Safest LPG Transport in America

TRAILER AIR FOIL QUALITATIVE ANALYSIS AND FIELD DATA

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INTRODUCTION

Blunt bodies traveling at sufficient speeds in an atmospheric pressure will result with flow separation at a changing geometry. This physical phenomena is a result of the fluid's (air stream) inertial forces as compared to the viscous forces, known as the Reynold's number (Re) and is written in the following dimensionless form:

$$Re = \frac{\rho V D}{\mu} \tag{1}$$

Flow where the Re number exceeds ≈ 2300 (Pipe), & 5.0×10^5 (over flat surface) is considered turbulent and will result with potential flow separation and vorticies. The resulting flow separation creates a low pressure region following the blunt body due to entrainment. The low pressure region then generates vorticies known as the von Kármán vortex street. Figure 1 shows the cyclical flow effects resulting from flow separation.

Figure 1: Figure shows flow separation after a blunt body with cyclical motion following low pressure regions

The vorticities along with low pressure regions cause increased drag force on the blunt body. This drag force can be thought of as a force pulling the object backwards.

TANK TRAILERS

Tank Trailers inherently experience the above flow characteristics when traveling at sufficiently high speeds. Assuming a tanker with a diameter of about 8ft and traveling at about $60\frac{mil}{hr}$ will have a $Re \approx 4.3 \times 10^6$, much greater than 5.0×10^5 and resulting with the tanker experiencing turbulent flows. The turbulent flows will result with flow separation and and thus drag. The drag force is equivalent to putting on the brakes which results with the need for extra engine power, and thus more fuel.

INITIAL STUDY

Initial Studies were performed with Star CCM Computational Flow Dynamics (CFD) software in order to get a qualitative understanding of flow behavior around traditional tank vessels as shown in the Figure 2 .

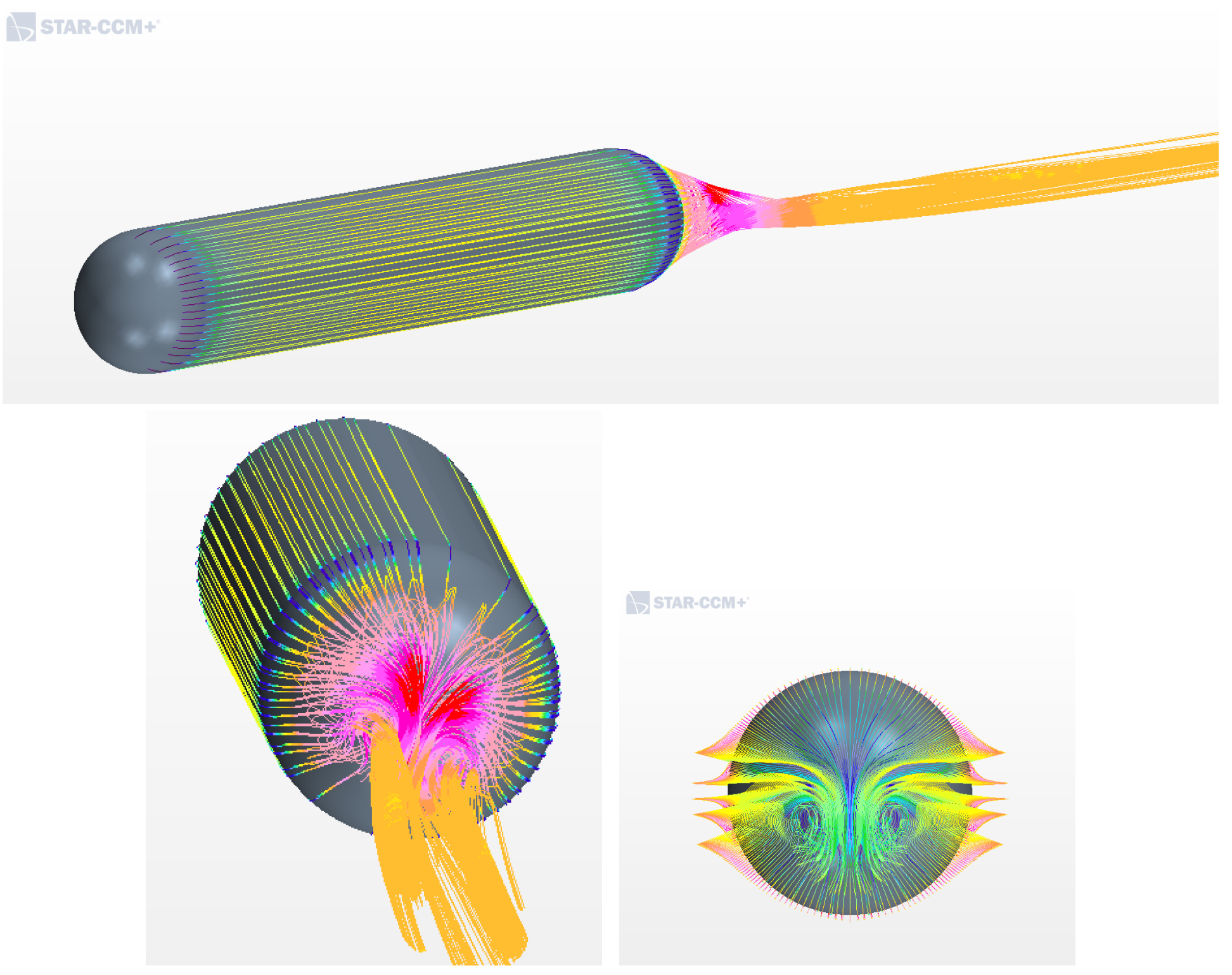

Figure 2: Figure shows Computational Fluid Dynamics (CFD) on a typical tank geometry. The low pressure region is indicated by the dark purple lines an the right end of the vessel, (Top).

Further studies were performed on Exosent's Low center of gravity tank as shown in Figure 3.

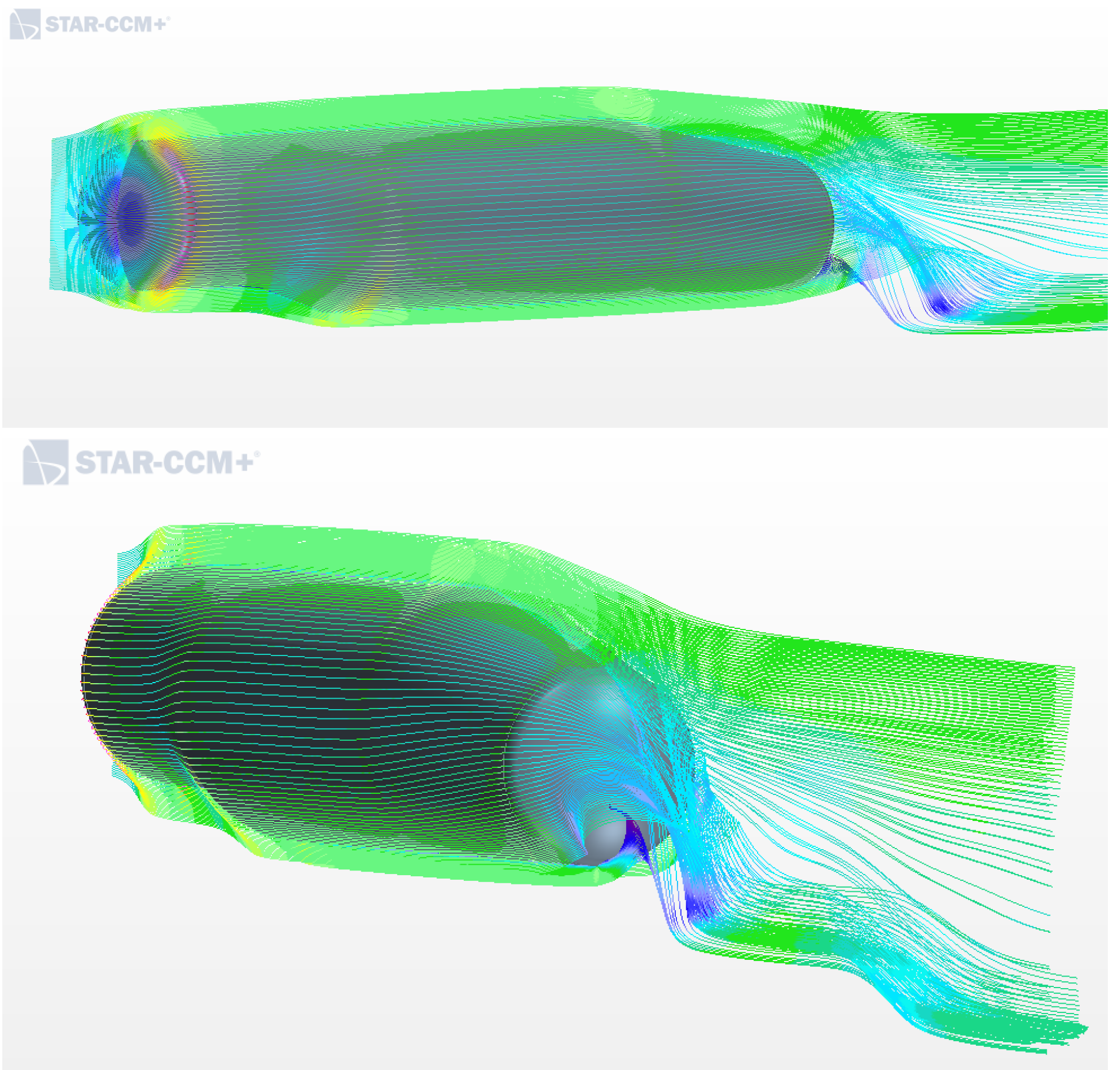

Figure 3: Figure shows Streamlines on an Exosent's Low Center of Gravity tank geometry. The low pressure region is visible at the end of the vessel with the curling light blue lines.

The CFD study revealed the expected low pressure region at the rear location of the tanker.

OBSERVATIONS

Qualitative observation from the Exosent's CFD led to the postulation that the low pressure region at the rear portion of the tank can be coalesced with the use of an air foil. An iterative design process was used with the following variables to achieve the desired air foil effect:

1. Span
2. Chord-Length
3. Mean Camber Line
4. Aspect Ratio
5. Vertical Placement
6. Aft placement

The design process utilized Star CCM CFD with a moving floor and a Re number of 4.3×10^6. End walls were implemented in the CFD as non variable.

CFD RESULTS

Qualitative observation from the CFD study showed a significant effect on the low pressure region. The low pressure region as shown Figure 3 was significantly reduced along with side vorticies. Additionally, the flow appears to be shifted downstream by $\approx$ seven length scales as shown in comparison Figure 4.

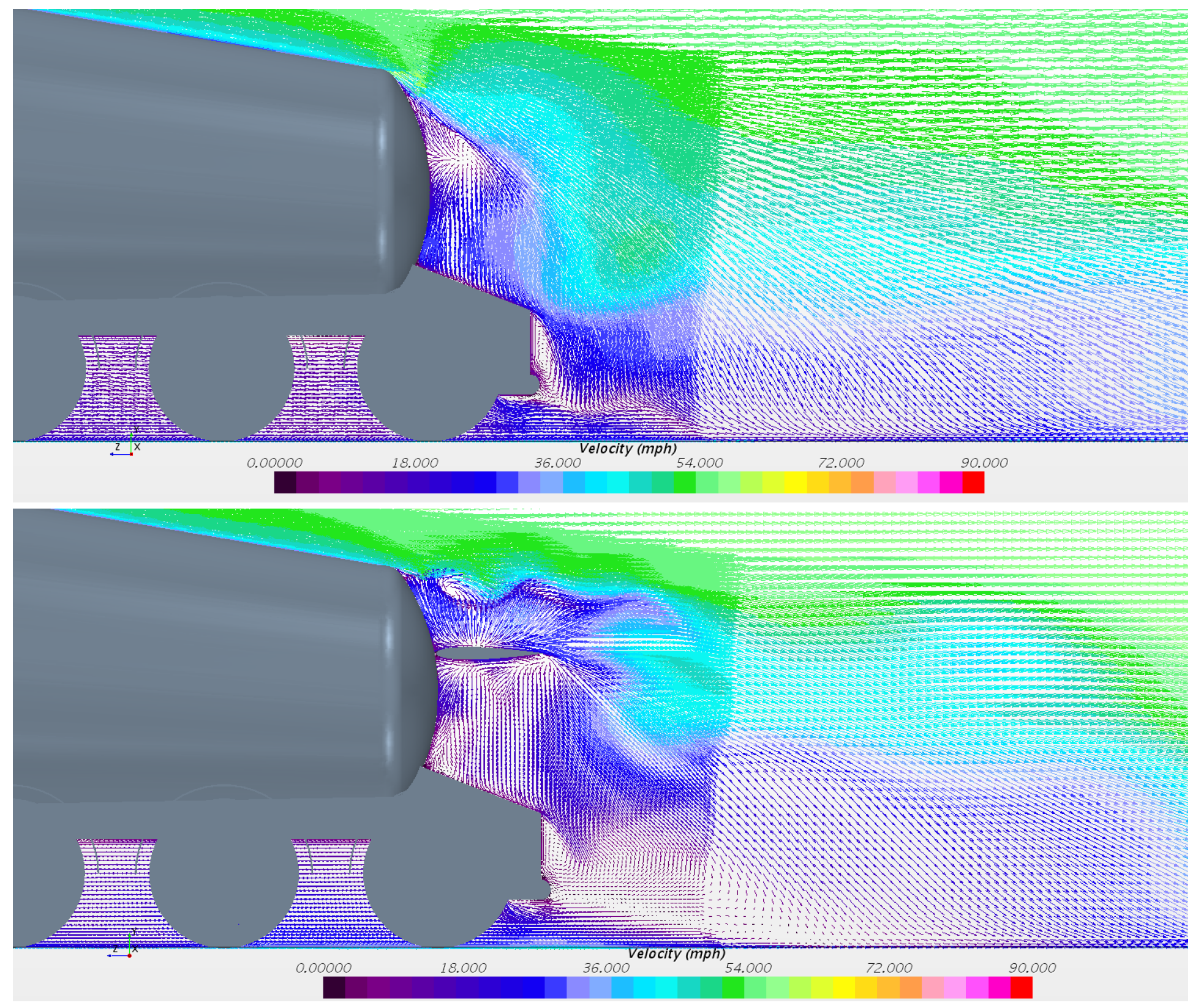

Figure 4: Figure shows comparison velocity vectors at the aft of two identical models with the exception of the air foil on the bottom figure which clearly shows a reduction of the low pressure region.

The final design yielded a symmetric airfoil with the following dimensions:

CFD RESULTS (CONT.

Span	72 in
Chord-Length	29.77 in
Mean Camber Line	29.77 in
Aspect Ratio	≈ 2.4
Vertical Placement	$\Uparrow$ 0.61 D
Aft Placement	1.25 in at the tip

The final Air foil design was created in Solidworks and is shown in Figure 5.

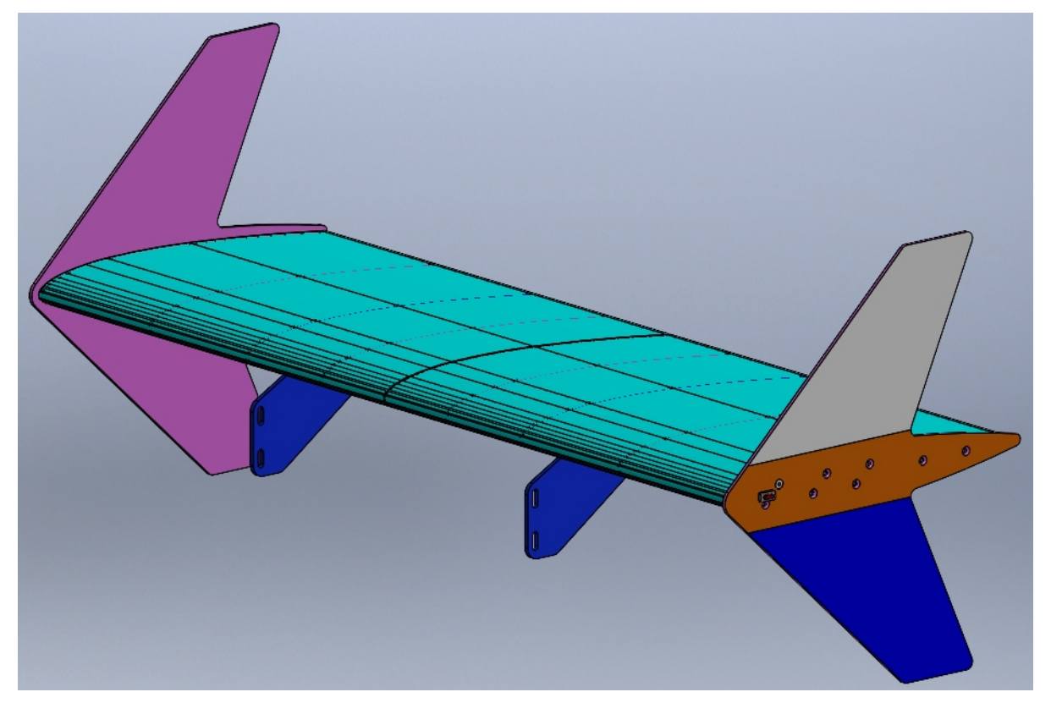

Figure 5: Final 3D Air Foil design in Solidworks.

MANUFACTURING

Manufacturing the air-foil needed to satisfy the following criteria:

1. light weight
2. Structural stability
3. Resistance to lateral wind loads
4. Flexure resistance to cyclical loading
5. Resistance to snow loads

Aluminum 6061 was chosen as the predominant material for the structure with 5052 for skin function. The completed wing weighs $\approx$ 85 lbs.

FIELD DATA

The first wing was installed in 2019 on a 15400 gallon Exosent Low center of gravity unit. As of August 2023, over 46 wings have been installed with companies reporting double digit fuel economy increase when integrated with complete Exosent Aero package. At the far extreme drivers have reported upwards of **18%** fuel efficiency increase when compared to a traditional vessel.

INQUIRE

Please feel free to ask for any further details regarding implementing the Exosent Aero Package with the Airfoil for your transport