DOE’s Effort to Improve Heavy Vehicle Fuel Efficiency through Improved Aerodynamics

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Overview

Timeline
A new integrated tractor-trailer design from ground up has been proposed that radically decreases the aerodynamic drag and improves the fuel economy. New aerodynamic treatments have been proposed for tanker-trailers

- Designed a first generation of an integrated tractor-trailer geometry which we have labeled as Generic Speed Form one (GSF1)
- Performed wind tunnel tests of selected aerodynamic devices for tractor-trailers and tankers to improve fuel efficiency

Barriers
- Reduce aerodynamic drag of class 8 tractor-trailers by approximately 25% leading to a 10-15% increase in fuel efficiency at 65 mph

Budget
- Funding for FY14, $600K
- Funding for FY15, $850K

Partners
- Navistar, Inc.
- Kentucky Trailer and Wabash National
- Freight Wing Inc. and ATDynamics
- Frito-Lay, Spirit, and Safeway
- Michelin
- Praxair
Class 7-8 tractor-trailers are responsible for 12% of the total US consumption of petroleum

2.5 million combination trucks\(^1\)
   - 66,161 average miles/\text{year/vehicle}
   - 5.8 average miles/\text{gallon}

Aerodynamic drag reduction contribution

15% reduction in fuel use = 4.2 billion gallons of diesel fuel saved per year and 42 million tons of CO\(_2\) emission

$12 billion saved/\text{year} ($2.78 per gallon diesel)

Tractor-Trailer integration radically decreases aerodynamic drag

Opportunity to double the savings offered by drag reduction add-on devices

Wide-base single tires add about 4-5% to overall vehicle fuel economy

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Tanker trailers are responsible for 1.3% of the total US consumption of petroleum

Approximately 200,000 tanker trailers\(^1\)
- 60,000 average miles/year/vehicle
- 4.5 average miles/gallon

Aerodynamic drag reduction contribution
17% reduction in fuel use = 0.6 billion gallons of diesel fuel saved per year and 6 million tons of CO\(_2\) emission
$1.7 billion saved/year ($2.78 per gallon diesel)

Tractor-Trailer integration radically decreases aerodynamic drag
Opportunity to double the savings offered by drag reduction add-on devices

Wide-base single tires add about 4-5% to overall vehicle fuel economy

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\(^1\) National Tank Truck Association, www.tanktruck.org
Objectives

- **In support of DOE’s mission**, provide guidance to industry to improve the fuel efficiency of class 8 tractor-trailers and tankers through enhanced aerodynamics

- **Demonstrate** new drag-reduction techniques and concepts
  - Class 8 tractor-trailers and tankers

- **Joined with industry in getting devices on the road**

- **Develop the next generation of highly aerodynamic and integrated class 8 tractor-trailers and tankers**

- **On behalf of DOE** to expand and coordinate industry participation to achieve significant on-the-road fuel economy improvement
Milestones

FY14

- Started the design process of the first generation of a highly aerodynamic and integrated tractor-trailer geometry called Generic Speed Form 1 (GSF1)
- Continue to improve the design/performance of selected aero devices
- Continue to improve the aerodynamics of tanker trailers
- Performed wind tunnel tests to validate the performance of aero devices and integrated design for tractor-trailers and tankers

FY15

- Analyzed wind tunnel test results on our first generation integrated tractor-trailer geometry (GSF1)
- Analyzed wind tunnel test results on aerodynamically treated tanker-trailers
- Continue to improve the design/performance of an integrated skirt and tail devices
- Investigated tractor-trailer underbody flow for drag reduction
- Investigated the performance of aero devices and integrated design for tractor-trailers and tankers
Science-based approach is used to create an aerodynamic and highly integrated vehicles

Validate aerodynamic concepts with industry collaboration and feedback

Aerodynamic design process
- Vehicle integration
- Add-on devices

Virtual testing environment
- Full-scale conditions
- Realistic truck geometry

Collaborative Efforts
- Industry
- National Labs

Track & on road demonstration
- Manufacturers and Fleets

Wind tunnel validation
- Army/NASA Ames 7'x10'
- NFAC/NASA Ames 80'x120'

Lawrence Livermore National Laboratory
Technical accomplishments

- Designed the first generation of an integrated tractor-trailer geometry from ground up that radically decreases aerodynamic drag and improves the fuel efficiency (GSF1).
  - Most of the GSF1 tractor design was completed with the aid of wind tunnel testing

- Conducted 1/8 scale experiments at the Army 7’x10’ wind tunnel facility at Ames Research Center

- Conducted computational simulations of GSF1 to better understand its aerodynamic performance

- Evaluated the aerodynamic performance of skirt and tail devices
  - Underbody flow investigation and integration of skirt and tail devices

- Improved the aerodynamics of a common tanker-trailer for significant gain in fuel economy

- Achieved international recognition through open documentation and conferences
Heavy trucks use most of their usable propulsion energy to overcome drag and rolling resistance at highway speed.

Losses in nearly all of these categories can be reduced by employing presently available technology.
Improved fuel economy is achieved through better aerodynamics

\[ \text{Drag} = C_D \times S \times \left( \frac{1}{2} \right) \rho U^2 \]

\[ \frac{\Delta \text{FuelConsumption}}{\text{FuelConsumption}} = \eta \times \left( \frac{\Delta C_D}{C_D} + \frac{\Delta S}{S} + \frac{3 \Delta U}{U} \right) \]

\[ \eta \approx 0.5-0.7 \]
As a nation we pay a significant price in moving corrugated shipping containers

Baseline configuration

Trailer body 12%

Wind tunnel test:
~10% decrease in fuel economy

Computation: ~8% decrease in fuel economy
Add-on aerodynamic devices show significant potential to improve fuel economy

Skirt + 48” tail (3-sided)

ΔC_D (%) (-25%, wind tunnel)

LLNL 48” curve tail with full skirt extension
Aerodynamic performance of skirt increases with adding more surface area
Tractor belly pan helps to improve underbody flow
Angled trailer aft short skirt with a combination of a short or a long tail shows no aerodynamic benefits.

\[ \Delta C_D = -0.157 \]
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Venting does not improve skirt aerodynamic performance

$\Delta C_D = -0.180$

$\Delta C_D = -0.179$
Since 2010 the rate of customers/fleets acceptance of aerodynamic add-on devices has significantly increased.

Fleets in the 2014 study included CR England, Challenger Motor Freight, Con-way Truckload, Frito Lay, Paper Transport, Ryder, Schneider, Werner, Bison Transport and United Parcel Service. The primary goal was to study the level of adoption of 66 technologies.

2014 Fleet Fuel Efficiency Benchmark Study: conducted by the North American Council for Freight Efficiency, August 31, 2014
Tractor-trailer integration is the next step in achieving a radical improvement in fuel economy

> 60% aerodynamic drag reduction compared to heavy vehicles on the road today
GSF1 radically reduces drag
GSF1 exhibits sailing effect in wind tunnel testing

Base drag increases with increasing yaw angle

Sailing effect
There are several major drag sources on a tanker trailer.

- $\Delta C_D$ bogie/base = 0.28
- $\Delta C_D$ hood = 0.22
- $\Delta C_D$ grill = 0.16

Performed extensive wind tunnel tests at Army 7'x10' facility in the NASA Ames Research Center.
Improved tanker aerodynamics can improve fuel economy by > 20%

- 26% drag reduction
- 39% drag reduction
- 41% drag reduction
- 33% drag reduction
We have started to collaborate with NREL to investigate the fuel economy benefits of platooning the line haul trucks.
Summary

- **Designed the first generation of an integrated tractor-trailer geometry from ground up that radically decreases aerodynamic drag and improves the fuel efficiency (GSF1)**

- Conducted 1/8 scale experiments at Army 7'x10' wind tunnel facility at the Ames Research Center

- Analyzed wind tunnel experimental results for GSF1 and different aerodynamic treatments for tanker

- Evaluated the aerodynamic performance of full skirts with an integrated tail
  - Various distance to the ground
  - Angled short skirt aft the trailer axle
  - Vented skirt

- Started to collaborate with NREL to investigate the fuel economy benefits of platooning the line haul trucks for two to three vehicles

- Achieved major reduction in aerodynamic drag for tanker trailers through geometry modifications
Future plans

- Continue with tractor-trailer integration design for radical improvement in aerodynamic drag and fuel economy
- Perform experiments to start the design of GSF2 integrated tractor-trailer
- Continue to perform scaled experiments to design and validate the performance of aerodynamic add-on devices an integrated tractor-trailers and tankers
- Start to design the next generation of highly aerodynamic tankers
- Continue to work with tanker fleets to improve fuel economy
- Probe the fuel economy benefits of platooning the line haul trucks in collaboration with NREL
- On behalf of DOE, continue to coordinate industry participation to design the next generation of highly aerodynamic heavy vehicles