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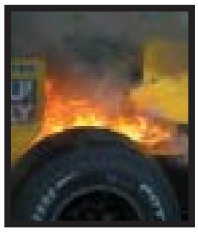

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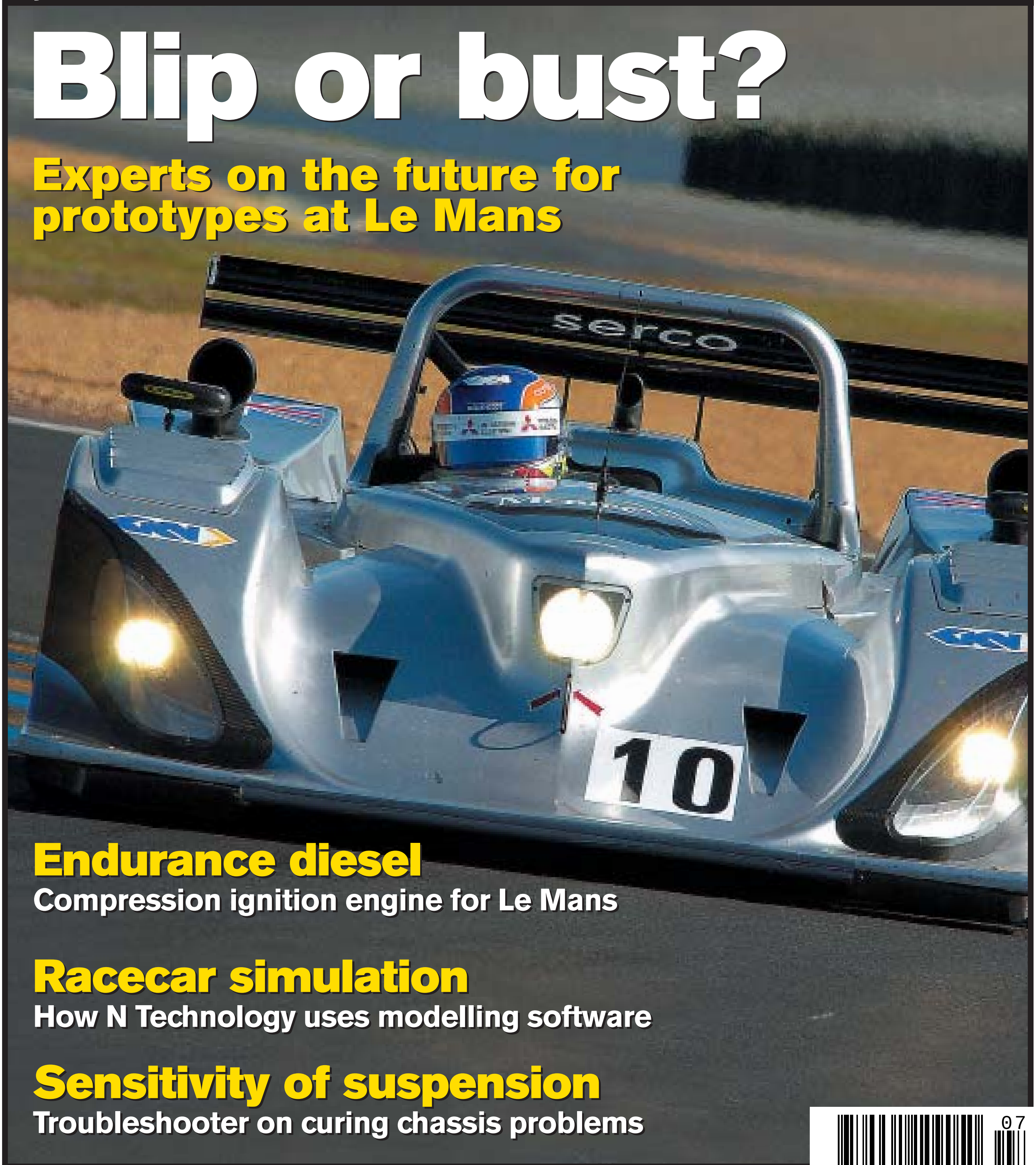

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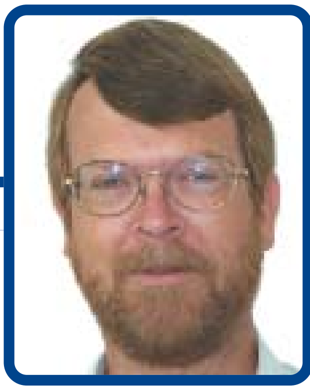

Wing thickness

Racecar wings can take many forms, we look at the effects of altering wing thickness

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Right: despite the appearance of new wing shapes, basic thickness is still a crucial factor in generating downforce

Wing downforce at any given speed is related to plan area (span × chord) and lift coefficient, C_L, as stated in the basic lift equation: **lift (downforce)** $= 1/2\rho \times A \times C_L \times v^2$ (where ρ is air density, **A** is plan area, and **v** is air velocity). Where rules specify wing maximum dimensions, limiting available plan area for downforce generation, extracting more downforce requires attempting to increase C_L.

Assuming that we are limited to running a single element wing, and that dimensional restrictions also apply, what parameters could we alter to increase C_L and so obtain more downforce? There are two parameters we could look at: thickness and camber. This month we'll look at thickness, and next month we'll consider camber.

The usual textbooks give somewhat contradictory information on wing thicknesses. One cites work done on NACA wing profiles suggesting C_L peaks at 12 per cent thickness (thickness expressed as a percentage of the chord dimension), while another intimates that increasing thickness over 12 per cent has little effect on maximum C_L. So, Advantage CFD took a new look at thickness using basic 2D methods, and the results were rather different to what either of those textbooks stated...

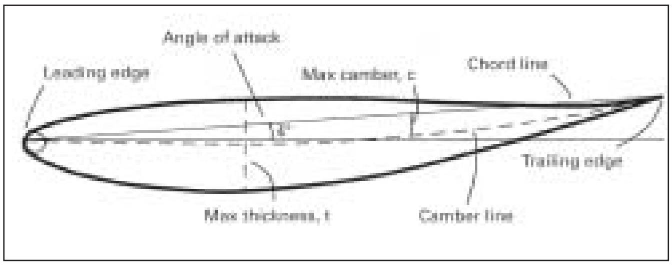

Figure 1: wing terminology

A range of wing models was drawn using the NACA 632-615 profile as a generic start point. This gave maximum thicknesses ranging from eight per cent of chord to 24 per cent of chord, all with maximum thickness located at the same point along the chord. The CFD evaluations were then run at 50m/s (180km/h or 112mph) at angles of attack ranging from zero to 16 degrees. Downforce values versus thickness at angles in this range are shown in figure 2, and a number of conclusions may be drawn.

First, it is very evident that maximum C_L does not peak at 12 per cent thickness. In fact, C_L continues to climb with increasing thickness, but peaks at values that are dependent on angle of attack. At the shallowest angles tested, zero degrees and four degrees, peak C_L occurs at the maximum thickness evaluated, although gains have begun to tail off at around 20 per cent thickness. At eight degrees, maximum downforce occurs with 20 per cent thickness, while at 12 degrees maximum downforce is achieved with 18 per cent thickness. What initially seems to be a trend towards slightly lesser thicknesses producing best downforce at steeper angles is, however, reversed by the 16 degree plot, which shows almost identical peak C_L values at 18 and 20 per cent.

From this we might reasonably conclude that we could expect downforce to increase with increased thickness, up to a practical top limit of around 18 to 20 per cent thickness if angles of attack up to 16 degrees are likely to be run.

It is apparent that some data points have been left off this graph, and the reasons could be significant when it comes to choosing an appropriate wing thickness. Specifically, the thinner sections exhibited what is known as 'leading edge separation' at the steeper angles of attack of 12 degrees and 16 degrees. This had the effect of causing early, abrupt stall, and highly unsteady flow conditions aft of the leading edge. In other words, the thinner wings evaluated here cannot, it seems, be run at steeper angles. While 2D CFD may make this potential problem appear worse than it actually is, leading edge separation is a well-known phenomenon

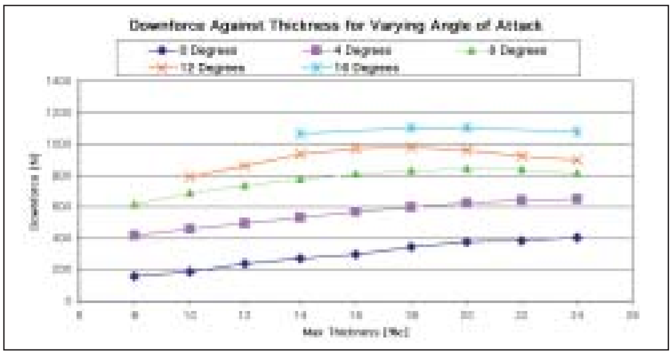

Figure 2: downforce versus thickness

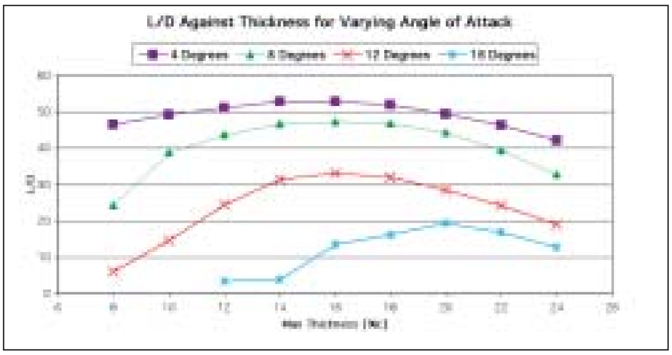

Figure 3: lift to drag ratio versus thickness

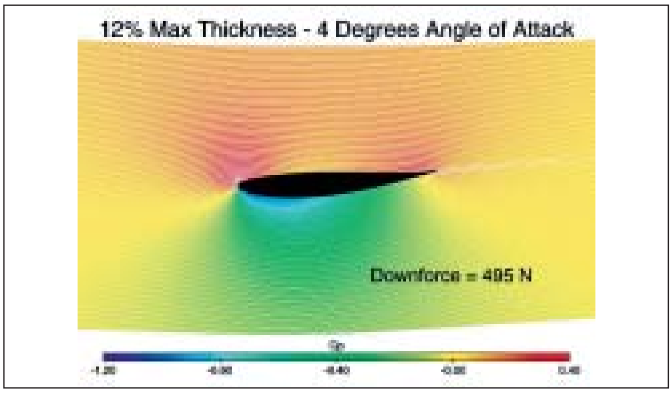

Figure 4: pressure-coloured streamlines at 12 per cent thickness, 4 degree angle of attack

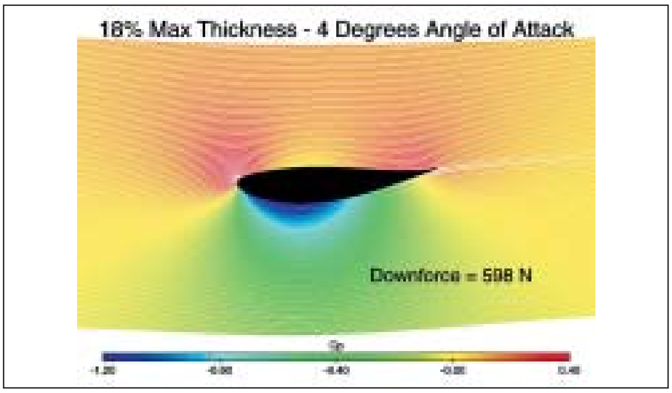

Figure 5: pressure-coloured streamlines at 18 per cent thickness, 4 degree angle of attack

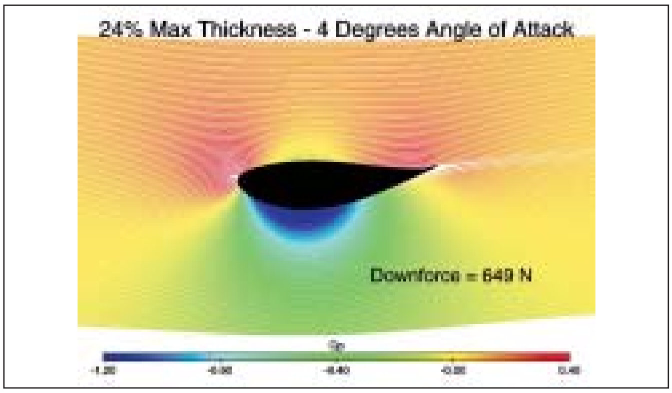

Figure 6: pressure-coloured streamlines at 24 per cent thickness, 4 degree angle of attack

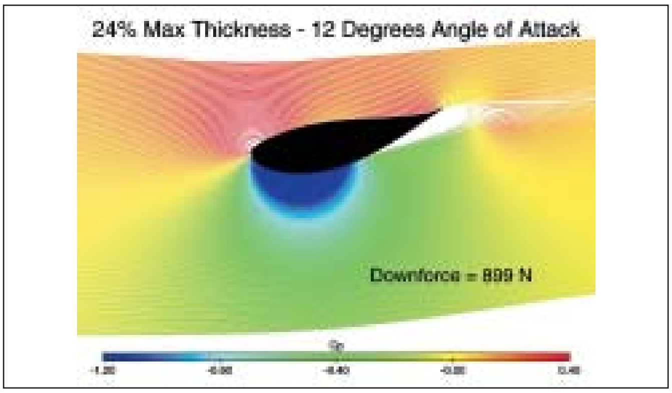

Figure 7: a step too far – too thick and too steep has caused trailing edge separation

that can be avoided in a number of ways. One way is to use a profile with a more generous leading edge radius that gives the air an easier passage around the forward part of the wing.

So, while thicker sections appear to be the way to go, as ever, maximising downforce may not provide a sufficiently complete picture.

What about drag?

Clearly, increases in downforce will lead to increased drag anyway. But what can be illustrated from these evaluations is that the thicker wing sections, not at all surprisingly, generate greater 'profile drag'.

Drag can be said to come in two main varieties: profile drag and induced drag. Profile drag is the sum of viscous drag (arising from friction between the wing and the air flowing over it) plus pressure drag (the sum of all the pressure variations over the wing caused by the air flowing around it). Induced drag, otherwise known as vortex drag, is directly associated with the generation of lift (downforce), and is invariably the major cause of drag associated with wings. 2D CFD, by definition, does not take 3D effects like vortex generation into account, so it does not calculate induced drag. But it does calculate profile drag which, like induced drag, also changes with angle of attack.

In order to gain an insight into the efficiencies of different wing thicknesses, figure 3 plots L/D (lift to drag ratio) against wing thickness. Again it is evident that efficiency changes according to angle of attack and thickness – L/D being at its highest at the shallower angles where lower drag is generated. But of more interest here is that in general, peak L/D occurs with a wing section of 16 per cent thickness from four to 12 degree angle of attack. Intriguingly, at the steepest angle of attack, 16 degrees, maximum L/D occurs with 20 per cent thickness, and this is obviously down to the high downforce generated in this case.

Best efficiency could generally be expected using a thickness of 16 per cent, unless it was anticipated that the wing would be run at its steepest angle most of the time, in which case a thickness of 20 per cent might be more efficient. A good compromise between maximising downforce and efficiency could be to run a wing with around 18 per cent thickness, inclining slightly one way or another depending upon the principal aim.

Figures 4 to 6 use pressure-coloured streamlines to illustrate the development of increased low pressure, and hence greater downforce, going from 12 per cent to 24 per cent thickness, all at four degrees angle of attack, while figure 7 shows a step too far, 24 per cent thickness proving to be excessive at 12 degrees, with trailing edge separation occurring. RE

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