

By: Kevin Linfield, Ph.D., P.E., and James Paul, P.E., Airflow Sciences Corporation

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AIRFLOW SCIENCES CORPORATION

Rail cars carrying ore or coal from mines to port or plants often travel great distances. The geometry of these cars plays a large role in the fuel usage. Mine operators may be looking at adding side/end boards to increase the payload of the cars, but at the same time there is a trade-off between increased car capacity and increased drag. A fuel usage spreadsheet analysis coupled with an aerodynamic study can provide detailed information into the economical feasibility of ore/coal car modifications.



Velocities in Vicinity of Loaded Bulk Commodity Car



Surface Velocities at Top of Bulk Commodity Car

The dynamics of open-top rail cars and the impact of aerodynamic modifications on train fuel usage can be investigated via wind tunnel testing, computer simulations, full scale over-the-track testing, and engineering handbook calculations. Input parameters are broad, and may include information on the locomotives (quantity, make and model, details of the engines, drag area, fuel tank capacity, weight), the number of cars in the train, car type (including empty weight, loaded weight, baseline aerodynamic drag), number of starts from a full stop, train starting resistance, details of the train route (distance from trip origin to destination, number of curves per mile, average curvature, average ambient temperature, elevation change), rolling resistance coefficient, and train speed histograms.

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Loaded Coal Car (left) vs. Empty Coal Car (right).

Recently, ASC performed a study to determine whether car geometry modifications can have significant impact on train fuel requirements. The study included two key tasks:

- 1. define inputs to a spreadsheet-based train energy calculation program, and
- 2. employ the spreadsheet-based program to determine energy required and fuel used to transport ore cars from the mine to the destination.

Train energy and fuel use calculations included all of the forces acting on the train over the selected route and multiplying these forces by the distance over which they act. The resulting energy demand is divided by the locomotive efficiency to obtain fuel use.



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A variety of techniques were employed to define the aerodynamic characteristic of the locomotives and ore cars as a function of the relative wind angle (yaw). These involved uses of wind tunnel test data, CFD simulation results, and "drag build-up", which involves defining the relative contributions of each component on the vehicle to the total drag. This consist of items such as wheel trucks, exterior side posts, skin friction, and integration of surface pressures. The drag areas for the locomotives and ore cars were defined as functions for the train energy and fuel use spreadsheet program. Since car drag varies with position in train, an additional input function was included to calculate the total drag area of the train as a function of yaw.

	Drag Change	Fuel Change
Ore Car Modifications (to increase capacity)	+5%	+3%
Adding Airfoils to the Modifications	-17%	-7%

After detailed analysis, ASC determined that a customer-specific modification to the ore cars would increase the wind-direction-weighted drag on the train by just over 5%. This increased the fuel use prediction for the train route by almost 3%.





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As a follow-on study, ASC examined the effect of adding airfoils on the modified ore cars to reduce the drag. The results indicated that the addition of these airfoils produced a wind-direction-weighted drag reduction of about 17%. Lowering the drag force by this amount produced almost a 7% decrease in fuel use. Fuel savings associated with other aerodynamic modifications for both gondola and hopper cars are shown in the graphs below.



Impact of Aerodynamic Modifications to Drag of Empty Coal Cars

ASC started improving vehicle aerodynamics on rail cars in 1975, and our focus has been to obtain accurate and efficient data to aid in design decisions. ASC has been awarded several patents for innovative product designs and test equipment to reduce drag and increase fuel efficiency of an open top gondola type railway car:

- Patent 4,738,203: Aerodynamically Structured Railway Car with Corner, Air Flow Guides
- Patent 4,569,289: Air Flow Guide Structure for Open Top Railway Cars
- Patent 4,620,487: Aerodynamically Structured Railway Car



Rail Car Tip-Over Flow Study

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High winds have caused numerous accidents involving freight or empty coal trains. Unfortunately, these derailments disrupt shipping, cause environmental damage, and cost the railroad companies millions of dollars in repair, clean-up costs, and lost revenue. In the unlikely event of a passenger coach being blown off the tracks, significant loss of life is possible. In 2019 there were at least three major derailments in the USA. In August, two trains derailed with over 100 rail cars leaving the tracks near Walton, KS. In April, 25 loaded tank cars derailed, leaking 74,000 gallons of ethanol in Fort Worth, TX. And in March 26 cars derailed off of a bridge near Logan, NM.

CFD Model of passenger coach



Using a combination of computer modeling and wind tunnel testing, ASC has developed a database of railcar rolling moments to predict impending tip-over conditions. Analysis included box cars, hopper cars, well cars, gondola cars, autorack, and trailer/flat cars. In order to determine the force/moment curves, a series of simulations/tests were performed at different wind speeds and different wind angles. The coefficients of these curves are then combined with current atmospheric conditions and relative wind velocities to predict actual forces and moments on the rail cars in real-time.



CFD results showing pressure on a locomotive under crosswind conditions.

Rail Car Tip-Over Flow Study

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ASC has also produced a real-time speed restricting system for locations prone to high winds. One of these devices is installed alongside the tracks at the Sandusky Bridge in Ohio. The system measures real-time wind conditions and communicates with dispatchers to provide immediate recommendations for safe speeds based on wind speed and direction for multiple car types.



Contacting ASC

Corporate Headquarters 12190 Hubbard Street Livonia, MI 48150 +1.734.525.0300 Contact: Kevin Linfield, Ph.D., P.E.

www.airflowsciences.com asc@airflowsciences.com Western Region Office PO Box 22637 Carmel, CA 93922 +1.831.624.8700 Contact: Jim Paul, P.E.



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