Reducing Drag Forces on a Tractor-Trailer

Patrick Morris
Faculty Advisor: Philip T. McCreanor, Ph.D.
Mercer University - School of Engineering, Macon, GA

Abstract

Drag is the opposing force applied to an object by the fluid it is moving through. Because drag can increase fuel consumption, the trucking industry is interested in ways to reduce drag on their tractor-trailers.

In order to find ways to reduce drag, a model tractor-trailer and wind tunnel will be used in conjunction with a rolling platform and dynamic sensor to gather data. The dynamic sensor will measure the force that the air applies to the tractor-trailer. The rolling platform will be moving at the same speed and direction as the airflow, which will eliminate the phenomenon known as "ground effect." Ground effect is a result of air traveling through the small space between an object and a stationary platform faster than the air moving above the object. This causes the object to "suck down" to the ground and induces error into data obtained from the dynamic sensor.

After obtaining base line data, modifications will be made to the tractor-trailer in an effort to reduce drag as much as possible. Modifications include a tractor top, trailer side skirts, and boat tail trailer door. A lower reading from the dynamic sensor will imply a lower drag force and vice-versa. Analysis of data will be used to draw conclusions about the effectiveness of the modifications.

Background Information

Drag, sometimes referred to as air resistance, is the opposing force applied to an object by the fluid it is traveling through. For a tractor-trailer, drag causes the tractor-trailer's engine to work harder in order to maintain a certain speed. This means an increase in fuel consumption and thus an increase in the cost to deliver goods from point A to point B.

For this experiment, the objective was to reduce drag as much as possible using drag reducing fixtures attached to the tractor-trailer. The fixtures that were chosen and designed were: a tractor top, trailer side-skirts, and a boat-tail trailer door.

The tractor top is designed to keep the tractor flush with the trailer so the there is less drag as the air flows over the tractor onto the trailer. The trailer side skirts are designed to reduce air traveling under the trailer and causing drag on the axle assembly. The boat-tail trailer door is designed to keep the airflow laminar as travels over the trailer and reduce drag from the turbulence.

The rolling platform that was used was built from MDF for the base and side supports. Two rollers made from PVC piping were connected with a sander belt to form the track. A motor was then attached to one of the rollers to turn the entire assembly

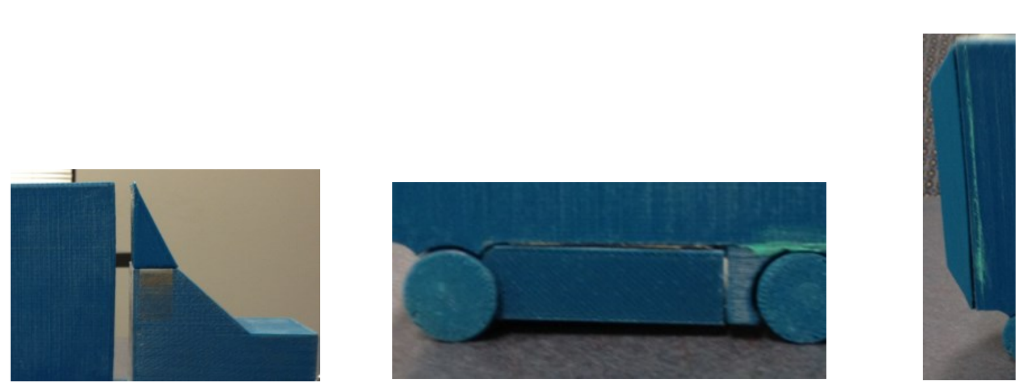


Figure 1: (From Left to Right)- Tractor Top, Trailer Side Skirt, and Boat-tail Trailer Door.

Building and Testing

For testing, the tractor-trailer and modification pieces were built using a 3-D rapid prototyping machine and solid modeling software. Each part was first built using Solid Works, then imported into the 3-D printer as an STL file. Once imported, each part was printed layer by layer until the part was finished.

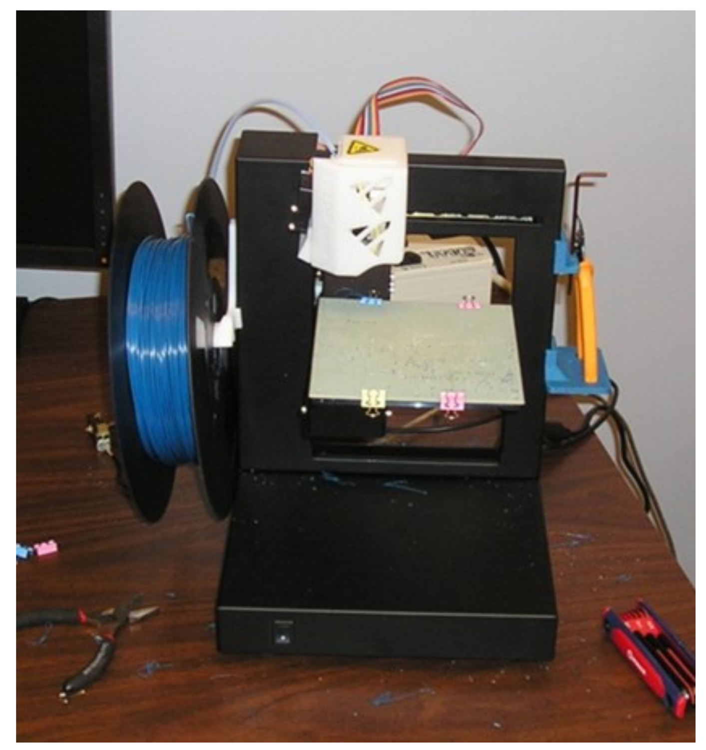


Figure 2: 3-D Rapid Prototyping Machine used to print tractor-trailer

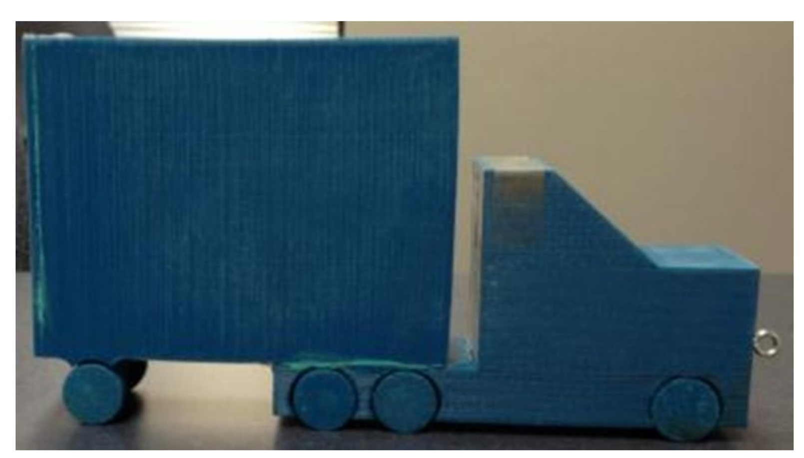


Figure 3: Tractor Trailer after being printed out

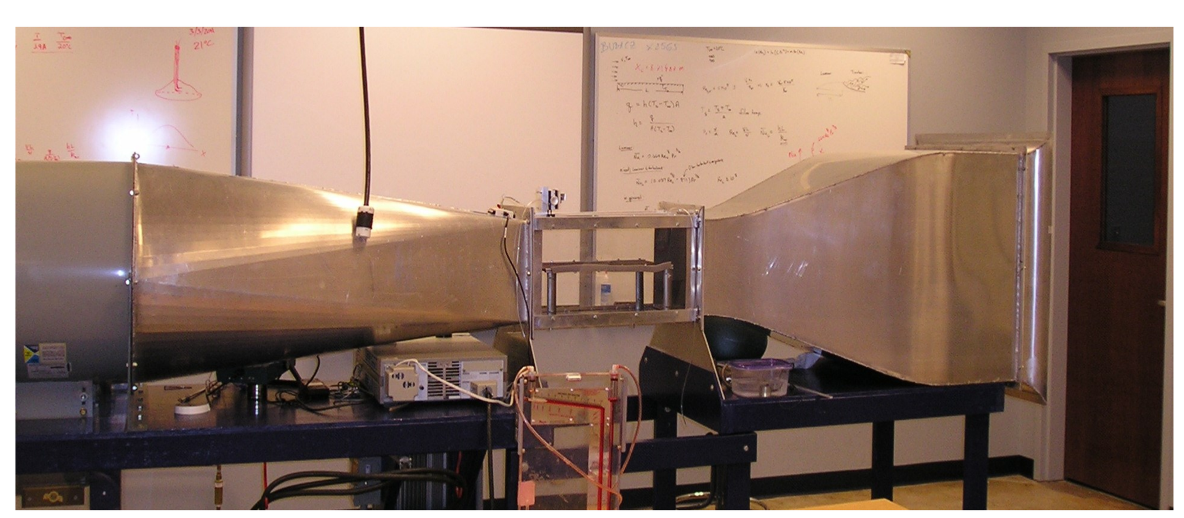
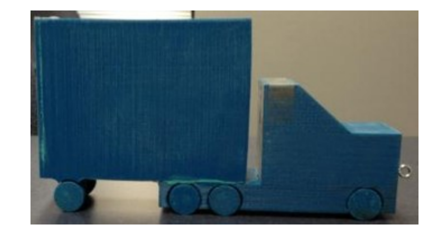


Figure 4. Wind tunnel that was used to produce air flow

Once finished printing, the model tractor trailer was place in a wind tunnel and connected to a wireless dynamic sensor. The tractor-trailer was first tested at 50, 60, and 70 mph to obtain baseline data. These speeds were chosen based on the speed necessary cause the tractor-trailer to move and the maximum speed at which the tractor-trailer could handle before losing contact with the platform. After testing on a stationary platform, the measured drag force was used in conjunction with the velocity and frontal area to determine the drag coefficient at the different speed for each fixture.

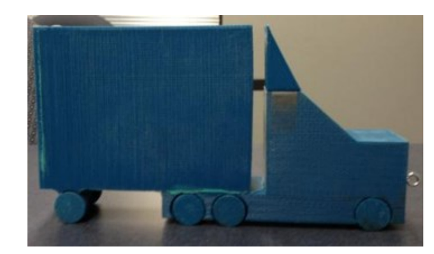
Results

Table 1. Stock Tractor-Trailer



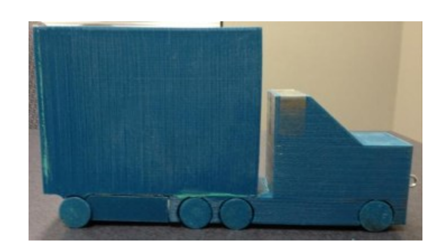
Wind Speed (mph)	Drag Coefficient (C_D)
50	0.45
60	0.34
70	0.37

Table 2. Tractor-Trailer with Tractor Top



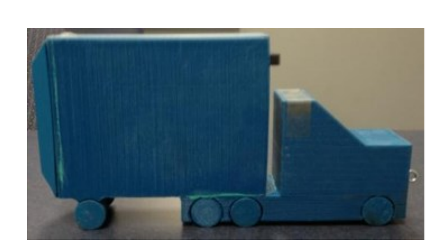
Wind Speed (mph)	Drag Coefficient (C_D)
50	0.47
60	0.34
70	0.35

Table 3. Tractor-Trailer with Trailer Side Skirts



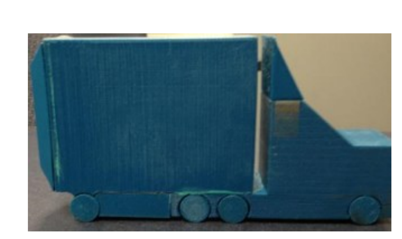
Wind Speed (mph)	Drag Coefficient (C_D)
50	0.40
60	0.38
70	0.36

Table 4. Tractor-Trailer with Boat-Tail Trailer Door



Wind Speed (mph)	Drag Coefficient (C_D)
50	0.47
60	0.41
70	0.36

Table 5. Tractor-Trailer with All Modifications



Wind Speed (mph)	Drag Coefficient (C_D)
50	0.24
60	0.30
70	0.36

Governing Equations

Reynolds Number

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

where ρ = density of fluid
V = velocity
D = diameter of flow area
μ = kinematic viscosity of fluid

Drag Coefficient

$$C_D = \frac{F_D}{\frac{1}{2} V^2 A}$$

where F_D = Drag Force
V = velocity
A = Frontal Area of object encountered by the flow

Conclusion

For the unmodified tractor-trailer, the drag coefficient increases then decreases as speed increases. When adding a tractor-top the drag increased at 50 mph but decreased at 70 mph. The trailer side skirts decreased the drag a 50 mph but increased the drag at 60 and 70 mph. For the Boat-Tail trailer door the drag increased at 50 and 60 mph but decreased at 70 mph. When using all three fixtures are used in conjunction the drag decreased for 50, 60, and 70 mph.

The increases in drag were very small and occurred at lower speeds. This can be attributed to the increase in the frontal area of the tractor-trailer encountered by the flow. At higher speeds the increase in drag due to the increase in area is mitigated by the decrease in turbulent flow around the tractor-trailer.

Future Work

The next step could be to develop a drag reducing skin surface for the tractor trailer. An example would be the surface texture of a golf ball. Golf balls have dimples on the surface that are design to reduce drags at lower speeds so that the golf ball will fly farther than a smooth ball.

References

http://en.wikipedia.org/wiki/Drag_%28physics%29

Acknowledgements

This work was supported by the Engineering Honors Program at Mercer University. I would like to thank Dr. Philip T. McCreanor, Director of the Engineering Honors Program, for his guidance in pursuing and documenting this project. I would also like to thank Dr. Rada for letting me use the 3-D rapid prototyping machine and Dr. Sumner for letting me use the wind tunnel for testing.