SERIOUS INCIDENT

Aircraft Type and Registration:	Edge 540, G-EDGY	
No & Type of Engines:	1 Lycoming AEIO-540-EXP piston engine	
Year of Manufacture:	1997 (Serial no: 18)	
Date & Time (UTC):	1 May 2021 at 1220 hrs	
Location:	Overhead Tempsford Airfield (disused), Bedfordshire	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - None
Injuries:	Crew - None	Passengers - N/A
Nature of Damage:	Loss of right aileron and damage to right wing skin	
Commander's Licence:	Private Pilot's Licence	
Commander's Age:	45 years	
Commander's Flying Experience:	598 hours (of which 51 were on type) Last 90 days - 4 hours Last 28 days - 3 hours	
Information Source:	AAIB Field Investigation	

Synopsis

During an aerobatic flight, as the pilot applied a full left aileron control input, the centre hinge attachment for the right aileron failed. This allowed the right aileron to bend up in the centre and fail before detaching from the aircraft; only a small inboard section of the aileron remained attached. The pilot had sufficient control remaining to make a safe landing.

The investigation found that the centre hinge attachment for the right aileron failed due to fatigue cracks developing to such an extent that the parts were no longer able to carry the required load. These fatigue cracks had multiple origins indicating that they were not due to a material feature or flaw. The aircraft manufacturer has issued a Service Letter to all known owners recommending regular detailed inspections of similar aileron centre hinge attachments. The UK LAA has contacted all affected owners in the UK to ensure they are aware of this mandatory Service Letter.

History of the flight

The pilot planned to undertake a 30-minute aerobatic flight from Little Gransden Airfield, Cambridgeshire, during which he intended to practice two pre-planned display routines. The visibility was greater than 10 km and the surface wind was northerly at approximately 10 kt. Prior to the flight he added half a quart of oil to the engine, confirmed the wing fuel tanks were empty and checked the fuselage fuel tank was full (66 litres). The start-up, taxi-out, control checks and power checks were all normal. He took off from Runway 28 at

approximately 1315 hrs and flew the short distance to his intended practice area overhead Tempsford disused airfield (approximately 4 nm west of Little Gransden Airfield). As he approached Tempsford he climbed to the base of the clouds to confirm the cloudbase, which was 3,700 ft aal, then completed two steep turns to visually confirm the area was clear of other aircraft.

The pilot commenced the first display routine with a 45° climb followed by a 540° left roll to put the aircraft in a 45° inverted climb. He then pushed the nose forward to a vertical climb and rolled 90° to the right. As the aircraft slowed, he performed a stall turn to the left followed by a two-and-a-half turn knife edge spin, then recovered to a vertical dive. He pulled out of the dive with approximately 5 to 6 g leaving the aircraft at approximately 160 kt and 1,100 ft aal. He then initiated an aileron roll to the left but almost immediately heard a loud bang. His initial thought was that he had collided with another aircraft. He gently rolled the aircraft back to wings level and looked for the other aircraft but, not seeing any other aircraft, concluded that no other aircraft had been involved. He saw that the right aileron had detached from the outer and central hinge but could not see if it was still attached and hanging below the aircraft. The aircraft was still flyable but it felt heavy in roll, and he was concerned the remaining aileron may jam. He mentally rehearsed his abandonment drill in case he lost control of the aircraft. He pointed the aircraft back towards Little Gransden Airfield and made a Mayday call on the airfield frequency stating he intended to land on Runway 10.

As the pilot flew the aircraft back towards the airfield, he reduced speed to confirm the low-speed handling was acceptable. He completed his normal landing checks and tightened his harness in case the loose aileron affected the ground roll. He made the approach at 100 kt rather than the normal 80 kt to account for the single aileron. He made a smooth landing with the crosswind from the left and was able to taxi back to the hanger. Figure 1 shows the aircraft after it had been parked. The total time from the failure to landing at Little Gransden was 2 minutes and 20 seconds.

Figure 1

G-EDGY after landing, showing inboard hinge with section of aileron still attached and the distorted outboard hinge

Recorded information

A camera was fitted to the left-wing tip which recorded the whole flight. There was no other recording device fitted to the aircraft.

The images in Figures 2, 3 and 4 were taken from the camera and show the aileron failure.

Figure 2

Aircraft entering the left roll showing the right aileron failing upwards (circled)

Figure 3

Right aileron failure continued (circled, behind canopy)

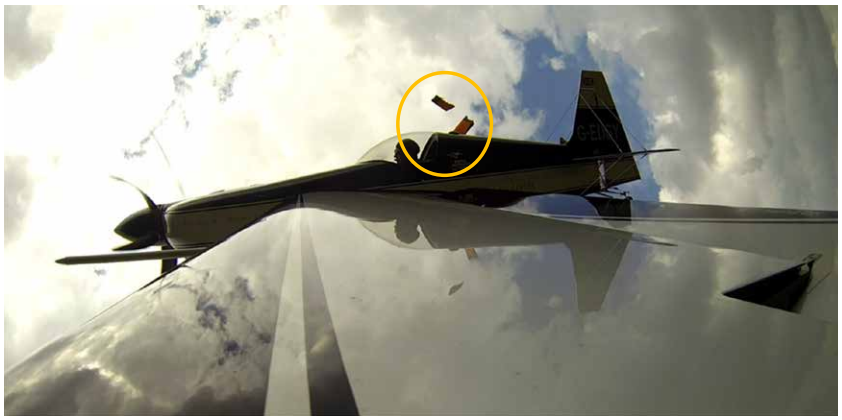

Figure 4

Parts of the right aileron departing the aircraft (circled)

Pilot information

The pilot held a private pilot's licence with a valid SEP rating and a Class 2 medical. He had accumulated 598 flying hours most of which were aerobatic flying. He regularly flew the aircraft in international aerobatic competitions at the advanced level.

The pilot reported that the routine he was flying was pre-planned to ensure that the aircraft remained within the limitations specified in the pilot's operating handbook for each manoeuvre. He was confident he had not exceeded any limitations during the accident flight. From his experience, he thought he would know if a manoeuvre had gone sufficiently wrong to exceed a limitation and that he would report this after landing. He was confident that the other people who flew G-EDGY would do likewise. So, he considered it was unlikely that the failure was caused by him or another pilot exceeding the aircraft limitations.

The pilot was asked what helped him manage the emergency when the aileron failed and how he was able to get the aircraft back on the ground safely. He reported that his aerobatic experience really helped as he was used to flying the aircraft into, and recovering from, unusual attitudes. He had also flown approximately 30 different aircraft types and he felt that this experience helped to reduce the startle effect when the failure occurred. He also recalled rehearsing his drill for abandoning the aircraft. It was useful to have a well-rehearsed drill to complete in the moments after the failure. He had previously experienced an engine failure and had needed to make a forced landing. He believed this previous experience helped him stay calm and manage the emergency.

Aircraft information

The Edge 540 is designed for unlimited aerobatics. The wings and full span ailerons are of composite construction. The ailerons are mass and aerodynamically balanced and are operated by push-pull rods. They are each attached by three hinge assemblies and a 'spade' is fitted to the inboard hinge attachment to assist control response.

There are three standards of aileron hinge attachment assembly fitted to Edge 540 aircraft.

There is an original standard of aileron hinge attachment assembly for which the manufacturer reported that there are no aircraft in service fitted with this design.

G-EDGY was fitted with aileron hinge attachment assemblies constructed from two aluminium, 2024-T3, 'L' shape brackets riveted to a flat distance piece containing a self-aligning bearing. These parts are anodised. The assembly is bolted to the rear spar of the wing and the aileron is attached by a bolt passing through the bearing (Figure 5). This standard of aileron hinge assembly has upgraded rivets compared to the original standard of aileron hinge assembly.

A new type of hinge, machined from a single piece of aluminium alloy, was introduced in 2010 when the aircraft underwent a design refinement and weight reduction review resulting in the Edge 540v3.

Figure 5
Image of centre hinge arrangement looking forward at wing rear spar

Maintenance information

The aircraft was built in 1997 and it had flown 1,270 hours. It was operated on a Permit to Fly which was valid until 31 March 2022. The last annual inspection was completed on 27 March 2021 and included an inspection of the aileron hinges in accordance with the manufacturer's service letter SB E54009. This required an annual inspection of the centre (and inboard) hinge mounting nuts and bolts, along with the rivets that hold the hinge attachment assembly together. This did not require the removal of the aileron. No anomalies were noted.

Aircraft limitations

The pilot's operating handbook specified a maximum manoeuvre speed (V_A) of 170 kt. The maximum speed for an aileron roll is also 170 kt.

Other operational information

The aircraft was primarily used for unlimited aerobatics during which roll inputs are often made aggressively to full deflection, up to V_A, to maximise the roll response of the aircraft. The aircraft is flown with the pilot's right hand on the control stick. Pilots of this aircraft type reported that they usually preferred to make rolls to the left as it is more natural to apply full stick to the left due to the position of their arm in the cockpit.

The owner was asked to make an estimate of the number of maximum control deflections used in left rolls that the aircraft had made, based on his experience in how the aircraft was used along with flying hours recorded in the aircraft log books. He estimated that around 23,000 cycles of rolls to the left with full control input had been completed.

Aircraft examination

The aircraft was initially examined at its home base along with the detached aileron parts, which had been recovered from the field in which they fell. The centre hinge attachment assembly for the right aileron had failed and the other two hinges, at either end of the

aileron, had been bent upwards. The aileron had separated from the outboard hinge, but a small section of aileron remained attached to the inboard hinge along with the 'spade' (Figure 1). This part appeared to have been flailing in the slipstream and had caused some damage to the wing skin.

The right aileron inboard hinge was disassembled to release the remaining part of the aileron, and the centre hinge attachment was removed from the aircraft (Figures 6 and 7). The intact centre hinge from the left aileron was also removed. The centre hinge parts from both ailerons and the failed aileron were taken to a specialist laboratory for detailed metallurgical examination.

Figure 6

Parts of the failed centre hinge attachment for the right aileron before removal from wing

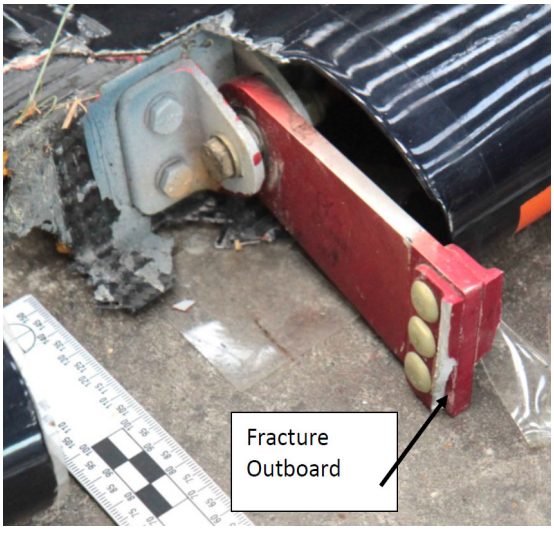

Figure 7

Remainder of the right aileron centre hinge attachment, still attached to the aileron

Detailed examination of the aileron centre hinge assemblies

Examination of centre hinges

A detailed examination of the failure surfaces was undertaken at a specialist laboratory using low and high magnification fractography techniques. This examination also included an assessment of the geometric and material conformity of the hinge parts and an estimate of the load cycles to failure using images obtained by scanning electron microscope.

The intact hinge assembly from the left wing was also examined. Evidence of cracking in the corner radii, in a similar area to those found on the failed right hinge assembly, was observed (Figure 8). To allow detailed examination, these parts were pulled open to failure using a machine. Once exposed, the failure surfaces were examined using the same methods as the failed parts.

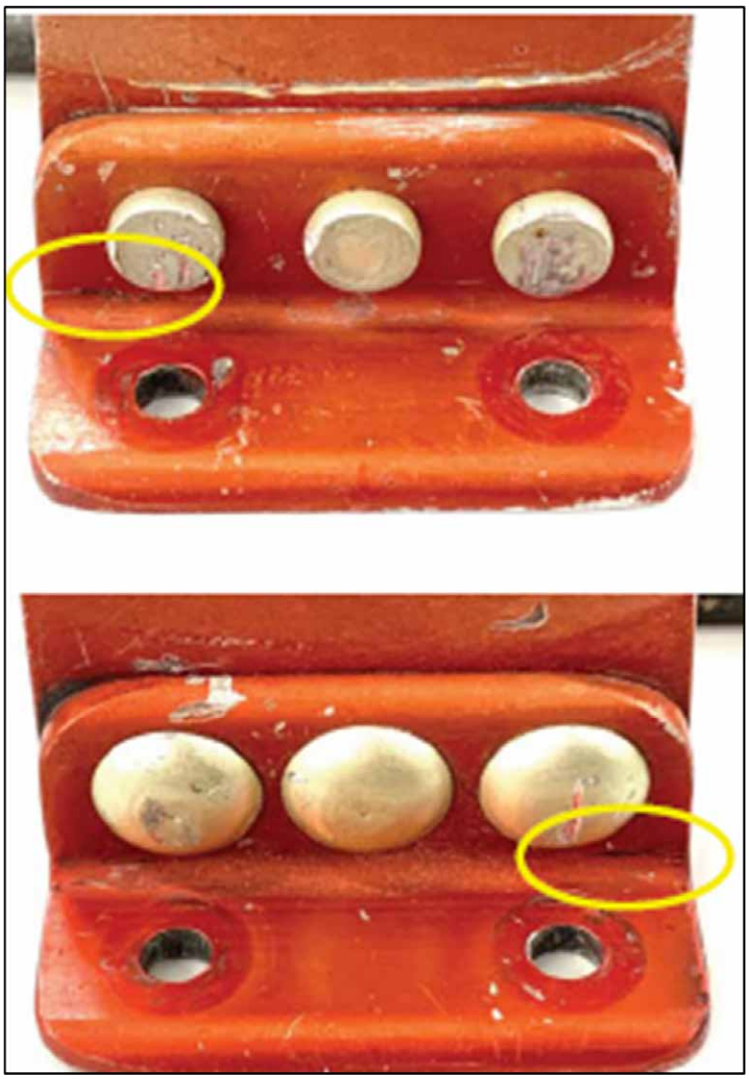

Figure 8

Evidence of cracking to left aileron centre hinge along corner radii

Examination findings summary

The following findings were made from the results of the detailed examination:

- The right aileron centre hinge attachment had failed through the corner radii of the two 'L' shaped brackets attaching the hinge assembly to the wing.
- Physical features of the right aileron centre hinge failure surfaces confirmed that both inboard and outboard sides had failed due to multi-origin fatigue.
- Checks of the microstructure and geometry confirmed that the part had been manufactured to, and still met, the specification.
- Pulling open and then examining the left aileron central hinge attachment revealed that the fractures present were very similar to those which resulted in the in-flight loss of the right aileron. These fractures had not yet grown to the same extent as seen on the right aileron hinge.
- On both the left and right aileron centre hinges, the cracks were multi-origin fatigue driven fractures. The right hinge had failed from the lower surface upwards and the left hinge from the upper edge downwards (Figure 9). This is consistent with control inputs to roll left.
- Striation counting of the failure surfaces suggested that the estimated number of load cycles to failure was approximately 14,000 cycles (Figure 10).

Analysis

As the pilot applied a full control deflection to roll left, the right aileron hinge attachment assembly failed. This allowed the right aileron to bend up in the centre and fail before detaching from the aircraft; only a small inboard section of the aileron remained attached. The pilot had sufficient control remaining to fly back to the airfield and make a safe landing.

The centre hinge attachment assembly of the right aileron failed due to fatigue cracks developing to such an extent that the parts were no longer able to carry the required load. These fatigue cracks were of multiple origin indicating that they were not due to a material feature or flaw.

The similar hinge attachment assembly on the left wing had not failed, but fatigue cracks like those on the right aileron hinge were found, although they had not developed so extensively.

From the striation marks, the metallurgy laboratory estimated that the hinge had been subjected to approximately 14,000 load cycles prior to failure. This is of the same order of magnitude as the owner's estimate of the number of full control deflections to roll quickly left which was 23,000.

The cracks on both the right and left centre hinge attachments had been developing over the life of the aircraft, but they had not been identified by routine inspections. The developing cracks were visible on the left hinge which had not yet failed. It is difficult to properly inspect the hinges without removing them and a service letter issued by the manufacturer (see safety action section below) addresses this issue.

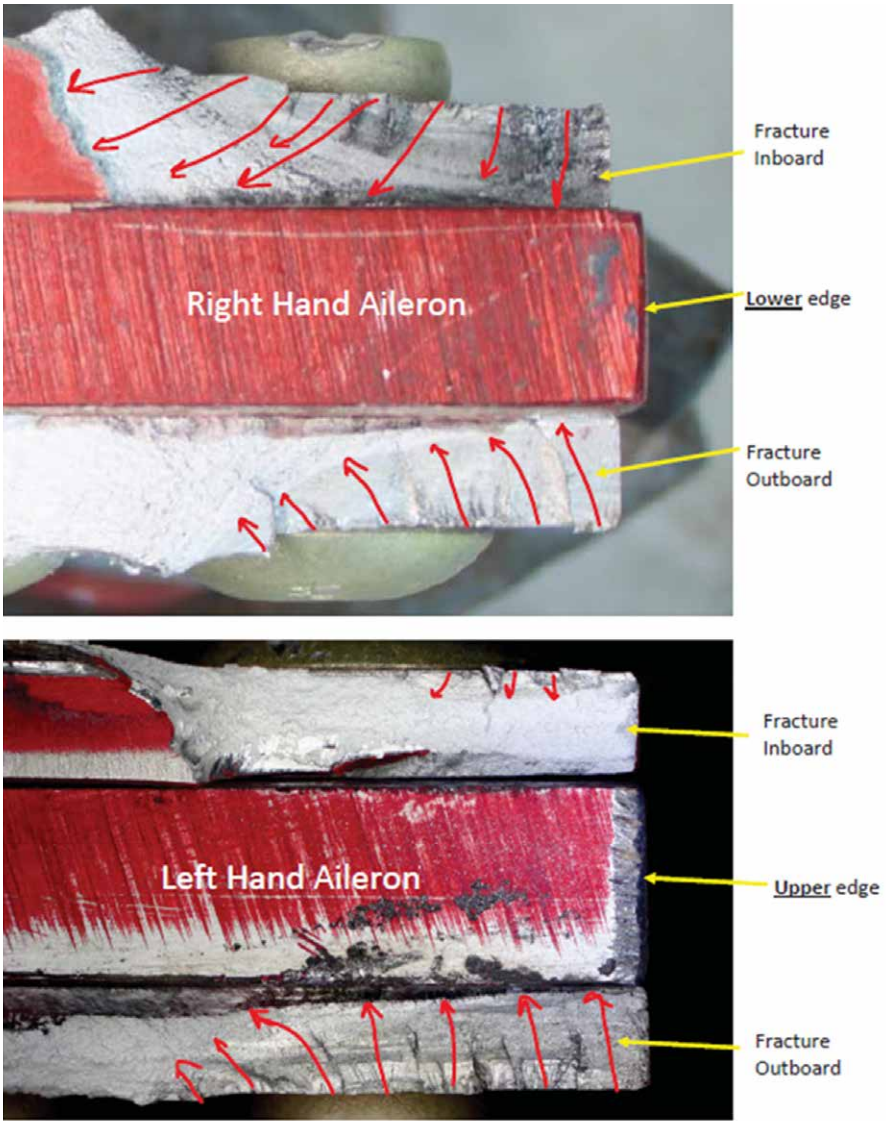

Figure 9

Fractographic summary of damage observed to centre aileron hinges
(red arrows indicate direction and extent of fatigue crack growth)

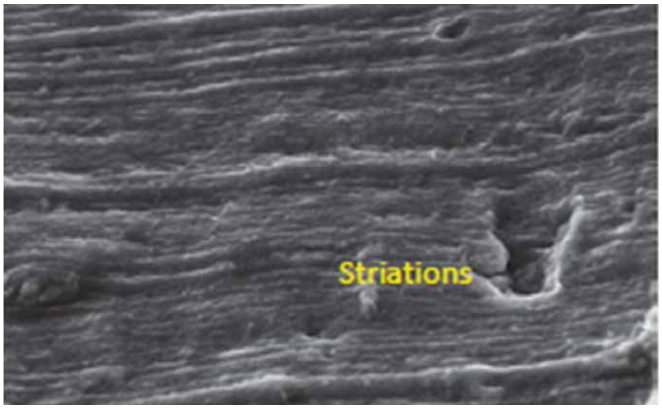

Figure 10

High magnification, scanning electron microscope image of fatigue striations on a fracture surface of the failed right hinge (each striation is the result of a load cycle)

Conclusions

Whilst performing aerobatics, the right aileron failed and detached from the aircraft. The pilot was able to fly the aircraft back to the airfield and make a safe landing.

The right aileron centre hinge attachment assembly failed due to fatigue cracks, similar cracks were found in the centre hinge attachment assembly on the left wing.

Safety actions

The aircraft manufacturer has issued Service Letter, SB E540015 to all known owners of affected aircraft. This letter is annotated 'MANDATORY' and recommends removal of the centre aileron hinge attachment assemblies at each 100 hour or annual inspection to allow inspection for cracks using a dye-penetrant method.

The UK LAA has contacted all affected owners in the UK to ensure they are aware of this mandatory Service Letter.

Published: 20 January 2022.