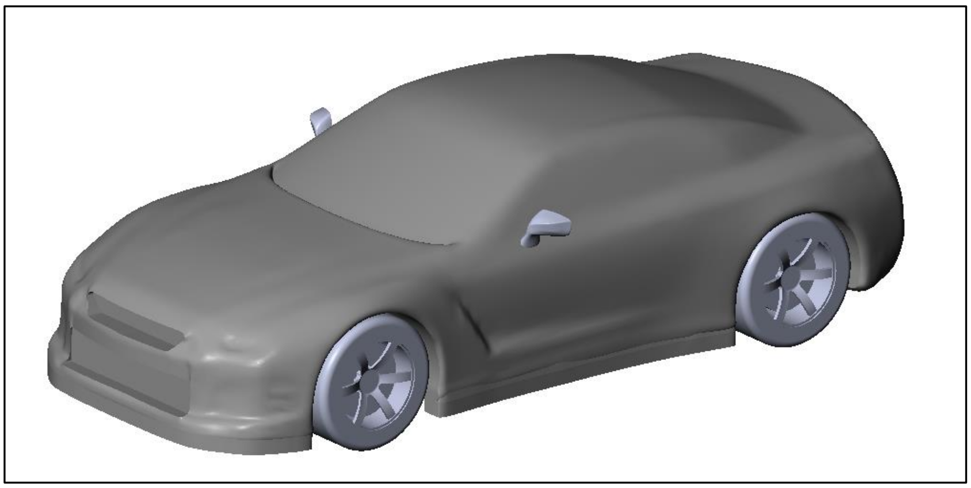

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Figure 2.1.1: Geometry Simplifications – Isometric

2.2. Setup

Some physical effects are removed from the analysis because it is not necessary for these cases. We are looking at the overall flow field around the Nissan GTR, some of the physical models are left out. The simplifications made were as follows:

- No radiator flow
- No under hood flow
- No engine intake
- No exhaust flow

3. MESH QUALITY AND METRICS

3.1. Metrics

A proper mesh is essential for a CFD analysis. With CFD, a poor mesh causes the simulation to not converge. Without convergence, the solution will never be reached, and without a good mesh, it is irresponsible to expect accurate results. Here at Verus Engineering we use two main metrics to evaluate mesh quality: skewness and orthogonal quality.

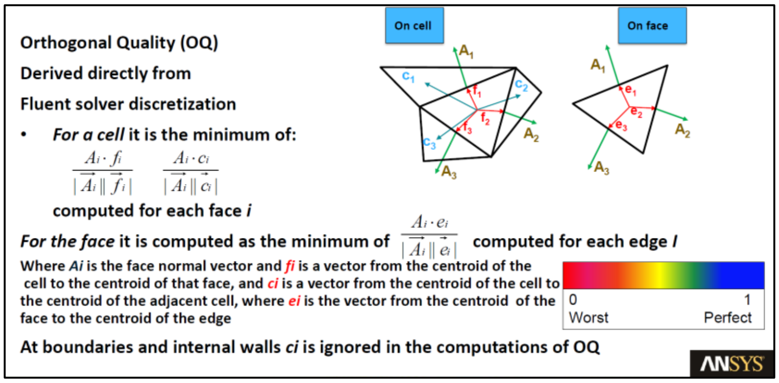

Figure 3.1.1: Orthogonal Quality Metrics

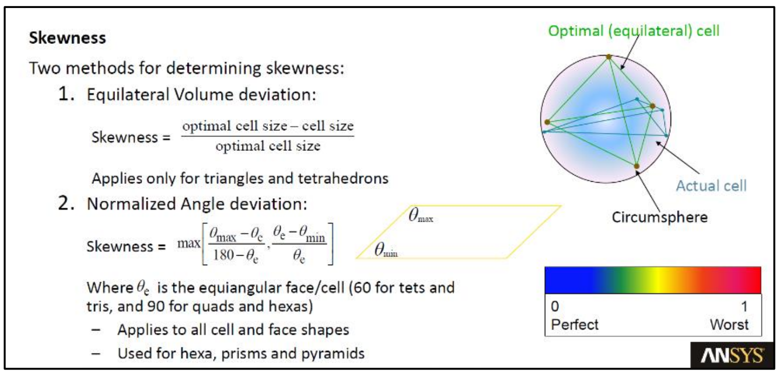

Figure 3.1.2: Skewness Quality Metrics

3.2. Quality

Low orthogonal quality and high skewness values are not recommended for a quality mesh. In general, we always want an orthogonal quality greater than 0.1 and skewness below 0.95. The value may differ depending on the physics and location of the cell.

Orthogonal Quality mesh metrics spectrum

Unacceptable	Bad	Acceptable	Good	Very good	Excellent
0-0.001	0.001-0.14	0.15-0.20	0.20-0.69	0.70-0.95	0.95-1.00

Figure 3.2.1: Orthogonal Quality Metrics

Skewness mesh metrics spectrum

Excellent	Very good	Good	Acceptable	Bad	Unacceptable
0-0.25	0.25-0.50	0.50-0.80	0.80-0.94	0.95-0.97	0.98-1.00

Figure 3.2.2: Skewness Quality Metrics

3.3. Types of Mesh

There are two main types of meshes, or grids: structured and unstructured. Structured grids generally have better convergence and higher accuracy with a more simple flow field. Unstructured grids are more commonly used for Verus Engineering applications since geometry and flow fields are complex.

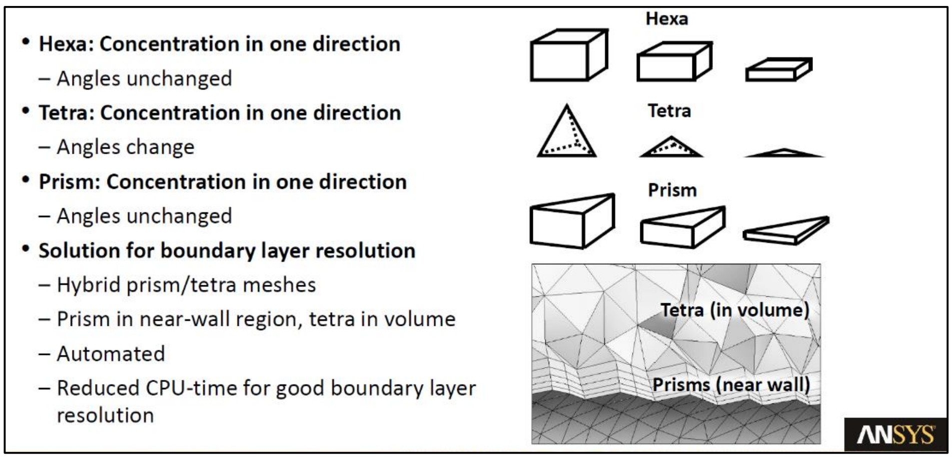

Figure 3.3.1: Hexahedral versus Tetrahedral

An unstructured mesh using prism layer for boundary layer resolution and tetrahedral in the volume was utilized for the GTR.

3.4. Mesh Quality

All meshing is completed using ANSYS Meshing. Verus Engineering uses ANSYS Meshing to combine the strengths of ICEM CFD, TGRID, CFX-Mesh, and Gambit. ANSYS Meshing allows Verus Engineering to setup a quality grid for proper solution and convergence.

Orthogonal quality did not drop below 0.17. This is in the acceptable zone for the minimum orthogonal quality. The majority of the mesh is in the very good to excellent range.

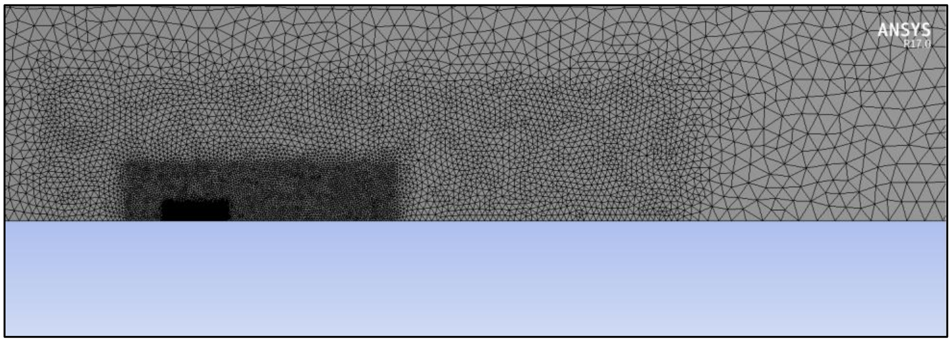

Figure 3.4.2: Mesh Domain

4. <u>ANALYSIS SETUP</u>

4.1. General

ANSYS Fluent – a finite volume discretization scheme - is used for solving all of Verus Engineering external aerodynamics cases. The solver used is the semi-implicit method for pressure-linked equations, SIMPLE. [2] These cases were solved using the steady-state method which ignores the higher order terms dealing with time.

4.2. Boundary Conditions

Boundary conditions are used to define the computational problem. Without boundaries, nothing can be solved, and proper boundary conditions are a must for an accurate analysis. A full understanding of the physics of the problem is a must. CFD only emulates the condition of the road and track, it does not reproduce it. Simulations inherently deviate from reality and it is often hard to quantify all the sources of error. The cases were solved using symmetry on the XZ Plane. This decreased the mesh quantity by cutting the computational domain in half, thus decreases the simulation time to convergence. Using symmetry on the XZ Plane is standard in the industry unless you are modeling yaw. The case is modeled using a virtual wind tunnel which is discretized and used as the fluid volume. The air then flows over the stationary car in the boundary. The ground and wind tunnel walls have the shear equal to zero to not have boundary layer growth which simulates the rolling road condition to have a proper flow regime. The wheels are setup as a rotational moving wall boundary.

Inlet	Inlet Condition	45 m/s
Outlet	Pressure Outlet Condition	0 Pa (Gauge)
Symmetry Plane	Symmetry	N/A
Ground	Wall Condition	Shear = 0
Wind Tunnel Walls	Wall Condition	Shear = 0
GTR	Wall Condition	No Slip Shear
Strakes	Wall Condition	No Slip Shear
Wheels	Wall Condition	126 rad/s

Figure 4.2.1: Boundary Conditions

4.3. Turbulence Modeling

The majority of fluid flows in engineering cases are turbulent. Because of this, a proper turbulence model is needed for proper results and flow regimes. The k-omega SST turbulence model was used in these cases. The k-omega is great for solving flows in the viscous sublayer (boundary layer). The SST allows the model to solve free-stream area where the normal k-omega was too sensitive to free-stream turbulences. [3]

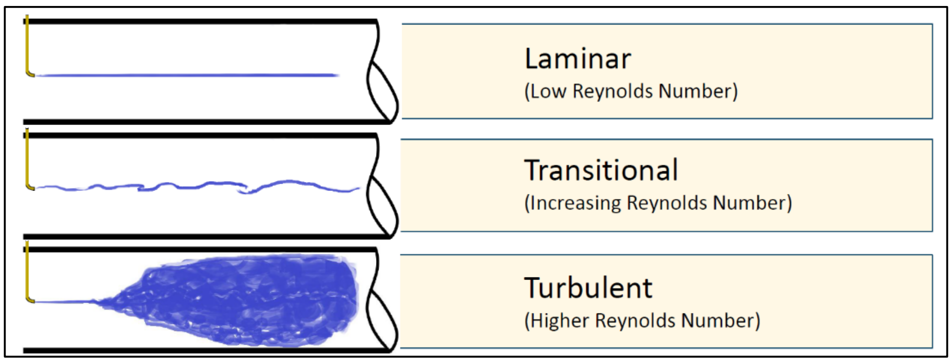

Figure 4.3.1: Flow Classifications

5. ERRORS IN SIMULATION

5.1. Physical Model

Some of the errors in the physical model were discussed in Geometry Assumptions. The substitution of a CAD model from a real physical model is an inevitable source of error. The CAD model only represents part of the physical system, others are either represented with boundary conditions or removed from the analysis.

5.2. Discretization Error

Discretization errors are those errors that occur from the representation of the governing flow equations and other physical models as algebraic expressions in a discrete domain of space and time. As the mesh is refined, the solution should become less sensitive to discretization error. These errors can be analyzed using grid convergence study. [4]

6. CONCLUSION

The Verus Engineering Rear Diffuser Strakes increase downforce with no gain in drag of the GTR. The overall aerodynamic efficiency was increased with the strakes over stock setup. The strakes help block the horseshoe vortices formed on the rear wheels from disrupting the fluid flow out of the diffuser. The strakes help keep disrupting airflow from the tires from hurting the diffuser’s efficiency. Adding Verus Engineering Diffuser Strakes maximizes the efficiency of the factory diffuser on the R35 GTR.

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7. REFERENCES

[1] Zikanov, Oleg. *Essential Computational Fluid Dynamics*. 1st Edition. Joh Wiley & Sons, Inc., 2010.
[2] Patankar, Suhas. Numerical Heat Transfer and Fluid Flow. 1st Edition. Hemisphere Publishing Corporation, 1980.
[3] Menter, Florian. Improved Two-Equation k-w Turbulence Models for Aerodynamic Flows. NASA Technical Memorandum, no. 103975 (1992).
[4] Slater, John. 2008. Uncertainty and Error in CFD Simulations. https://www.grc.nasa.gov/WWW/wind/valid/tutorial/errors.html (Accessed 2016-09-20).