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HONING THE PERFECT EDGE
Using CFD to chase down the optimum shape for aerodynamic efficiency

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Wing end plates

How big should wing end plates be? It's a frequently asked question, and this month we provide some pointers

The regulations in many categories provide at least some limitations on the size of wing end plates that can be utilised at the front or rear of a racecar. Maximum height above the ground or a reference plane is usually restricted and, if the rules don't limit minimum height too, then other practical constraints such as the ground or other parts of the racecar will. There is also the dictum of minimum weight – of some importance with parts that are generally well beyond the wheelbase and, at the rear, high up as well.

The question still remains though – how big, aerodynamically speaking, is good? To attempt to answer that, first let's examine what end plates do. The usual textbooks tell us what we intuitively appreciate – that end plates help to maintain the pressure difference between the upper (pressure) and lower (suction) surfaces of a racecar wing by preventing the 'spillage' of air from the former to the latter around the wing tips. The important variable is said to be the height of the end plate, h, relative to the span, b, of the wing (see figure 1).

Bigger end plates have the effect of increasing the effective 'aspect ratio' (AR) of the wing by reducing this spillage, and this benefits both the downforce and induced drag (the portion of drag directly resulting from downforce generation, and the dominant source of drag from most racecar wings) generated by the wing. Indeed the aeronautical textbooks indicate that an increase in lift coefficient and a decrease in induced drag coefficient should be expected with an increase in AR.

Relating this to end plates, Milliken and Milliken tell us that the effective aspect ratio is proportional to h/b up to values of h/b 0.6, when the gains begin to tail off. In other words, bigger is better, up to a point. But we need to get a bit more practical. For one thing, end plates rarely protrude the same distance above a racecar rear wing as below it, usually because of maximum height restrictions, but also the general desire to run the wing as close to maximum height as possible to try to find some 'clean' air above and behind the racecar.

So Advantage CFD looked at the effects on a two-element wing in 'free stream air' of some more realistic-looking end plate variations compared to the no end plate case – as shown in figure 2. The force results are shown in the table (right), and do indeed show a trend toward more downforce and lower drag.

Produced in association with Advantage CFD

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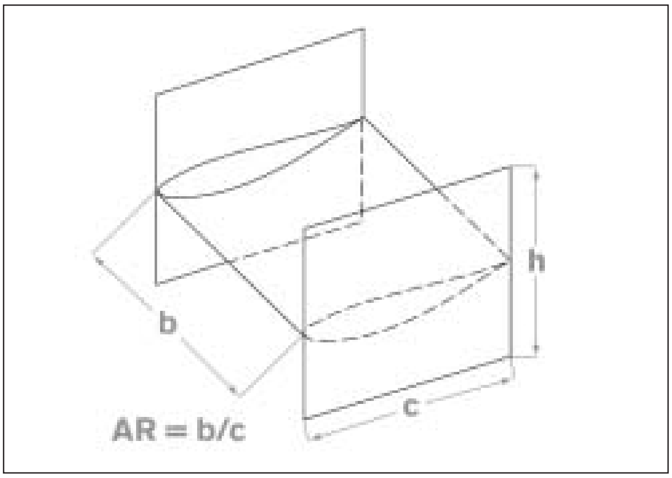

Figure 1: end plate and wing terminology, where h = height and b = span and c = length

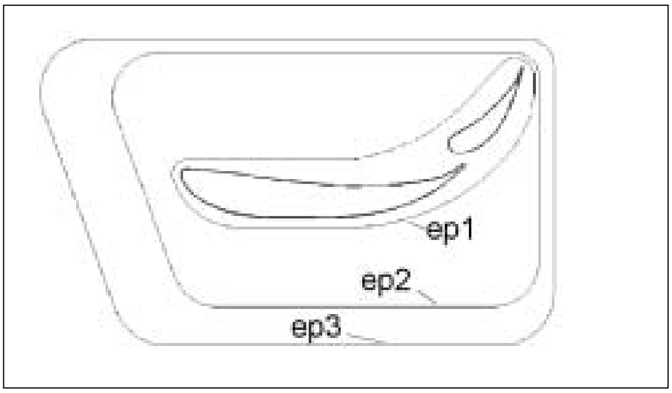

Figure 2: end plate variations tested, in the case of a two-element wing in free stream air

Force results

Case	Downforce (N)	Drag (N)
ep0	769.2	194.8
ep1	786.7	188.3
ep2	873.4	183.8
ep3	900.1	178.1

The graph in figure 3 is a plot of the lift coefficients across the wingspan, from the wing centreline on the left of the graph to the wing tip on the right. The downforce generated near the tips declines far more drastically with no end plate, or just the small end plate, compared with the medium and large end plates where the reduction is much less marked. →

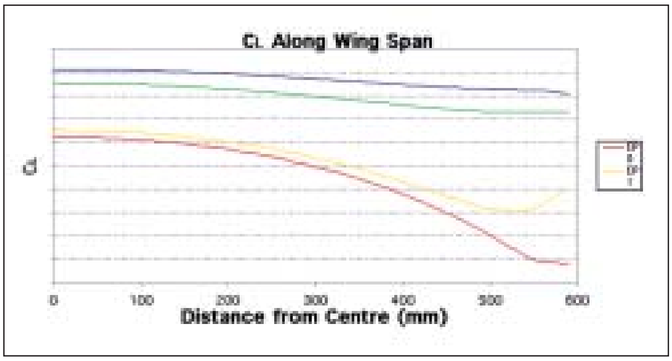

Figure 3: lift coefficients along the wingspan from the centreline to the wing tip

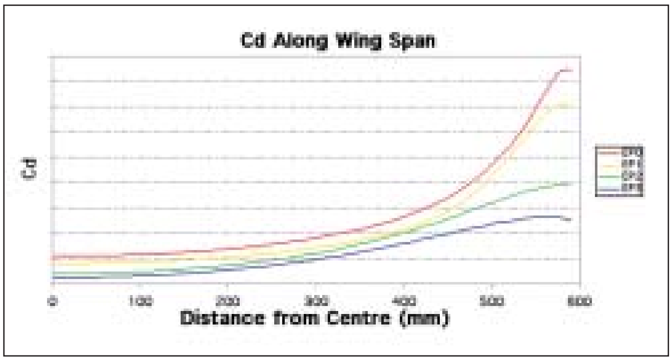

Figure 4: drag coefficients across the wingspan from the centreline (left) to the wing tip

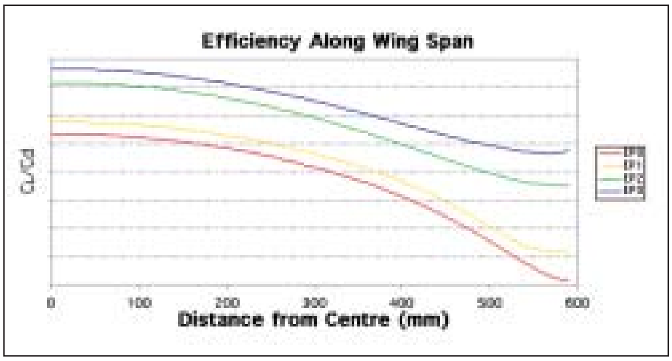

Figure 5: efficiency along the wingspan from the centreline (left) to the wing tip (right)

Thus, with decent sized end plates fitted, the lift coefficients near the wing tip are more akin to the values they would be at a similar distance from the centreline of a much wider wing without end plates. This confirms the notion that end plates effectively increase the aspect ratio which, for a given chord dimension, is the same as saying that end plates have effectively increased the wingspan.

Figure 4 plots the drag coefficients across the wingspan in a similar way, and again it is evident that drag increases near the wing tips far more with no end plate or the small end plate than it does with the medium and large end plates. Figure 5 plots lift divided by drag in the same way to indicate how the wing's efficiency changes across the span.

As always, CFD can help to visualise what's going on. Figure 6 shows the wing tip vortices in the no end plate case. The flow from the upper (pressure) surface to the lower (suction) surface, initiating these powerful vortices, is evident.

Figure 7 shows the large end plates installed. The vortices are now produced at the tips of the end plates, moving their influence away from the wing itself. Furthermore, there are pairs of vortices formed, at the top and bottom of each end plate, and these merge downstream into a single vortex. Thus, taller end plates move the vortices further from the wing where they have less detrimental effect on its performance, reinforcing the idea that increased efficiency is related to end plate size.

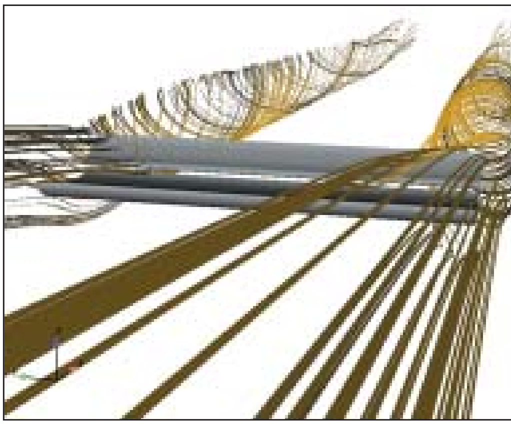

Figure 6: vortex manifestation with no end plates

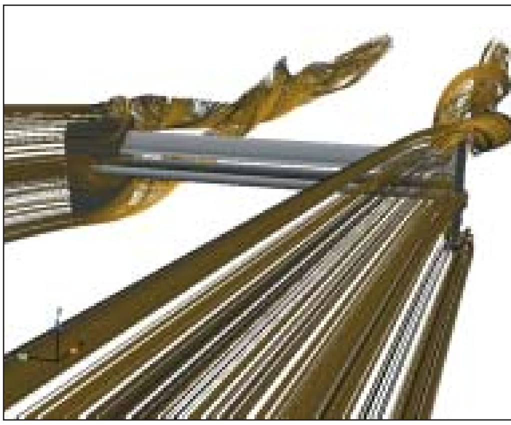

Figure 7: vortex manifestation with the large end plates

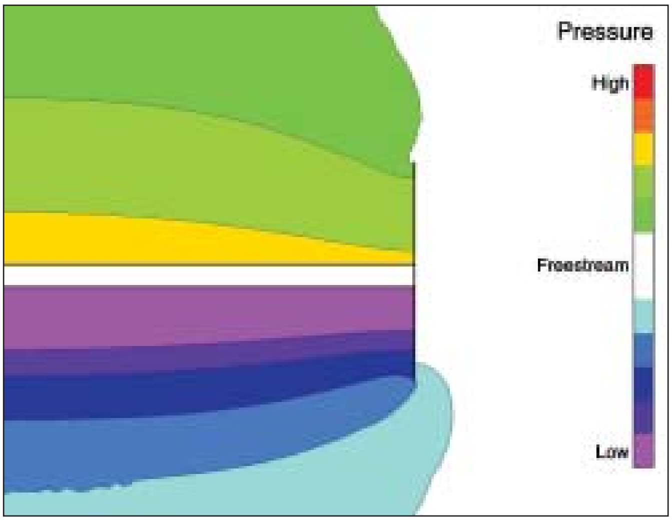

Figure 8: pressure contours near the end plate itself, as viewed from ahead of the wing

However, there are reasons for thinking that we should have more end plate below the wing than above it. First, as already mentioned, it is probable that the rules and the high mounting of a wing will make this inevitable. Second, the pressure distributions above and below the wing also suggest this is a good idea. Figure 8 illustrates the pressure contours near the end plate above and below the wing, just downstream from the leading edge (before the flow gets complicated by vortex formation).

The pressure increase above the wing is much smaller than the pressure decrease below it. Thus, the influence of the wing extends further below it than above it. Put simply, this means we need more end plate below the wing if vortex formation is to be reduced to the same extent as above it.

Extending this notion, the ideal size of end plate will also depend on the downforce level of the wing. Lower downforce wings create smaller pressure changes, and hence the wing's influence on the pressures in the air around it extends less far, meaning smaller end plates can be used. RE

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