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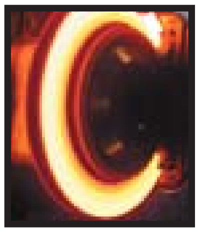

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AEROBYTES

with Simon McBeath

Front diffusers

Less visually obvious than some downforce-generating devices, the front diffuser can be found in various guises on a wide variety of closed-wheel racecars

In the last couple of issues we have looked at the effects of airdams and splitters on the front of a virtual model of a generic NASCAR racer with which we've taken many more liberties than the NEXTEL teams are allowed! As such, very efficient (low drag and even drag-reducing) gains in downforce have been achieved.

An extension (in both senses) of the airdam/splitter is the front diffuser which, when permitted, is a rearwards continuation of the splitter under the front of the car that then sweeps upwards. Variations that have been used on saloon/sedan and sports racecars include a single, wide diffuser, a pair of separate narrower diffusers in line with the gap between the wheels and the chassis and even four smaller diffusers. Advantage CFD modelled a single, wide diffuser as shown in figures 1 and 2. A simple 'with versus without the diffuser' study was performed in 3D at an airspeed of 50m/s (180km/h or 112mph).

The result of installing this simple diffuser on this model with a 100mm deep airdam and a 150mm long splitter (see the previous two issues) was a 3.9 per cent increase in overall downforce (the benefit was concentrated at the front, with rear downforce reducing slightly) and a 1.4 per cent increase in drag. This represents a more modest benefit than the airdam or the splitter achieved, but is nevertheless a worthwhile and reasonably efficient gain. Bigger gains could, no doubt, be achieved with optimisation, but the purpose here was to investigate why the benefit occurs.

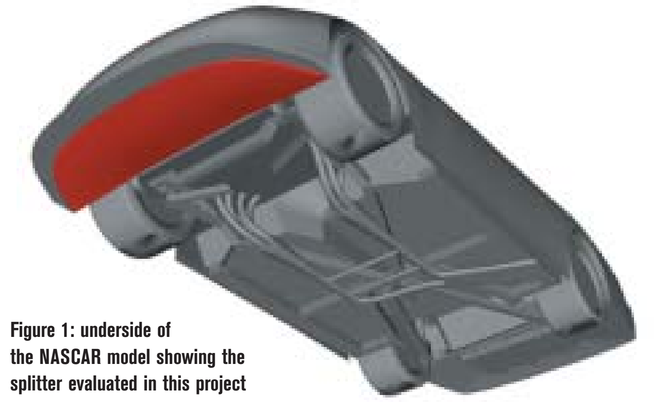

Figure 1: underside of the NASCAR model showing the splitter evaluated in this project

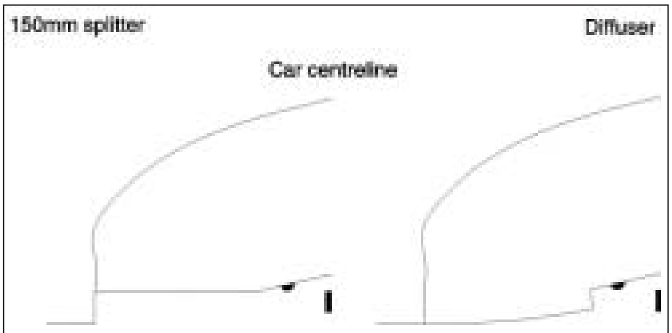

Figure 2: centreline profile showing the geometry with and without the diffuser fitted

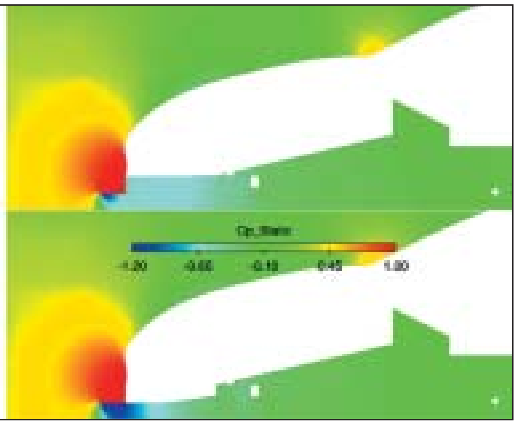

Figure 3: static pressures show the differences created under the forward underbody by fitting the diffuser

Looking first at figure 3, it is apparent that after 'fitting' the diffuser, the high-pressure zone (red) above the splitter has remained pretty much unchanged but there has been a significant decrease in static pressure under the splitter, evidenced by the larger zone of darker blue which also extends under the forward part of the diffuser. This creates more downforce. However, under the rearward part of the diffuser the static pressure is now higher (green rather than pale blue) than it was in the underbody here with no diffuser, which means less downforce is being created here than before. So as always, the picture is not a simple one.

Moving to figure 4, showing velocity coloured streamlines, a couple of things become apparent. Most obviously the large re-circulation zone behind the airdam now has nowhere in which to develop. But importantly, the diffuser allows the airflow to expand, where the re-circulation zone previously acted as a barrier to this expansion. By facilitating →

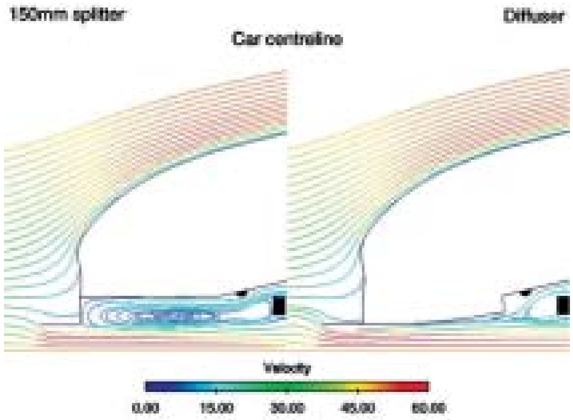

Figure 4: velocity coloured streamlines along the centreline without and with diffuser

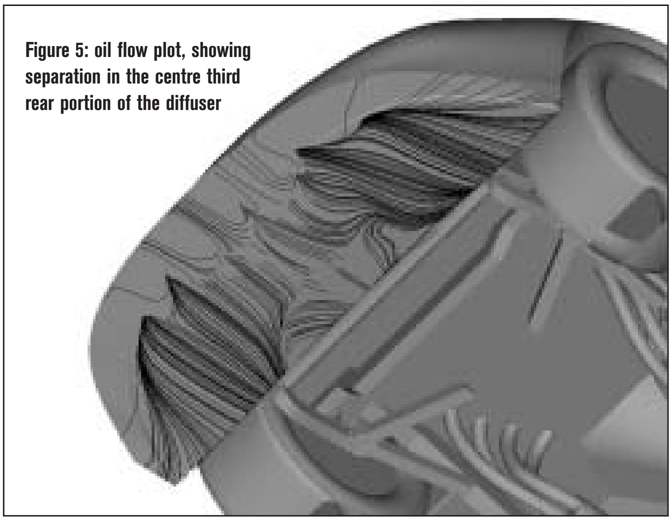

Figure 5: oil flow plot, showing separation in the centre third rear portion of the diffuser

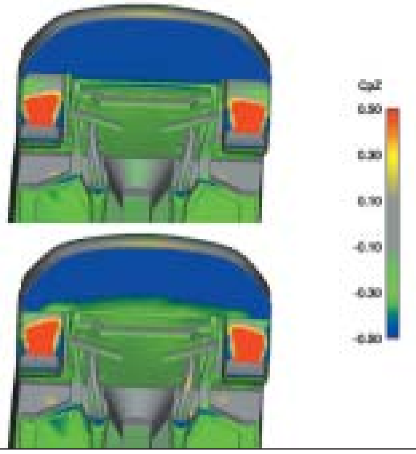

Figure 6: Cp_Z plot showing pressure was not so low in the rear part of the diffuser (bottom pic)

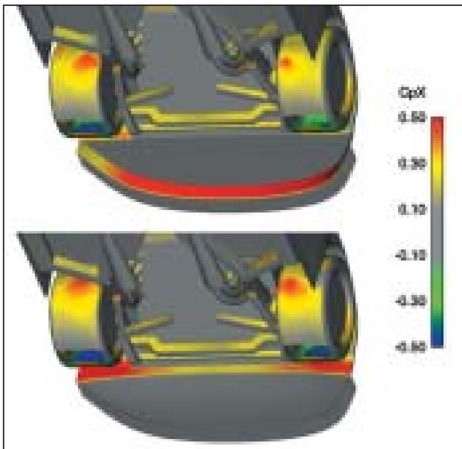

Figure 7: Cp_X plot showing how sources of drag have moved when the diffuser was fitted (diffuser case at bottom)

expansion the diffuser promotes increased flow under the splitter. This results in an increase in velocity under the splitter, which contributes to the decrease in static pressure there, in true Bernouilli fashion. There are also losses here resulting from the sharp leading edge of the splitter that cause a drop in total pressure and hence, a further drop in static pressure, though this is not evident in the diagrams here.

However, moving aft along the diffuser, a closer look at the topmost streamline in the diffuser suggests the flow might have actually separated here. Figure 5 confirms much more clearly that this is the case. This is an 'oil flow plot' which simulates the real world flow visualisation technique using an oily fluid to show surface flows. The change in the pattern of surface flow in the centre third, towards the rear of the diffuser, is the result of flow separation. So why has this happened, and what are the consequences?

We have seen in previous Aerobytes that separation can occur when fluid (including air) is flowing against too steep an 'adverse pressure gradient', that is to say where pressure goes from low to high too rapidly for the flow to be able to manage the 'climb', or to slow down in time. In this instance, the low pressure under the splitter has been amplified by the presence of the diffuser, but this has also created an increase in mass flow under the splitter which, when it expands again in the diffuser, rises to higher total pressure (and hence higher static pressure, as shown in figure 3) than it did without the diffuser. Thus the pressure goes from lower to higher as before, but the gradient has now become too severe and the flow has separated. This is an area where further study could provide improvements.

Figure 6 shows a Cp_Z plot indicating static pressures in the vertical or Z-direction only, viewed from below to show the front section of underbody. Blue and green colours show downward acting pressures (downforce production), and it is apparent that the static pressure across most of the rear of the diffuser is not as low as it is under the same region of underbody when there was no diffuser. Thus, as is often so, it's a case of swings and roundabouts again, but the swings win overall.

Figure 7 is a Cp_X plot showing the static pressure components in the horizontal or X-direction only in the front underbody region. Positive (red and yellow) colours indicate drag. An area where drag occurs can be seen behind the airdam when there is no diffuser, but this shifts to behind the diffuser when it is fitted, and calculations showed that the magnitude of the drag in this region barely changes. Notably, the diffuser itself does not create any significant drag. There was, however, a slight increase in drag overall, and this was mainly due to increases from the underfloor protuberances and the rear of the front wheelarches, presumably because of the increased mass flow under the splitter/diffuser that runs into these components. Design optimisation could again provide improvements here.

Conclusion

This simple diffuser has provided an additional increment of reasonably efficient downforce to those substantial gains already achieved by the airdam and the splitter. Improvements could of course be made, perhaps to the splitter, the shape and dimensions of the diffuser and other detail aspects (assuming technical regulations permitted) to provide further gains in downforce. Moreover, close study of where drag occurs would enable design changes that could further improve efficiency. RE

More next month on the virtual NASCAR model