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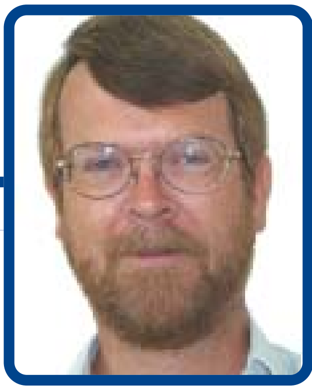

Dual element wings

Still more downforce required? Try adding more wing elements… We explain the benefits and pitfalls

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Multiple element wings bring benefits through less separation and consequently more downforce. There are, however, downsides

In the last three issues we've revisited the basic parameters of single element wings, and reminded ourselves that in the presence of dimensional constraints, squeezing more downforce from a wing requires manipulating its 'lift coefficient'. Increasing its angle of attack, thickness or camber can achieve this. If you want still more downforce, and the rules permit it, you could also consider adding wing elements. This month we'll use some CFD analysis and imagery to show the advantages that dual element wing configurations can bring.

The model set up by Advantage CFD on this occasion used as the main element the generic wing section on which the single element analysis of the last three issues was based. A second element, or 'flap' as we'll call it for brevity, with a chord approximately 40 per cent of the main element, was located near the trailing edge of the main element at a position the writer had established (on a different wing) in wind tunnel testing a few years ago (documented in V10N2). To enable direct comparison with the single element data, the overall chord dimension of the dual element device was made the same as that of the single element. A virtual airflow of 50m/s (180km/h or 112mph) was again used in these 2D simulations.

The two parameters that were altered in this set of trials were the angle of attack and the overall camber of the dual element device. Camber in this case represented the curvature of the wing from the leading edge of the main element to the trailing edge of the flap. Camber values of 9, 12, 15 and 18 per cent were investigated, where this value represents the maximum deviation of the camber line (the line joining the mid-points between upper and lower surfaces) from the chord line (leading edge to trailing edge). Figure 1 shows the base model used. The slot gap between the two elements was kept constant throughout in order to maintain the same flow incidence between them.

Figure 2 plots the results of all the variously cambered dual element wings against angle of attack, and figure 3 displays the results of the cambered single element wings, also against angle of attack, but this time scaled to the same chord value for a direct comparison.

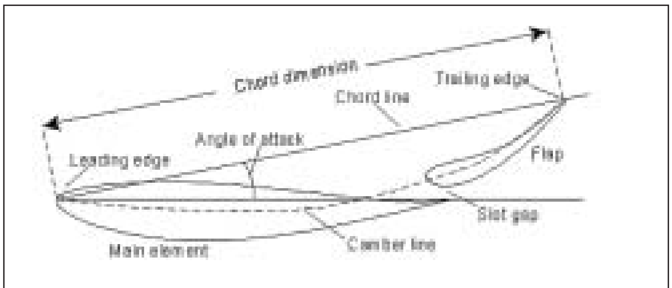

Figure 1: guide to dual element wing terminology as used in the feature

Produced in association with Advantage CFD.

advantage CFD

Tel: **+44 (0)1280 846806**
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Initial observations

A number of observations relating to the dual element configurations are immediately apparent. First, the downforce values were higher than those generated by the single element wings right across the range of angles and cambers studied. Second, the stall angles were higher – around 19 degrees – compared to 12–14 degrees, enabling more downforce to be generated. And third, higher camber values could be used, 12 per cent camber being an effective maximum in the case of the single element example whereas gains were still accruing at 18 per cent camber in the dual element case, this again enabling increases in downforce to be generated. Table 1 gives some comparative results at the same angles and camber values, scaled to the same chord value.

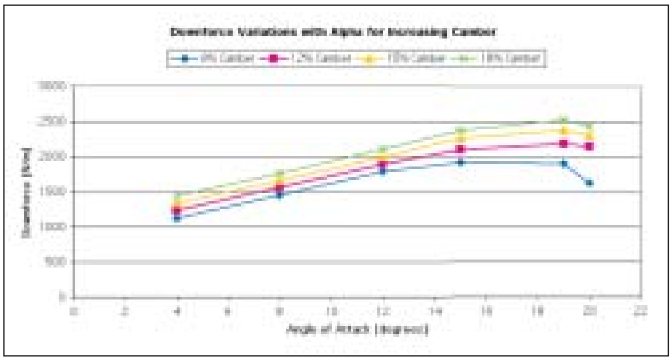

Figure 2: downforce versus angle of attack for a dual element wing over a range of different camber options

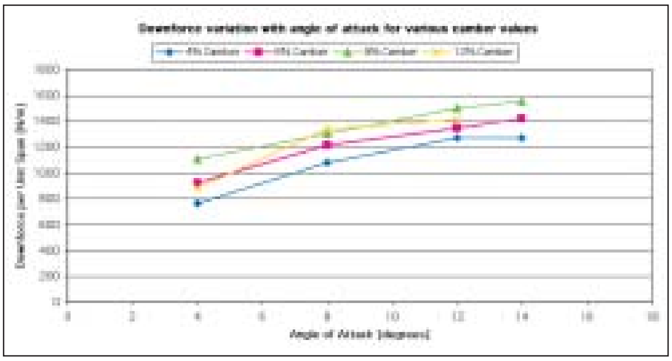

Figure 3: downforce versus angle of attack for a single element wing over a range of different camber options

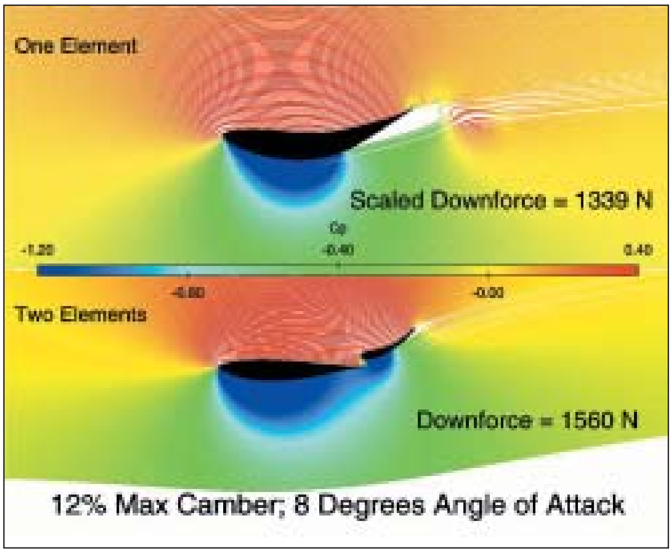

Figure 4: pressure-coloured streamlines at 12 per cent camber and 8 degrees on the single and dual element wings

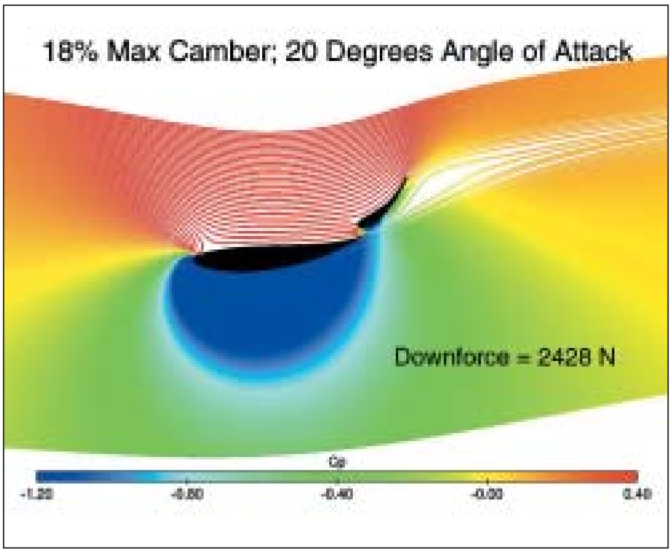

Figure 5: pressure-coloured streamlines around the dual element wing at 18 per cent camber and 20 degrees

Table 1

Angle of attack, degrees	Camber, %	Single element downforce, N	Dual element downforce, N	Increase, dual over single, %
4	9	1107	1122	1.4
8	9	1302	1452	10.3
12	9	1501	1784	15.8
4	12	1158	1237	6.4
8	12	1339	1560	14.1
12	12	1410	1886	25.3

Clearly, at low angles of attack there is little to choose between single and dual element (of the same chord) in terms of downforce, but as angle and camber are increased the gains from the dual element device get ever larger, with substantial gains being available at high angle and camber values. (Where permitted, if a flap were added to a main element so that chord actually increased, then downforce would also increase in proportion to the increase in chord, as well as the increase in lift coefficient.)

What mechanism(s) enables these much higher downforce values to be generated? Figure 4 gives a clue. It can be seen that the single element device is exhibiting flow separation at 8 degrees and 12 per cent camber, whereas at the same angle and camber the dual element device shows a much more extensive low pressure (blue) region beneath the whole main element and the flap. Figure 5 shows how far this particular set-up can be pushed. At 18 per cent camber and 20 degrees, which is just past the downforce peak of 19 degrees, the flow is still fully attached to the lower surface of the main element, and substantially attached to the flap, with significant downforce being generated.

The interaction between main element and flap is clearly a powerful one. In the aforementioned article 'Wings and flaps' in V10N2 we covered current theory on the mechanisms involved in this complex interaction. In essence, the main element and the flap modify the flow on each other beneficially to reduce the likelihood of separation on both. Needless to say the slot gap, which was the main topic in V10N2, is important too, though that aspect was not looked at in this particular study. These factors enable a multi-element wing to run at steeper angles without stalling, and to develop greater pressure differentials between their upper and lower surfaces, as is very apparent from the graphics here.

No free lunch

But whereas downforce gains are large, it will be no surprise that there's no free lunch here. Drag increases as wings are worked harder, and 'efficiency', as defined by the lift to drag ratio, tends to suffer. But notwithstanding increases in drag, it is apparent that large increases in downforce are available through the use of a dual element wing instead of a single element device. Clearly though, 3D CFD, or some other form of testing, or theoretical calculations (probably backed up by, at best, inspired guesswork) would be required in order to determine the efficiency of any wing configuration in relation to its potential use.

We may come back to look at more complex wings later in the series. Meanwhile, next month we'll start looking at airdams and splitters.

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