Cambridge University is using a new test procedure to examine the air flow around an artic, especially beneath the trailer, where aerodynamic drag is at its worst. Brian Weatherley reports

Knowing with the

Reducing the aerodynamic drag on a top-weight truck is a rare 'win-win' for the industry and the environment. The less drag, the less fuel needed to overcome it. The less burned, the less CO_2 produced. It's doubtless why truck manufacturers spend so much time, and money, on honing the aerodynamics of their products before they're launched. However, full-scale wind tunnel testing doesn't come cheap. As for trailer manufacturers and bodybuilders, who don't have the deep R&D pockets of the chassis manufacturers, the cost of wind tunnel testing can seem even less achievable. Consequently, in recent years many have turned to using computational fluid dynamics (CFD) software programs to predict the efficacy of their streamlined designs, at a significantly lower cost.

But both full-scale wind tunnel testing and CFD have their own drawbacks. The former invariably involves a static vehicle – thus air flow disturbance created by wheel rotation can't be measured. Moreover, it's usually positioned 'head-on' into the wind, so there's little or no opportunity to examine the effect of side-winds and vehicle 'yaw'. As for CFD, some form of real-world validation is inevitably required to confirm the computer's predictions; for trailer manufacturers that usually means extended operator trials.

However, there is a third way to determine the air flow around an artic, which is also capable of providing a much greater understanding of what's causing drag, particularly in an area normally out of sight – if not out of mind: underneath the trailer. Since 2014, the University of Cambridge Engineering Department has been examining the effects of air flow using a 7,000-litre 'Tow Tank' test rig (see box, p22). The project is currently funded by the Centre for Sustainable Road Freight – the joint collaboration between Cambridge and Heriot-Watt Universities and the University of Westminster, with major participating industry partners including John Lewis/Waitrose, Wincanton, Denby Transport and Turners of Soham.

The work has been conducted by two postgraduate PhD research students: initially, from 2013, Richard Stephens, but since 2016, Isabel Vallina-Garcia (pictured, p22). The project is due to run for another 18 months.

AIR SUBSTITUTE

The Cambridge Tow Tank is a highly cost-effective method of studying aerodynamic drag and air flow, not least as water behaves in exactly the same way as air, but with the 'flow' easier to visualise. The work currently being conducted by Vallina-Garcia involves an experimental procedure called Particle Image Velocimetry (PIV), whereby

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millions of small particles of titanium dioxide (it looks like washing powder) are mixed with the water in the tank.

As the 1/10th scale model artic (representing a typical 16.5m combination with a trailer height of around 4.0m) moves along the glass and Perspex tank, the particles follow the water flowing around it. By illuminating them with a laser, their movement in relationship to the truck can be filmed by cameras taking up to 3,000 photos a second. Using PIV, it is also possible to determine the velocity of the flow in 3D space around different body configurations.

Once the imagery has been downloaded to a computer, the data can be used in a variety of ways. The most obvious is an animated view of the air flow around the scale model (pictured, p22, inset). Secondly, through vector calculations it's possible to pinpoint the regions of high and low flow around the truck. Those high and low-flow velocities can be represented graphically, with different colours denoting different flow speeds (a turbulent flow is pictured in the inset, left).

One obvious advantage of the Tow Tank is that the flow around the moving truck can be observed directly from below – something that can't normally be done in a wind tunnel. Why does that matter? Vallina-Garcia explains: "It's not been previously studied in detail, therefore there's a lack of understanding of the underbody flow physics. So there are no clear guidelines for the effective design and optimisation of underbody aerodynamic devices."

There's another reason for focusing on the trailer's underbody. It's packed with 'bluff' bodies – landing-legs, air tanks, fuel tanks (on a reefer), cross-members, axles and suspension components – all of which block air. She adds: "Essentially we've got this high-energy flow that moves along the side of the trailer which is undisturbed. But if it's 'entrained' into the underbody, it collides with all these bluff bodies and loses its energy – and that essentially is drag. If we can prevent this flow from going under the body and allow it to continue to move along the trailer, it conserves its energy, and that's how we obtain improvements in aerodynamics."

So why not simply block off the underbody ahead of the landing legs with an air dam? "That's something we can definitely test here," confirms Vallina-Garcia, although she maintains it's possible to gain air flow improvements through less radical interventions – such as repositioning some existing underbody components like air tanks, or surrounding the landing leg uprights with an aerodynamic moulding.

Wheel covers also deliver surprising benefits. "Not as much as side-skirts obviously, but they're definitely effective," affirms Vallina-Garcia, although she adds that the full flow topology analysis has yet to be completed. Watching the animated PIV film footage, you can clearly see the titanium particles being drawn around the rotating wheels of the trailer in a lively swirling motion, especially around the inner side by the axle-ends. Turning wheels clearly disrupt air flow, and being able to see it happening with PIV is another benefit of the Tow Tank.

SKIRT LENGTH

Talking of side-skirts, common sense suggests that the lower their bottom edge is to the ground, the more effective they'll be in improving air flow along the side of a trailer. However, that's not the case, asserts Vallina-Garcia. She states: "Beyond a certain depth, the drag plateaus. When the wheels rotate, they squirt air outwards, so by making

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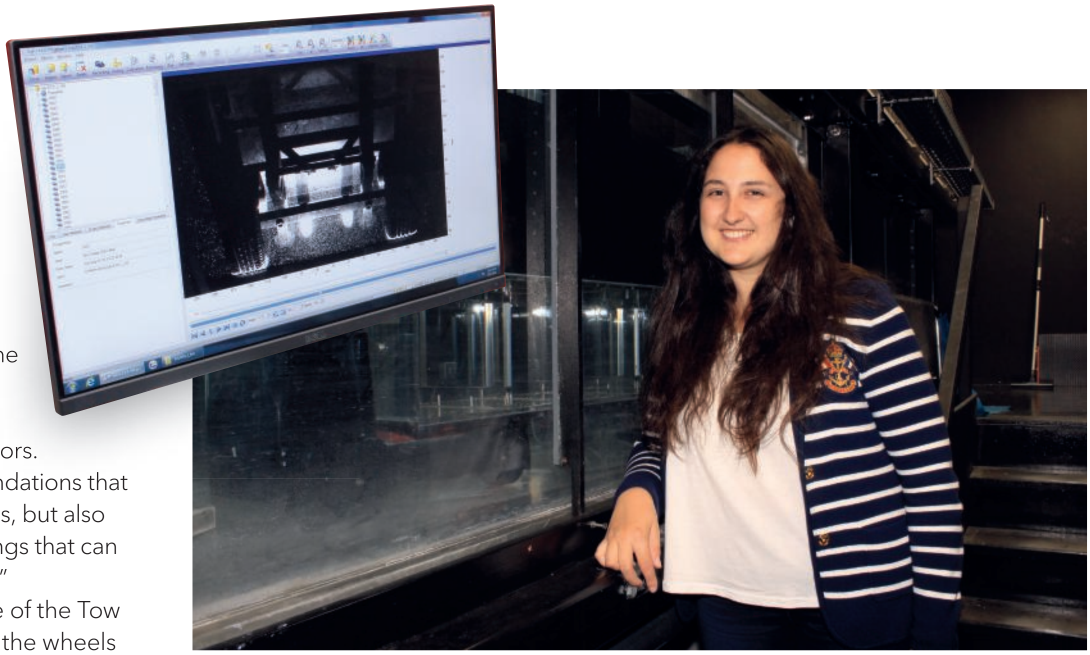

the side-skirts too low you're preventing that air from leaving. The optimum height [for the lower edge] is at the same level as the centre of the axles." Doing so not only prevents the build-up of road dirt, it also reduces the risk of damage. She adds: "Maintenance issues are a big deal for vehicle operators. We try to make recommendations that are good for aerodynamics, but also in terms of operability, things that can easily be put into practice."

Another key advantage of the Tow Tank is that the 'road' and the wheels are moving relative to the vehicle. In wind tunnels, this can only be achieved with very expensive rolling roads (it's what F1 teams do); but even these are not without their problems. Because the scale model is towed through still water, it correctly replicates road conditions, but at a much lower cost, while allowing improved access for measurements.

As well as examining air flow disturbances under the trailer, Vallina-Garcia is looking at the interaction between the underbody and the wake flows – the air-stream that exits the rear of the trailer. Reducing the turbulence within such wake-flows has long been a goal for trailer manufacturers and bodybuilders. Ultimately, says Vallina-Garcia, "we're exploring a new methodology, looking at how simple changes to the geometry and location of devices can improve aerodynamics."

Beyond the current research, could the Cambridge Tow Tank be used by truck operators to pre-test the effectiveness of various body configurations before purchasing the real thing? It would prove a useful addition to on-road trials. Holger Babinsky, professor of aerodynamics, and deputy head (graduate studies) at the University of Cambridge's Department of Engineering, states: "At the moment we don't offer this – but it's something we've thought about."

Meanwhile, David Cebon, professor of mechanical engineering at the University, and director of project sponsor the Centre for Sustainable Road Freight, confirms that the project is already delivering benefits to everyday HGV operations. He states: "The short-term plan is to demonstrate that aerodynamics modifications are effective in service. In parallel with Isabel's project, we're working on an InnovateUK project with Tesco, SDC and Lawrence David which is building lightweight aerodynamic double-deck trailers. Six trailers will enter service in the Tesco fleet over the next few months as part of the Low Carbon Freight and Logistics Trial. They'll incorporate some of our new understanding of aerodynamics, as well as some of our work on lightweighting. We're hoping to save 12-15% fuel with these vehicles compared to conventional trailers." TE

TOW TANK TECH FILE

The Cambridge University Tow Tank measures 6m long by 1m high and 1m wide. Constructed out of glass and Perspex, it is supported by a steel frame and contains 7,200 litres of water.

An overhead belt-driven carriage, powered by an electric motor, is connected to a 1/10th scale model artic by vertical aluminium struts. To avoid unnecessary flow vortices, they are surrounded by an aerofoil-shaped moulding. The generic model travels through the water at 3.0m/sec, which equates to a motorway speed of 85-90kph. As the combination's wheels are in contact with the tank floor, they rotate. A laser beam projected through the tank's glass floor creates a vertical 'light screen' through which the model passes.

As it does so, two high-speed cameras underneath take images of the trailer's underbody. The motion of the titanium dioxide particles around the model is tracked in each frame. To ensure a robust measurement, a total of 17 runs are conducted with each model configuration; only their average is analysed. Also, a load cell is used to measure the resistance of the model to being pulled through the water.