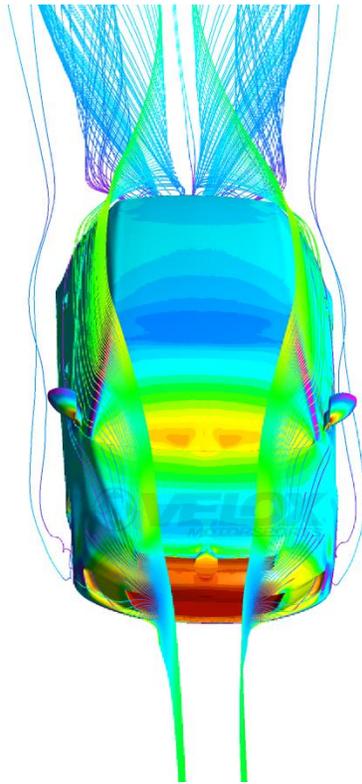


VERUS ENGINEERING

Mk7 Golf R

Performance of Verus Engineering Rear Diffuser



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Approvals: P. Lucas, E. Hazen

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2	2017/08/07	P. Lucas	Company Name Change From Velox to Verus

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Mk7 Golf R– Performance of Verus Engineering Rear Diffuser

CONTENTS

1.	<u>Executive Summary</u>	3
	1.1. Coefficient Deltas	3
	1.2. Aerodynamic Forces	3
	1.3. Summary Plots	4
2.	<u>ASSUMPTIONS</u>	8
	2.1. Geometry	8
	2.2. Setup	8
3.	<u>MESH QUALITY AND METRICS</u>	8
	3.1. Metrics	8
	3.2. Quality	9
	3.3. Types of Mesh	9
	3.4. Mesh Quality	10
4.	<u>ANALYSIS SETUP</u>	10
	4.1. General	10
	4.2. Boundary Conditions	11
	4.3. Turbulence Modeling	11
5.	<u>ERRORS IN SIMULATION</u>	12
	5.1. Physical Model	12
	5.2. Discretization Error	12
6.	<u>CONCLUSION</u>	12
7.	<u>REFERENCES</u>	13

Mk7 Golf R– Performance of Verus Engineering Rear Diffuser

 1. Executive Summary

- Increased downforce
- Decreased drag
- Improved overall 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 (Fr/Rr)
-0.027	-0.044	49/51

Figure 1.1.1: Coefficient Deltas

1.2. Aerodynamic Forces

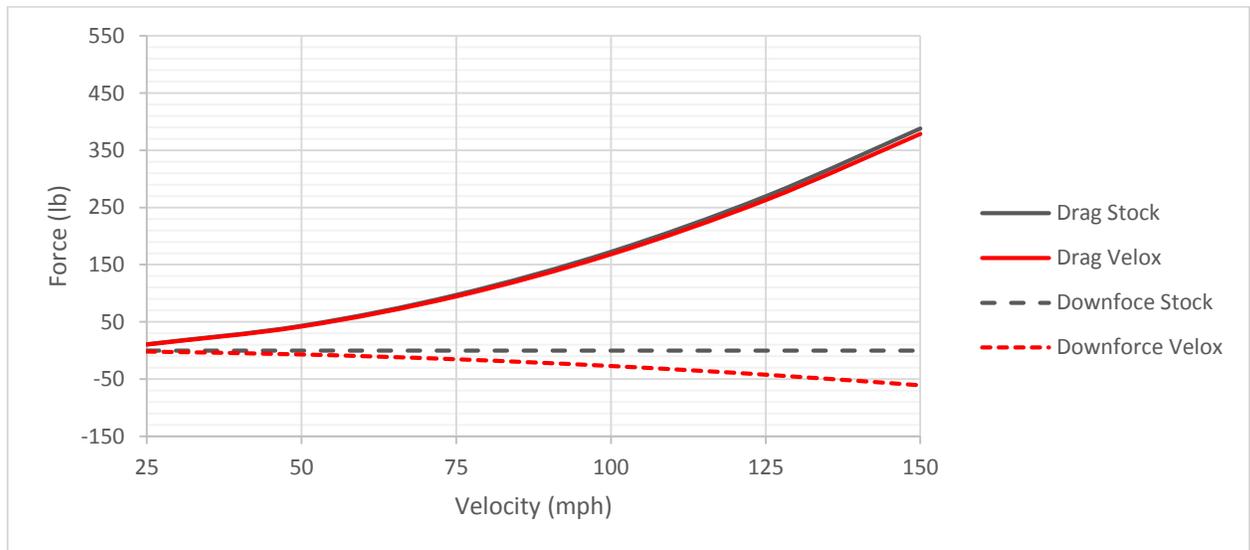


Figure 1.2.1: Aerodynamic Forces at Speed

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 Golf R is not in this category. Notice Figure 5.2.1, the factory Golf R creates no lift or downforce from factory. With the Verus Engineering rear diffuser, downforce is increased.

Mk7 Golf R– Performance of Verus Engineering Rear Diffuser

1.3. Summary Plots

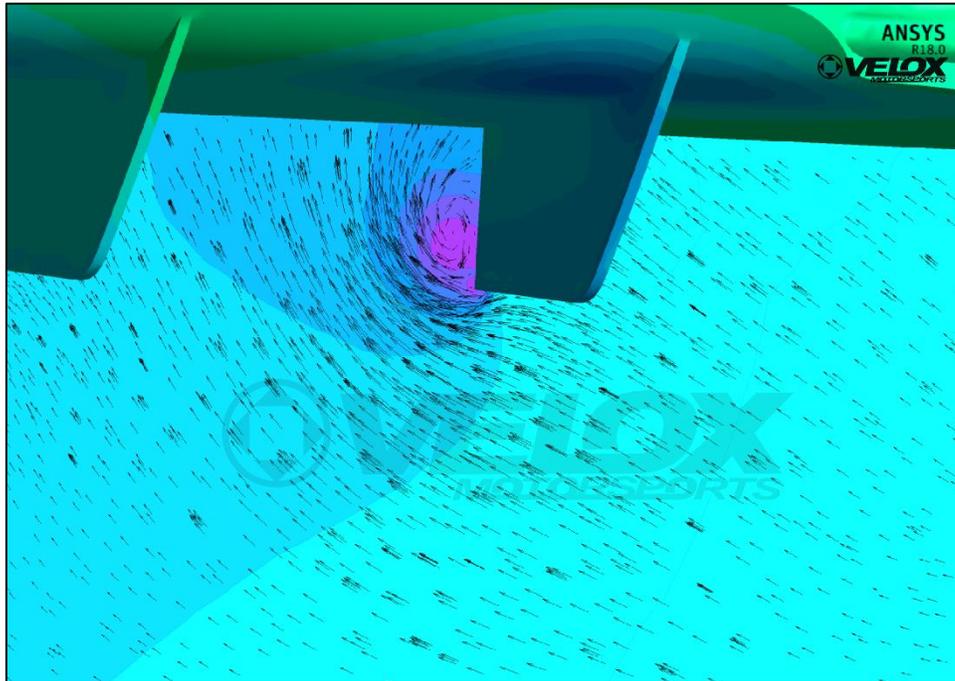


Figure 1.3.1: Strake Vortices

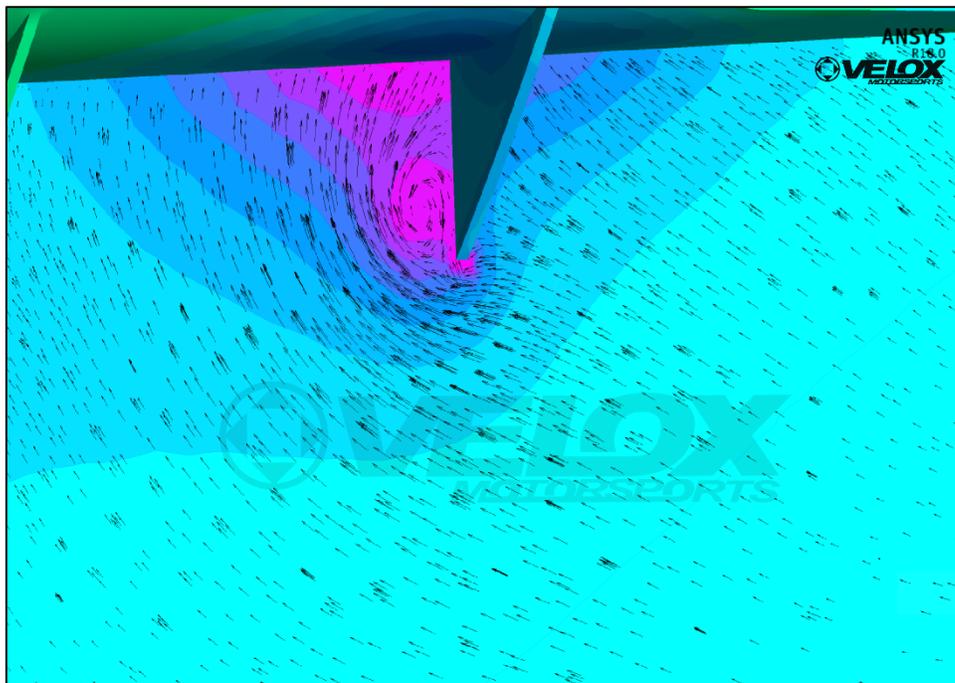


Figure 1.3.2: Strake Vortices

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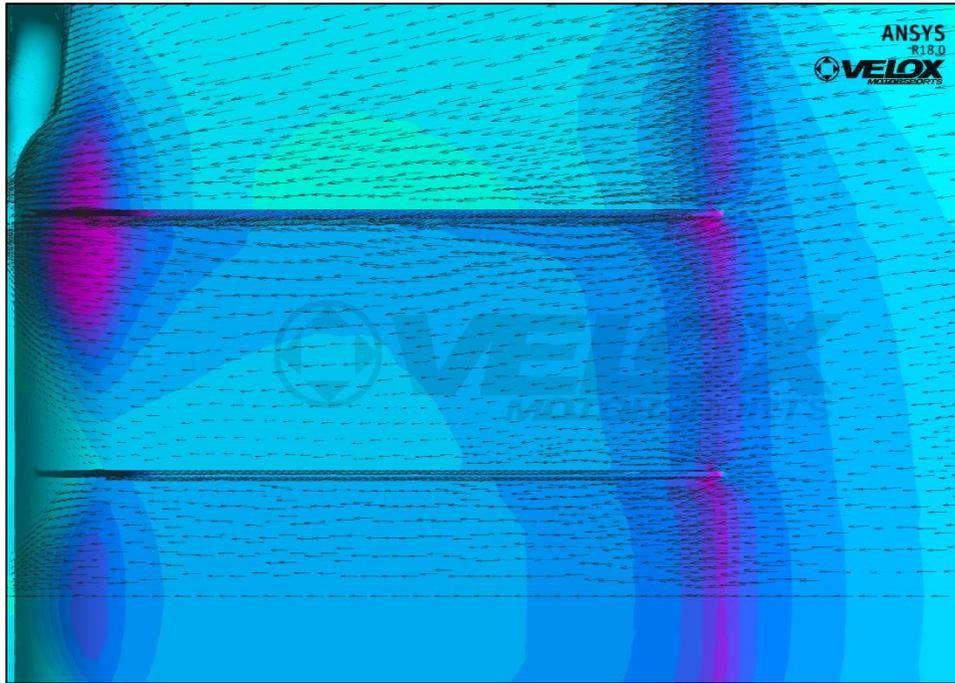


Figure 1.3.3: Diffuser Underside Flow

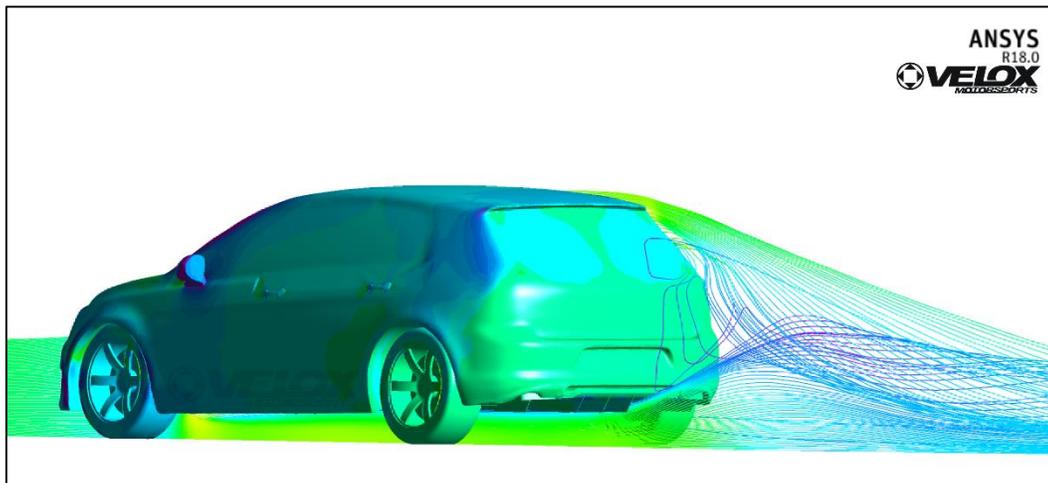


Figure 1.3.4: Streamlines in Rear

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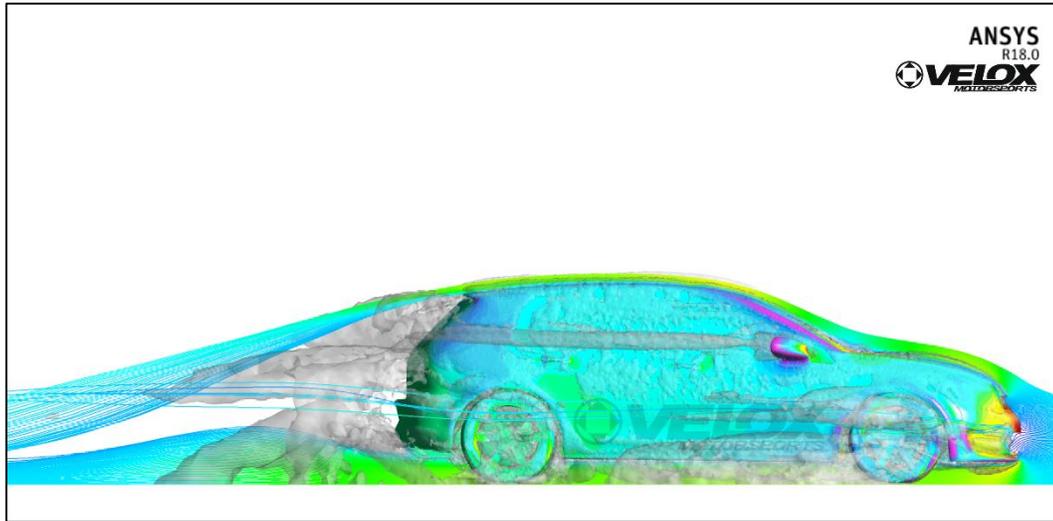


Figure 1.3.5: Streamlines and Q-Criterion

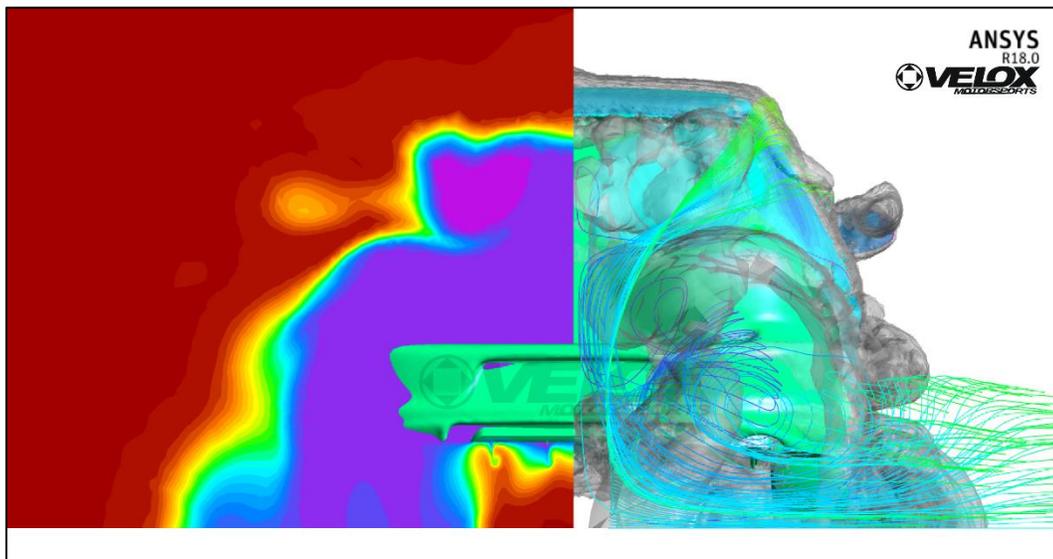


Figure 1.3.6: CpT and Streamline/Q-Criterion

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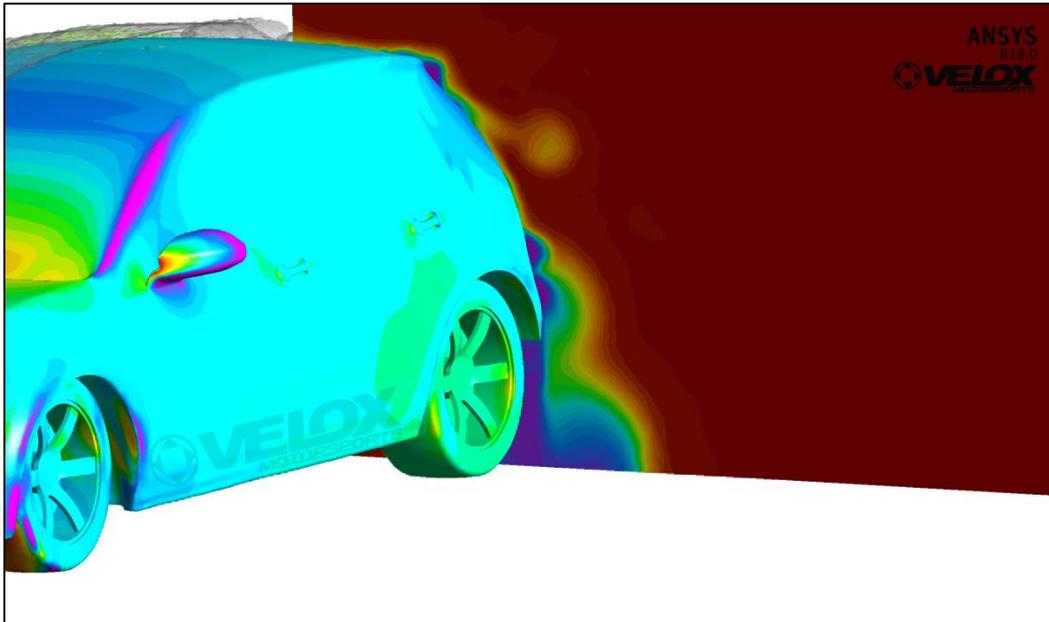


Figure 1.3.7: CpT Cut Plane Behind Rear Tire

Starting with Figure 1.3.1 and 1.3.2, we can notice the vortex coming off the strakes. Vortices in these locations have a positive impact on diffuser performance. We use vortices to optimize many aspects of our components which ultimately improves performance.

Figure 1.3.3 is the underside Cp (coefficient of pressure) plot which shows that there is low pressure on the underside of the diffuser. Purple on the post-processing Cp plot is the locations of the lowest pressure. Low pressure on the bottom side of the car equates to a reduction in lift or downforce.

Another tool we use to optimize components, including a rear diffuser, is streamlines and Q-Criterion. Both streamlines and Q-criterion are good ways to visualize the flow field around the vehicle. Streamlines can be seen in Figure 1.3.4. Q-criterion is a plot technique to show vortex locations. Figure 1.3.5 show both streamlines and Q-criterion plots in a single figure.

CpT (total pressure coefficient) locates free stream flow. The red in the CpT plot is free stream flow and the other colors represent disruptions in free stream flow. Figure 1.3.6 shows CpT on the rear of the Golf R. Notice the good quality flow under the diffusers which is caused by proper strake design and placement. This good flow signifies proper attached flow on the rear diffuser.

The rear tire causes horseshoe vortices which decrease diffuser efficiency. This natural occurrence was decreased as can be seen in Figure 1.3.6 and Figure 1.3.7. The disrupting flow can be seen on the outside of the tire in Figure 1.3.7. Our rear diffuser strake keeps this bad flow out to improve flow and rear diffuser function.

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Mk7 Golf R– Performance of Verus Engineering Rear Diffuser

2. ASSUMPTIONS

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 Golf R and how the Verus Engineering rear diffuser improves the aerodynamic efficiency. The simplifications made were as follows:

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

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 Golf R, 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.

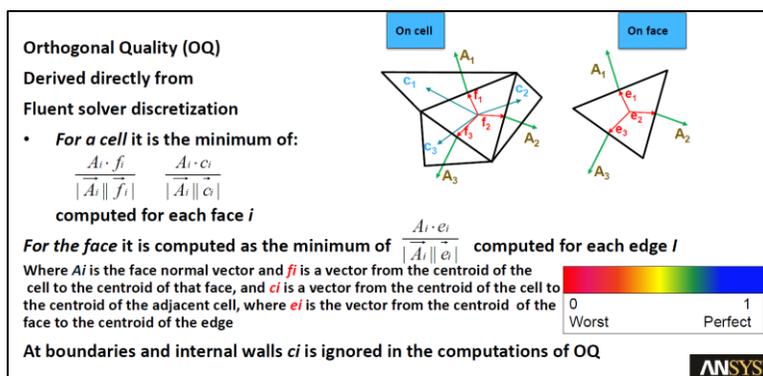


Figure 3.1.1: Orthogonal Quality Metrics

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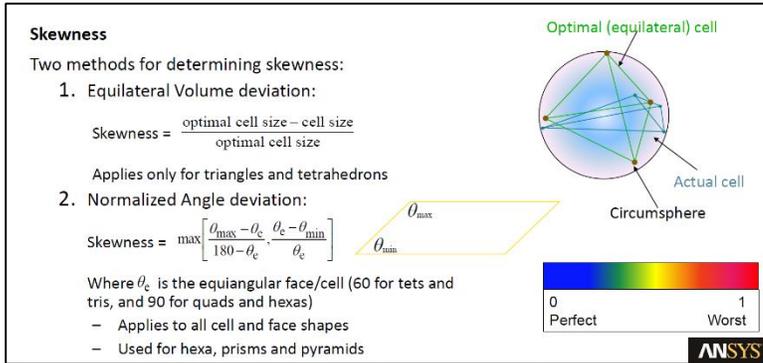


Figure 3.1.2: Skewness Quality Metrics

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.

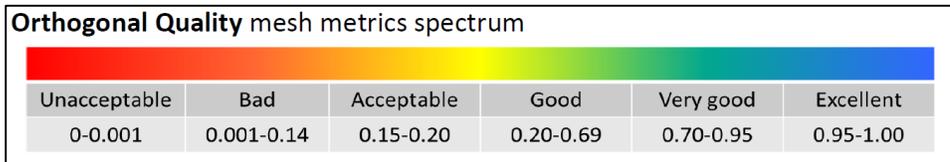


Figure 3.2.1: Orthogonal Quality Metrics

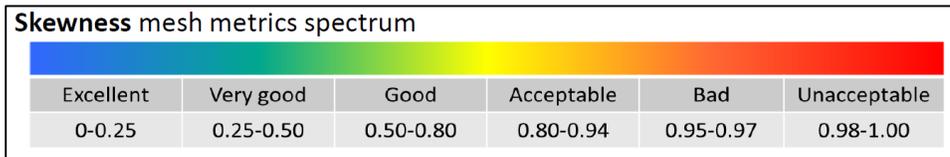


Figure 3.2.2: Skewness Quality Metrics

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.

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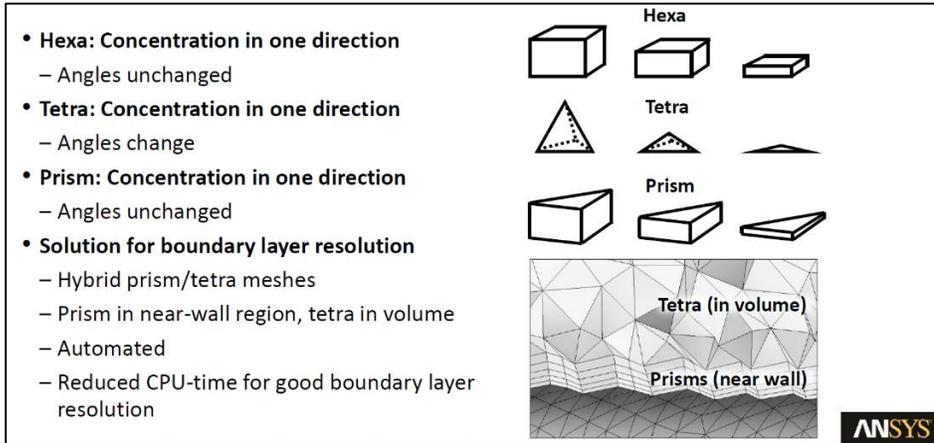


Figure 3.3.1: Hexahedral versus Tetrahedral

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

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 0.21. This is in the acceptable zone for the minimum orthogonal quality. The majority of the mesh is in the very good to excellent range.

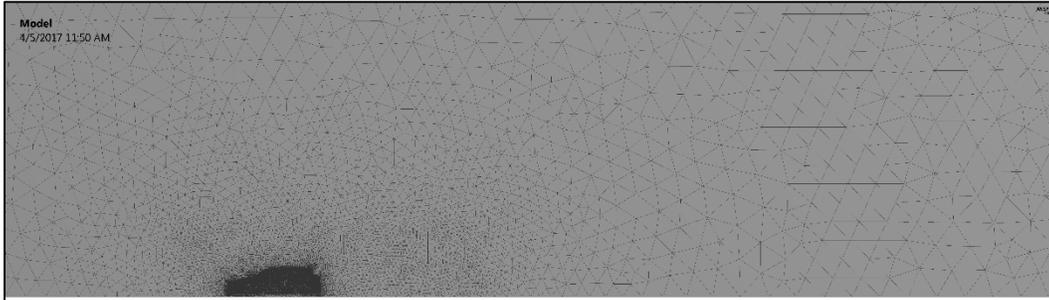


Figure 3.4.2: Mesh Domain

4. ANALYSIS SETUP

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.

Mk7 Golf R– Performance of Verus Engineering Rear Diffuser

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
Golf R	Wall Condition	No Slip Shear
Wheels	Wall Condition	144 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]

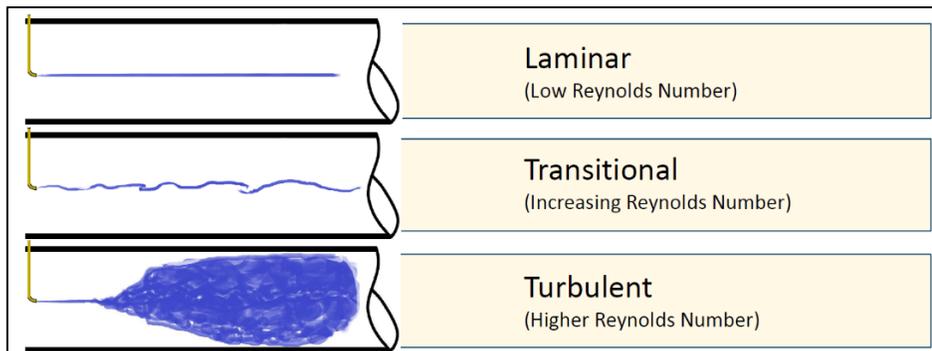


Figure 4.3.1: Flow Classifications

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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 goal of the Verus Engineering Rear Diffuser for the Golf R is to improve its aerodynamic performance over stock. The rear diffuser was scientifically designed using cutting edge technology to maximize performance. Not only will the diffuser help traction via downforce, it reduces drag. Reducing drag will make the Golf R faster by reducing the rearward force on the Golf. Not only does this make the car faster, it will get better gas mileage on the interstate. The Verus Engineering Rear Diffuser is a great performance addition to the Golf R.

Mk7 Golf R– Performance of Verus Engineering Rear Diffuser

7. REFERENCES

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