The MCR 4S wing

How can you cruise at 130 kt, land at 45 kt, and lift four adults, fuel and luggage on just 100 hp? The answer lies in a very clever wing design that might well point to the future for GA.

By ***Christophe Robin****.*

WE SET OUT TO design an aircraft which on 100 hp would be genuinely capable of carrying four people, their luggage and adequate fuel, with performance equivalent to some of the best cross country aircraft on the market. Furthermore, it had to be capable of operating from short grass airfields.

Basically, once you've chosen your engine (a Rotax) and made space for four people, you have your fuselage. From then on, it's all down to the wing.

The main problem is resolving an impossible dilemma: you need a small wing for low drag, but a large one for STOL performance on little power. Then there are the structural questions—finding space for fuel, and making the wing strong enough for undercarriage loads, yet light; our target weight for the equipped wing was just 70 kg.

Much of the work had been done and tested on the ultra-light version of the MCR two-seater in 1998; the MCR ULC wing was designed in 1996 in conjunction with Monsieur Colomban. The

When you fly it, the MCR 4S feels as though a much smaller aeroplane has been grafted onto a roomy four seat cabin—and the secret's in the wing.

wing for the 4S was a development of this earlier wing, and part of Dyn'Aero's continuous program for transforming the efficiency and performance of small, light aircraft.

To resolve the small/large wing dilemma we copied the solution on Boeing airliners. The big jet makers aim for a cruise speed four times higher than stall speed—in our little four-seater, 140 kt and 35 kt—and achieve this ratio by using high lift devices. These provide first, high lift and high drag for landing, second, high lift and low drag for take-off, and third, low drag and moderate lift at cruise.

It was clear that the key to our problem would be a very efficient high lift device which would somehow provide all these three very different combinations.

In order to start with some good solid wind-tunnel-tested data, we looked at existing profiles like the four- and five-digit NACA series. At an early stage we decided to avoid laminar profiles because, though low drag in cruise, they don't work well with large secondary surfaces—flaps and ailerons—generating a strong nose-down pitching moment and giving rise to load difficulties.

Once having chosen a likely NACA five-digit profile, we worked on improving it with step by step modifications. The hundreds of wind tunnel tests that had been carried out provided empiric ratios that enabled us to predict mathematically the effect of changes in dimensions or shape. We also worked by eye, less scientifically, but 'what looks right, flies right'.

The solution to our requirements was to have two flaps, one contained inside the other. The main flap would be the Fowler type that when retracted forms part of the wing profile, but when lowered also moves back, leaving a slot between the wing and the flap and increaseing effective wing area. Because air is forced through the slot, it is a means of enhancing airflow over the upper surface of the wing, lowering relative pressure, and increasing lift. By 'blowing' the trailing edge, the airflow at the trailing edge is accelerated, which delays the stall on the main body. Nothing is free, of course, and the downside is a considerable increase in drag, but this is acceptable during take-off when the airspeed is relatively low.

The second, intermediary flap would only come into operation in the landing phase, when the main flap was fully lowered. The intermediary flap then interposed itself in the enlarged slot between the main flap and wing, making

two slots and increasing lift even further, and also dramatically increasing drag and helping to slow the aircraft down.

As this double-slotted flap structure took shape it became apparent that we would need an even thicker wing section to support the flaps, which were going to be exceptionally large. Even with this thicker wing, we would have to design it carefully to make it adequately strong and stiff.

Before leaving slotted flap theory, I might mention one more benefit. Normally you increase lift by raising the angle of attack, but this creates a big requirement for download from the tailplane and elevator, which is very inefficient. It creates drag and necessitates large surfaces that must be built strong and therefore heavy. A much more elegant solution is to increase lift without raising the angle of attack, which is where the slotted flaps come in. Actually, the cruise load on the horizontal tail surfaces in the 4S is just about neutral, so they create very little drag.

Finally, a small wing behaves much better in turbulence—another benefit of slotted flaps, and the high aspect ratio wing improves roll rate.

The double-slotted flaps gave us a maximum lift coefficient for the wing in landing configuration 2.5 times greater than in its cruise configuration—an enormous improvement on the usual figure on similar aircraft of around 1.5. Also, we achieved a ratio of 1.5 (usually 1.15) with the flap in the take-off position together with a lift-to-drag ratio equivalent to the cruising position. This gives the

The sculpted wingtips help, but are not essential—early MCR 4S aircraft flew well without them.

The trick lies in the Fowler flaps.

same rate of climb with better climbing angle with the flap at take-off position as without the flap. Usually, on light aircraft, the first position of flap creates a lot of drag and reduces the rate of climb. (This advantage allowed us to make a very efficient glider towing version of the MCR ULC in 1999.)

Once you have the profile, you still have to install it on a wing. Keeping the characteristics of a wing section on a completed wing is not the easiest thing to do.

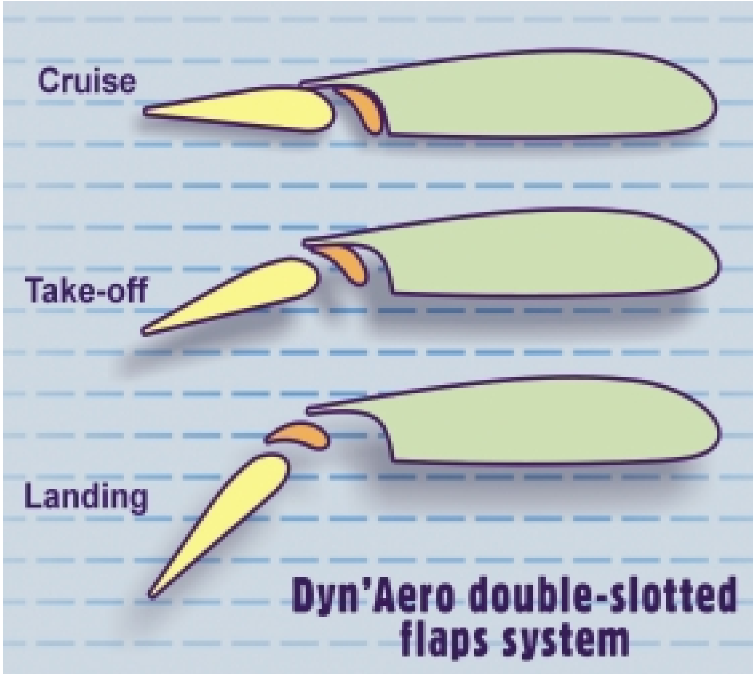
The flaps were so integral to our solution, we wanted to install as much flap as possible on the wing span. That meant designing an efficient aileron with the smallest possible span. Having a short span, long-chord aileron would have implications for the structure and the lateral characteristics of the aircraft.

We designed a very deep aileron—more that 40% of the wing chord—with a tiny span of less than 3 feet. The whole design had to be optimized for a very high efficiency, so to prevent adverse yaw the leading edge of the aileron was designed to protrude underneath the wing when the trailing edge was raised and we built in a differential between the up and the down aileron.

Three-quarters of the wing trailing edge is fitted with flaps, a very high proportion.

The aspect ratio of 9.4 is also is also quite high for a light aircraft. The wingspan of 28 ft 7 in is modest enough to make parking and hangarage easy.

As the wing was first designed for the MCR ULC with a much lower take-off weight (450kg) than the 4S, we added washout to the tips of the four-seater. This was primarily to improve the stall characteristics for what is intended to be a family aircraft, but it has also had a beneficial effect on the

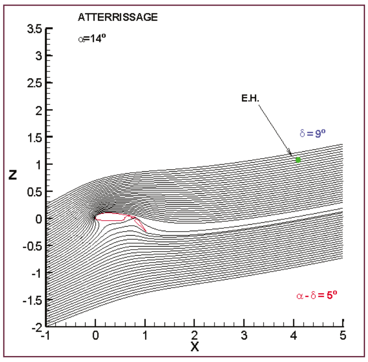


Two flaps double the slot effect, and massively increase wing area. The flaps are huge in relation to the wing and leave little room for the ailerons.

rate of climb.

A lot of development went into designing the winglets (sculpted wing tips), and this came late in the wing's design. The first year of flight (2000) was made with the standard MCR ULC wing tip that was designed more for cruising conditions. Meanwhile we were working with ONERA (Office National d'Etude et de Recherche Aéronautique, the main aerodynamic office of France) on a special winglet. The objective was, while keeping the wingspan, to lower the drag in the climb condition without creating any additional drag in cruise.

This was done with three-dimensional aerodynamic optimisation numerical methods, then tested in a wind tunnel and in flight trials. We ended up with an 8% gain of the drag coefficient in climb and no penalty in cruise. It has also added a lot of directional and lateral stability, which is always



a good thing for cross-country aircraft. The winglets are now standard on the MCR 4S.

The wing design doubles the lift coefficient from the cruising configuration to the landing configuration. The lift coefficient on the landing configuration is similar to a B737 or A320.

We had to be very careful in testing all new aerodynamic features of this wing especially near and through the stall, including fully developed spin testing. (Mostly pioneered, as was much of the wing's development, on the MCR ULC that preceded the 4S).

One risk of our design was the very high pitch down effect of the flap that could give rise to an elevator stall, with a complete loss of control of the aircraft on the horizontal axis. We chose a T-tail configuration partly to minimize this risk. In the 4S the pilot does not even feels the pitch-down effect of the flaps because it is compensated by an automatic deflection of the tailplane.

The wing, both in the MCR ULC and in the 4S has been successfully tested through the JAR 23 standard, including spinning, and more than 150 aircraft have flown successfully. At the time of writing 12 MCR 4Ss are flying in France, Germany, Italy, and Holland.

Our aim was that the aircraft should weigh less than 350kg empty, when all the four-seaters on the market were at least 75% heavier than this. It was important that the wing was strong, but also

Note the small tail surface to minimise drag. The wing is designed to keep down pitch moment from extending flaps. Even so, the tailplane is automatically deflected to relieve the load, and benefits from being set on top of the fin, away from turbulent airflow.

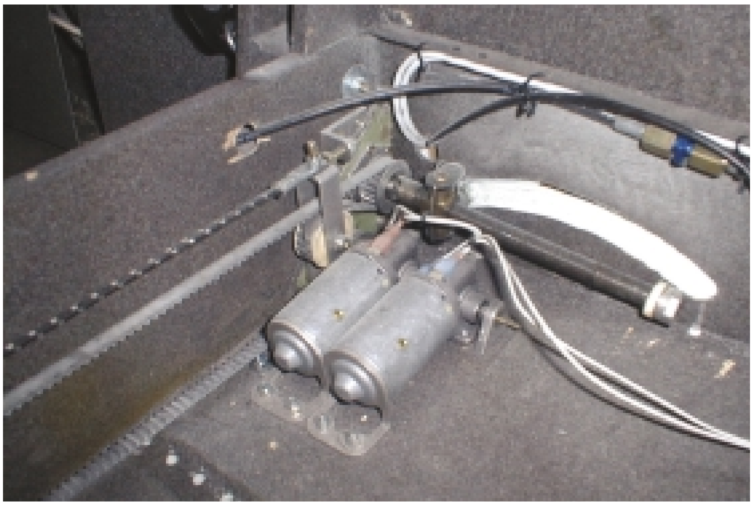
very stiff because of its high cruising speed, so it was clear that we would have to make extensive use of carbon fibre. The wing is skinned with an unsymmetrical sandwich of carbon fibre. Its inner layer is designed to take the tortional load, and the 'meat' is 6 mm PVC foam. The fibres in the inner skin are laid at opposing 45° angles to line of flight, but in the outer layer the fibres are laid chordwise. The inner skin thickens progressively towards the root.

Inside each side of a wing there are eight equally spaced ribs. Structural ribs and those near the fuel tanks are beefed up with carbon fibre, but those outboard are made from foam. The tanks are in three compartments, each holding 42 litres. (A long range alternative has five compartments per wing.)

The spar technology had been initially designed in 1993 for the Dyn'Aero aerobatics aircraft, especially the CR100 (the two seat, side by side, 180hp training and competition aircraft that started the company in 1992). It is a wood, foam and carbon fibre technology that ends up with very light wing spar, and very easy quality controlled to ensure safety. The spar caps are wood and fibre, both with opposing 45° grain, separated by wood at attach points, and foam elsewhere. This technology has been continuously improved through all Dyn'Aéro aircraft (1996: MCR01, 1998 MCR ULC and MCR CLUB, 2000 MCR 4S).

On the MCR 4S we chose a one-piece wing with a double spar. The landing gear is mounted on the wing, and the aircraft is not designed to be de-rigged very easily like the two-seater versions. The two spars were required to fit the feet of the passengers in between, and made a thinner, more aerodynamic and lighter fuselage. Also, we wanted to be able to put as much as 200 liters of fuel (10 hours of flight at cruise setting), which meant filling up the entire wing.

We ended up with a 52 kg (118-lb) wing without equipment and 70 kg (159 lb) with flaps, ailerons, fuel tank, winglet and landing gear attach structure, which met our design criteria. The MCR 4S reached all its objectives with a 130 kt cruising speed on 100 hp (145 kt in altitude with the turbo), a stall speed of 45 kt, and an empty weight of 350 kg for a maximum take off weight of 750 kg.



To be effective, the ailerons have to make up in chord what they lose in span.

The massive control surfaces put additional strain on the wing, but carbon fibre has enabled it to cope without becoming in the least heavy.