Iowa State University
Mechanical Engineering

Research in the Capitol
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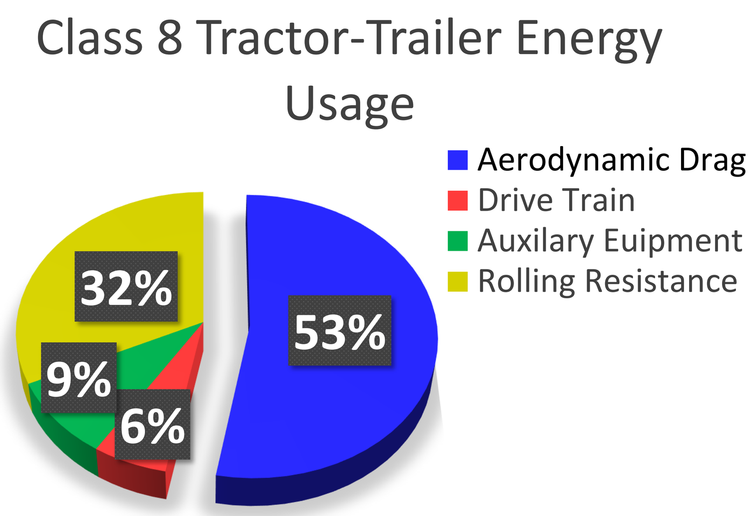
Improving Semi-Truck Fuel Efficiency by Optimizing Trailer Tail Design

Introduction and Motivation



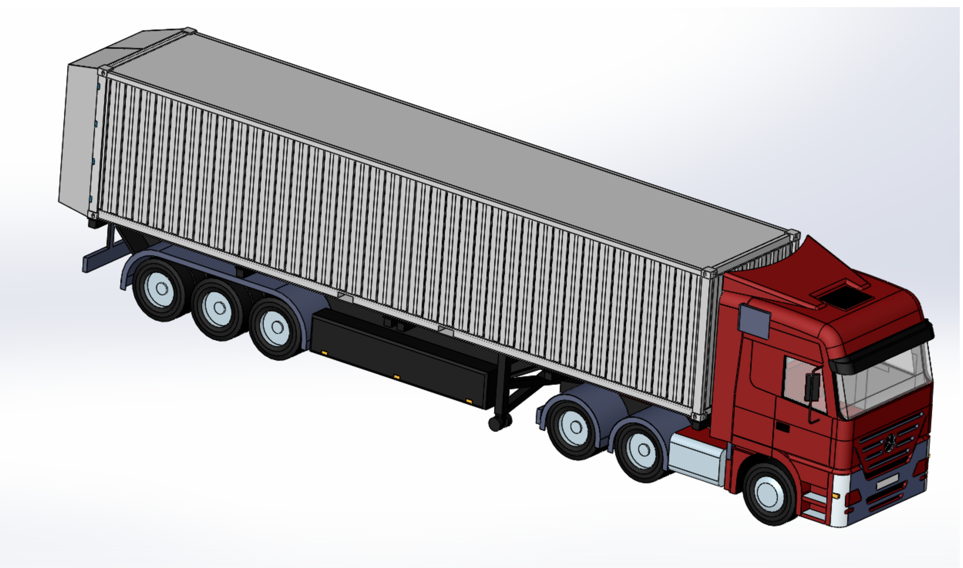
Class 8 tractor-trailers consume roughly **12% of total US petroleum consumption** and emit substantial amounts of green house gases. *(Salari 2008)* Aerodynamic tests on drag reducing add-on devices are **expensive** and **time consuming** which may lead to less than optimal designs.

Hypothesis: The trailer tail has been shown to significantly reduce drag in wind tunnel and road tests, but can be **further optimized using novel techniques of computational fluid dynamics analysis that are much more flexible and time efficient than traditional methods.**

Tractor-trailer equipped with a trailer tail

NURBS Based B-Rep

Complicated geometry such as the one used in this study poses challenges to traditional meshing techniques. This analysis directly uses CAD models for **higher efficiency** and **improved accuracy.**



CAD model of complex truck geometry analyzed in this study

Non-Boundary-Fitted Method

Immersogeometric method is a class of immersed finite element methods that can **faithfully represent the geometries** of immersed objects. *(Kamensky et al. 2015)*

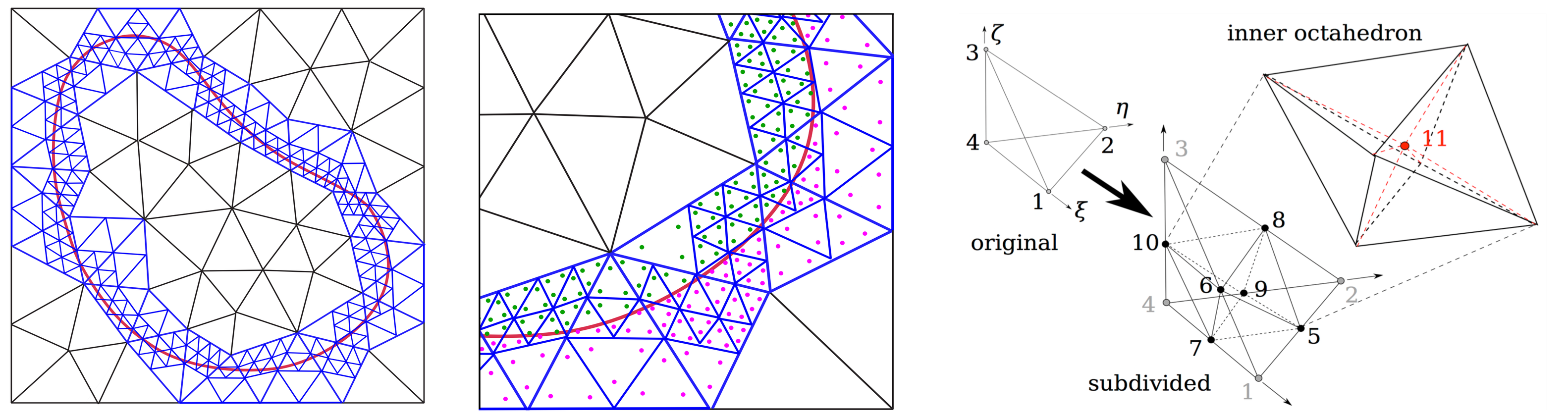
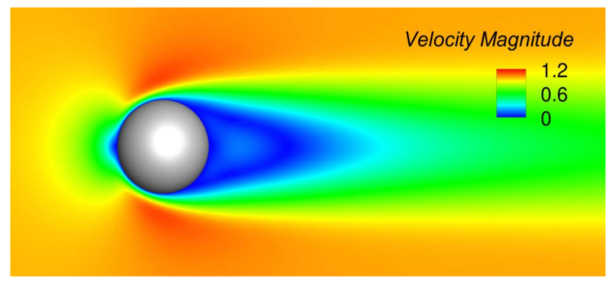


Illustration of novel meshing method

Benchmark Test

Past research has shown **good agreement** between novel and conventional methods with benchmark problems. *(Xu et al. 2016, Hsu et al 2016.)*

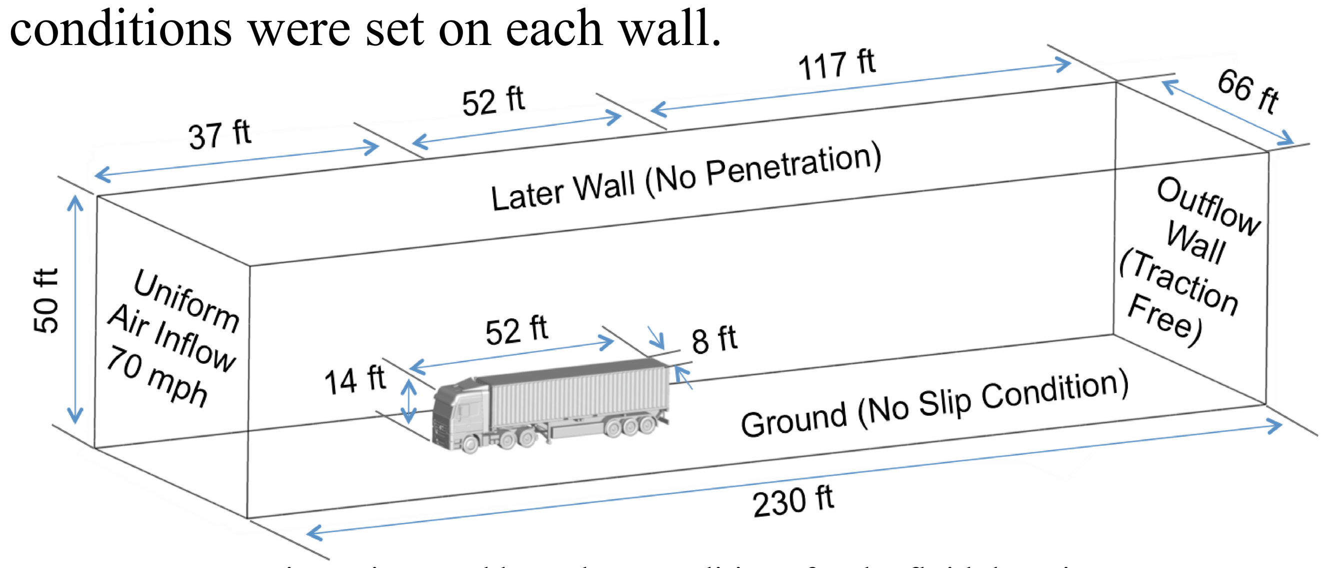


NURBS B-Rep benchmark result

	C_D	L/d
Boundary Fitted Mesh	1.094	0.855
Triangulated Surface Mesh	1.095	0.855
NURBS B-Rep	1.094	0.856

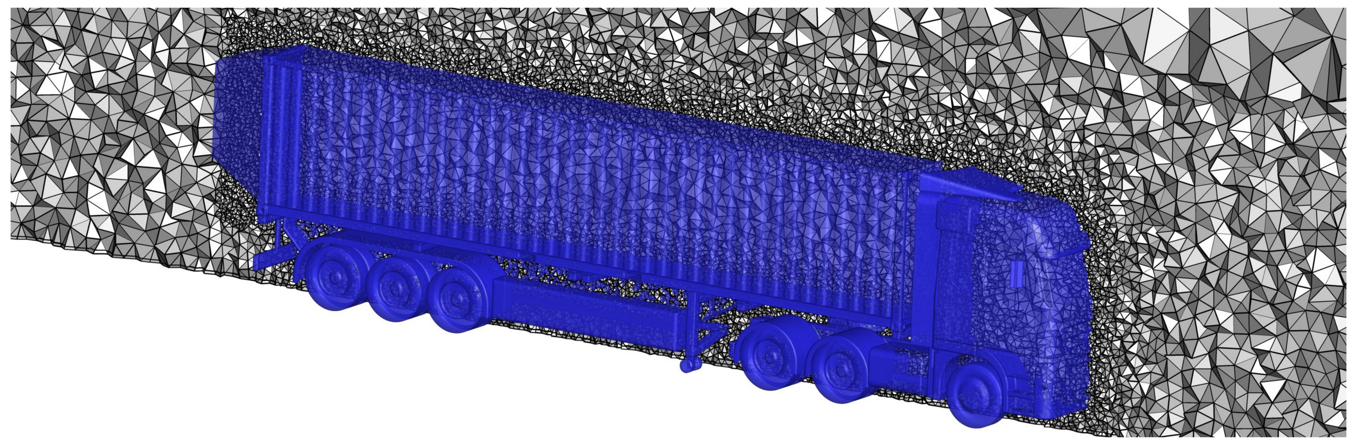
Problem Set-Up

Under analysis is a Mercedes Class 8 tractor trailer with an inflow airstream velocity of 70 mph. Various boundary conditions were set on each wall.



Dimensions and boundary conditions for the fluid domain

Flow Field Mesh



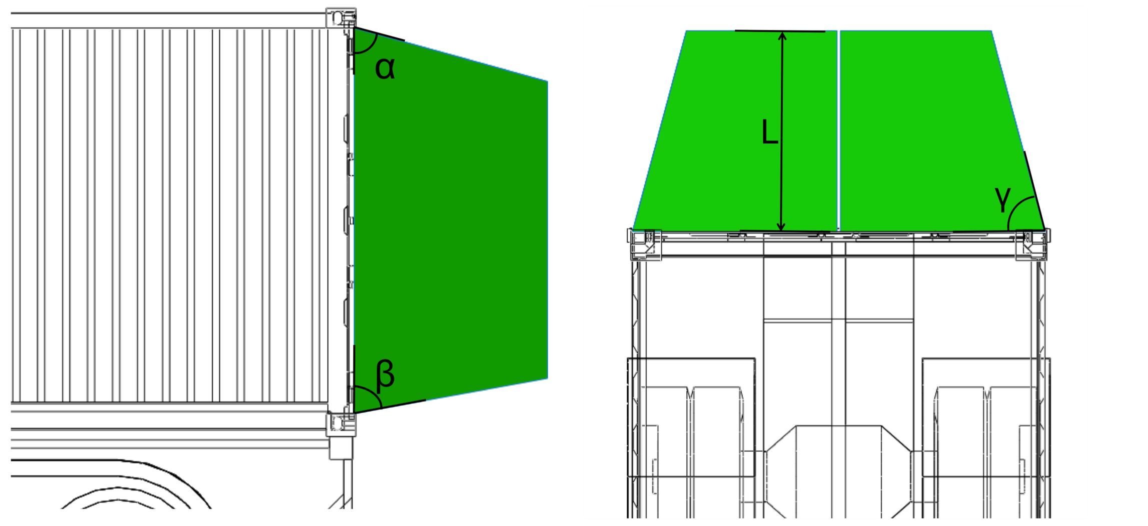
Visualized 3D immersogeometric mesh used in simulation

The mesh for the flow field is generated in open sourced meshing software, Gmsh, in about **10 minutes** and includes approximately **5 million elements** ensuring accurate results.

Design Optimization

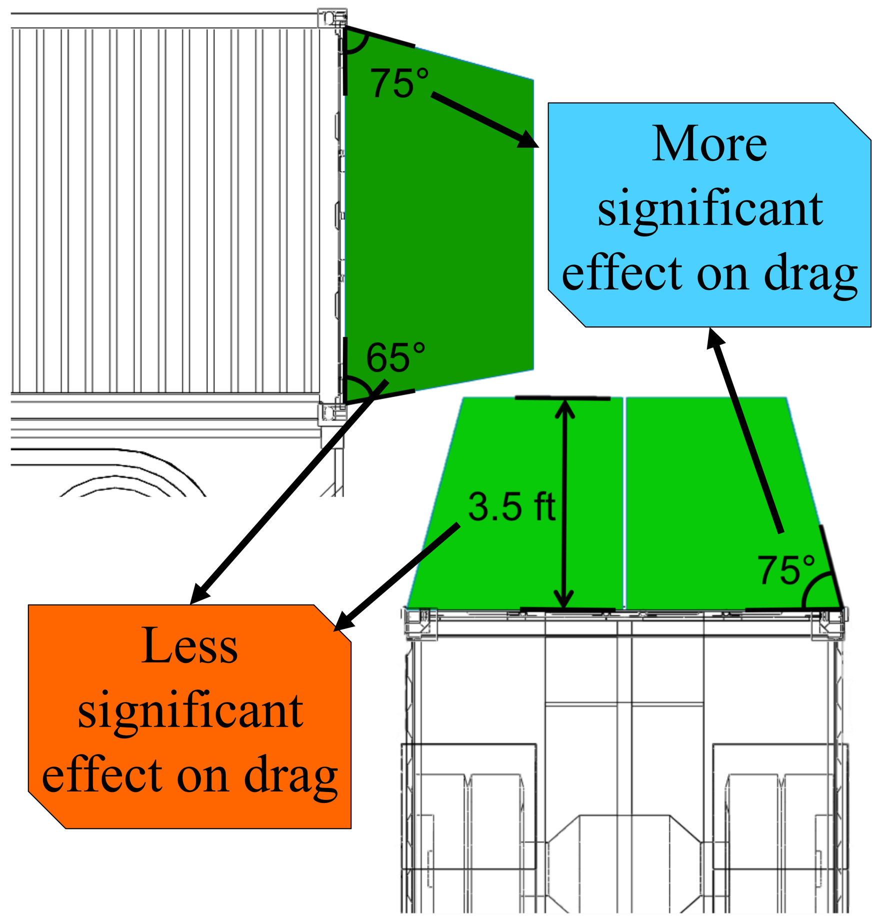
4 geometric dimensions were chosen as design variables (3 angles and 1 length).

9 sets of these variables were analyzed to determine **maximum drag reduction.**

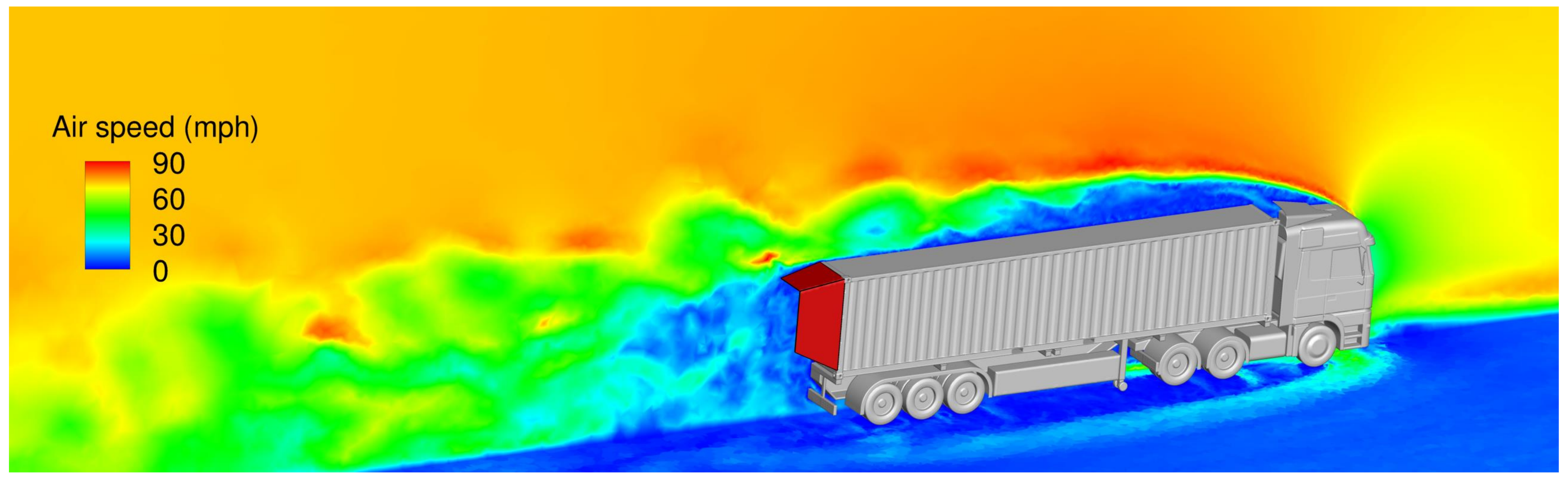


Side and top views. Labeled dimensions are changed to determine optimal design

Results



Design	α (deg)	β (deg)	γ (deg)	L (ft)	C_D
1	75	90	75	3.5	0.8653
2	75	65	75	3.5	0.8609
3	75	90	45	3.5	0.8749
4	75	45	75	3.5	0.8645
5	75	90	75	4.5	0.8614
6	45	90	75	4.5	0.8687
7	75	65	75	4.5	0.8633
8	75	90	45	4.5	0.8785
9	75	45	75	4.5	0.8662



Future Work

- Advanced algorithm to perform point membership classification based on GPU
- Consider the fluid structure interaction between the air and the trailer tail that could cause vibration and alter the flow-field
- Use surrogate optimization method to find global drag minimum within the geometric constraints of the trailer tail

References:

Hsu et al., "Direct immersogeometric fluid flow analysis using B-rep CAD models," Computer Aided Geometric Design, accepted (2016). doi:10.1016/j.cagd.2016.02.007.

Kamensky et al., "An immersogeometric variational framework for fluid–structure interaction: application to bioprosthetic heart valves," Computer Methods in Applied Mechanics and Engineering, 284 (2015) 1005-1053.

Salari, K. (2008). DOE's effort to reduce truck aerodynamic drag through joint experiments and computations. DOE Annual Merit Review, 14-18.

Xu, Fei et al. "The tetrahedral finite cell method for fluids: Immersogeometric analysis of turbulent flow around complex geometries," Computers & Fluids, accepted (2016). doi:10.1016/j.compfluid.2015.08.027.

Trailer tail photograph retrieved from http://vogeltalksrving.com/2013/11/will-intelligent-aerodynamics-change-the-shape-of-your-rv-at-highway-speed-to-maximize-fuel-efficiency/