Shaping up blunt bodies

Aerodynamic tail improves lorry fuel economy

Lorries are great for transporting goods, but their inferior aerodynamics means they get fewer kilometers a liter of fuel. Bad news indeed for the environment, and for hauliers' purses. But according to researchers at Delft University of Technology, cones and wings attached to the rear end along with technical tricks suspended under the vehicle could reduce fuel consumption by up to fifteen percent.

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Photos: Sam Rentmeester/FMAX

"Well, here it is, our witch's hat." Wearing a dustcoat many sizes too large, Gandert van Raemdonck, a doctorate student at the Faculty of Aerospace Technology, walks up to a shiny white lorry. The giant shed at the Kees Mulder coach-building company in Katwijk houses many more lorries, but this one stands out with its cone-shaped rear end. On the back of the lorry, four sections of plastic sheet have been attached to form a kind of pyramid with its apex missing. This boat tail structure improves the aerodynamic properties of the vehicle, reducing its fuel consumption by as much as ten percent. This was the conclusion Aerospace student Ronald Assen drew from computer calculations and wind tunnel tests.

'We still don't know how the airflow along the trailer interacts with the size of the wake and the energy of the vortices'

Van Raemdonck's small team of researchers are investigating airflows on lorries, and together with transport companies and coach builders are looking for ways to improve the aerodynamic properties of these vehicles. Lorries provide ample scope for innovation. With their rectangular shape, known as blunt bodies to the experts, they are never going to win any prizes for aerodynamic design. The researchers are hoping to find a solution that will reduce the fuel consumption of lorries by fifteen percent.
The front end has already been taken care of. Walking along the lorry, Van Raemdonck points out the modifications that make the front end more aerodynamic. He calls our attention to the rounded corners and the vehicle's rear-view mirrors. "This lorry also has a roof wind guide to provide a more gradual transition between the cab and the trailer." The purpose of it all is to make the lorry smoother in order to enable air to flow more easily around it. "It's rather like an airplane wing; you don't want to bang a nail into that either, not unless you want to create all kinds of strange vortices."

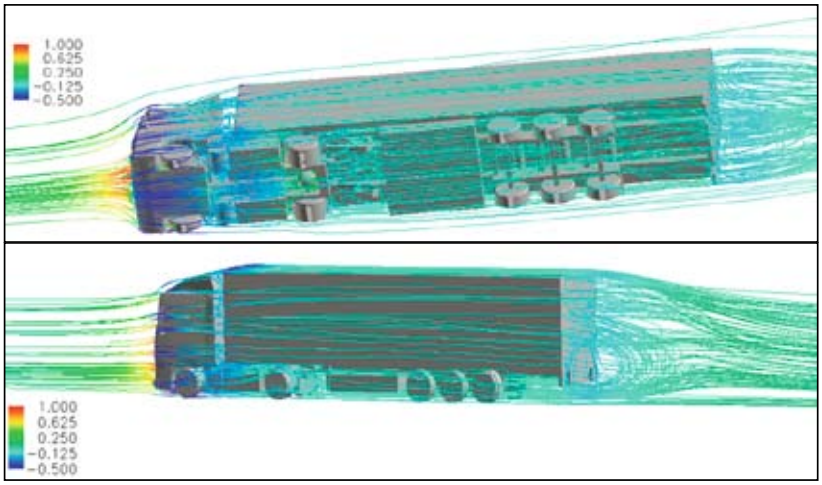
Rear end

Such vortices are also created at the rear end of a lorry. According to De Vlaming and his supervisor, Michel van Tooren, this is why there is more to be gained by improving the rear end rather than the front.
"Aerodynamic guides on the back can reduce drag by about twenty-five percent on an average, representative trip through the Netherlands. For large distances with more constant speed, the reduction will be even greater," says Van Tooren.
A large part of the drag to which a lorry is subjected, is caused by its wake. At the rear, at the point where the vehicle has just gone past, a vacuum is created for a short while. Air rapidly flows back to fill the void, and the result is that two counter-rotating vortices are created behind the moving vehicle as well as any number of chaotic airflows around them. Thus within the lorry's wake there is a low-pressure zone holding the lorry back as it were. This effect increases as the lorry moves faster.
"The more we can reduce the wake, the better," Van Raemdonck says. He searched through patents and publications of the past hundred years looking for ways to reduce the wake. All the devices he found worked by helping the air that flows along the sides of the moving trailer to fill the vacuum behind it as quickly as possible. The airflow cannot negotiate the sharp angle at the transition from the trailer's side to the rear end. The cone-shaped boat tail helps the air to flow more evenly. "It works on the same principle as the pointed rear end of a cycling helmet," Van Raemdonck explains.

Blowpipes

In another application discovered by Van Raemdonck the airflow is helped around the square edges by adding air. The rear end of the trailer is fitted with a kind of frame with rounded edges. Extra air is blown from tubes to pull the airflow around these edges. Van Raemdonck is very fond of this solution. "It is an active system, so it can always be adapted." Instability in the wake for example, can cause the trailer to rock from side to side, so the lorry driver constantly needs to correct its course to keep a straight line. Adding more or less air could possibly cancel the instability. To what extent this Coanda effect could reduce the wake is something that Van Raemdonck intends to investigate. From the United States comes news of varying results. In wind tunnel tests drag was reduced by half but road tests yielded greatly inferior results.
As an Aerospace Engineering graduate student, Marius van Straaten did research on an old solution to make lorries more aerodynamic. He rejuvenated a concept invented in 1933 by Frei, a researcher at the Danzig Polytechnic, in which the air that is left wandering in the wake of the trailer is captured by metal slats and pushed inwards. Van Straaten tested these wings in the wind tunnel and did some computer calculations on them. The results were an estimated improvement in fuel economy of approximately ten percent. Van Raemdonck: "Who knows, I might just develop an enlightened new idea during my research. Not knowing which method is best makes it all very exciting."
In spite of computer calculations and extensive wind tunnel experiments and road testing, the most effective way of reducing drag still eludes the researchers. Intuition plays a major part in their designs, for example when determining the angle of the boat tail. If the test results fall short of expectations, the researchers change the angle and test again to look for any improvement. Van Raemdonck thinks that more knowledge about the airflow around a lorry will be needed to improve design methods. ▸▸

Researchers design mostly by intuition



Gandert van Raemdonck aims to gain greater insights into how airflows stream along a truck when it is driving. He uses *computational fluid dynamics* to model the airflows of the truck. The computer program allows him to turn the truck in such a way that he can study it from all sides.

Like a washing machine

In fact, there should be a stamp of approval for lorries, is what Professor Michel van Tooren thinks. There should be a label to indicate how aerodynamic a lorry is. A vehicle with protruding air horns and spotlights would end up in the lowest category, while a smooth vehicle with rounded corners and other means of reducing drag would be classified as 'good'. "Just like the labels for washing machines that indicate how much electricity and water they use," says Van Tooren. It will be a long while yet before such a label is introduced, if ever. First, a method must be devised to measure how aerodynamic each type of vehicle is. "And of course, the hauliers must support the idea."

The numbers

Fifteen percent less fuel consumption sounds great, but even if the Aerospace Engineering researchers can manage that, what's in it for the haulier? Gandert van Raemdonck does the sums on a piece of paper. Suppose a lorry travels 250,000 kilometres a year, and does three kilometres to a litre of fuel. Each year, it would use 83,000 litres of diesel. If a litre of diesel costs one euro, reducing the fuel consumption by five percent would save four thousand euros per lorry per year. A reduction of fifteen percent would save twelve thousand euros per lorry in a year.

"Although this subject has been researched in the United States, we still don't understand how exactly the air flowing around the trailer interacts with the size of the wake and the energy of the vortices in it."
Van Raemdonck intends to unravel the mystery by doing some fundamental research in addition to his experiments. Using a scale model and old as well as new measuring techniques in the low-speed wind tunnel, he hopes to gain enough insight into the airflows to enable researchers to use computers to come up with improved solutions. Soon Van Raemdonck and other researchers will be able to start their road tests with improved designs.

Flesh and blood driver

The real testing ground, of course, is on the road with a flesh and blood lorry driver coaxing a real lorry though the wind and rain. Although his fundamental research isn't finished yet, Van Raemdonck is already preparing himself for the first real-life test drives on the road. The rear end of the white Scania lorry has been fitted with a boat tail, and now the vehicle, which is used to train lorry drivers to drive fuel-efficiently, makes the same trip around the town of Barneveld twice a day. These trips are all identical so they can be readily compared. In fact, Van Raemdonck would have preferred it if the lorry had been used for regular long-distance trips from Amsterdam to the south of Italy. "Long-distance driving at constant speed offers much greater fuel economy benefits than short trips around town."
Whatever the case may be, the boat-tailed lorry won't be on the road yet, as Van Raemdonck failed to obtain the required permission for the test vehicle from the RDW, the Dutch vehicle certification authority. Mechanic Jeffrey van Rijswijk found it hard to believe when he was told he would have to remove his creation the next day. He had spent two days putting the boat tail together, and he had some difficult moments. "The top sheet in particular was hard to fit, and I had to use a cherry-picker to reach the spot." He managed to complete the job in time, but without the prerequisite permits there is no way the boat-tail lorry will be allowed out on the road. "It's a great shame we have to dismantle the thing," Van Raemdonck says, "But the truck is in almost constant use. I just wanted to put the boat tail together to make sure we could fit it in a couple of hours once the permit comes through."
Dutch legislation stipulates a maximum length for vehicles. An articulated lorry must not exceed 16.5 metres. Hauliers want to use as much of the permitted length

The lorry does the same trip around Barneveld twice a day. This helps in the research because the trips are then easier to compare

as possible to carry goods in. "This is why our lorries are always snub-nosed," says Aerospace Engineering Professor Michel van Tooren. "In the United States lorries have more aerodynamic cabs, with pointed snouts." And road testing with the boat tail is allowed in the States.

Safety

"The boat tail extends a few metres behind the trailer, and presents a safety problem as well as one of length," says Allert van Meurs, who works at the RDW. "Normally, a car colliding with the rear of a lorry would be stopped by a crash bar. But the boat tail doesn't have one so a car crashing into the back could slide underneath." Van Raemdonck is currently looking for a way to satisfy the regulations while still managing to innovate the lorry. Meanwhile the test lorry will soon take to the road without its boat tail, but with an advanced measuring system. This system, which was developed by the researcher himself, records 'practically everything', from wind direction and wind speed to vehicle speed and fuel consumption. "This will provide us with a baseline measurement, i.e. the fuel consumption under various conditions without aerodynamic features. When the vehicle with the boat tail can go on the road, we will have a clear record of the improved fuel economy," says Van

'A car could shoot straight underneath the boat tail on impact'

Raemdonck, who is busy installing his data acquisition system inside the vehicle's cab.
A short while beforehand he had been lying prone on top of the lorry to install an anemometer. And once the cone is removed from the back, he will start mucking about with resin and synthetic fibres. He points up to a small platform three metres above the ground, screened off by a slender chain. "That is going to be my laboratory."
Last year, Van Raemdonck developed a method of reducing drag on lorries without contravening the law. His substructure fits below rather than behind the vehicle, and channels the air that currently blows all over the place. "Aerodynamically speaking, the underside of a lorry is a mess. My research also provides solutions to that problem." As he is currently working on a patent application, he cannot divulge any details. Even so, wind tunnel tests have demonstrated that the relatively simple solution will improve fuel economy by five to nine percent. "Perhaps even more, if I manage to improve the shape. However, I'm not selling daydreams, so I want to test the system on the road first."

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Turn them into trains

Better aerodynamics aren't the only way of improving a lorry's fuel economy. A lot of fuel is used to simply keep the engine running. It takes a lot of energy to overcome the friction of mechanical parts inside the engine and gearbox. An efficient engine can save a lot of fuel. The road drag of the vehicle's wheels must also be overcome. Reducing a lorry's weight would be one option. Researchers at the Aerospace Engineering department have developed the 'Cold Feather', a refrigerated trailer for transporting flowers and vegetables. The weight of the Cold Feather has been made 'as light as a feather' by removing part of the steel supporting structure and replacing it with a new material. A single sample was built, which weighs three tonnes less than a normal trailer. "The weight reduction will save up to two thousand litres of fuel per trailer in a year," Professor Adriaan Beukers says.
Yet another way of reducing the rolling resistance is to use different tyres. Thinking aloud, Beukers reinvents an age-old idea. "Turn them into trains." Steel on steel offers much less friction than rubber on tarmac. He can just imagine the system and lets his imagination run riot. "It's simply a great idea. Trailers would be carried abroad on flat-bed wagons. Trains would run along every motorway in Holland, with pick-up places for trailers all over the country. An instant solution to traffic jams."