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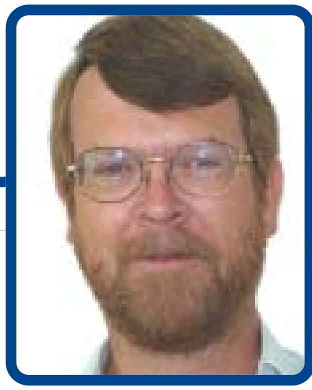

Airdams

Often present, potentially very beneficial, but frequently misunderstood, we explain how airdams work

The textbooks agree on the benefits of airdams to both downforce and drag, but explanations of the mechanisms involved are mixed. We've used CFD to measure and 'see' what actually happens to a racecar fitted with an airdam.

Advantage CFD used a similar full-scale model NASCAR racer to that used in the study reported in V11N11. This incorporated detail such as a 'rough' underside with exhaust pipes, chassis rails and cavities, and also a rear spoiler (see figures 1 and 2). Simulations in 3D CFD were run at 50m/s (180km/h or 112mph) air speed, and three different airdam depths.

The plots in figure 3 show the results of downforce and drag (as dimensionless CDfA and CdA values, the product of frontal area and the relevant coefficient) and show total downforce increasing and drag decreasing with airdam depth. [Note: downforce is treated as 'positive' and lift and as 'negative'.] The downforce benefit dominates at the front end of the car. Furthermore, the rear end actually loses some downforce. The trend is heading towards a more even front to rear balance and greater aerodynamic efficiency (downforce to drag ratio).

As only three depths were evaluated it would be a little careless to suggest these trends would continue beyond the deepest airdam measured here, and the textbooks suggest that drag would actually start to rise again at some greater depth. However, our purpose here is to explain the effects.

Looking first at how the airflow is modified by the airdam, figure 4 shows that less air passes beneath the car and more air is pushed around the sides with an airdam. In figure 5 we can see there is a region of recirculation behind the airdam. Furthermore, the so-called 'stagnation point' – where the air hits the car head on – is lower when the airdam is fitted, more air being pushed over the bonnet (hood) and therefore less being pushed under the car.

Changes to the pressure on the upper and lower body surfaces occur because of these flow modifications. Figure 6 shows the change in pressure coefficient, ρCp (deltaρCp), plotted on the main surfaces. But only the vertical (Z-direction) component is shown, so that the effect on downforce is isolated for clarity, hence the ρCpZ designation. Thus reds and yellows indicate additional lift while blues and greens indicate additional downforce.

The forward upper surface shows a small positive (upward) change in pressure, indicating the airdam causes some additional lift over the bonnet. The underside however shows a large area of negative (vertically downward) change in pressure, indicating 'suction' on the underside caused by the airdam. This extends roughly halfway along the car then changes to a slight positive value, indicating some lift under the rear after the airdam was fitted. The net result is the gain in downforce we see, which is concentrated at the front.

Figure 7 shows the ρCpρX plot, indicating pressure changes in the X-direction, where positive (red and yellow) is an increase in rearward acting pressure (more drag) and negative (blue and green) is a decrease in rearward acting pressure (less drag). Clearly the airdam itself creates drag where the air runs into it, but there is less drag on the forward part of the bonnet above it. There is also a reduction in drag from the wheels and significant areas of the underfloor and associated clutter. The net result is the decrease in drag.

Can we explain these changes using Bernouilli's Equation? Well, the

Figure 1: NASCAR model showing three different airdam variations

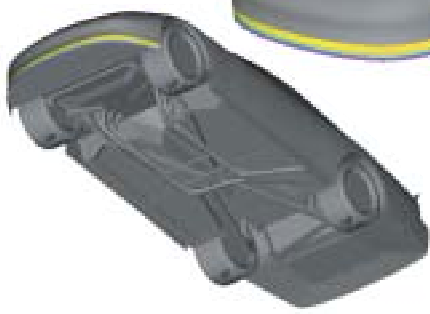

Figure 2: NASCAR model showing the realistic 'rough' underside

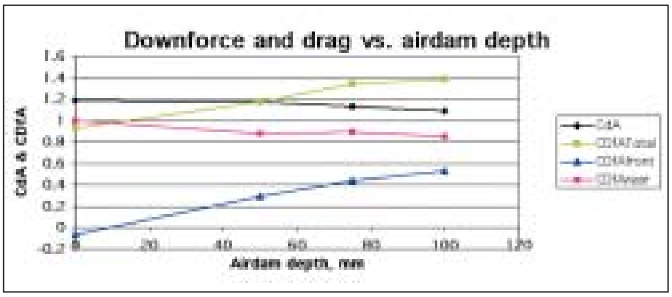

Figure 3: effect of airdam length on downforce at the front and rear, and overall drag

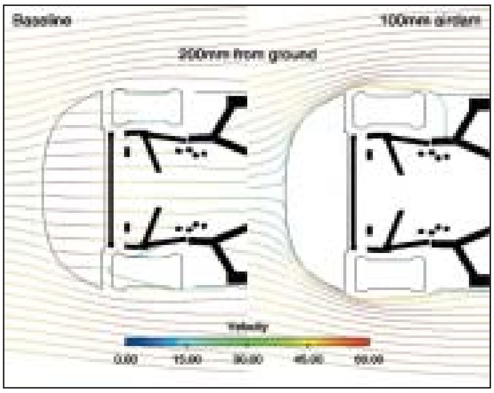

Figure 4: overhead view of streamlines for the no airdam and 100mm airdam cases at 200mm from the ground

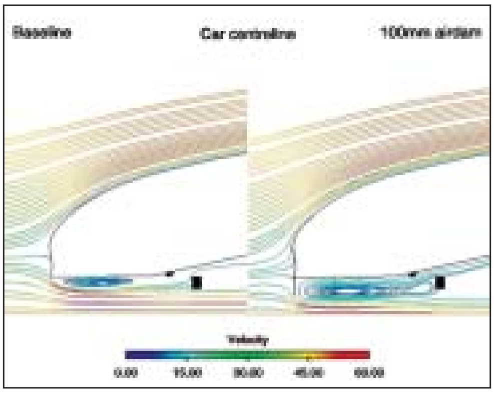

Figure 5: side view of streamlines at the car centreline for the no airdam and a 100mm airdam

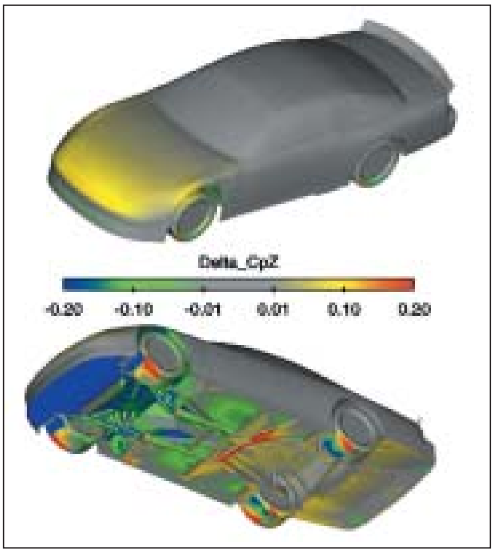

Figure 6: effect on downforce of adding a 100mm airdam

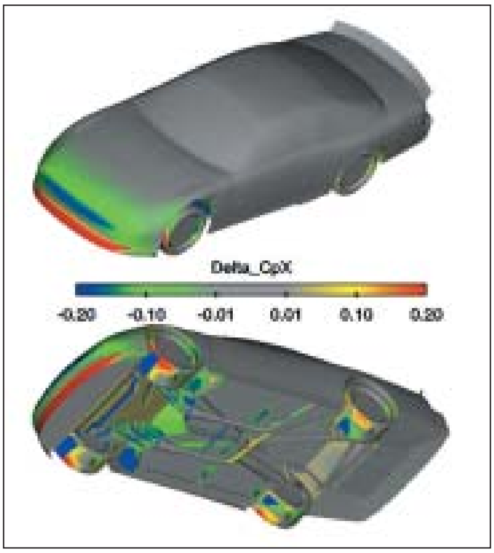

Figure 7: effect on drag of adding a 100mm airdam

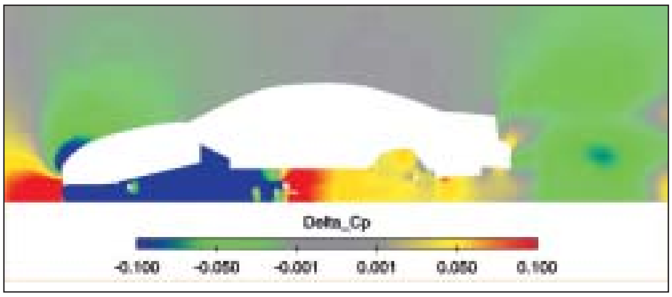

Figure 8: the effect of adding a single 100mm airdam on static pressure around the car

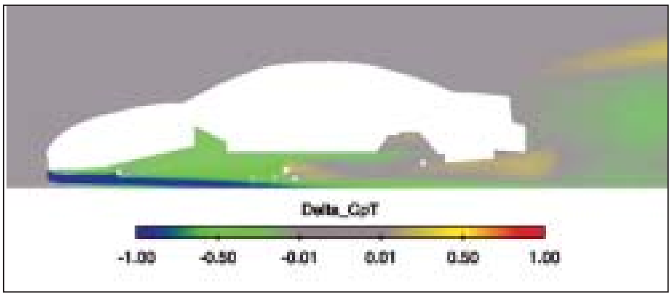

Figure 9: effect of adding a 100mm airdam on total pressure movement around the car

reduction in lift and drag over the forward part of the bonnet can both be explained by the increased flow over this area caused by the airdam, which leads to an increase in velocity and a Bernouilli-type drop in pressure. The slope of the bonnet means there are forward and vertical components to this pressure reduction, leading to decreased drag and increased lift over this region. The additional drag on the airdam is also simply explained by Bernouilli, the airflow coming to a virtual stop here, leading to low velocity and high static pressure acting rearwards.

The underside region behind the airdam is not so simple. As we saw in figure 5, the air behind the airdam is re-circulating and moving relatively slowly and yet, as we saw in figure 6, the pressure is reduced behind the airdam. This seems to contradict Bernouilli, and the effect more readily falls into what Erik Zapletal referred to in V12N4 as 'aerostatic downforce that is non-Bernouilli in nature'. Advantage CFD's explanation goes back to a modified version of Bernouilli's Equation to explain the mechanism:

$$ps + 1/2rV2 + \text{losses} = \text{constant}$$

where ps is static pressure and $1/2\rho V2$ is dynamic pressure (ρ, Greek letter 'rho' is air density, V is air velocity).

We tend to think of Bernouilli's equation as describing 100 per cent efficient interchange between static and dynamic pressure, so that when velocity and hence, dynamic pressure increases, static pressure decreases. As a statement based on the Conservation of Energy that's fine but, as Erik Zapletal pointed out, it assumes there will be no addition to, or subtraction (losses) from, the total pressure energy in a system. But in reality there always will be losses. Bernouilli also assumes the flow will be smooth, and around a non-streamlined device like an airdam, the airflow is turbulent.

So we've got a region of turbulent, low velocity flow that is also at low pressure. How can CFD help explain this? Figure 8 shows a ρCp plot that reveals the changes in static pressure along the car centreline that occurs when the airdam is fitted. This shows clearly that there is a very marked drop in static pressure behind the airdam, which is where our front-end downforce originates. We know that the velocity here is low, so we know that the dynamic pressure is also low. So we must conclude that losses from the flow have increased here. Figure 9, showing a ρCpρT plot, the change to total pressure, confirms this by showing that total pressure has in fact dropped behind the airdam.

Next month we'll add a splitter to the airdam.

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