Midland Ultralights Sirocco 377GB, G-MNDW

AAIB Bulletin No: 11/2004	**Ref: EW/C2004/01/04**	**Category: 1.3**
Aircraft Type and Registration:	Midland Ultralights Sirocco 377GB, G-MNDW	
No & Type of Engines:	1 Rotax 377 piston engine	
Year of Manufacture:	1985	
Date & Time (UTC):	27 January 2004 at 1630 hrs	
Location:	1nm north-east of Ashby-de-la-Zouch, Leicestershire	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - None
Injuries:	Crew - 1 (Fatal)	Passengers - N/A
Nature of Damage:	Aircraft destroyed	
Commander's Licence:	CAA Airline Transport Pilot's Licence	
Commander's Age:	53 years	
Commander's Flying Experience:	9,475 hours (of which 2 were on type)	
	Last 90 days - 80 hours	
	Last 28 days - 16 hours	
Information Source:	AAIB Field Investigation	

Synopsis

The aircraft experienced an in-flight structural failure of the tailplane, which rendered it uncontrollable. This is the second such occurrence within the United Kingdom. Following a previous fatal accident in 1995, UK Sirocco aircraft were modified to address concerns over the design of the tailplane and its attachments. Although these modifications had been accomplished on G-MNDW, the tailplane had failed through loss of structural integrity and in a similar manner. The investigation identified shortcomings in the method of accomplishment of the modifications and raised further concerns over the design and construction of the tailplane and its mountings. Early during the investigation the continued airworthiness of the aircraft type was discussed with the British Microlight Aircraft Association (BMAA). Interim action to suspend the type's Permit to Fly was taken by the BMAA on 6 February 2004. Design changes are recommended to restore the airworthiness of the Sirocco 377GB.

History of the flight

The pilot acquired the aircraft on 10 January 2004, 17 days prior to the accident flight, and drove it in its trailer to Derby Airfield where he planned to keep it until he could arrange to fly it from a field close to his home. On 12 January he spent several hours rigging the aircraft and then flew it from Derby on a local flight which was of 30 minutes duration. During the flight he experienced a minor problem with the throttle lever, which would not return fully to the idle position, but this was resolved satisfactorily afterwards. The aircraft was not fitted with a radio and he had obtained permission from the airfield operator to operate non-radio.

On 27 January, the day of the accident, he arrived at Derby Airfield around midday, and spent several hours rigging the aircraft. He declined various offers of assistance that were made to him because he particularly wanted to become adept at completing the process on his own.

He took off from grass Runway 23 at Derby at 1520 hours on this, his second flight in the aircraft which was later seen to the west of the airfield carrying out some general handling manoeuvres. It is believed that he then flew across country in a southerly and then an easterly direction, keeping clear of the south side of the East Midlands Airport Control Zone. The aircraft was seen in apparently normal flight by the pilot's son during the afternoon some 8 nm south of East Midlands Airport.

At 1630 hours two people in a car just to the east of Ashby-de-la-Zouch saw the aircraft crossing above them from behind travelling in a north-westerly direction. They watched it fly across some large industrial buildings ahead of them and then noticed it bank sharply to the left and saw what appeared to be part of the left wing bend upwards. They then saw the aircraft descend rapidly in a spiral before it disappeared from their view.

Other witnesses in the area saw the aircraft in apparently normal flight before seeing it suddenly bank to the left and descend in a steep spiral to the ground. They generally described either the left wing or both wings folding upwards. Witness information regarding the engine sound varied, some described the engine as running throughout, whereas others described hearing the engine stop before the aircraft was seen to go out of control. A number of people saw or heard the impact and went to assist, but the pilot had suffered fatal injuries in the accident. There was no post-crash fire.

Meteorological conditions

The local weather conditions were reported as follows: surface wind westerly at 8 kt, good visibility, a few clouds at 4,000 feet, temperature 0ºC and dewpoint -3ºC. The area ballooning forecast indicated that the airmass was stable and there was no thermal activity. The local time of sunset was 1646 hrs.

Pilot experience

The pilot was a professional pilot in full-time employment with an air carrier and he also held a current Flight Instructor Rating. He had originally obtained his Private Pilot's Licence in 1979; since then he had flown a variety of different types of aircraft. He had recorded some 10 hours of flight time in various microlight aircraft although he had not recorded a flight in a microlight since 1996.

Medical and pathological information

The pilot held a current Class 1 JAA medical certificate and had no significant medical history. A post mortem examination revealed no evidence of any pre-existing medical condition, drug or toxic substance which could have either caused or contributed to the accident. The pathologist's report indicated that the crash was not survivable and that the pilot sustained multiple injuries which would have been immediately fatal.

Recorded information

Video

The pilot had carried a small video recorder with him on the flight and a few minutes of footage from the early part of the flight was recovered. This imagery showed the flight proceeding uneventfully, with the aircraft in level flight on a heading of 210° M at around 1,000 feet amsl, at an indicated airspeed of between 40 and 45 mph with the engine running at an indicated 5,000 rpm. The pilot was heard to comment on the tape that the maximum cruise speed that he could attain was 60 mph. However, he also remarked that 45 mph was more comfortable because at speeds above 45 mph the aircraft exhibited a tendency to turn to the left and required a corrective control stick input to keep it flying straight. There was no recording from close to the time of the accident.

Radar

Recorded radar data for the area in which the aircraft was believed to have been flying was reviewed. From Clee Hill Radar, located some 40 nm to the south-east of the area, a sequence of primary returns was identified west and south-west of Derby Airfield, believed to be G-MNDW. The returns correspond well with the time and location of the aircraft as determined from the video recording. The radar returns gave an average derived ground speed of around 50 kt (equivalent to 57.5 mph). There were no returns detected in the area further to the south and east where the aircraft was seen later on that afternoon.

Aircraft description

General

The Sirocco 377GB is a single seat, high wing, three-axis control microlight aeroplane powered by a two-cylinder two-stroke engine driving a two-bladed pusher propeller. The pod and boom type fuselage is of a glass-reinforced plastic (GRP) monocoque construction. The main wing, which is braced with upper and lower tensioning wires, is constructed of fabric reinforced with a GRP leading edge and an aluminium box-section rear spar. The aerofoil contour is provided by shaped battens, which locate into chordwise pockets in the top and bottom fabric of the wing.

The aircraft may be fitted with a glassfibre and perspex canopy, designed by the original aircraft manufacturer, but this had not been tested and approved for use on UK-registered Siroccos. According to pilots who have flown with the canopy installed, the drag reduction increases the cruise speed by about 5 mph. According to one Sirocco owner consulted by the AAIB, it is not possible to exceed the 86 mph 'Never Exceed speed' (V_{NE}) in level flight with the canopy installed, even at full power, but it may be exceeded in a shallow dive.

Tailplane Design and Construction

The Sirocco has a rectangular-planform, all-moving tailplane that is comprised of thin top and bottom GRP skin mouldings of approximately 1 mm thickness, bonded to a thin GRP 'C'-section spar. Solid foam half-ribs are bonded in front of and behind the spar at regular intervals. There are a total of ten rib stations, five each side of the centreline. The top skin of the tailplane overlaps the lower skin by approximately 15 mm around the leading edge and tips whereas the skins are butt-jointed at the trailing edge. A supplementary spar bonded into the centre section of the tailplane supports a tube into which the tailplane actuating tube locates. All of the structural components are bonded together with vinyl ester adhesive.

An anti-balance tab, which also operates as a trim tab, is attached to the trailing edge of the tailplane. Pitch trim is adjusted via a trim lever on the left side of the cockpit. A cable connects the trim lever to the trim bellcrank which is mounted on a cross-tube at the back of the fuselage (see Figure 1).

Figure 1 Tailplane attachment fittings

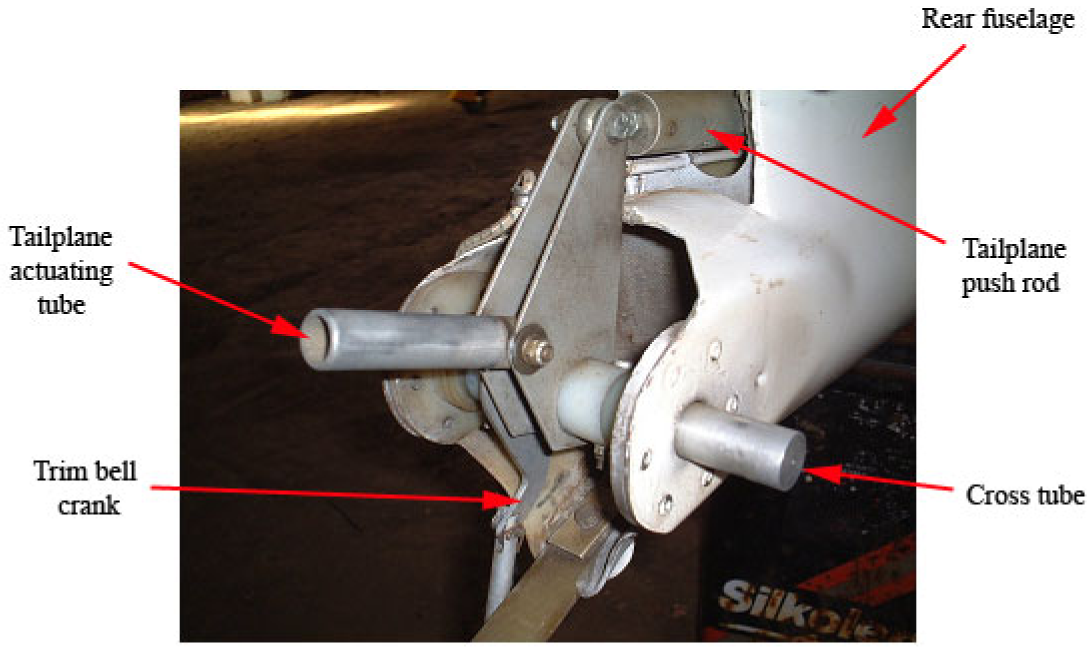

Figure 1 - Tailplane attachment fittings

The cross tube is mounted in nylon bearings to allow it to rotate. A rod attached to the output arm of the bellcrank drives the trim tab. The control stick is connected via a pushrod to the tailplane bellcrank, which is also mounted on the cross-tube. Its output arm is connected to an actuating tube which slots into the tube in the centre of the tailplane. Fore and aft stick movement rotates the bellcrank and hence the tube, thus varying the angle of the tailplane. Whilst on the ground, the control stick is kept in the neutral position by a bungee cord which is attached to the tailplane and secured to the fuselage.

The cross tube also provides for retention of the tailplane. The tailplane has a central cutout in its leading edge, with plywood ribs located either side of the cutout (see Figure 2).

Figure 2 Tailplane central cutout

Figure 2 - Tailplane central cutout

The two ribs are angled inwards from front to back, such that the opening is widest at the front and the ribs have 20 mm wide slots cut into them. The tailplane is attached to the fuselage by engaging the slots in the ribs onto the cross tube and sliding the tailplane forward. It is then secured to the cross tube with retaining bolts that are inserted into the ribs in front of the cross tube. The bolts bear directly onto the cross tube in point loading contact. A schematic of the tailplane attachment is presented in Figure 3.

Figure 3 Schematic of Sirocco tailplane attachment

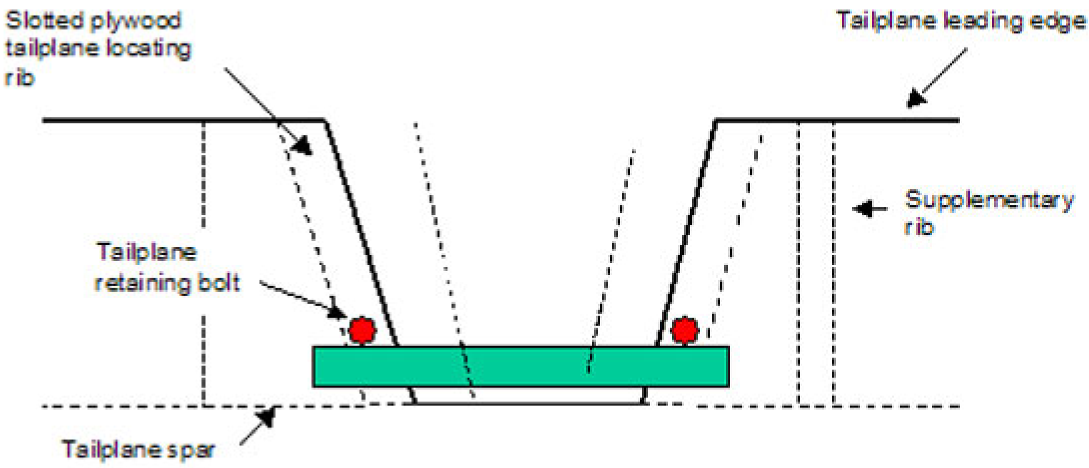

Figure 3 - Schematic of Sirocco tailplane attachment

Limiting Airspeeds (VNE/VA)

Note: All airspeeds quoted are indicated airspeed (IAS).

The French manufacturer's specified 'Never Exceed' airspeed (V_{NE}) is 120 km/h (75 mph). With the absence of any design or construction standards for microlight aircraft at the time that the aircraft was originally designed and built, the V_{NE} was chosen somewhat arbitrarily, whilst ensuring that it was well below the maximum demonstrated airspeed of 150 km/h (93,75 mph) attained during flight testing. When the Sirocco was granted its Type Approval by the UK Civil Aviation Authority (CAA) in May 1985, the V_{NE} was specified to be 86 mph for UK aircraft. This figure is quoted in the Sirocco Type Approval Data Sheet and on the limitations placard in the cockpit. The reason for the difference between the UK and manufacturer's V_{NE} speeds is not clear.

The 'Manoeuvring Airspeed' (VA), the maximum speed at which full control deflection may be applied without causing structural damage, is quoted as 53 mph for UK aircraft.

Aircraft history

G-MNDW held a current Permit to Fly, which was most recently validated in May 2003 for one year. Before the Permit could be validated, the aircraft was required to pass an engineering inspection by a British Microlight Aircraft Association (BMAA) Inspector and complete a test flight in accordance with a specified flight test schedule (this included diving the aircraft to V_{NE} (86 mph IAS) to check for positive pitch stability). Both of these were completed satisfactorily and the owner flew the aircraft a number of times that summer. Some time prior to renewing the Permit, the owner at the time discovered that the fuselage had been previously damaged and poorly repaired and he considered it to be non-airworthy. He decided to replace the fuselage with that from another Sirocco, G-MNDV, which he had procured as a spares aircraft. The wings and tailplane from G-MNDW were used on the replacement fuselage. The owner had at one point advertised the aircraft for sale, but subsequently decided that it needed further maintenance work and so withdrew it from sale.

The accident pilot had been looking for a Sirocco aircraft for some time and, as a result of seeing the earlier advertisements, believed that G-MNDW might be for sale. He contacted the owner and after some discussion, arranged to view the aircraft. On the day he went to see it, he spent a considerable amount of time looking over the aircraft with the owner, time which included a review of rigging and operating procedures, which he recorded on video for future reference. The aircraft was also flown by the owner for a short hop along the runway to demonstrate its take off performance. This was also captured on video. The owner advised the pilot that a certain amount of work was required before the aircraft should fly, but he was eventually persuaded by the pilot to sell it in its existing condition. One of the items highlighted by the owner was that the tailplane retaining pins, which were not approved for flight, needed to be replaced by bolts secured with wing nuts. The sale was completed on the same day and the pilot towed the aircraft in its purpose-built enclosed trailer to Derby Airfield.

It is not known what work the pilot had carried out on the aircraft before he first flew it. Together with the aircraft he also received a number of spare parts, including an unmodified tailplane that had originally been installed on G-MNDV and a canopy to enclose the cockpit area. On his first flight he had flown the aircraft without the canopy installed and had worn a helmet, whereas on the accident flight the canopy was fitted and no helmet was worn.

It is estimated that the aircraft had completed a total of around 250 flying hours at the time of the accident.

History of the Sirocco type

Introduction

The Sirocco was originally designed and manufactured in France and was imported into the UK in kit form. The aircraft kits were assembled in the UK by a CAA approved company. It was granted a Type Approval by the CAA (Type Approval Data Sheet No BM-7 Issue 1 refers) after completion of the necessary work to demonstrate compliance with the BCAR Section 'S' Airworthiness Requirements for microlight aircraft that had recently come into force in the UK. The type was designated 'Sirocco 377GB' and around 14 of these were produced in the UK. G-MNDW was first registered and issued a Permit to Fly in 1985. Altogether to date there have been approaching

200 examples of the aircraft produced in Europe, although the number currently flying is not known. The original aircraft manufacturer has since ceased trading.

Previous Accident

The AAIB investigated a previous fatal accident to a Sirocco, G-MNFC, which occurred on 28 April 1995 during the climb after takeoff and which was reported in AAIB Bulletin 9/95. From the distribution of the parts in the wreckage trail, which included pieces of the tailplane ribs, the rudder and the tailplane itself, it was concluded that an in-flight structural failure of the tailplane had occurred, leading to a loss of control. The investigation highlighted various deficiencies in the tailplane, including poor bonding of the adhesive on the left-hand tailplane locating rib, possibly associated with a previous repair. The ribs had completely disbonded from the skins and spar and the tailplane upper and lower skins had also separated from each other over a large area of the tailplane. It was found that there had been insufficient engagement of the retaining pins on the cross tube and that the wall of the cross tube had been crushed by large loads transmitted by the retaining pins, although it was not clear what had produced these loads. After this accident a number of modifications were made to UK Sirocco aircraft, which were mandated under Microlight Airworthiness Approval Note (MAAN) 1336, issued by the BMAA in May 1996.

Mandatory Tailplane Modifications (MAAN 1336)

The changes introduced by MAAN 1336 are described as follows. The length of the cross tube was increased from 170 mm to 200 mm, to ensure sufficient engagement of the retaining pins on the tube, and solid plugs were inserted into the ends of the tube to stop the tube walls from being crushed by the loads from the retaining pins. The partially slotted 8 mm plywood tailplane locating ribs were replaced with double thickness (16 mm) fully slotted ribs (fully slotted ribs were necessary in order to accommodate the increased length of the cross tube). Supplementary 8 mm plywood ribs were inserted outboard of the new locating ribs to restore any strength lost by introducing the full-length slot. After cutting out the original ribs, the new ribs were installed by applying vinyl ester resin around the edges and then sliding them into position, thus avoiding the need to separate the upper and lower skins. Once bonded in position, the accessible faces of the ribs were covered with a single ply of glass cloth overlapping onto the upper and lower skins and the front face of the spar. The lap joint between the upper and lower skins was reinforced around the leading edges and tips by applying a single layer of glass cloth over the joint. Finally, the tailplane retaining pins were replaced with bolts and wing nuts to prevent the slots in the ribs from opening up and causing the top and bottom skins to part at the leading edges. A flight test was performed on the first aircraft to be modified, which included a check for flutter throughout the speed range, up to a dive speed of 95 mph IAS. This test proved satisfactory.

In October 2000, the BMAA became concerned that the modifications may not have been carried out to the required standard on some aircraft and the Sirocco type was grounded until it could be verified by BMAA inspection that they had been completed satisfactorily on all aircraft. The anomalies found included poor bonding of the supplementary ribs and the omission of the reinforcing strip of glass cloth around the leading edge and tips. G-MNDW was inspected by the BMAA on 22 September 2000 and the aircraft logbook was annotated to reflect that the modifications were considered to have been satisfactorily accomplished.

Mass Balance Modification

Test flights conducted by the French kit manufacturer demonstrated that the aircraft was flutter-free at airspeeds up to 150 km/h (93.75 mph) IAS. The manufacturer subsequently became aware of a flutter event that had occurred at an airspeed of between 100 and 110 km/h (62.5 to 68.75 mph) and which had caused serious damage to the tailboom. Consequently, a modification was released in September 1987 to install mass balance weights on the tailplane. Details of this were promulgated by the manufacturer in 'Sirocco News No 13', which strongly recommended that all Sirocco owners incorporate this modification on safety grounds. The modification was not required to be adopted on the UK aircraft, for reasons that could not be established. UK aircraft are required to be test flown annually for the purposes of the renewal of the Permit to Fly. Whilst this includes diving to the V_{NE} of 86 mph to check for positive pitch stability, it does not include a specific check for flutter due to the hazards involved.

Engineering examination

Accident site information

The accident site was located on the edge of a field, near a housing estate, approximately one mile to the north west of Ashby-de-la-Zouch. The depth of the ground impact marks and the extensive damage to the front of the fuselage showed that the aircraft was pitched steeply nose down with a high rate of descent at impact. The partially shattered canopy was still attached to the fuselage. The aircraft was fitted with a lapstrap and twin shoulder strap harness arrangement which was found to be intact and fully functional.

Pieces of debris from the tailplane, including fragments of foam rib and the outer section of the lower skin from the left side of the tailplane, were found up to 150 metres away from the main wreckage, trailing back in the direction from which the aircraft had come. The rudder had torn from its attachments and was found 30 metres away from the main wreckage. The wing leading edge structural members had failed symmetrically approximately 120 cm inboard from each wingtip.

The tailplane was still attached to the fuselage by its left-hand locating rib and the tailplane actuating tube. The right-hand locating rib had become detached from the surrounding structure. The top and bottom skins of the tailplane had parted from each other at the joint line along much of the leading edge, around the tips and at the trailing edge, except where the rivets of the trim tab hinge were still holding them together. All of the foam ribs had detached and were found loose inside the tailplane, lying on the ground at the crash site, or in the wreckage trail. The top and bottom skins had suffered extensive creasing and cracking in the spanwise and chordwise directions and had lost much of their stiffness. The spar had completely detached from the top and bottom skins and buckling failures due to spanwise bending were visible in several locations. The overall impression was one of the tailplane having shaken itself apart in the air. The damage was very similar to that seen on the tailplane of G-MNFC (Figure 4). It was noted that pins had been used to attach the tailplane, rather than bolts with wing nuts, as required by mandatory modification MAAN 1336.

Figure 4 Comparison between tailplanes of G-MNFC and G-MNDW

Figure 4

Comparison between tailplanes of G-MNFC and G-MNDW showing similar failure chaacteristcs with extensive disbonding of structure

Although the fuel tank was damaged and had leaked, it contained an estimated one gallon of fuel when examined and fuel was present in the fuel lines to the carburettor. Propeller slash marks in the wing fabric and a propeller strike mark on a fence post showed that the engine was running at the time of impact. The relative lack of damage to the propeller itself was consistent with low engine power at impact and the throttle lever was found at a low power setting. The flying controls were connected at the time of impact and the wing tensioning wires were intact.

Detailed Wreckage Examination

The cross tube was found to be securely attached to the fuselage, with no observed play in the bearings. Witness marks from the tailplane retaining pins on the cross tube showed that the pins were contacting the tube at a position between 15 and 20 mm from the ends of the tube and thus had been fully engaged on the cross tube. Black deposits were observed near the ends of the slots in the tailplane locating ribs which were attributed to abrasion of surface oxides from the aluminium cross tube. Numerous indentations were found on the forward facing surfaces of the cross tube from contact with the retaining pins due to relative movement between the tube and pins.

Both retaining pins showed evidence of deformation in the form of bending about the middle of the pin, where they contacted the cross tube. The right-hand pin showed the greatest deformation. A corresponding deep indentation and gouge from the pin were visible on the front face of the right-hand side of the cross tube. It was apparent that the pins had been pressed rearwards against the cross tube with considerable force, although the origin of the force was not immediately apparent, as the normal in-flight loads would not be expected to be sufficiently large.

Whilst the top and bottom skins had disbonded over much of the area of the tailplane, the leading edge joint was still intact in the vicinity of the locating and supplementary ribs, which suggested that the right-hand locating rib had been pulled out in a sideways rather than a forward direction.

The inboard face of the detached right-hand locating rib was protected with a layer of GRP, as required by mandatory modification MAAN 1336. However, the outboard face was unprotected and the wood was grey and weathered in appearance due to the effects of long term exposure to moisture (Figure 5). It was evident that moisture could enter the front of the tailplane through the slots in the locating ribs and become trapped between the locating and the supplementary ribs because no drain holes had been incorporated to allow accumulated moisture to escape.

Figure 5 View on outboard and inboard faces of G-MNDW right-hand tailplane

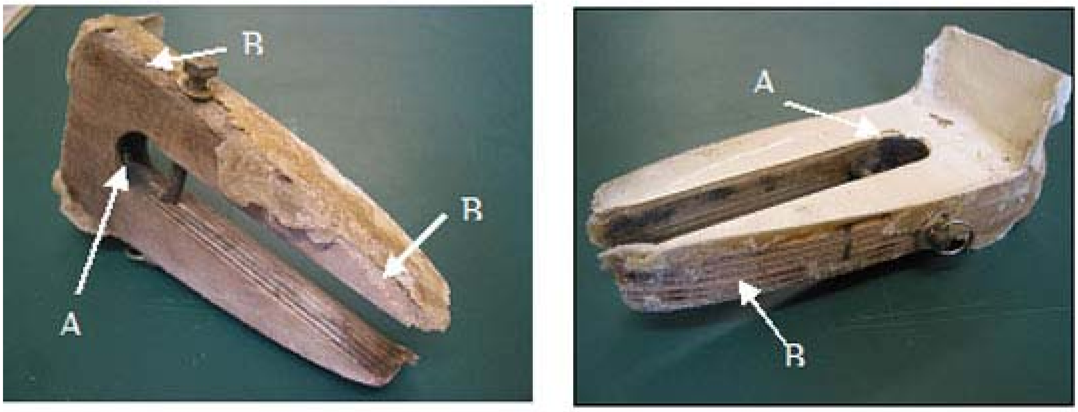

Figure 5

View on outboard and inboard faces of G-MNDW right-hand tailplane locating rib showing general weathering of wood and areas of chafing (A) and poor adhesive coverage (B)

The output arm of the trim bellcrank was found to be severed, which raised concerns that had this occurred in flight it would have left the trim tab unrestrained, possibly inducing the tailplane to flutter. Fractographic examination showed however, that the failure was due to static overload from the ground impact and this was borne out by the condition of the broken off section of the output arm, which was heavily distorted and still connected to the trim rod. Witness marks were found on the inside surface of the rear fuselage, where the trim bellcrank output arm had been rubbing against the fuselage, due to excessive lateral play of the bellcrank on the cross tube, but no evidence was found of the trim bellcrank having jammed.

The tailplane and rear fuselage section were examined in detail by materials scientists from QinetiQ at Farnborough, who produced a comprehensive report. Their report concluded that the bonds between the internal components and skins were poor in many places. The skins were also porous in some areas where they had not been fully wetted with resin when the tailplane was manufactured. Such defects would have produced a matrix of sites where disbonding could have initiated under the application of flight loads. It also pointed out that the reinforcing layer of glass cloth applied over the joint between the top and bottom skins had not been effective in preventing them from separating from each other.

The QinetiQ report further highlighted erratic bonding of the right-hand tailplane retaining rib and supplementary rib, where the adhesive had been partially 'dragged' away from the ribs as they were slid into position inside the tailplane leading edge (Figure 5). The ribs had also been exposed to the prolonged effects of moisture, which had led to some degradation of the wood and reduced its bearing strength, allowing movement of the cross tube within the slots. Damage to the cross tube caused by the retaining pins suggested that significant movement of the tailplane had occurred at some time, possibly in flight.

Due to the erratic nature of the bonding, it was not possible to map the directions of fracture across the tailplane to identify the origin of the failure.

Sirocco In-Service issues

The AAIB and BMAA conducted a field visit to examine a Sirocco aircraft to determine if there were any in-service issues that could have affected the long-term structural integrity of the tailplane. Several issues were identified during this visit.

The owner of the aircraft examined pointed out that when the aircraft is fully rigged, with no pilot on board, the centre of gravity is well aft and the tailplane rests on the ground. As an aircraft rocks in the wind, large forces can be transmitted to the tailplane locating ribs, retaining bolts and the cross tube. The owner stated that he took great care in ensuring that the tail was propped up to keep it clear of the ground and thus protect it from damage. The owner explained that he frequently found the tailplane retaining bolts to be bent, though the reason for this was not clear, and he had taken to replacing the bolts as necessary.

His experience also showed that the locating ribs can absorb moisture, causing the wood to swell, making the tailplane difficult to fit. Considerable force may be required to engage the tailplane fully onto the cross tube. The retaining bolts may also be difficult to fit for the same reason and some owners have reportedly taken to hammering them into position. In the long term, accumulated moisture may also have a detrimental effect on the integrity of the adhesive bonds within the tailplane structure.

Examination of spare tailplane

In order to understand better the structural characteristics of the Sirocco tailplane, a spare tailplane unit from G-MNDV was examined in detail. Although this tailplane was unmodified, the basic structural characteristics were not considered to be significantly different from those of a modified unit. When a coin 'tap-test' was performed to check for disbonding of the skins, both the top and bottom skins were found to have partially disbonded from the spar in the area of the leading edge cutout, between the locating ribs. It is believed that this damage may have occurred during the time that it was installed on G-MNDV. The disbonding was found to have a profound effect on the spanwise bending stiffness of the tailplane, to the extent that even a relatively small amount of force applied at the tip would cause the skin in the centre section to buckle, inducing peeling stresses which were likely to promote further disbonding of the skins. It was evident that once this process had begun, it would progress at an increasing rate with the application of flight loads, to the point where structural failure of the tailplane could occur.

Analysis

Weather conditions for flying microlight aircraft, although somewhat cold, were good with little wind and so weather could be ruled out as a factor in the accident. The aircraft appeared to be on a direct course towards Derby Airfield when the accident occurred, so it is unlikely that any extreme manoeuvres were being carried out, indeed the witness evidence suggested that the aircraft was in straight and level flight.

It is possible that the aircraft was flown in excess of the V_{NE}, but this seems unlikely, based on the pilot's comments on the video that 60 mph was the maximum cruise speed that he could attain. Furthermore, given that the aircraft was laterally trimmed at 45 mph, had he flown at a higher speed, the pilot would have had to continually apply force on the control stick to keep the aircraft flying straight, which would have been uncomfortable for any length of time. If he had exceeded the V_{NE} of 86 mph, this of itself should not have caused a problem, provided that the tailplane was structurally sound, because the first aircraft with a modified tailplane had been tested at up to 95 mph without any indication of flutter. There were 16 minutes of daylight remaining and the pilot was approximately 5 minutes of flying time away from Derby, so it is unlikely that he was overly concerned about the time or hurrying to return, particularly given his level of piloting experience.

The possibility of a pitch trim system failure was investigated, but given the lack of any evidence for this, it was considered unlikely.

It was apparent from the distribution of the parts in the wreckage trail that the initiating event had been the in-flight structural failure of the tailplane. The symmetrical failure of the outer section of both wings may have been due to the sudden large loads induced by the rapid change in the pitch angle that occurred as the tailplane failed. Another possibility is that the outer sections of the wing failed in a torsional mode due to the design speed being exceeded in the resultant dive. The fact that this accident was so similar to that of G-MNFC, is a matter for concern, given that the tailplane of G-MNDW had been modified to prevent such a failure from recurring. Moreover, similar but unexplained forces had crushed the cross tube on G-MNFC and distorted the tailplane retaining pins on G-MNDW.

Based on the eyewitness evidence, it appears that the onset of the failure was very sudden. The extensive cracking of the tailplane skins and buckling failures of the tailplane spar are indicative of the tailplane having experienced flutter, although it was not clear what had initiated the event. The fact that the aircraft had been airborne for over one hour, without any apparent problems until the time of the accident, may be suggestive of a gradual degradation in the integrity of the tailplane structure or its mountings during the course of the flight. If this had been the case, the tailplane may have operated normally until the point where its stiffness was reduced to the extent that flutter occurred, which would then have rapidly led to a catastrophic structural failure and loss of control.

Whilst it has been demonstrated that the aircraft normally has an acceptable flutter margin, the report received by the kit manufacturer of a flutter event at 65 mph suggests that this is not always the case. The aircraft kit manufacturer considered this problem to be so serious that the company issued a modification to mass balance the tailplane to improve its flutter protection. It also strongly recommended that all operators incorporated this modification on safety grounds but the exact distribution of this recommendation could not be determined because the manufacturer has ceased trading. The fact that UK registered Siroccos do not have this modification (see Figure 6) exposes them to a significantly greater risk of tailplane flutter.

Figure 6 Sirocco tailplane with mass balance modification incorporated

Figure 6
Sirocco tailplane with mass balance modification incorporated

The reason for the difference between the original manufacturer's quoted V_{NE} and the CAA stipulated figure is not clear and in the light of the two fatal accidents in the UK involving tailplane flutter, it would be prudent to review this discrepancy. Reducing the V_{NE} to the manufacturer's figure of 75 mph would provide a greater margin of flutter protection, although whether it would have prevented this accident is not clear, given that the pilot is thought to have remained below 60 mph during the flight.

Whilst the exact reason for the tailplane failure could not be identified, the detailed scientific examination of the tailplane from G-MNDW identified major deficiencies in the standard of its original construction, with poor adhesion in the bonded joints between the skins, the ribs and the spars. Furthermore, when the modified locating ribs and supplementary ribs were installed during incorporation of modification MAAN 1336, the technique of sliding the ribs into place had caused the adhesive to be dragged off the edges of the ribs, producing a poor bond between the ribs and the skin and spar. The presence of poor bonding cannot be detected visually and is a significant airworthiness concern. With such a lightly constructed structure as the Sirocco tailplane, it is critical to maintain the integrity of the whole structure because a disbond, whilst not initially critical, would rapidly spread until the bending and torsional stiffness of the structure is reduced to the point where flutter becomes inevitable. Moisture ingress due to lack of drainage in the tailplane can have a further detrimental effect on the adhesive bonds over a long period of time. It is therefore imperative to ensure that all of the adhesive joints are well bonded and remain so in the long term.

The fact that the distortion of the tailplane retaining pins seen on G-MNDW had been experienced by the owner of another Sirocco suggests that this may not have been a feature of the accident and could have occurred during rigging or ground handling of the aircraft, or whilst in flight. However, the arrangement with the tailplane retaining pin or bolt bearing directly on the cross tube is undesirable since the point loading tangential contact greatly increases the local stresses in the bolts and the cross tube. On unmodified aircraft, such stresses caused crushing of the cross tube whilst on modified aircraft with the solid plugged cross tube, it is the bolts that deform. In either case, the tailplane is no longer rigidly restrained which makes it more prone to flutter. The fact that the cross tube bears directly on the wooden locating ribs, causing them to chafe and wear is also undesirable, as it further contributes to increased clearances. The design of the tailplane mounting also renders it susceptible to being damaged if excessive force is used during assembly, such as may be the case if the wood of the locating ribs has swollen due to moisture absorption. It may also be damaged if the aircraft is left rigged with its tail in contact with the ground.

The fact that the leading edge joint between the top and bottom skins was still intact in the vicinity of the locating ribs suggests that the slots in the ribs had not opened up and so the pilot's decision to use retaining pins to attach the tailplane instead of the required bolts and wing nuts did not appear to have been contributory to its failure.

Whilst not considered to be a contributory factor to the accident, the excessive lateral play of the trim bellcrank which allowed the output arm of the bellcrank to contact the inside of the fuselage was considered to be highly undesirable. This is because the interference could eventually lead to the failure of the output arm and a subsequent loss of pitch trim control.

Conclusions

The aircraft experienced an in-flight structural failure of the tailplane due to aerodynamic flutter. Despite the aircraft having been modified to prevent such a failure from recurring, the mode of failure was almost identical to that of a previous accident in the UK.

Whilst the exact cause of the flutter event could not be identified, several shortcomings were identified in the design and construction of the Sirocco tailplane that could compromise its long-term structural integrity and the airworthiness of the aircraft. These included poor adhesive bonds throughout the structure from the original manufacture and poor bonding of the ribs introduced by the modifications.

The design of the tailplane attachments does not ensure positive location of the tailplane and encourages the development of high stresses in the mounting during assembly, ground handling and possibly in flight. The lack of provision for the drainage of moisture and absence of protection of the outboard side of the locating and supplementary ribs are also significant concerns.

These two accidents and one incident reported to the French manufacturer demonstrate that the Sirocco can experience flutter in the normal operating speed range, although the circumstances required for this to occur are not fully understood. Mass balancing the tailplane increases the flutter margin, but this modification, although available, was not adopted on UK registered Siroccos. UK registered aircraft also have a higher specified V_{NE}, which also reduces the flutter margin.

In order to restore the airworthiness of UK registered Siroccos, at least the following issues should be resolved:

i) Poor bonding of the adhesive joints at original manufacture and of the ribs introduced during accomplishment of modification MAAN 1336.

ii) Doubts over the long-term structural integrity of the Sirocco tailplane and the difficulty of detecting any disbonding within the structure that may occur with time.

iii) The lack of rigidity of the tailplane attachments, the point loading tangential contact of the retaining bolts on the cross tube and the lack of a proper bearing surface for the cross tube within the slotted ribs.

iv) The susceptibility of the current tailplane design to the long term detrimental effects of moisture ingress on the integrity of the structure.

v) The fact that the tailplanes on UK Sirocco aircraft are not mass balanced, given that the manufacturer issued a modification to install mass balance weights and strongly recommended that this be incorporated on safety grounds.

vi) The wisdom of the adoption of a higher V_{NE} on UK aircraft than that specified by the aircraft kit manufacturer.

vii) The undesirable condition of excessive lateral play in the pitch trim bellcrank which can allow the output arm of the bellcrank to contact the inside surface of the fuselage, placing side loads on the arm which could induce it to fail.

Safety Recommendations

Shortly after the accident, when disintegration of the tailplane was evident but not fully understood, the AAIB discussed appropriate interim action with the BMAA. On 6 February 2004 the BMAA decided to suspend the validity of all Permits to Fly issued to UK registered Sirocco aircraft pending the outcome of the investigation. Multiple airworthiness issues have since been identified, the majority of which can only be resolved by design and modification action. Therefore, in order to prevent further in-flight structural failures of the Sirocco tailplane, the following Safety Recommendation is made:

Safety Recommendation 2004-76

It is recommended that the British Microlight Aircraft Association (BMAA) indefinitely suspends the Permits to Fly of all UK registered Sirocco aircraft until appropriate design and modification action have been taken to restore the airworthiness of the aircraft.

Immediate safety action taken

On the 6 February 2004 the BMAA took action to suspend the validity of the Permits to Fly for the remaining Sirocco aircraft registered in the United Kingdom, pending the outcome of the AAIB investigation.