ACCIDENT

Aircraft Type and Registration:	Dyn'Aero MCR-01 ULC, G-BZXG
No & Type of Engines:	1 Rotax 912ULS piston engine
Year of Manufacture:	2001
Date & Time (UTC):	30 December 2007 at 1210 hrs
Location:	Burgham Park Golf Course, near Felton, Northumberland
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - 1 (Serious) Passengers - 1 (Serious)
Nature of Damage:	Aircraft destroyed
Commander's Licence:	Private Pilot's Licence
Commander's Age:	38 years
Commander's Flying Experience:	2,000 hours (of which 50 were on type) Last 90 days - 20 hours Last 28 days - 5 hours (All hours are approximate)
Information Source:	AAIB Field Investigation

Synopsis

The pilot and his passenger, who each owned a half-share in the aircraft, were making a short flight between two airfields about 4 nm apart. As the aircraft joined the circuit to land, at a height of around 800 ft, there was a 'bang' as the tailplane separated and fell to the ground. The aircraft became uncontrollable and descended into trees. The occupants survived the impact but both received serious injuries.

The tailplane attachment lugs had failed in upload and metallurgical evidence showed that a stress corrosion mechanism had been present. Two Safety Recommendations are made.

History of the flight

The pilot and his passenger, a professional pilot, planned to fly the aircraft from a farm strip at Longframlington to nearby Eshott Airfield. At Eshott they were to meet some friends who had another aircraft and the plan was to fly both aircraft in company further afield.

The pilot prepared the aircraft for flight, which included putting in around 15 litres of fuel. With both persons on board, the aircraft taxied and took off from the north-easterly grass runway. The takeoff and initial climb to around 1,000 ft agl were uneventful and en route only light turbulence was encountered. As the aircraft was approaching the crosswind leg of the circuit for Runway 18 at Eshott a 'bang' was heard by both occupants as well as by a number of persons on the ground.

The passenger looked backwards and saw that the tailplane had detached and was floating away behind the aircraft, which then started to turn and tumble. He made a brief 'MAYDAY' call and took over control but was unable to do more than attempt to steer the aircraft towards an area of trees.

The aircraft fell through the trees and crashed into the bank of a small stream. Both occupants were seriously injured but remained conscious, despite being trapped in the wreckage. A number of persons quickly arrived at the scene but it was some time before the pilot and his passenger could be cut free by the rescue services.

The pilot was taken to hospital by air ambulance and to avoid further delay the passenger was taken to hospital by police helicopter.

Pilot information

The pilot had started flying on flex-wing microlight aircraft types, qualifying for his PPL (Microlight) in 1999. In April 2006 he converted to a three-axis fixed wing microlight type. In June 2006 he purchased G-BZXG and since then he had flown regularly, accumulating a total of around 50 hours on the aircraft.

The passenger was a professional pilot. Since buying his half-share in the aircraft he had flown it only a few times.

Meteorological information

The synoptic situation showed a weak occluded front lying over northern England at the time of the accident. There was an overcast layer of cloud between 2,000 and 3,000 ft; visibility beneath the cloud was good. The surface winds were light and variable, as were the low level winds. The passenger on the aircraft reported that the flight conditions had been good.

Aircraft description and history

The Dyn'Aero MCR-01 ULC is a very light kit-built aircraft with a low wing and an all-moving tailplane mounted on top of the fin. It has two seats, side by side, and a predominantly carbon fibre composite structure. The aircraft has manual primary flying controls, with feel augmentation achieved by the use of elastic bungees. The tailplane is controlled via carbon fibre pushrods operated by the dual control sticks. The tailplane also has a trim tab, operated on G-BZXG by a fixed rod connected between the tailplane and an electric pitch trim motor located in the fin. The pitch trim motor was operated via a switch on the instrument panel; this electric trim system is not standard on the MCR-01 but was fitted by the original builder.

G-BZXG, built in 2001, was the first MCR-01 ULC in the UK and as such, it was flight tested by the Popular Flying Association (PFA), now the Light Aircraft Association (LAA). Their report commented that the

> *'aircraft had generally weak but positive pitch stability, static and dynamic, stick-fixed and stick-free'.*

In 2006 the PFA became aware of an incident involving G-BZXG which had occurred in 2002 that resulted in damage to the tailplane. The PFA grounded the aircraft for the fitment of a new, factory-supplied tailplane and pitch control rod. Once this work was complete, the Certificate of Validity was re-issued on 9 June 2006.

G-BZXG was registered to the current owner on 18 September 2006, since when it had flown in the order of 50 hours. When not in use, the aircraft was parked inside a hangar at Longframlington Airfield. The pilot used a purpose-made trolley to manoeuvre the aircraft on the ground.

Tailplane attachment

The tailplane is attached to the top of the fin via lugs which form the hinge point about which the tailplane rotates in response to pitch inputs (see Figure 1).

Early MCR-01 models, prior to 2001, have 4 mm thick aluminium lugs (‘Type 1’) which are integral to the tailplane and are riveted and glued to the vertical web of the spar during tailplane manufacture (Figure 2). This was superseded by the ‘Type 2’ fixing, with 7 mm thick aluminium lugs and external attachments, which was introduced for the MCR4S, a four seat model, and extended to all models from 2001. A ‘Type 3’ lug was introduced subsequently. This is similar to the Type 2, but has a 4 mm thick lug, to fit the fin mountings on early models.

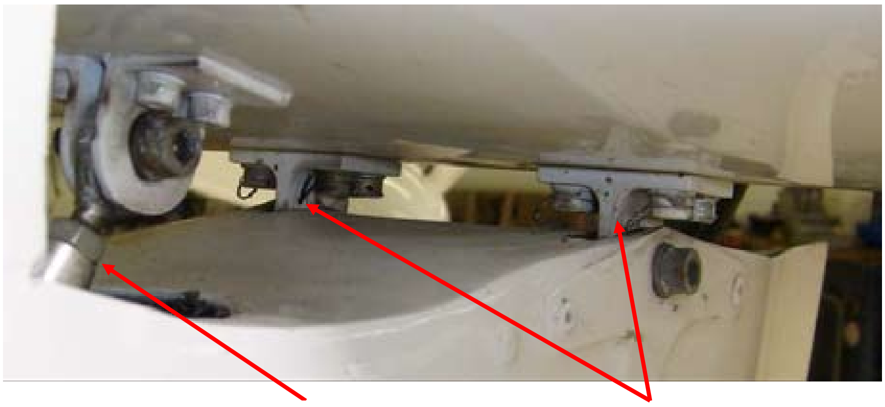
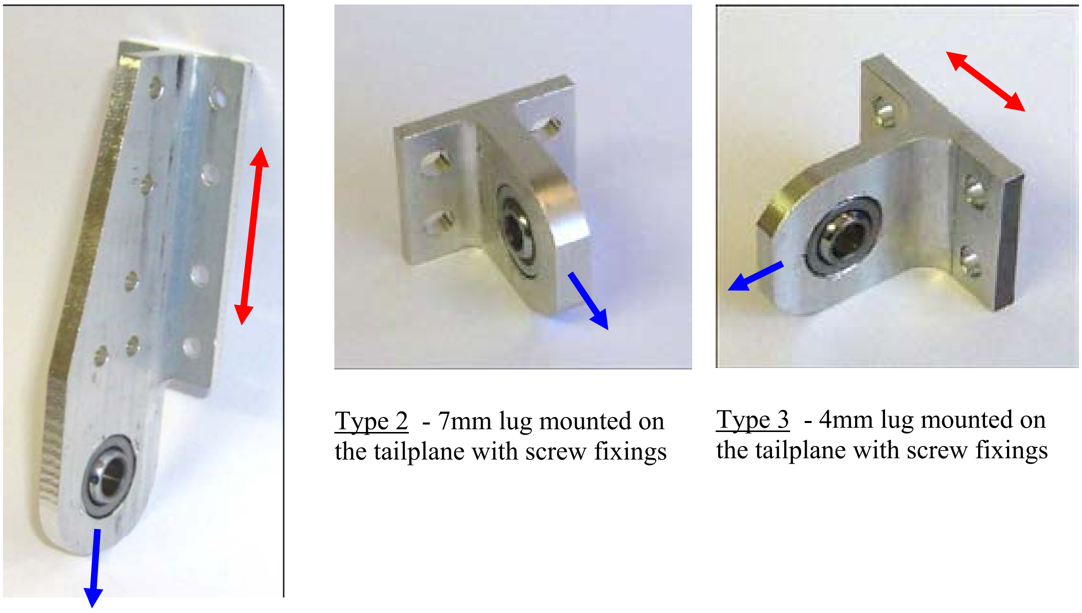


Figure 1

Tailplane attachment

(Photograph from Dyn'Aero BS 08 B 0034)

G-BZXG was originally fitted with Type 1 lugs. However, following the replacement of the damaged tailplane in 2006, newer Type 3 lugs were used, to enable the new tailplane to fit into the original fin mountings.



Type 1 - 4mm lug riveted and glued to tailplane spar vertical web

Type 2 - 7mm lug mounted on the tailplane with screw fixings

Type 3 - 4mm lug mounted on the tailplane with screw fixings

Figure 2

Different standards of tailplane fixing

(red arrows depict material grain direction and blue arrows the direction of applied loading)

(Photographs from Dyn'Aero BS 08 B 0034)

The lugs are machined from solid, rolled aluminium block in which the predominant grain direction of the material is parallel to the direction of rolling of the block. Figure 2 shows the material grain direction specified for the Type 1 lug and the grain direction for the Type 3 lugs examined by the AAIB. Material properties can be markedly different when applying load parallel, or perpendicular, to the direction of the material grain boundaries. The Type 1 lug is manufactured with the grain direction oriented longitudinally, such that the applied loads act along the direction of the grain, which is the ideal condition. The grain direction for the Type 2 and 3 lugs is not specified and thus, in theory, can be in any orientation. However, all the Type 3 lugs examined by the AAIB, including those from G-BZXG and new lugs provided by the manufacturer for testing, had a transverse grain direction. For such lugs, the applied loads act perpendicularly to the grain direction, which is the least preferable condition as the material is weakest in this direction. The aluminium alloy used for all three types of lug is a French specification AU4GN, which is similar to 2017 T4 or T451 alloys.

On-site wreckage examination

The aircraft had come to rest on the edge of a stream with steep, wooded banks, between an area of open fields and a golf course. The aircraft had descended through the tree canopy and from the damage to the right wing it was evident that the aircraft had fallen with very little forward speed and in an approximately level, or slightly nose down attitude. The aircraft was intact apart from the tailplane which had detached completely and was found approximately 150 metres from the main wreckage.

The separation of the tailplane had resulted from the failure of the two lugs attaching it to the fin. The subsequent failures of the pitch control rod eye end and the trim tab control rod, which was probably the last connection to fail as it sawed through the underside of the composite tailplane skin (Figure 3), allowed the tailplane to finally detach.

The roll control and rudder system were checked and found to have been connected at the time of impact. The

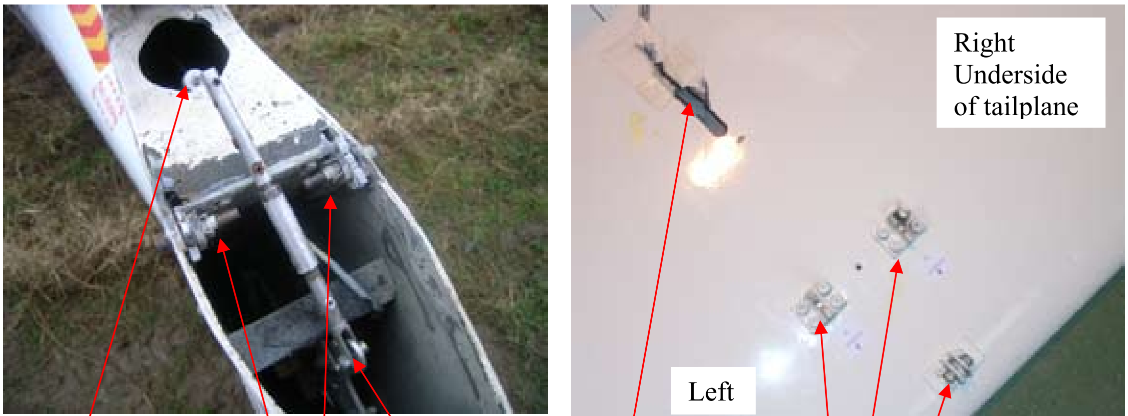


Figure 3

Top of fin (left) and underside of tailplane (right) pitch control system was intact and correctly connected, apart from the failure in bending overload of the pitch control rod eye-end that was attached to the tailplane.

The seat harness stitching was found to have been pulled through on both harnesses, although the attachment point for the shoulder harnesses was still intact.

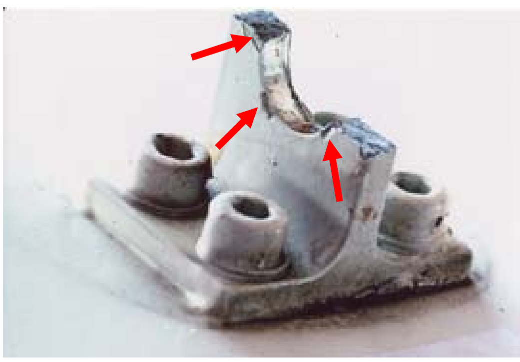
Metallurgical examination of the tailplane attachment lugs

The tailplane and its attachment lugs were subjected to specialist metallurgical examination. The separations in both tailplane lugs had occurred due to tensile overload, with the fracture surfaces aligned parallel to the grain direction. However, the left lug contained evidence of a stress corrosion mechanism, which was present prior to the accident and had weakened the lug.

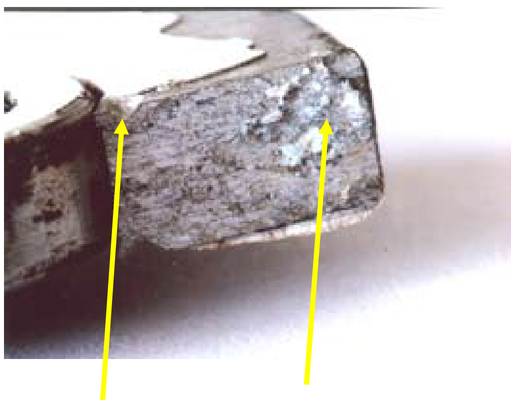
Some aluminium alloys are susceptible to stress corrosion, an intergranular cracking process, when simultaneously exposed to corrosive environments and tensile stresses of sufficient magnitude. (G-BZXG, although kept in a hangar, would have been exposed to an atmosphere conducive to stress corrosion in the normal ambient conditions present in the UK.) The stresses required for crack initiation and growth may be pre-existing or due to the applied loads, or a combination of both and can be far less than those required to fail the material in overload. Stress corrosion is aggravated when tensile stresses are applied perpendicular to the predominant grain direction.

The hinge bearings were of a spherical self-aligning type. The bearing in the left lug had been an interference fit, with hinge material having been pushed into the bore of the lug during assembly. The bearing was also rotationally tight and showed evidence of corrosion. The bearings were retained by means of staking. Significantly, the separations had all initiated at positions coincident with staking marks (Figure 4). (Staking is a method in which a tool, usually a punch, is used to locally deform the material at various locations around the bearing, thereby 'retaining' the bearing in place.) In this case the staking marks appeared deep and could therefore have given rise to areas of increased stress concentration with local distortion of the material.

A potential source of pre-existing (ie static) stress in the left hand tailplane lug is a misalignment between



Staking marks (arrowed)



Staking mark Area of stress corrosion

Figure 4

Left hand tailplane lug

(Photographs courtesy HT consultants)

the lug and the corresponding lugs in the fin, such that force would be required to engage the lugs with one another. However no evidence of lug misalignment was found.

No evidence was found of any surface conversion process such as anodising having been applied to the lugs. No primer had been used and the top coat of paint was not well-adhered.

Material testing

Testing of the lug material confirmed that it met the hardness requirements for AU4GN aluminium alloy. A test was also carried out to determine the maximum tensile strength of new 4 mm Type 3 lugs. The test was performed by applying a direct pull force to a new lug; the failure load was 1,776 daN. A further test was performed in which one side of the lug was deliberately severed in order to simulate the damage that, in this accident, had occurred due to tensile overload failure initiated by stress corrosion. In this test the lug failed at 138.1 daN.

CS-VLA requirements

The airworthiness requirements for the MCR-01 are laid down in EASA Certification Standards for Very Light Aircraft (CS-VLA). The structural requirements are specified in terms of limit loads (the maximum loads to be expected in service) and ultimate loads (limit loads multiplied by prescribed factors of safety). Unless otherwise provided, a factor of safety of 1·5 must be used. The tailplane is required to withstand balancing loads (loads to maintain equilibrium), manoeuvring loads, gust loads, as well as asymmetric loads arising from yawing and slipstream effects, in combination with the former factors. There is also a special requirement in CS-VLA ACJ 443:

> *'for aircraft where the horizontal tail is supported by the vertical tail, the tail surfaces and their supporting structure including the rear portion of the fuselage should be designed to withstand the prescribed loadings on the vertical tail and the roll-moments induced by the horizontal tail acting in the same direction.'*

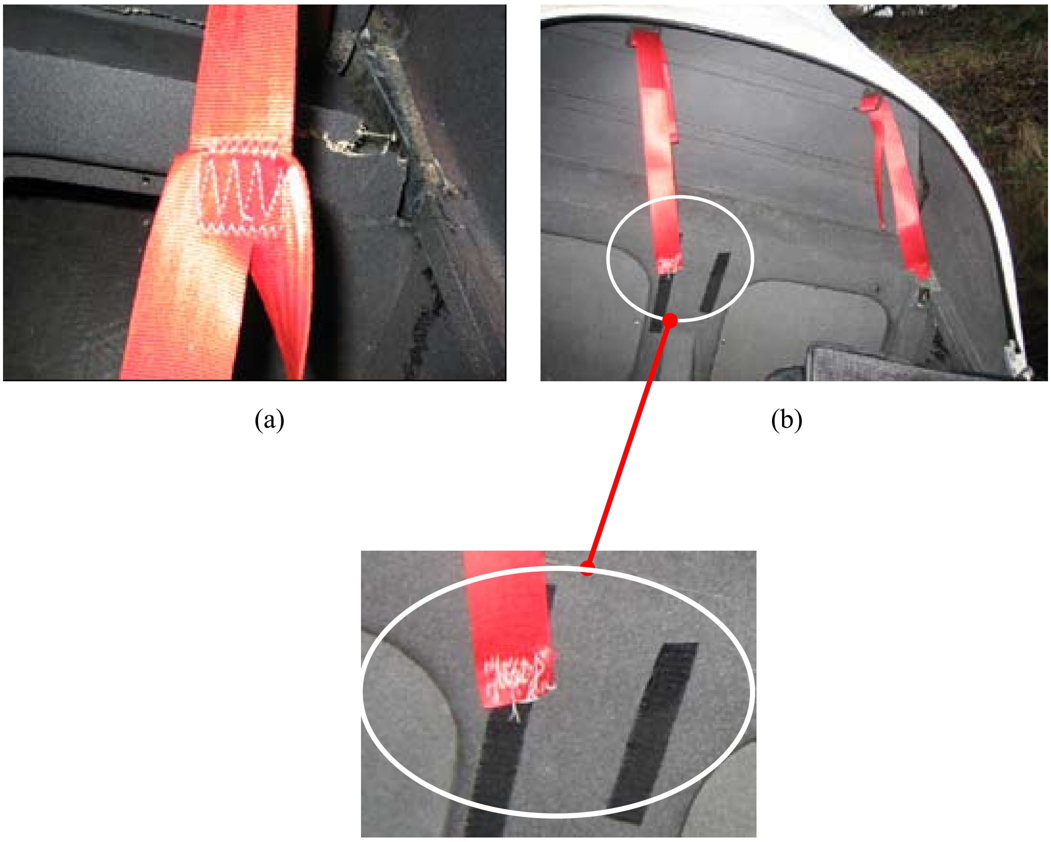
In the case of the MCR-01 this is the most limiting design criterion and the ultimate tensile load on the Type 1 or 3 lug is 1,162 daN.

Tailplane maintenance

The manufacturer's maintenance programme for the aircraft requires a check of the security of the tailplane attachments to be performed every 50 flying hours and calls for the tailplane attachment lugs to be greased at 3 month intervals. The maintenance records for the aircraft were not available for examination and so it could not be determined whether these maintenance requirements had been adhered to.

Survivability

The aircraft was fitted with two three-point harnesses. A single strap comes from the fuselage attachment point and is stitched onto the folded shoulder strap material. Both harnesses had failed in the area of stitching where the upper attachment strap was joined to the main harnesses (see Figure 5). CS-VLA requires the design of the seat harnesses and attachments to be capable of withstanding a 9g forward deceleration (CS-VLA.561). Shortly after the introduction of the aircraft type to the UK in 1998, the PFA issued a mandatory modification (MOD /301/001), to reinforce the harness attachment fittings with additional carbon fibre 'straps' at the rear of each fitting to improve the structural integrity of the fitting. The accident aircraft,



(a) (b)

Figure 5

Shoulder straps of pilot's harnesses showing (a) intact stitching from another aircraft and (b) failed stitching from G-BZXG

built in 2001 had this modification incorporated during its build.

The stitching on the harnesses was compared to a number of other examples of MCR01 and there was found to be significant variability in the stitching.

A static test was carried out by the aircraft manufacturer on a similar harness; the shoulder harness attachment failed at a load of 682 kg and the lap harness failed at a load of 1,115 kg. The CS-VLA requires the harness to withstand a longitudinal deceleration of 9g with an occupant weight of 86 kg. Thus the failure load required by CS-VLA would be 774 kg, and this load would be divided between the shoulder and lap harness attachments. The CS-VLA does not specify the load distribution; the manufacturer assumes 45% of the load to be reacted through the shoulder harness and the remainder through the lap harness attachment. The shoulder harness failed in the area of stitching where the upper attachment strap was joined to the main harness webbing, identical to the failure that occurred in the accident. There was also some deformation in the test of the upper attachment fitting which was not present on G-BZXG.

Safety action

As a result of this accident the UK Civil Aviation Authority (CAA) issued a Mandatory Permit Directive (MPD) 2008-002 on the 6 February 2008 which grounded all MCR-01 aircraft and variants. The French Direction Generale de l'Aviation Civile (DGAC) issued an Airworthiness Directive No F-2008-002 on 27 February 2008 which mandated an inspection and/or replacement of the tailplane attachment fittings in accordance with Dyn'Aero Service Bulletin (BS 08 B0034 issued on 13 February 2008).

The Service Bulletin (SB) required the identification of the type of fitting installed on each aircraft. If found to be the 4 mm Type 3 lug as described above, the lug must be removed and returned to the manufacturer for a replacement. The replacement is of similar dimensions, but manufactured from stainless steel with 'loose-fit' bearings which are glued in position, rather than the 'press-fit' bearings and staking previously used, which can introduce stress concentrations.

For aircraft fitted with the Type 1 or 2 lugs, the SB requires the removal of the fittings, or the entire tailplane in the case of the Type 1 lugs, to perform a detailed inspection of the lugs for corrosion or other defects. This must be repeated every 100 hours.

Dyn'Aero stated that the SB has been applied on around 500 aircraft in France, Germany and Switzerland and no defect has thus far been found. Some of the aircraft are 12 years old and are operated in potentially as corrosive an atmosphere as G-BZXG. There were only three aircraft flying with the Type 3 lug; these were removed and replaced with stainless steel lugs. No defects were reported on the returned lugs.

In the UK, the Civil Aviation Authority (CAA) have additionally required the replacement of the Type 2 lugs with a stainless steel equivalent (Dyn'Aero Procedure M EH NO 01, dated 13 March 2008) and for the Type 1 lug, the addition of a stainless steel external attachment bracket (Dyn'Aero procedure M BE NO TL, dated 14 May 2008).

Analysis

The aircraft was carrying out a short flight between two local airfields. The weather conditions were suitable and the flight conditions were good with perhaps some light turbulence. Given that the aircraft was joining the circuit to land when the accident occurred, the loads on the tailplane are unlikely to have been excessively high at this point. Without any warning, the tailplane detached from the aircraft and thereafter control was lost. The passenger, a professional pilot and the more experienced of the two pilots, took over control and sent a 'MAYDAY' radio message. He attempted to guide the aircraft towards the trees although there was little or no effective control. The aircraft then descended through the trees, a factor which probably reduced the severity of the final impact and made the accident survivable.

Both harnesses had failed in the impact, although the loads experienced were probably greater than the design requirement. Testing showed that the single row of stitching, where the upper attachment strap was joined to the main harnesses, is the point at which the harness will fail first.

The tailplane lugs had failed in upload; normal loading on a trimmed aircraft would place a download on the tail. However, in turbulence, manoeuvring or ground handling, uploads could be generated. The metallurgical evidence showed that stress corrosion had been present, weakening the left lug. The most likely failure mechanism would be for the stress corrosion to develop and cause one side of the left lug to initially fail. The remaining side of the lug would then fail at a much lower load as demonstrated by the testing. The complete failure of the left lug would then expose the right lug to much higher loads, causing it to fail rapidly. The subsequent overload failures of the pitch and trim tab control rods allowed the tailplane to detach.

There were a number of factors which could have contributed to the stress corrosion mechanism which precipitated the failure of the left hand lug. A key factor was that the applied loads were perpendicular to the orientation of the material grain in the failed lug. This situation had arisen because whilst the material grain direction was specified for the Type 1 lug, there was no such requirement for the Type 2 and 3 lugs. All the Type 3 lugs examined by the AAIB had a transverse grain direction. The material is weakest in the direction transverse to the grain orientation and loading in this direction is most likely to result in stress corrosion.

Other possible contributory factors may have been the deep bearing staking marks, which could have caused increased stress concentration in those areas around the lug, and the poor corrosion protection of the lug. It was also noted that the left bearing was rotationally tight and showed evidence of corrosion. This could have introduced additional stresses in the lug from elevator control inputs.

The fleet inspection indicated no evidence of any other similar failures although it would be very difficult to see and detect stress corrosion. The new design of Type 3 lugs, in stainless steel and without the requirement for staking the bearing with the attendant stress concentration effect, are designed to eliminate the possibility of a similar failure mechanism.

The Type 1 lug has been in use for up to 12 years, without any reported failures. This design, although having potentially similar issues regarding the staked bearing retention, does have a longitudinal grain direction and so may not be as susceptible to a similar stress corrosion mechanism. However, the Type 2 lug is of a similar design to the Type 3 and, although thicker dimensionally, and therefore able to sustain higher loading, does still have similarities in the method of staking the bearing. As the material grain direction is not specified, its orientation could be unfavourable. The following Safety Recommendations are therefore made:

Safety Recommendation 2008-45

It is recommended that the Direction Generale de l'Aviation Civile (DGAC) considers mandating the replacement of Type 2 tailplane attachment lugs on all variants of MCR models with a stainless steel replacement as described in Dyn'Aero Procedure M EH NO 01, dated 13 March 2008.

Safety Recommendation 2008-46

It is recommended that the aircraft manufacturer, Dyn'Aero, should consider informing owners of all variants of MCR models with the Type 2 tailplane attachment lug fitted, as identified from Dyn'Aero Service Bulletin (BS 08 B0034 issued on 13 February 2008), of the availability of a stainless steel replacement, as described in Dyn'Aero Procedure M EH NO 01, dated 13 March 2008.