# Agusta A109A, G-USTA

## AAIB Bulletin No: 3/2001

## Ref: EW/C1999/03/02 - Category: 2.2

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| **Aircraft Type and Registration:** | Agusta A109A, G-USTA |
| **No & Type of Engines:** | 2 Allison 250-C20B turboshaft engines |
| **Year of Manufacture:** | 1980 |
| **Date & Time (UTC):** | 27 March 1999 at 1750 hrs |
| **Location:** | Hurstpierpoint |
| **Type of Flight:** | Private |
| **Persons on Board:** | Crew - 1 - Passengers - 1 |
| **Injuries:** | Crew - None - Passengers - None |
| **Nature of Damage:** | Tail rotor gearbox torn out, extensive damage rear of tail boom and lower fuselage |
| **Commander's Licence:** | Private Pilot's Licence (Helicopters) |
| **Commander's Age:** | 52 years |
| **Commander's Flying Experience:** | 734 hours (of which 33 were on type) |
| | Last 90 days - 40 hours |
| | Last 28 days - 3 hours |
| **Information Source:** | AAIB Field Investigation |

**History of the flight**

The helicopter was returning to the pilot's home field after a local flight of some 25 minutes duration. During the final approach to land, when the helicopter was at about 30 feet agl and at low speed, there was a loud bang and the helicopter started to rotate rapidly to the right. The pilot assumed that he had lost tail rotor authority and so lowered the collective, to reduce the rate of rotation, before landing heavily after about two rotations. The helicopter remained upright and the pilot shut down both engines, but was unable to open his door to vacate the cabin. However, he was able to follow his passenger out of the co-pilots door without difficulty. Neither occupant suffered significant injuries in the accident.

**Examination of damaged helicopter**

All three landing gears had been driven upwards during the heavy landing, and the fuselage underside had been deformed. However, apart from the induced jamming of the pilot's door the cabin had suffered no major structural deformation or main rotor blade strikes. The tail rotor assembly, complete with the 90° gearbox but with the outer part of one tail rotor blade (TRB) missing, was found approximately 12 metres back along the approach path, and had clearly separated from the helicopter whilst it was still airborne. The missing outer section of TRB was found on the ground, further back along the approach path.

**Preliminary examination of TRB**

Preliminary AAIB examination of the separated TRB part number 109-0132-02-121, serial number A3-685, showed evidence of a chordwise fatigue fracture in the outboard-facing (tension) skin of the blade at approximately 25 per cent span, immediately adjoining the outer end of a bonded reinforcing doubler, as shown in Figure 1. Examination of the separated gearbox and associated mounting structure in the tail boom showed that the gearbox had torn free of the aircraft due to out-of-balance forces following blade separation in flight.

**TRB construction**

The failed TRB was of conventional bonded construction comprising an aluminium honeycomb core with an aluminium alloy outer skin 0.8-1 mm thick. The leading edge was protected by a thin stainless steel anti-erosion cap. The root end of the blade was reinforced externally on each side by two bonded doublers, each two laminae thick. The longer laminate was bonded directly to the skin, and extended outboard approximately 196 mm from the blade root attachment pin. The failure had occurred immediately adjacent to the outer end of this doubler.

**Inspection history**

The aircraft documentation showed that the failed TRB, serial number A3-685, had been installed on G-USTA 339.9 flight hours prior to the accident. This TRB had already accumulated a total of 851.8 flight hours whilst installed on a series of other aircraft (making a total of 1, 291.7 flight hours). The Agusta 109 TRB is lifed at 1, 400 flight hours.

An entry in the log book dated 26 November 1998, 47 flight hours/94 flights prior to the accident, certified that the tail rotor blades had been subject to a dye penetrant inspection for cracks in the area where the failure on G-USTA had occurred, in accordance with CAA FAD T87-1/TB 109-5 Pt III. (T87-1/TB 109-5 was a Telegraphic Technical Bulletin issued by the aircraft manufacturer following a previous instance of TRB fatigue failure on an A109 helicopter, which had occurred at the same location as the failure on G-USTA.)

The Technical Log, signed by the pilot on the day of the accident, certified that a Check A/daily inspection had been completed. The operator's 'A' check inspection checklist included, under 'Area N° 4 (Fins, 90° Gearbox, Tail Rotor and Tail Skid)', item 7 'Tail rotor hub and blades . . . . Condition, security, freedom of flapping, and evidence of cracks.' In addition, T87-1/TB 109-5 Pt II required a visual inspection of the tail rotor blades for cracks in the relevant area, if necessary using a X3 to X5 magnifying glass, at every airworthiness check; this would have included the 'A' Check.

**Metallurgical examination of TRB fracture**

Detailed examination of the blade fracture by metallurgists at DERA confirmed the presence of a chordwise fatigue crack on the tension (outboard-facing) side of the blade immediately adjacent to the outboard end of the longer of the two laminae of the bonded doubler. The paint finish had previously been removed from this area, evidently as part of the dye penetrant inspection procedure specified in T87-1/TB 109-5 Pt III. Figure 2 shows the fracture face on the inboard section of the failed blade.

When first examined the fracture surface was dirty, and difficulty was experienced in observing detail. However, it was notable that no evidence of any red discoloration or dye residues, of the kind usually associated with the application dye penetrant in the vicinity of an existing crack, could be seen anywhere on the fracture faces.

After ultrasonic cleaning of the fracture region with MEK (methyl-ethyl-ketone) solution, which also dissolved the adhesive bond between the honeycomb and the skins allowing improved access to the failure region, the fracture details were more clearly revealed. The origin of the fatigue was identified as a small 'thumbnail' area, at the position shown by the arrow in Figure 2, which extended to a depth of approximately 70 per cent of the skin's thickness (approximately 0.6 mm), and was approximately 1.5 mm long at the surface of the skin. From this origin, the fatigue crack had propagated towards the trailing edge for a distance of approximately 112 mm, at which point the failure mode had changed to a 45° shear rupture (overload). The fatigue crack had also propagated forward from the origin towards the leading edge, for a distance of approximately 41 mm, making a total fatigue crack length of approximately 153 mm. A number of dark-stained regions were noted on the fatigue fracture surface, extending towards the trailing edge from the origin region; these marks had the appearance of crack-arrest marks, but were randomly spaced.

The edges of the fracture within the thumbnail origin region were slightly damaged, and it was not possible to identify the initiation mechanism by reference to the fracture characteristics alone. It was noted that the outer surface of the skins adjacent to the fracture were heavily scored, and similar scoring was noted on the opposite (intact) blade within the area where paint had been removed previously as part of the dye penetrant inspection process. However, there was no obvious relationship between any of these scores and the fatigue crack origin, and no sign of any other surface defect or abnormality which could have influenced crack initiation.

Efforts were made to correlate the fatigue fracture propagation characteristics with the recent service history of the blade, with a view to establishing the age of the fatigue crack, but no correlation could be found.

In the absence of any alternative explanation, it was considered most probable that the initiation of the fatigue crack had been due primarily to stress concentrations in the skin associated with inherent stiffness changes at the termination of the bonded doubler. No evidence was found to suggest that the affected blade had been operated in a significantly adverse environment, such as underslung load operations, but it was not possible to rule out the possibility that transient abnormal loading had occurred at some time in the blade's history, for example a temporary period of higher than normal vibration, prior to the blades being installed on G-USTA.

**Theoretical estimation of crack growth rate**

A theoretical study was undertaken, by specialists in fracture mechanics at DERA, to estimate the rate of growth of the fatigue crack once it had become established, based on static and dynamic stress data for a typical flight envelope of 30 minutes supplied by the aircraft manufacturer. This analysis suggested that an initial crack of 5 mm length would have grown to 55 mm over a period of 94 flights, equivalent to the interval between the time of the most recent dye penetrant inspection and the accident. Given that the actual length of the fatigue crack at the time of blade separation was approximately three times this size (153 mm length), it was considered likely that a crack of potentially detectable size would have been present at the time of the last recorded dye penetrant inspection.

**History of A109 tail rotor blade failures**

There had been two previous instances of TRB cracking on Agusta A109 helicopters prior to this failure on G-USTA.

The first occurrence, in January 1987 at Dartmouth, Massachusetts, resulted in TRB separation seconds after take off, with consequent detachment of the 90° gearbox caused by resultant out-of-balance tail rotor forces. The helicopter landed heavily, resulting in minor injuries to the seven occupants. The National Transportation Safety Board (NTSB) investigation report identified a chordwise fatigue fracture of the TRB, approximately 105mm in length, immediately adjoining the outer end of the bonded doubler, on the tension side of the blade. This was therefore an identical failure, for all practical purposes, to the failure which occurred on G-USTA. The NTSB report quoted a helicopter total time of 566.8 hours, but did not specifically state the in-service time of the failed blade. In response to the findings of the NTSB investigation, the aircraft manufacturer issued Telegraphic Technical Bulletin No 109-5, dated January 27 1987, which required all operators of A109A and A109A II helicopters equipped with tail rotor blades part number 109-0132-02, with 400 hours or more in-service time, to perform specified inspections of the affected area of the TRB. Specifically, operators were required to undertake the following:

- Within 10 flight hours of receipt of the Bulletin, to identify and mask off specified areas (encompassing the ends of the doublers) on both sides of the blade and to remove any finish paint using lacquer thinner, without removing the primer underneath, and to perform a dye penetrant inspection. Upon completion, if no cracks were found, the stripped areas were to be cleaned with a specified solvent and protected with a clear acrylic lacquer (also specified).

- At every 100 hour inspection, to remove the coat of clear lacquer and to repeat the dye penetrant inspection, re-protecting the affected area with clear lacquer afterwards if no cracks were found.

- During every airworthiness check, to perform a visual inspection of the tail rotor blade for cracks in the area coated with lacquer, if necessary with the use of a 3X to 5X magnifying glass, and if the presence of cracks is suspected to carry out the dye penetrant inspection specified.

  Note**:** The log book entry for G-USTA recording the dye penetrant inspection referred to the 100 hour inspection specified in the Bulletin. The 'visual inspection' element of the Bulletin would have applied to the A check, recorded in the aircraft's Technical Log.

The second instance of TRB cracking was reported in July 1991, when a short fatigue crack (of unspecified size) was found at a location slightly inboard of the end of the root doubler. It is understood that this crack was detected during a dye penetrant inspection carried out in accordance with Telegraphic Bulletin No 109-5. The affected blade had accumulated a total flight time of 1087 hours.

**Liaison with manufacturer and airworthiness authority**

Engineering specialists from the aircraft manufacturer and from the UK Civil Aviation Authority (Airworthiness Division) attended the initial inspection of the failed TRB and were kept informed of all relevant developments subsequently. The manufacturer also carried out a separate metallurgical examination of the fractures, initially of the outboard half of the blade which was made available at an early stage of the investigation, and subsequently of the inboard fracture surfaces which were forwarded upon completion of the detailed examination by the AAIB and DERA.

**Failure to detect the TRB crack during the dye penetrant inspection (G-USTA)**

The available evidence suggested that the fatigue crack should have been present at the time that the most recent dye penetrant inspection had been carried out on the TRBs on 26 November 1998, only 94 flights and 47 flight hours prior to the accident. However, no evidence was found of any dye residue on the cracked surfaces, which under normal circumstances would have been expected if the crack had been exposed to penetrant dye.

A possible explanation, both for the absence of dye residues and a failure to detect any crack at the time of the last dye penetrant inspection, might have been that during the process of dissolving the lacquer (and/or paint) using thinners, a thin slurry of dissolved lacquer may have seeped into the crack, effectively sealing it against penetration by the dye.

**Safety action**

The possibility that the paint removal procedures in preparation for the dye penetrant inspection might have resulted in occlusion of any cracks present, potentially compromising crack detection effectiveness, raised serious concerns about the adequacy of the procedures specified in Telegraphic Technical Bulletin No 109-5. These concerns were drawn formally to the attention of both the UK CAA and the manufacturer by means of telefaxed letters from the AAIB on 9 June 1999.

The manufacturer responded by reviewing Telegraphic Technical Bulletin No 109-5 and issuing a revised Technical Bulletin No 109-110, dated 28 July 1999, which superceded the original Bulletin 109-5. The underlying inspections required by the revised Bulletin remained fundamentally unchanged, but additional detailed instructions were given to improve their effectiveness, as described below:

> Part III (the dye penetrant inspection every 100 hours): Additional detailed instructions covering the procedures and materials to be used both when removing the paint/lacquer prior to the dye penetrant inspection, and when carrying out the dye penetrant procedure itself. The former included an explicit caution highlighting the importance of the paint removal procedure and emphasising that failure to remove all paint may lead to the occlusion of cracks.
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> Part II (the visual inspection, to be carried out at every check inspection including the A Check): Revised to include a requirement to clean the area covered by the

clear lacquer with aliphatic naptha or equivalent, prior to carrying out the visual inspection. Additionally, a specific caution was added requiring reference to the Maintenance Manual in the event of other damage (nicks, dents, corrosion etc) being detected.

In light of the revisions made by the manufacturer to the relevant Telegraphic Technical Bulletin, no additional safety recommendations were judged necessary.