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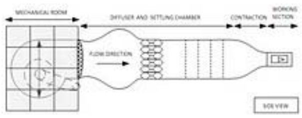

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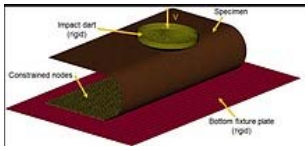

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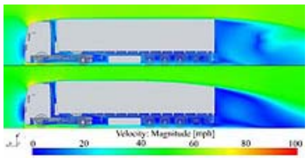
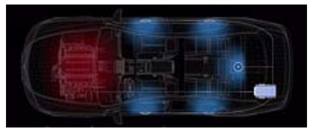


Variable trailer design drastically cuts aerodynamic drag



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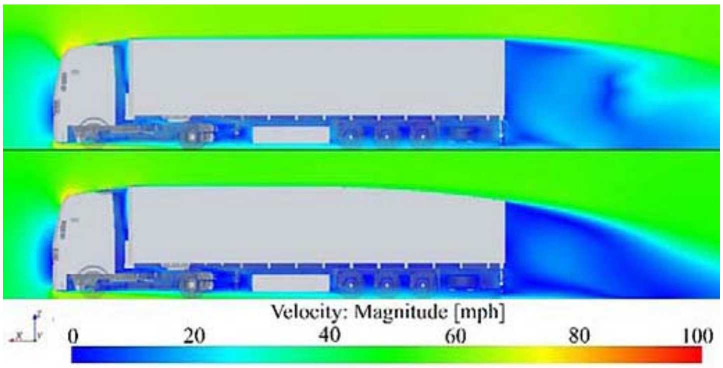
Variable trailer design drastically cuts aerodynamic drag

11-Feb-2014 10:55 EST Article



Flow velocity of the reference truck (top) and Truck A (bottom). The reference truck shows a large irregular dead water area behind the rear end due to its brick-shaped outer contour; the aerodynamic-optimized shape of Truck A enables the fluid a smooth changeover to the road surface, which leads to a smaller dead water area.

Tractor-trailer design is significantly influenced by legal conditions regarding the vehicle dimensions and the provision of a maximum transportation volume. These boundary conditions lead to brick-shaped trailer outer geometries, especially at the rear ends. That is why investigations of aerodynamic optimization of commercial-vehicle (CV) trailers are predominantly restricted to detail measures.

Researchers from Graz University of Technology studied the aerodynamic characteristics of general modifications to the outer contour of long-distance haulage trailers, including a new approach for the realization of a variable trailer rear end. The variable adjustment of the sidewalls and the top of the trailer's rear end can take the actual space requirements of the transportation load into account, thereby resulting in optimal transportation efficiency.

The aerodynamic studies were based on truck models according to the European legislation. Because the investigations focused on the rear end of the trailers, the findings are applicable to the aerodynamic characteristics of trailers in different markets, including the U.S.

The first step of the research work entailed the derivation of a generic virtual reference vehicle, which was created as a 3D-CAD model. Therefore, several cab-over-engine semi-trailer tractors for long-distance haulage from six different European truck manufacturers were evaluated and compared. From this investigation, the configuration and dimensions for an average tractor were determined. The same procedure had been performed to collect information of typical semi-trailers with curtain-side configuration for long-distance transport.

Aerodynamic investigations

The semi-trailer truck optimization process was split into two main parts: a coarse geometrical concept study by use of a simplified vehicle model, and a detailed study based on a high-resolution reference truck model.

The coarse concept study was based on a simplified reference model, designed in the shape of a single-volume model. During this study, principal geometrical modifications were performed at the outer contour of the semi-trailer. Following that, the air drag of each simplified model variant was assessed by application of 3D-CFD simulations by use of a commercial software.

For the coarse concept study, 10 different trailer variants with varying payload-space V were created. The simulation results consider the payload space in comparison to the reference configuration R. The variant models 1 to 8 were modified by using different vertical tapers at the semi-trailer. In contrast to those, the semi-trailer variants 9 and 10 had been equipped with horizontal boat tails as additional modification. As a result of this study, each geometrical modification decreased the air drag coefficient, but also reduced more or less the semi-trailer's payload space.

The coarse study demonstrated that geometrical modifications of the trailer had a big impact on the aerodynamic resistance. The researchers selected two variants (models 1 and 9) with a significant reduction of air resistance for further detailed aerodynamic studies. Besides the reduction of air drag, these two variants were selected because of their comparative small decrease of payload space.

The detailed study was carried out to validate the results of the coarse concept study due to higher simulation resolution and to compare the simulation results with the characteristics of present market-available semi-trailer trucks. The geometry of the detailed generic reference truck model was modified to create two optimized truck configurations with a high degree of geometrical information.

Out of the shape of selected model 1, the optimized Truck A was designed with a vertical taper of 20 in (508 mm) at the semi-trailer's rear end. Model 9 (with an additional boat tail) was used as a template for the detail study Truck B. The difference between the geometries of these two configurations was the horizontal boat tail of 10 in (254 mm) on each side at the semi-trailer of Truck B. To enable a comparison of the modification's impact on the trailer rear end, the tractor model remained the same during all variations.

Finally, the aerodynamic drag characteristics of Truck A and Truck B were assessed in detailed 3D-CFD simulations by application of the same boundary conditions as they were applied during the simulation of the generic reference truck.

In contrast to Truck A, the reference truck shows a big irregular dead water area behind the rear end of its semi-trailer due to its brick-shaped outer contour. The aerodynamic-optimized shape of Truck A enables the fluid a smooth changeover to the road surface, which leads to a smaller dead water area behind the rear end. As a result of Truck A trailer's bent roof, the flow is exposed to a deceleration that further increases the static pressure at the back panel in contrast to the reference. Simultaneously, the influence of the static pressure was reduced by the downsized effective vertical area at the rear end. The result is a significantly lower air resistance force in the driving direction.

Results—and the variable trailer rear-end concept

The fuel consumption of each variant was calculated in longitudinal vehicle dynamics simulations by use of predefined engine characteristics of a typical semi-trailer truck engine. The optimized semi-trailer trucks, Truck A and Truck B, obtained a declination of the aerodynamic drag coefficient between 15% and 23% related to the reference truck. Due to these significant aerodynamic improvements, a reduction of fuel consumption up to 6.5% by Truck A and 10.2% by Truck B could be reached. In contrast to the decrease of fuel consumption, the payload space was comparatively slightly reduced, between 3.2% (variant Truck A) and 6.1% (variant Truck B).

The transport efficiency of CVs depends on their payload and different cost factors. Regarding the results of the two optimized truck configurations with respect to aerodynamics, a reduction of fuel consumption and thus a decrease of the operating costs could be reached. On the other side, the payload space shrank, because of the geometrical modifications at the trailers' rear ends. In this way, an improvement of the transport efficiency depends on the type of payload, or more exactly on the freight density.

A large number of trips is carried out with a payload that does not require the entire trailer volume. A considerable share of trips is even performed without payload (in the U.S., the range is 10-13%). This leads to the cognition that the overall transport efficiency can be raised significantly by application of a variable trailer rear end.

A new approach has been developed to support high transport efficiency of future long-distance haulage trailers. With this approach, it is possible to adjust the trailer outer contour according to the required transportation volume, combining both advantageous aerodynamic behavior and improved transportation efficiency.

The researchers presented a lowered trailer rear end that contains an exemplary load configuration with prismatic packets. The complete mechanism can be built into the vertical stakes of a typical trailer and does not enlarge its dimensions. In this configuration, 95% of the total payload space is available for transportation purposes. At the same time, the aerodynamic drag of the truck combination is reduced about 6.5%.

This article is based on SAE International technical paper 2013-01-2414 written by Mario Hirz and Severin Stadler of Graz University of Technology.

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Topic: Bodies and Structures Vehicles and Performance Fuels and Energy Sources Design Engineering and Styling Transportation Systems Environment

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