Aerodynamic Drag Reduction of Class 8 Trailer Trucks Using External Attachments

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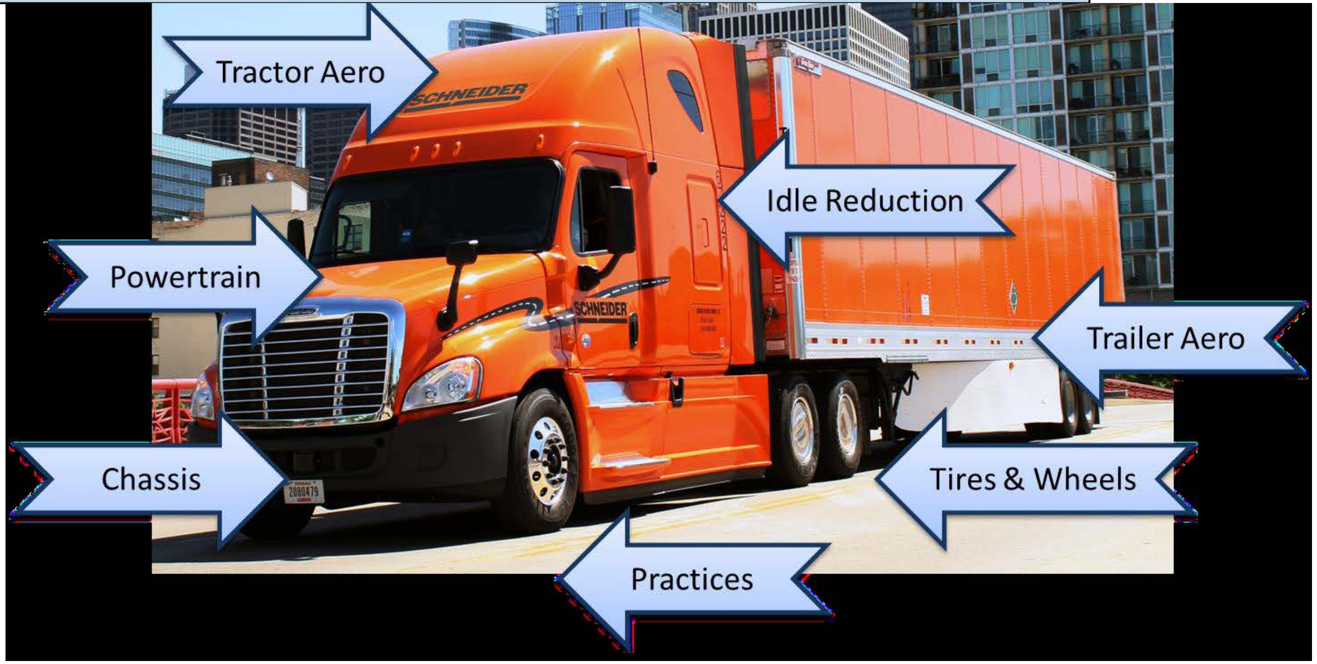
Class 8 Trucks

- The **Class 8 truck** gross vehicle weight rating (GVWR) exceeding 33000 lb (14969 kg), and upto 80,000 lbs.
- These include tractor trailer tractors as well as single-unit dump **trucks** of a GVWR over 33,000 lb;
- Such **trucks** typically have 3 or more axles.

Trucking Statistics (~2006)

- Estimates of 15.5 million trucks operate in the U.S..
- **2 million are tractor trailers**.
- In 2006 the transportation industry logged 432.9 billion miles.
- Class 8 trucks accounted for 139.3 billion of those miles, up from 130.5 billion in 2005, a 6.7% increase
- The US economy depends on trucks to deliver nearly 70 percent of all freight transported annually in the U.S., accounting for $671 billion worth of goods. + $295B Canada + $196B Mexico
- trucks consumed 53.9 billion gallons of fuel for business purposes.
- So, just 1% fuel efficiency increase would save 539 million gallons

Trucking Efficiency.Org



Identifies 7 areas where efficiency can be improved:

1. Idle Reduction
2. Chassis
3. Tires, Rolling Resistance
4. Powertrain
5. **Tractor Aerodynamics**
6. **Trailer Aerodynamics**
7. Operational Practices

Our study focuses on the aerodynamic shape design

Source: Truckingefficiency.org

Tractor Aerodynamics evolved

Aerodynamic **sleeper model** shapes generally

- have rounded leading edges especially at the crown and grille edges, cab A-pillars, and sleeper roof edges.
- Have conformal headlamps integrated into the fenders, curved outer end to bumpers, bumper air dams, hoods that slope downward at the front, and aerodynamic cab access steps.
- Designed to lower the drag on the front of the vehicle.
- Since the early 2000s, aerodynamic sleepers have become the predominant type of tractors in production.
- Classic sleepers still exist with long and tall hoods, but sacrifice as much as **30% in fuel** savings.

Tractor - Aerodynamic Technologies

- Aero Hoods, Fenders and Headlamps
- Aerodynamic Bumpers
- Aerodynamic Mirrors
- **Roof Fairing**
- Part Removal / Relocation (Tractors)
- Chassis Fairings
- Drive Wheel Fairings
- 5th Wheel Settings
- **Cab and Roof Extenders**
- Wheel Covers (Tractors)
- Vented Mud Flaps (Tractors)

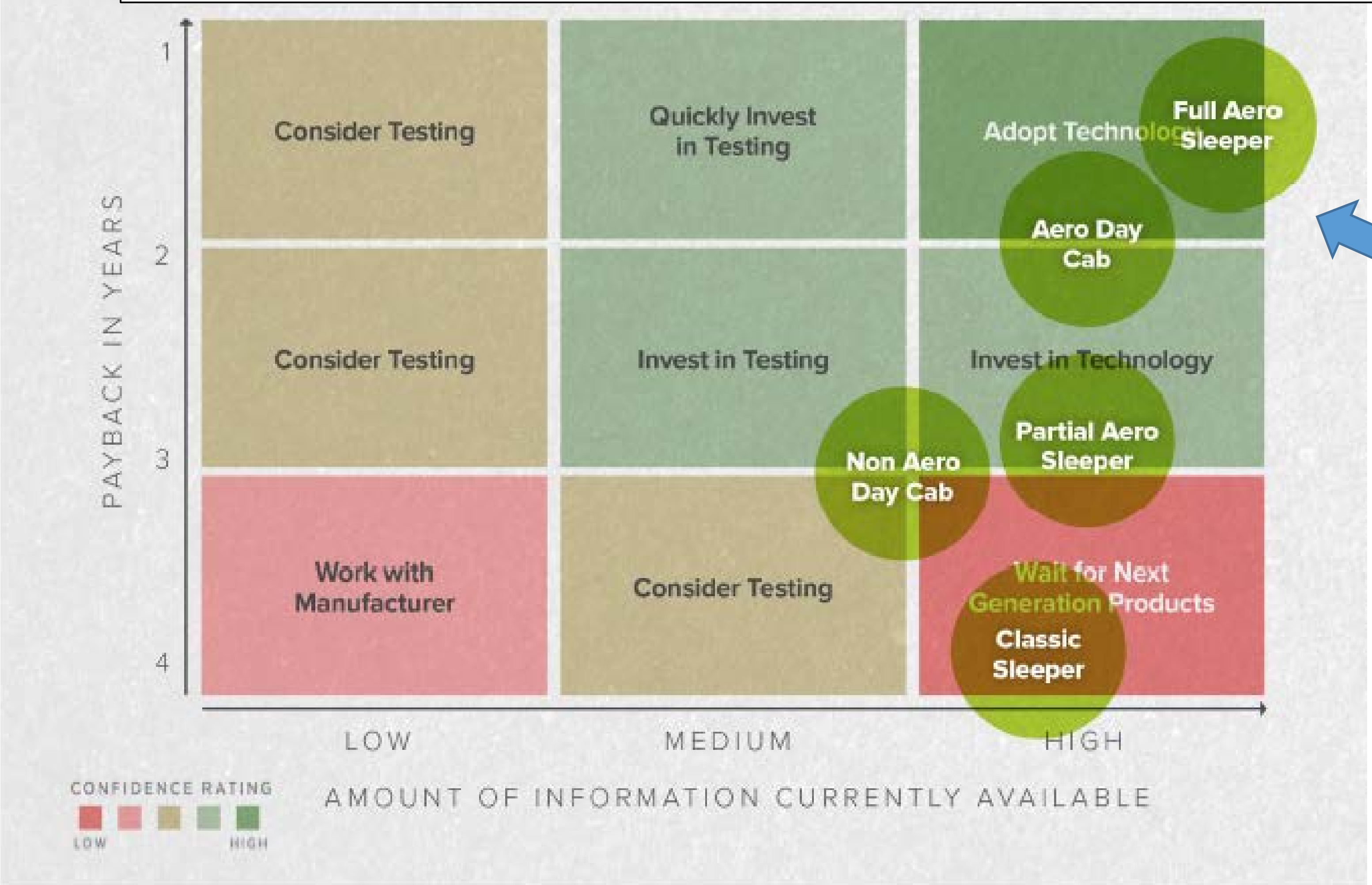
Trailer - Aerodynamic Technologies

- **Trailer side Fairings**
- Double / Triple Trailers
- **Gap Devices**
- Part Removal / Relocation (Trailers)
- Narrow Mud flaps
- Vented Mud Flaps (Trailers)
- Wheel Covers (Trailers) -
- Trailer Underbody Devices (bogie fairings)- Move away airflow
- **Trailer Rear Devices – reduces wake (pressure drop)**
- Vortex Generators – streamline side airflow
- **Streamlined Half-body on top of trailer**(non existent in industry, devised in-house)

These are most effective and targeted in the study

Technology/Information VS Adoption Strategy

Helps make decisions about adopting tractor aerodynamic devices

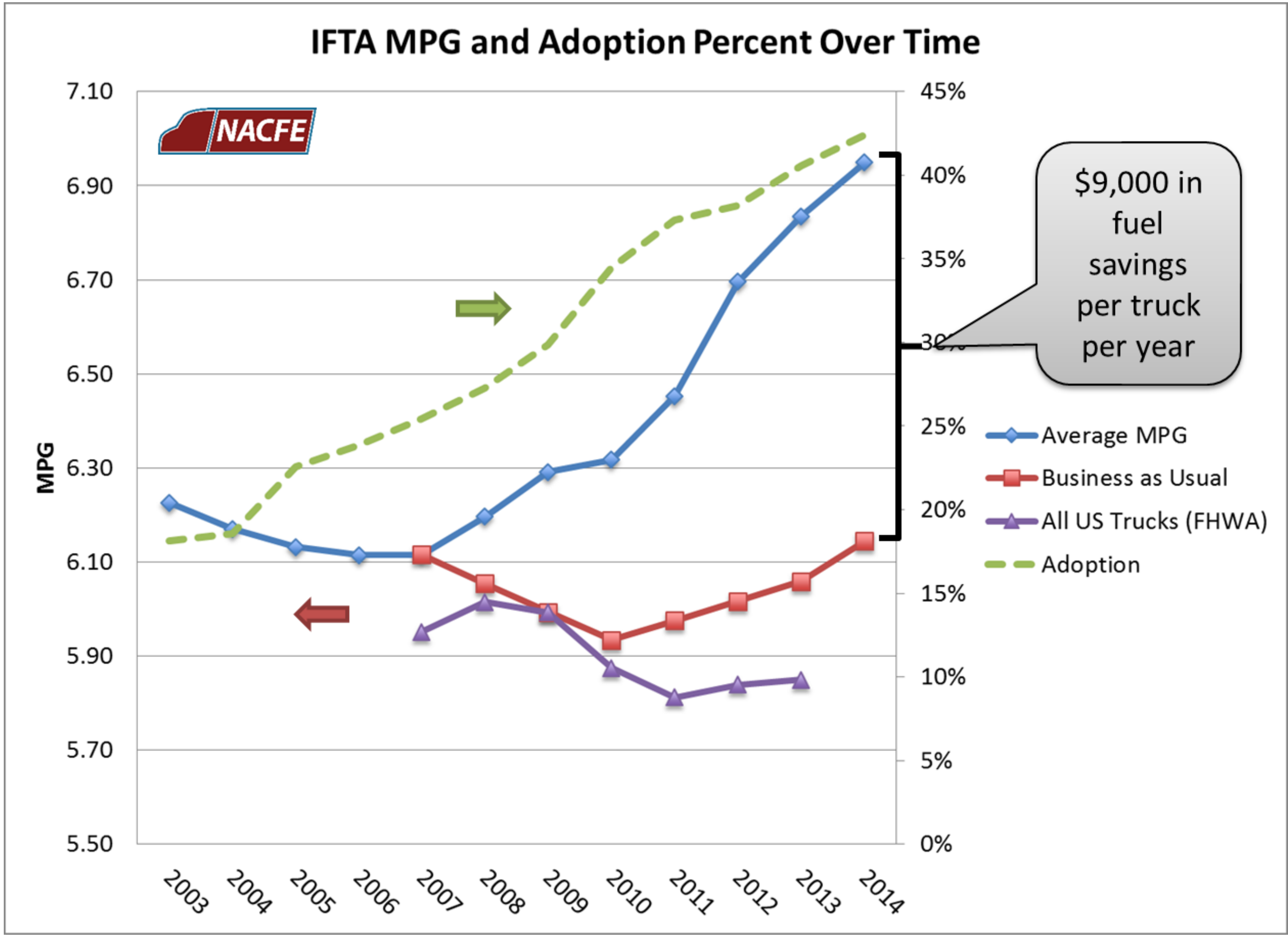


Some can pay back in just 1-2 years.
E.g Full aero Sleeper Tractor

Source: Truckingefficiency.org

Technology Adoption and Fuel Mileage

$9,000 savings/truck/year
X 2 million tractor trailer
=$18Billion in fuel cost
5% fuel eff. Increase=$1B savings



Motivation of this work

- The Environmental Protection Agency (EPA) has proposed legislation to reduce greenhouse has emissions among Class 8 trucks
- increase fuel economy by 40% by year 2027
- Class 8 trucks typically achieve fuel economy in the range of 5-6 miles per gallon of diesel fuel
- Much of the fuel inefficiency is from **non-aerodynamic shape** of the trucks
- The current study is focused on studying the specific geometry/shape of the truck that contributes to added aerodynamic drag
- Design add-on shapes and when attached, will give aerodynamic shape to the otherwise 'boxy' truck.
- Computer Simulate the effects of these add-on attachments using CFD
- 3D print scale model of the trailer Truck and the various add-on attachments.
- Validate these effects by testing scale model in wind tunnel

Study Approach

1. DESIGN AIM reduce aerodynamic drag coefficient
2. CAD of add-on devices Gap, top, and back
3D print these
3. Aerodynamic study of the model in wind tunnel
4. CFD Simulation of the models

Wind Tunnel Test/Calc. of C_d

CAD models using SolidWorks;

Drag force Equation

$$F_d = C_d \frac{1}{2} \rho V^2 A$$

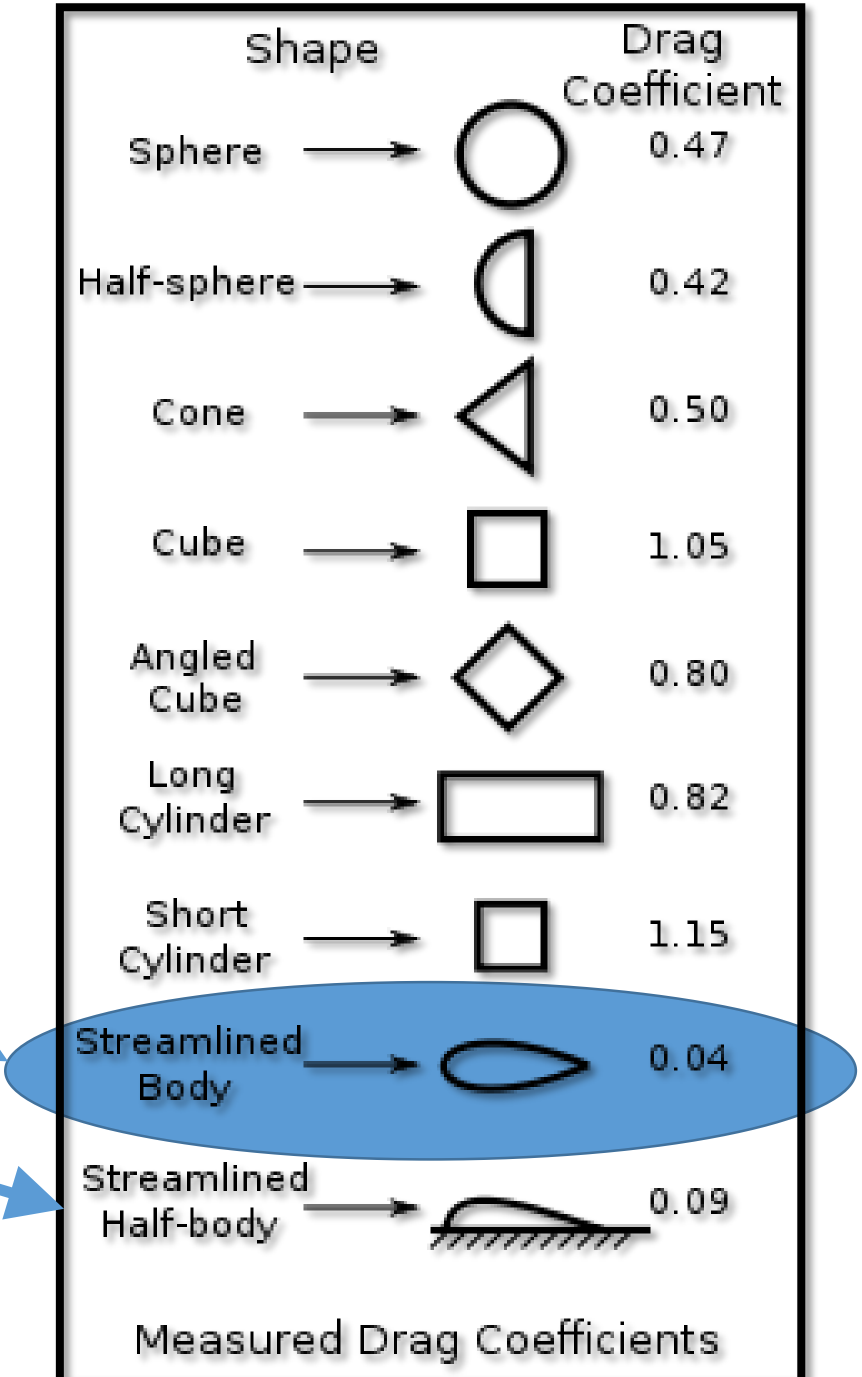
Drag coefficient Equation

$$Cd = F_d / (A * .5 * \rho * V^2)$$

This is a dimensionless quantity that is used to quantify the drag or resistance of an object in fluid flow, such as air or water.

F_d= force of the drag
ρ= the density of the fluid (1.2kg/m^3)
V= the speed of the object relative to the fluid
A=frontal area
C_d= the drag coefficient

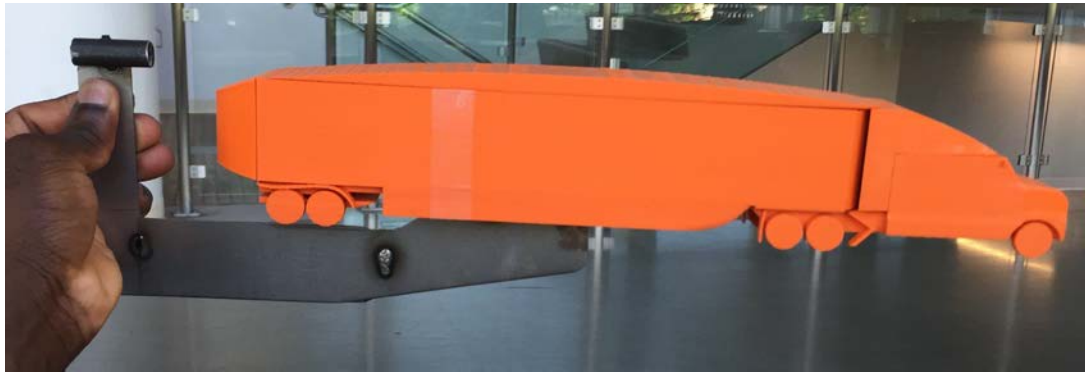
Drag coefficient (Cd)is a characteristic of the shape and orientation



Aerofoil shape is best.

We can try using streamlined half-body on a truck

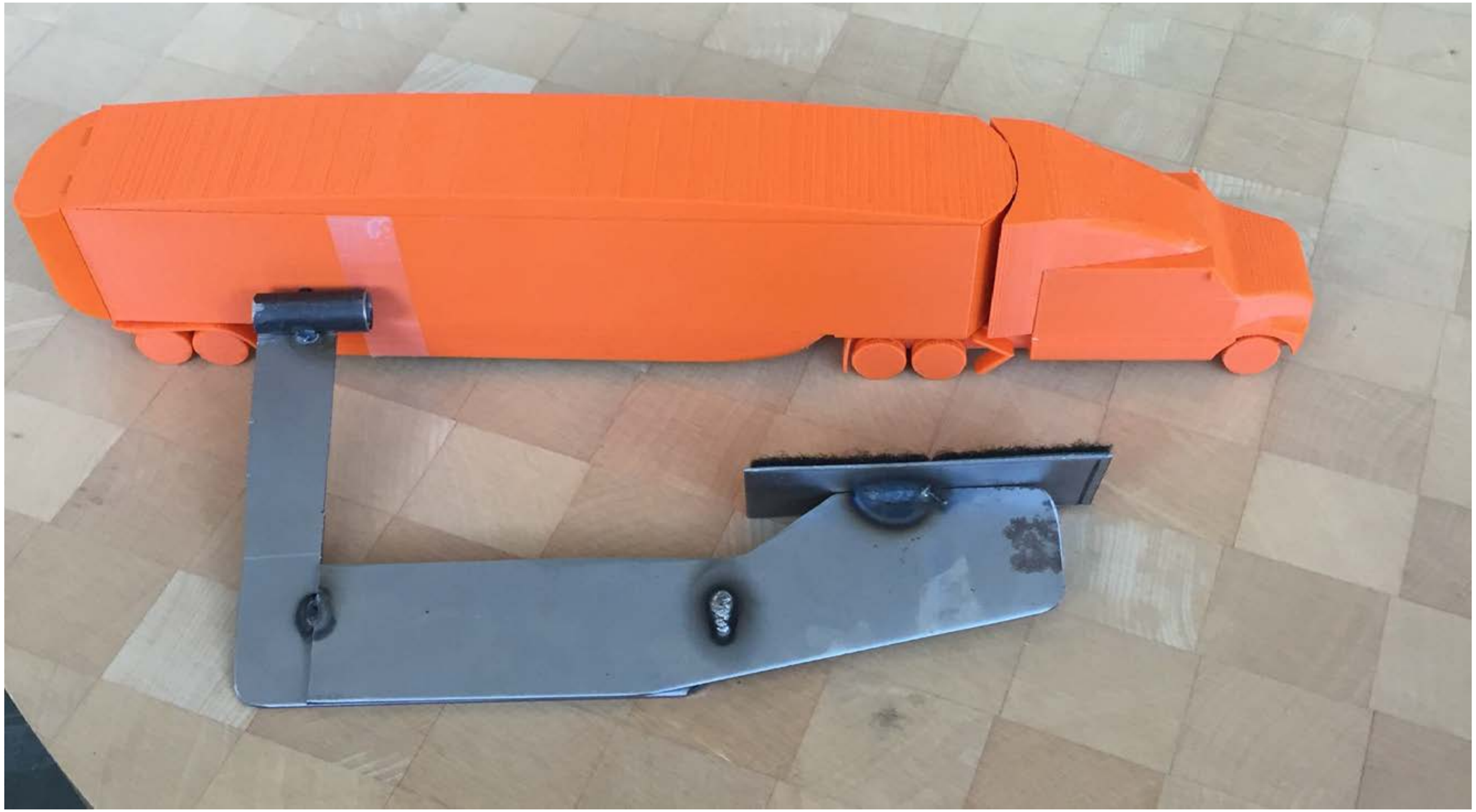
3D printed models of Various Add-on components



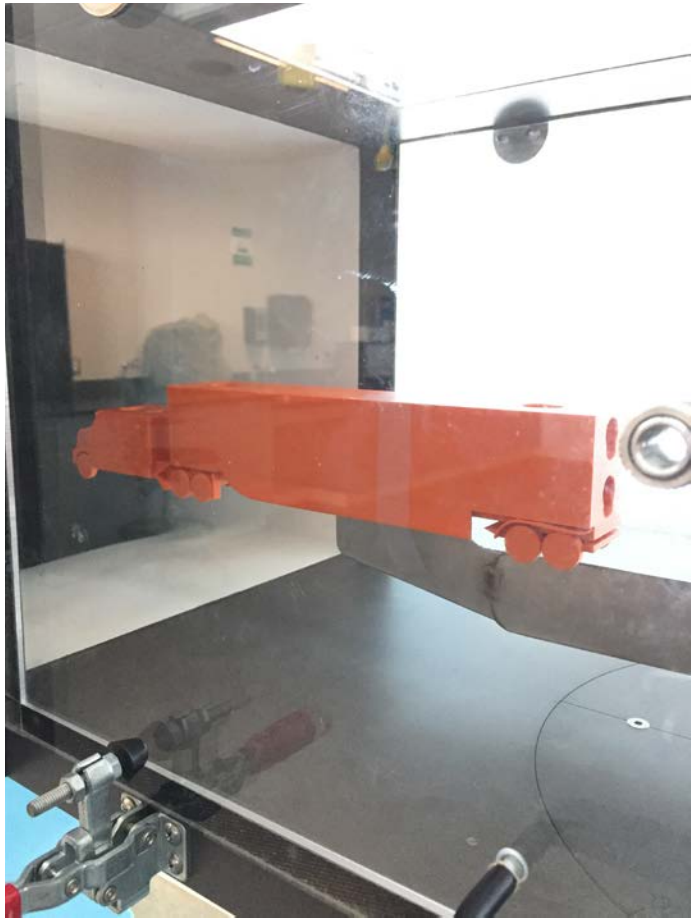
Various Add-on components

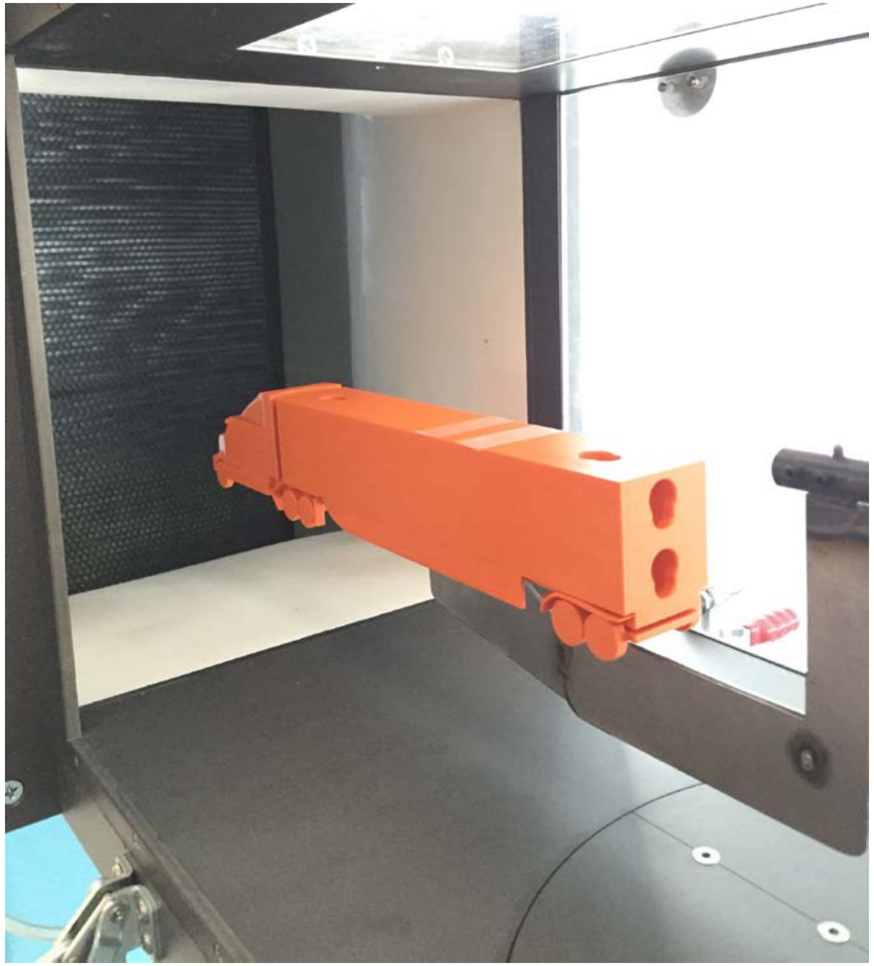
Tractor and trailer are being assembled

CFD Model ready



Tractor Trailer model in the wind tunnel



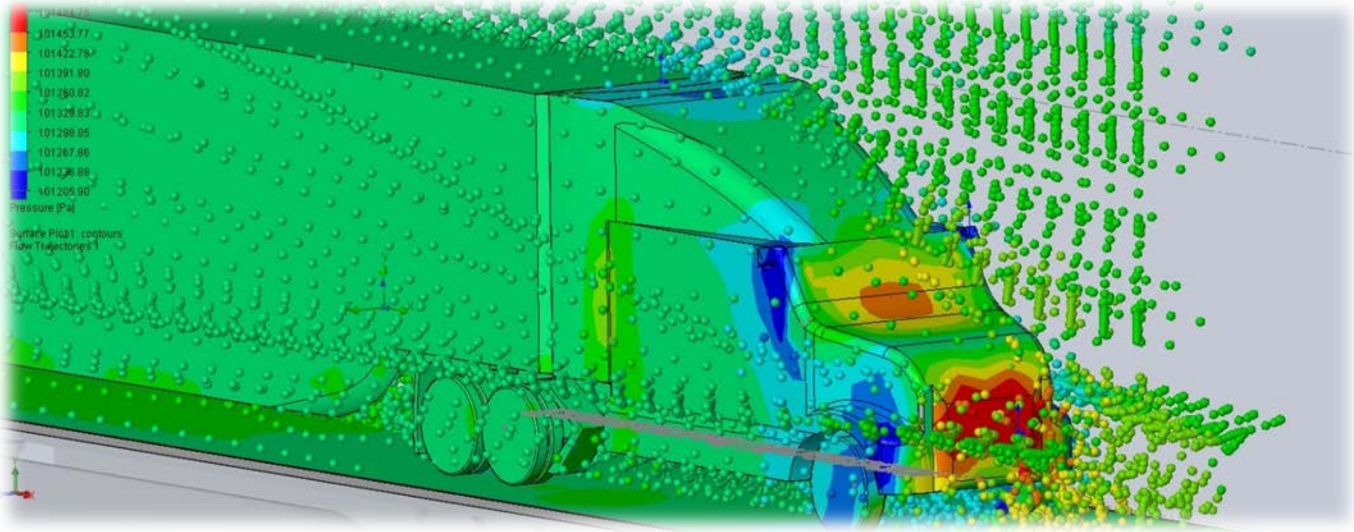


Computational Fluid Dynamics (CFD)

CFD is the use of applied mathematics, physics implemented in computational software to simulate and visualize:

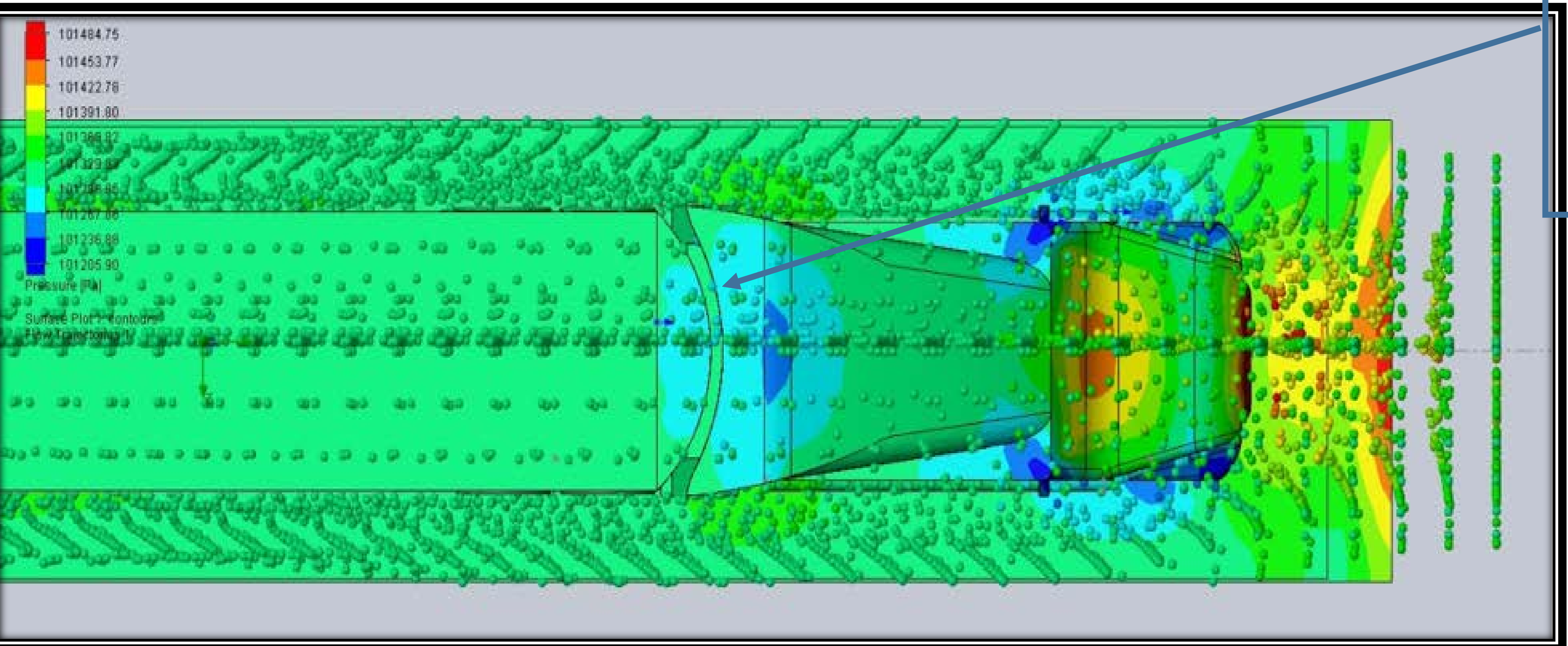
- How a gas or liquid flows especially over a soild, often stationary object.
- How the gas or liquid flow determines pressure, velocity, etc. at a certain velocity.
- Various other physical phenomena can be calculated, e.g. pressure on an object, forces in various directions, flow rate at or within certain area, etc.
- CFD module within SolidWorks package was used for trailer truck CFD analyses.

High Pressure region at the frontal/grill area due to air flow



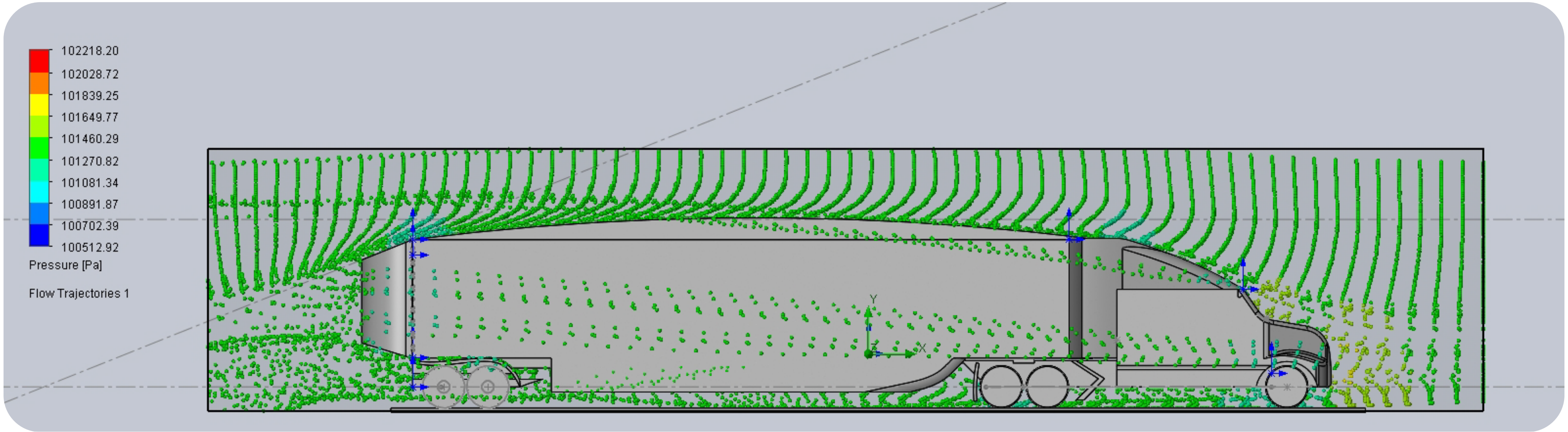
Pressure profile around the truck

- Semi-Tractor Top Fairing- This device has existed for several years and the design shape has been slightly overlooked. Some of the present fairings are either just on the top of the semi-truck or top and gap. The top cabin and gap has the best optimization for aero flow. However, better aerodynamic flow could be achieved with that same concept but redesigned.



Trailer and Tractor Curved interface. Allows turning. (6.3% more efficient)

Application of streamlined half-body on top of trailer



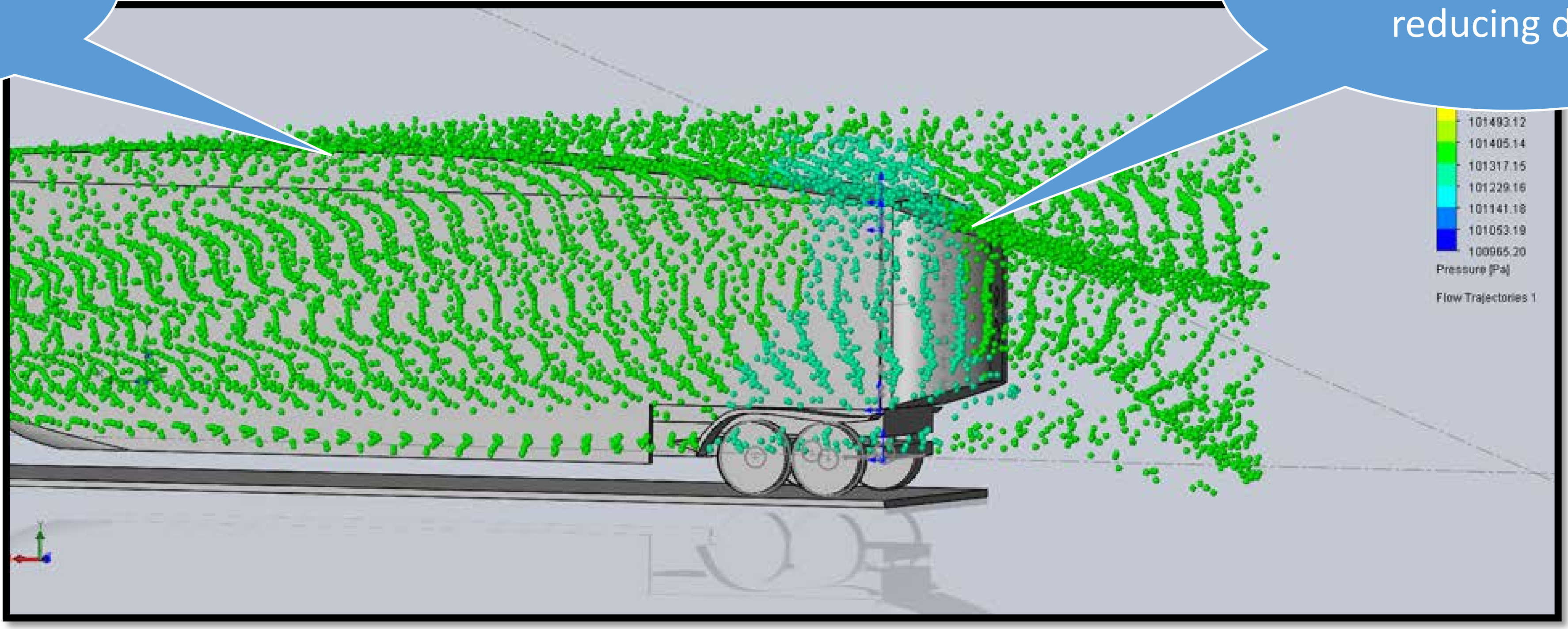
Moderate pressure profile on the entire top, especially near the rear end

Top and rear fairing – Pressure profile

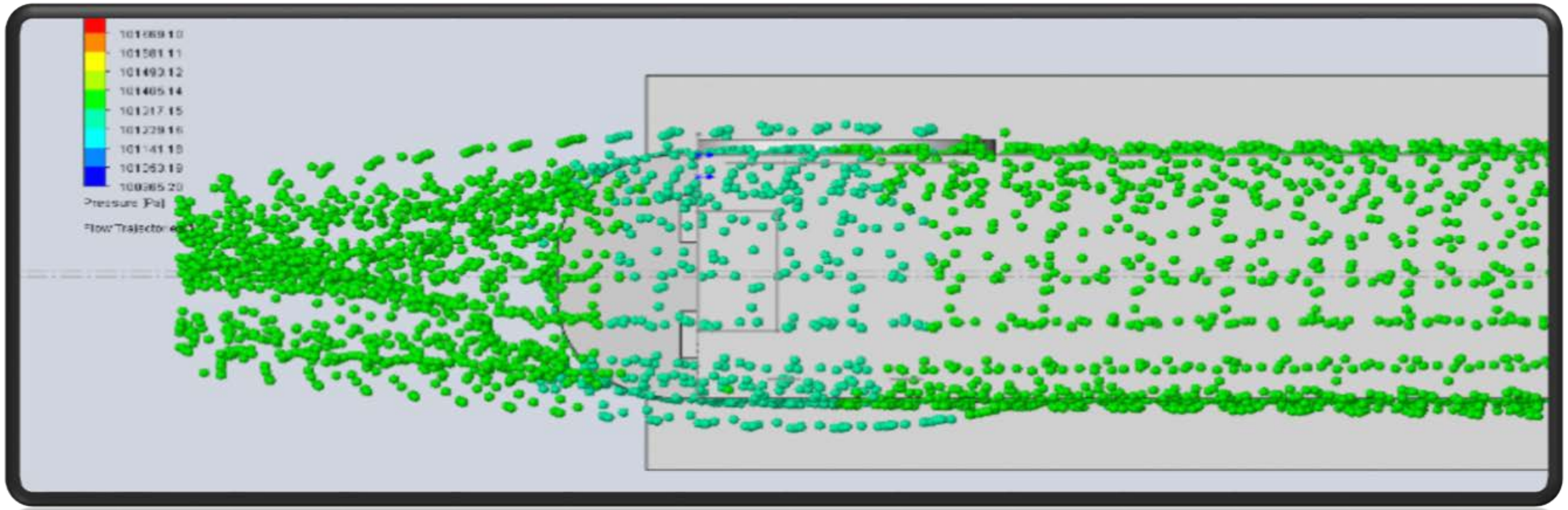
The newly top add-on along with the gap clearance reduced the drag by 18%

30^0 angle for streamlined air flow, reducing drag

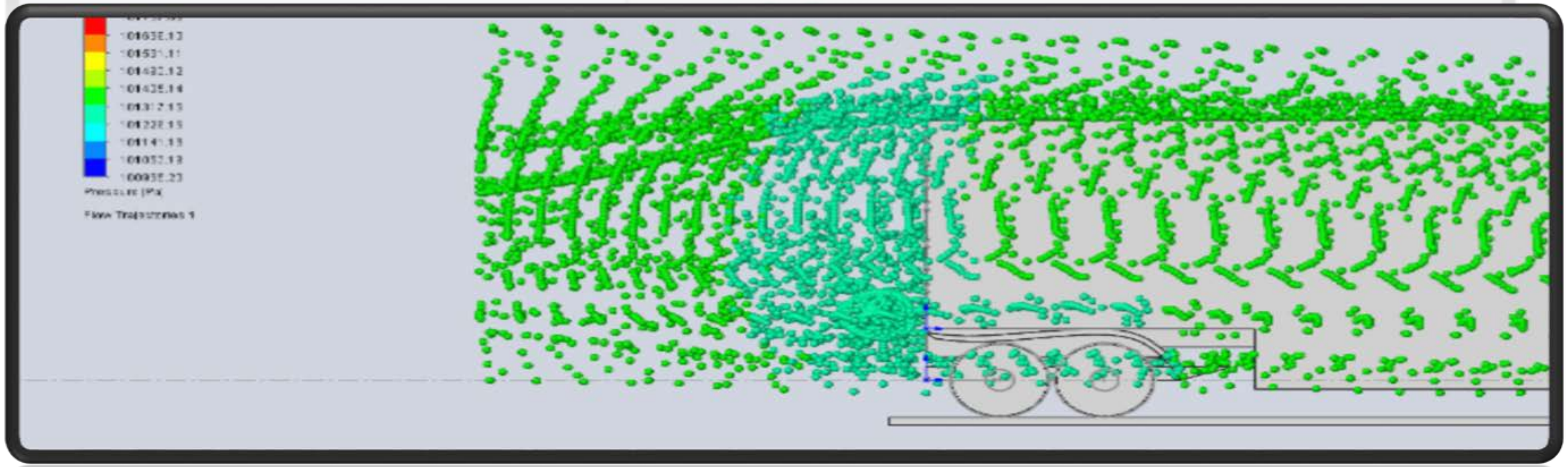
15.2 feet



Pressure profile

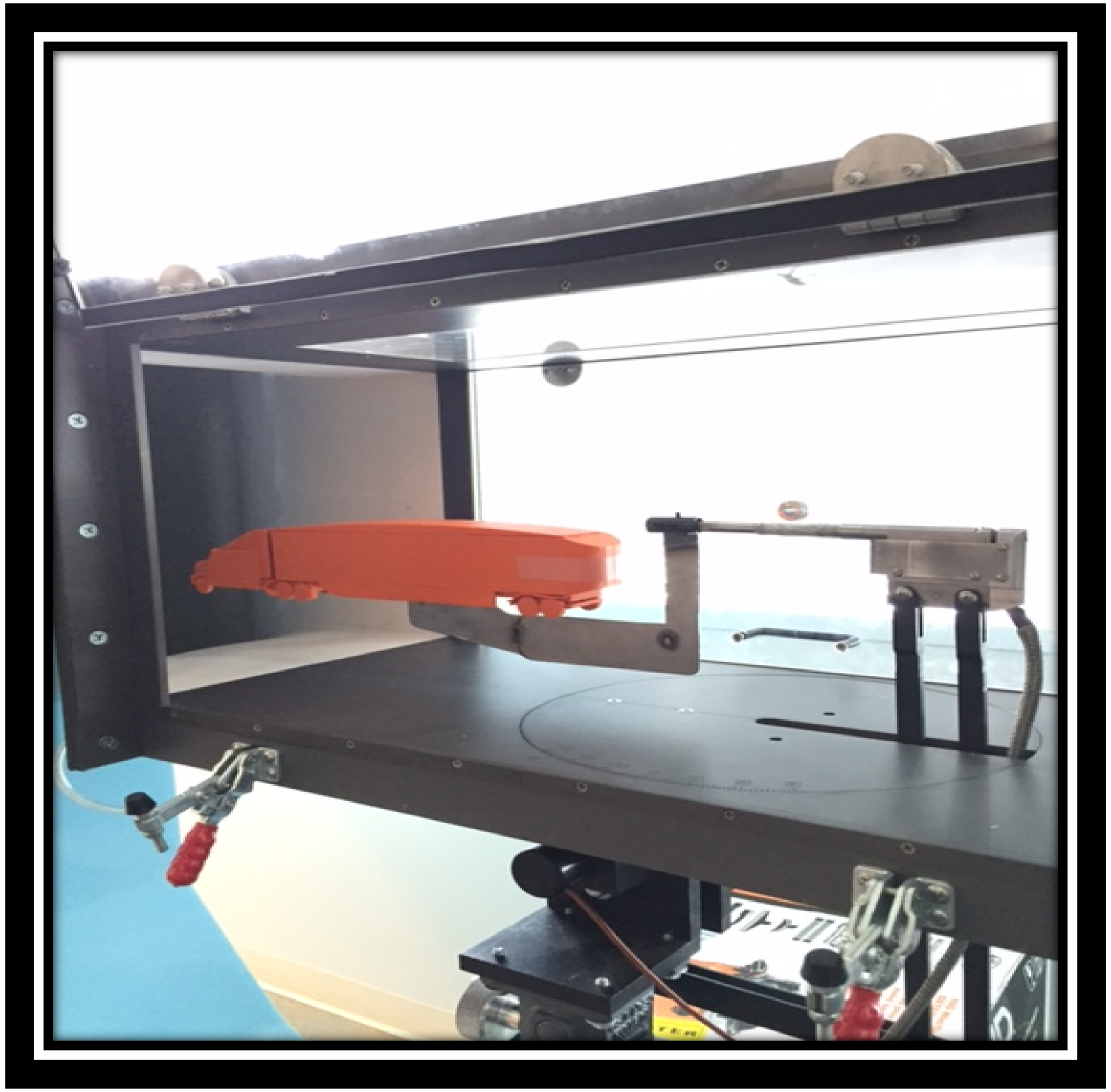


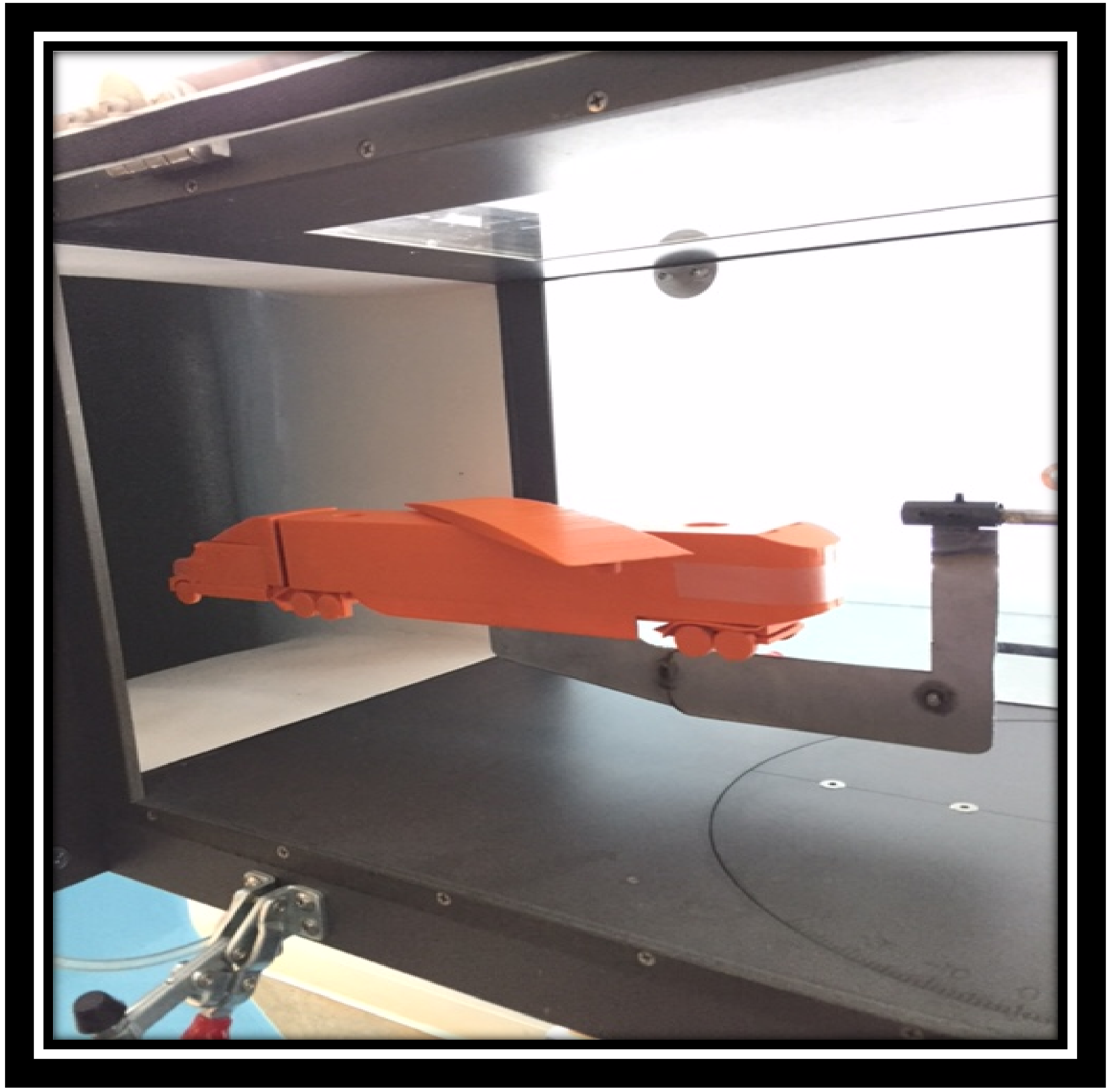
Top view
With tail
fairing=better
pressure profile



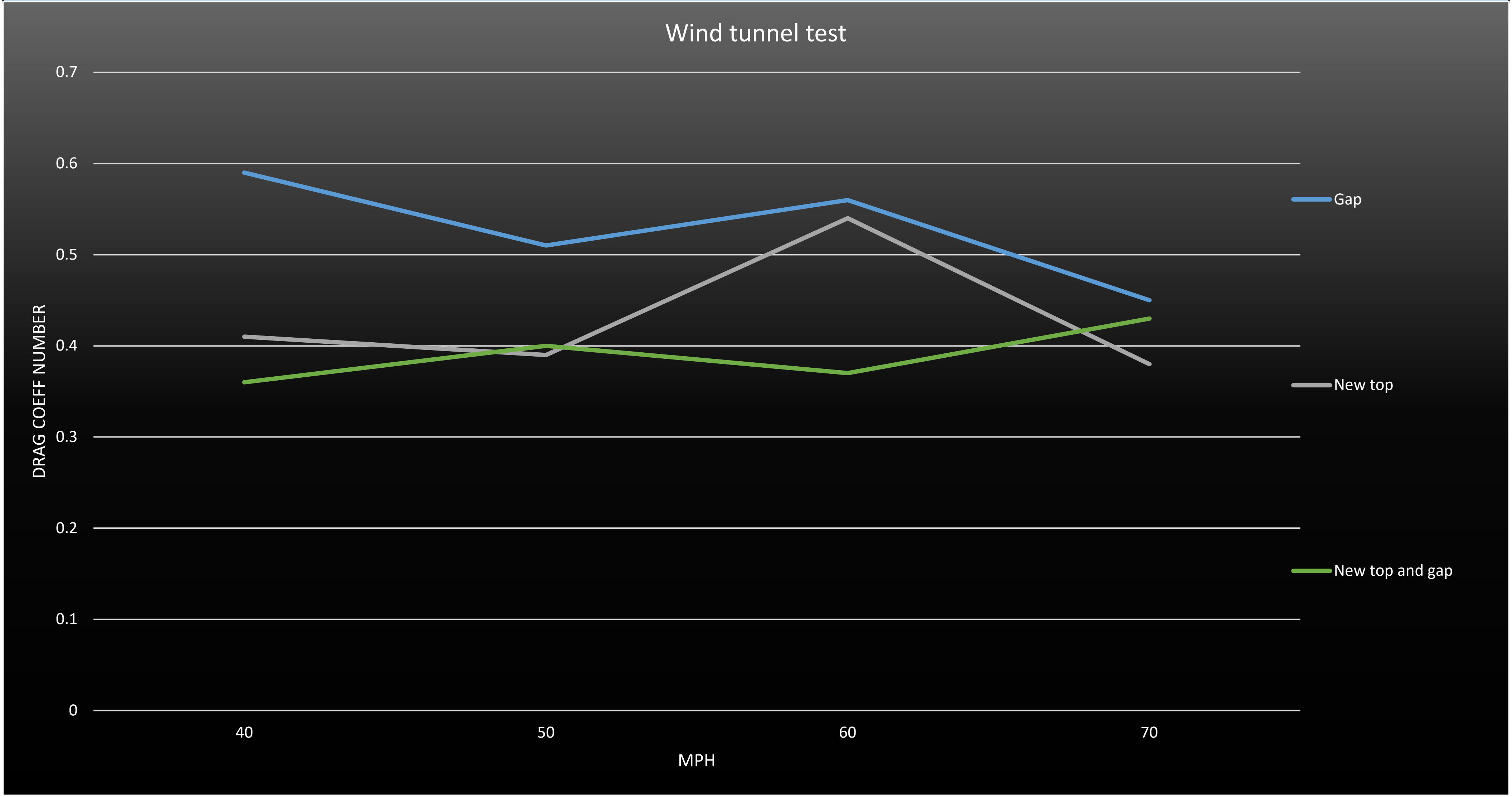
Side view
No tail fairing
=Low pressure
wake

Wind Tunnel Testing Setup

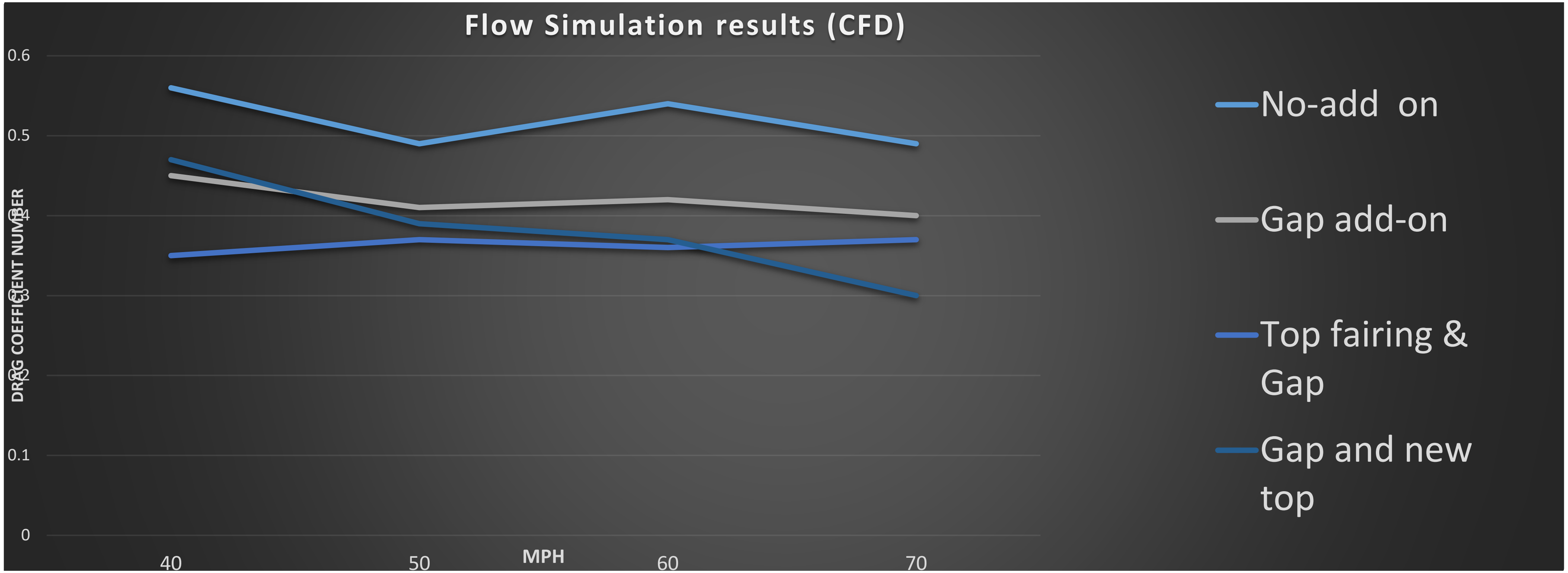




C_d results from Wind Tunnel Testing
Combined add-ons produce lower drag Co-eff.



Drag Coefficient at 40-70 MPH
Effects of various combination of fairings



Conclusion

- Aerodynamic drag is a serious reason for lower fuel efficiency in trailer trucks
- Areas of air drag reduction approaches are identified
- 3D printed scale model of trailer truck and various attachemtns were manufactured, followed by wind tunnel test
- Using the CFD module in SoldWorks was used to simulate the effects f various add-on fairings.
- Drag coefficient is reduced when one or more of the fairings are used
- Overall the fairing seem to be promising in reducing Cd for trailer trucks
- Wind tunnel bracket should be stiffer to avoid vibration.
- More study is needed at more speeds for developing smooth curves

Future Trailer Trucks

Acknowledgements

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ANY QUESTIONS?