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Diffuser design

Investigating what's good and what's not so good for maintaining effective airflow through a diffuser

In the last couple of issues we've concentrated on lessons learned during a session in the MIRA full-scale wind tunnel with a pair of Lotus Exige S2s, and this month we continue to tease out a few more invaluable nuggets of information from this very interesting session. To quickly recap, one of the cars was pretty well externally standard except for a modified exhaust system that exited in a different location to normal, while the other was adorned with assorted aerodynamic aids that had been developed essentially for GT3 and Britcar. The aerodynamically modified car utilised the standard exhaust system.

> **A triumph of poor detailing over aerodynamics**

The initial focus of this month's column is on the exhaust system and, more specifically, where it emerges on each car. Let's start this month by looking at figure 1. This shows the standard road car's rear end, and where the modified exhaust emerges in the rear panel. This system features a single tailpipe that turns 90 degrees from the engine to protrude directly out of the rear panel, exiting above the central diffuser panel. But notice that the airflow emerging from under the 'roof' of the central section of the diffuser is remarkably smooth, illustrating that the flow has remained fully attached to the diffuser roof, in spite of a reasonably steep angle. This is as one would hope the flow from a diffuser to be.

However, and one hesitates

FIGURE 1
An exhaust system that exited above the diffuser allowed a clean exit for the airflow from the central diffuser section

FIGURE 2
But the Lotus Exige comes as standard from the factory with the exhaust emerging into the central diffuser section

FIGURE 3
This compromised the airflow in that section, making it very untidy near the central roofline area of the diffuser

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to be critical of something made by a company with the heritage and reputation of Lotus, the standard exhaust system doesn't do so well... Figure 2 shows such a system, which can be seen on this brand new Exige to emerge into the central diffuser. Is this a crucial detail? Well, the smoke plume in figure 3 suggests it is. Here the smoke 'wand' was located close to one of the tailpipes, and it can be seen that the airflow is very untidy near the central roofline area of the diffuser. And by running the wand across the whole centre section of the diffuser it was apparent that the flow was separated in pretty much all of this section, with the exception of the portions adjacent to the intermediate vertical fences. This, unfortunately, would appear to be a triumph of poor detailing over aerodynamics. And this from the company whose GP team 'invented' racecar ground effect!

Regrettably, we can't quantify the extent of this difference in packaging on the aerodynamics because a back-to-back comparison was not possible in a short session like this. But it stands to reason that compromising the airflow in the diffuser will have lost some potential downforce and possibly added some drag. This may not be a particular problem for the road car, but it's galling if you're looking for aerodynamic help towards quicker times. 'Fixes' obviously include installing an exhaust that does not emerge in the diffuser, while mitigating modifications might involve isolating those tailpipes with additional vertical fences either side, or with a moulded, streamlined fairing.

UNDERBODY IMPROVEMENTS

If we next examine the airflow in the outer diffuser sections (see figure 4) we can see that the flow here on the standard car is totally stalled, and in this shot is completely reversed, although very unsteady flow conditions prevailed here. This was also the case on the modified car, which in this case utilised exactly the same diffuser (apart from the exhaust exit). The first modification that was done to try and combat this problem was to panel over the gaps in the floor at the front of the outer diffuser sections that are cut away to allow the lower suspension links to droop without clashing with the diffuser. However, rather surprisingly, this made only a very small difference to total downforce, showing just 1.8 per cent less of it than in the previous configuration. Reductions occurred front and rear so balance was barely affected, but clearly this was not the expected result.

Next, wide sill extensions were added (see figure 5) in the hope and expectation that more underbody downforce would again accrue. This time total downforce was completely unchanged, but there was a slight rearward shift with a one per cent increase in rear downforce. Again, the extent of this change was surprisingly small, though the effect of the next modification may help explain why the previous two had such a small effect.

> **"The flow had to have been much improved under the whole car"**

The final configuration of this test saw the outer diffuser fences extended vertically downwards to be about 40mm clear of the ground and reaching forwards to the front of the diffuser. This time we saw a substantial change in the aerodynamic indicators: 18.3 per cent more total downforce and 10.6 per cent less drag (a combination to bring a smile to any aerodynamicist's face), along with eight per cent more front downforce, 23.7 per cent more rear downforce and a 32.5 per cent higher lift-to-drag ratio. This was indeed a successful configuration change, and it seems likely from the size of the gains that the presence of these deeper fences may have done more than just help the diffuser by isolating the adverse flow around the rear wheels. It may well be that with this final 'tidy up' the hoped-for benefits from the previous two configuration changes were also released, producing improvements from much of the rear underbody. Clearly, if more front downforce was being generated too, the flow had to have been improved under the whole car. And who knows whether a further significant gain could have been achieved if those tailpipes were not spoiling the flow in that central diffuser section?

Once more, the culmination of this session was a reminder that being able to actually measure the effects of configuration changes is incredibly valuable. And further, that there are no certainties as to what will or will not work as expected, especially where interactions occur.

Thanks to Simon Farren at Reverie and friends for exposing their cars to open scrutiny

FIGURE 4
Even with the modified exhaust, the airflow in the outer diffuser sections on the standard car was still highly disturbed

FIGURE 5
Wide sill extensions were added to increase downforce. These worked well in concert with...

FIGURE 6
... vertical extensions to the outer diffuser fences