SERIOUS INCIDENT

Aircraft Type and Registration:	EC135 T1, G-CCAU
No & Type of Engines:	2 Turbomeca Arrius 2B1A-1 turboshaft engines
Year of Manufacture:	1997
Date & Time (UTC):	4 December 2008 at 1330 hrs
Location:	Hindlip Hall, Hindlip, Worcestershire
Type of Flight:	Aerial Work
Persons on Board:	Crew - 3 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Damage to engine/gearbox cowlings
Commander's Licence:	Airline Transport Pilot's Licence (Helicopters)
Commander's Age:	Not applicable
Commander's Flying Experience:	Not applicable Last 90 days - Not applicable Last 28 days - Not applicable
Information Source:	AAIB Field Investigation

Synopsis

Shortly before the aircraft landed, one of the two rotating scissor link assemblies, which connect the rotating swash plate to the main rotor mast, became detached from the swash plate. The helicopter landed immediately without further incident. The investigation revealed that, during recent maintenance, the scissor link had not been correctly re-attached to the rotating swash plate. Since the incident, the maintenance organisation involved has introduced a number of changes to minimise the possibility of a similar event occurring again.

History of the flight

The helicopter had been returned to the operator on 3 December 2008 following maintenance to rectify a vibration defect. The next day, it was tasked to carry out a routine photographic flight. Approximately 50 minutes into the task, whilst flying towards the West Mercia Police Headquarters at Hindlip Hall, there was a noticeable increase in vibration throughout the speed range. The helicopter made a normal approach to the landing site at Hindlip Hall until it was approximately three feet above the ground. There was then a loud bang, followed by further repetitive banging and heavy vibration at the same frequency as the main rotor rpm. The commander landed immediately and completed an emergency shutdown, during which the vibration increased significantly. After confirming that there was no further danger, the flight crew examined the rotor system and found that one of the rotating swash plate

scissor link assemblies had become detached from the swash plate. There were no injuries to the flight crew or personnel on the ground.

Initial examination

The EC135 is fitted with two identical scissor link assemblies, mounted on the main rotor mast (see Figure 1), which connect the rotating swash plate to the mast. Initial examination confirmed that one of the two scissor links (the one located between the yellow and green main rotor blades) had become detached from its mounting stud on the rotating swash plate. Damage was also found on the engine/gearbox cowlings, where the scissor link had struck them whilst rotating. No other damage was identified.

The scissor assemblies are made up of two sections, the helical tube and the helical lever (see Figure 1), which are secured to the rotor mast and rotating swash plate respectively.

The helical lever is secured to a mounting stud on the rotating swash plate by the use of a cup washer, castellated 'nyloc'-type nut and a split pin. The mounting stud was intact and the threads undamaged. The castellated nut and cup washer were recovered from the engine/transmission deck; the split pin was not recovered.

Maintenance history

On 20 November 2008 the maintenance organisation received a report from the operator of in flight vibration on the helicopter. The engineers dispatched to investigate the problem found several defects, amongst which was damage to one of the scissor link assembly/rotor mast attachment bolts and bushes. The helicopter was then recovered by road for rectification. During this rectification the damaged scissor link attachment bolt and bushes were replaced and a series of 'track and balance' flight tests were conducted prior to the helicopter being declared serviceable on 2 December 2008. The helicopter then flew for a further 4 hours before the incident occurred.

Investigation

In view of the rectification work completed on the helicopter immediately before the incident, the investigation focused on this maintenance input. Examination of the castellated nut showed no evidence of damage to the castellations or threads. However, the nylon insert did appear to show significant signs of wear, possibly indicative of the nut being reused. A number of split pins from the same production batch as those installed on the scissor links were obtained; tests identified no material abnormalities and confirmed that these items met their production specification.

In order to remove the main rotor blades, for example, when transporting the helicopter by road, all the blade pitch control rods must be removed. This requires the disconnection of both the rotating swash plate scissor links from the rotating swash plate. Removal and reinstallation of the scissor link is classified by the manufacturer as a 'vital system' task. This requires an independent duplicate inspection upon completion. During the initial phase of the investigation it became apparent that the scissor link which had become detached in flight was not the same as the assembly which had the damaged mounting bolt and bushes. For clarity, the scissor link assembly involved in the incident is referred to as scissor link A in the report, and the assembly which had the damaged mounting bolt and bushes, scissor link B.

Maintenance activity

The Master Signature Sheet within the work pack indicated that 10 members of staff had been involved

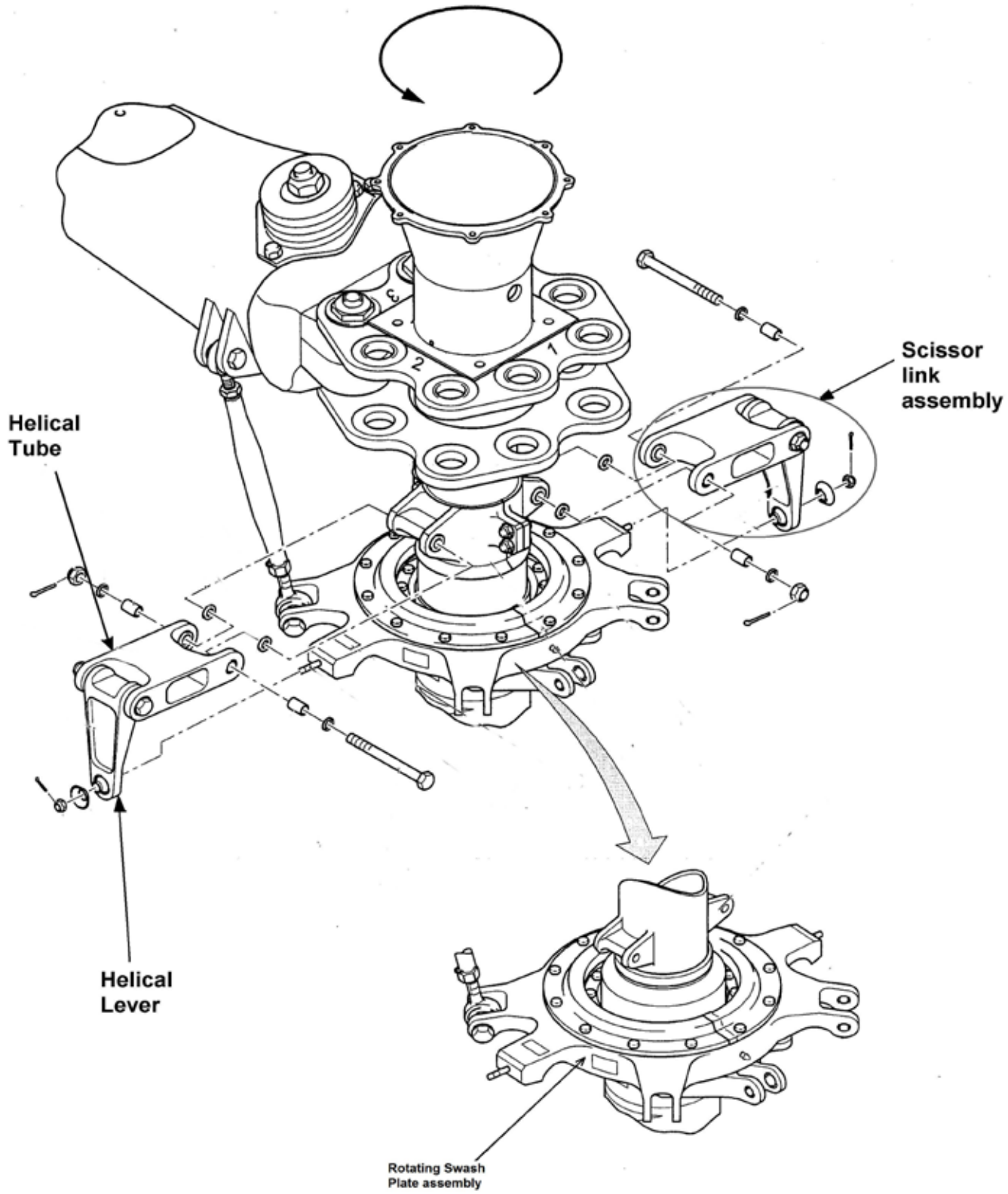

Figure 1

Rotor mast and scissor link assemblies

in the maintenance input. In addition the company identified three other people who had been involved in the input but did not appear on the signature sheet. It was determined that seven of these people, two fitters and five Licensed Aircraft Engineers (LAE's) had been involved in work carried out in the area of the swash plate scissor links. Interviews were carried with all of these personnel; these are referred to as Fitter 1 and 2, and LAE's 1 to 5 in the description of events which follows. In discussion with both managers and maintenance personnel it became apparent the removal of the main rotor blades and hence the disconnection of the scissor links was a very frequent occurrence, and was considered by all to be a routine task.

From the helicopter's arrival on 20 November until the late afternoon of 28 November, LAE1 had been responsible for the maintenance input. Fitters 1 & 2 had also been allocated to the aircraft and had completed various tasks during the input, as well as working on the scissor links. A routine work card, Task 5, had been raised in the work pack detailing the damage to scissor link B. This task card did not provide any additional information to identify which scissor link required rectification. Two additional work cards, Task 19 and 21, were raised for the removal and reinstallation of the blade pitch links and both scissor link assemblies, respectively. The description of the work requirement written in Task 21 stated:

> *'1) MAIN ROTOR SCISSOR ASSY'S TO BE REMOVED TO FACILITATE INSPECTION*
>
> *2) TO BE REFITTED POST WORK'*

Early in the input, Scissor link B was removed from the rotor mast, the damaged bushes were removed from the helical tube and a replacement set of bushings was obtained from the aircraft manufacturer. These were installed in accordance with the manufacturer's Repair Design Approval Sheet (RDAS) 1756. After completion of this task an attempt to refit scissor link B to the rotor mast was made but it was found that the replacement bushes appeared to be too large to allow the helical tube to fit around its locating lug on the rotor mast. At this point scissor link A was completely removed for comparison purposes. This confirmed that the replacement bushings were oversized. Subsequent communication with the manufacturer revealed that the bushes required honing before installation, which was not detailed in the RDAS. It was not possible to remove the newly installed bushings without damaging them so a second, replacement set of bushings were ordered from the manufacturer and scissor link B remained uninstalled. Scissor link A was reattached to the rotor mast by Fitter 2, who fitted the castellated nut on the bolt and installed, but did not 'bend over' the split pin; this was subsequently done by LAE1. The helical lever of scissor link A was not attached to the rotating swash plate.

In order to ensure that as much of the required work was completed prior to the arrival of the second set of bushes, all the main rotor blades and pitch control rods were refitted by LAE1 and Fitter 2. This task was certified within the work pack and the task closed. During this process Fitter 2 had placed the helical lever of scissor link A over the stud on the rotating swash plate and reinstalled the castellated nut. The nut was 'finger tightened' but not torqued up or split pinned, as Fitter 1 believed that there may have been a need to remove scissor link A again for comparison purposes. No documentation was raised to record the status of scissor link A in the work pack and the components were not 'tagged' in any way to identify that the installation was incomplete. Due to the approaching weekend and the fact that LAE1 was required to attend

a two-week training course on the following Monday, the helicopter was handed over to LAE2. LAE1 stated that, on the afternoon of 28 November, he carried out a verbal handover of the helicopter and its outstanding tasks to LAE2, who had been assigned to complete the input in the absence of LAE1. LAE1 also stated that, as the work pack still contained an open task card to refit the scissor link assemblies, he had no doubt that scissor link A would be checked for its correct installation prior to certification of the open work card, Task 21. Company records show that LAE2 was then reassigned to support a customer's helicopter 'off base', approximately 2 hours after being assigned to G-CCAU, and no handover was given to either the hangar supervisors or any other LAE.

After the arrival of the replacement bushes on 1 December they were honed and installed by Fitter 1, Fitter 2 having been assigned to another helicopter. This task was overseen by LAE3 and LAE4, both hangar supervisors, who appeared to be sharing the responsibility for G-CCAU. As far as they were aware, the only outstanding item on the helicopter was the replacement of the bushes on scissor link B and its re-installation. On completion of the task, scissor link B was reinstalled by Fitter 1.

The position of G-CCAU within the hangar meant that, with the rotor blades installed, the rotor head could not be turned. Maintenance platforms were in place on the right side of the fuselage allowing access to install scissor link B, but access to scissor link A could only be achieved by climbing up the left side of the helicopter. After installation, LAE3 inspected scissor link B and then climbed up the left side of the fuselage to inspect scissor link A. He recalled that the transmission cover had been refitted on the left side but noticed no abnormalities with the installation of scissor link A and certified the work card. In order to complete the duplicate inspection, Fitter 1 requested assistance from LAE4 who was engaged in supervisor duties elsewhere within the hangar. LAE4 conducted the inspection from the maintenance platforms on the right side of the fuselage, leaning across the transmission system to confirm the presence of the nuts and the split pins on scissor link A by touch. The second part of the duplicate inspection was carried out by LAE5 who climbed up the left side of the fuselage to view the installation of scissor link A. Neither LAE4 nor LAE5 noticed any abnormalities with the installation of scissor link A. All the remaining cowlings were refitted and a Check 'A' inspection was carried out and certified by LAE5. The Check 'A' included a specific task to check the condition of the swash plate drive (scissor) link assemblies.

On completion, the helicopter carried out a total of eight track and balance flights, amounting to 1.3 hours of flight time. After removal of the rotor track and balance equipment, LAE5 handed the helicopter over to LAE2 to rectify a separate outstanding defect, after which he completed a further Check A before the helicopter was declared serviceable on 2 December. The helicopter was flown from the maintenance facility by the operator on 3 December and accumulated a further four flying hours prior to the incident.

Maintenance facility organisation

The maintenance facilities consisted of two hangars. The day-to-day running of the hangar was controlled primarily by two supervisors who were LAE's. In addition to the day-to-day running of the hangars, the supervisors were heavily involved in liaison with customers and manufacturers on technical issues. It was also common practice for supervisors to be requested to carry out duplicate inspections of tasks and, in times

of high workload, to fill in for shortfalls in available manpower on the hangar floor.

In order to support its customers, the maintenance organisation had committed to provide engineering support 'in the field'. To support this activity it had a number of 'field' engineers. In the event that one of these engineers became unavailable, LAE's from the hangar work force were dispatched, sometimes at very short notice, to support customer's aircraft away from base, as was the case with LAE2 on 28 November.

For planning purposes, the normal workload within the maintenance facility was planned at 80% of the total available man hours, not including the use of supervisory staff or overtime. Examination of the workload for the period when G-CCAU was undergoing maintenance showed that, for the majority of this time, the actual workload within the facility exceeded this figure, and on several occasions exceeded the normal available capacity of the facility. Information obtained during the investigation indicated that personnel were routinely moved onto different tasks in order to meet production targets.

Maintenance facility paperwork

The revision standard of the maintenance manual used during the maintenance input was found to be correct for the period of the inspection. As previously mentioned, two work cards were raised involving the swash plate scissor links, Task No 5 (detailing the original defect, including replacement of the bushes and bolt in accordance with RDAS 1756) and Task No 21 which covered the removal and reinstallation of both scissor link assemblies. The certification information for Task No 21 indicated that both scissor assemblies had been removed on 25 November and reinstalled on 1 December. There were no additional work cards raised to cover the earlier installation of scissor link A, its subsequent removal (for comparison with scissor link B, after fitting the oversized bushes) or its partial reinstallation whilst awaiting the arrival of replacement bushes. After the final installation of scissor link B, Fitter 2 signed for action on the appropriate work card, Task No 21, and, as no additional task cards had been raised, he also signed for the installation of scissor link A, which he played no part in fitting.

Company procedures required a documented handover during changes of certifying engineers. No evidence could be found of a documented handover having been completed during the maintenance input on G-CCAU between 20 November and 2 December. During the interviews it became apparent that the handover process was only considered to be necessary when changing from a day shift to a night shift. It was also apparent that the use of verbal handovers between LAE's was considered to be normal.

Analysis

The tests carried out on the batch of split pins showed no evidence of an abnormality which may have led to the failure of a correctly installed pin. There was no evidence of unusual wear or distress on the castellations of the nut used to secure scissor link A to the rotating swash plate, or the corresponding stud on the swash plate. These facts, together with the information provided during interviews indicated that a split pin had not been inserted through the nut and stud securing scissor link A to the rotating swash plate. The condition of the nylon insert in the castellated nut indicated that this nut had been installed previously. Had the nut been new, it may not have been possible to hand-wind the nut fully onto the stud thread, thereby providing an additional visual cue to the incomplete installation.

The work cards raised for the original defect did not identify which of the two scissor link assemblies required rectification. This could have been achieved by making reference to its position in relation to the main rotor blades, for example as in between the yellow and green blades. The repair scheme provided by the manufacturer (RDAS 1756) did not identify the need to hone the bushes before installation - this has since been rectified - with the result that scissor link B could not be refitted as planned. As a result, scissor link A was removed for comparison and then partially installed. The absence of any paper work being added to the work pack to reflect this situation meant that the true condition of the scissor link assembly was only known to Fitter 1 and LAE1.

The delay in obtaining a replacement set of bushes for scissor link B, coupled with the need to attend a training course, meant that LAE1 was unable to oversee the completion of the maintenance input. The use of a verbal handover, which appeared to be the established norm, from LAE1 to LAE2 could have led to a possible misunderstanding of the outstanding tasks on the helicopter. No evidence was found of the use of a written handover during the input. The organisation's policy of providing field support for customers meant that LAE2 was taken off G-CCAU two hours after receiving the handover from LAE1 and any information that had been passed to him was lost.

All the remaining personnel involved in the final installation of scissor link B believed, incorrectly, that the only outstanding task was the refitting of scissor link B. The fact that the main rotor blades and blade pitch rods had been refitted, tasks normally associated with the refitting of the scissor links to the rotating swash plate, and the lack of maintenance platforms on the left side of the fuselage would only have served to reinforced this opinion.

The workload within the facility during the maintenance input on G-CCAU's resulted in the hangar supervisory staff who had no direct involvement with G-CCAU being required to act as certifying engineers, in addition to their normal supervisory duties. This may have introduced an element of distraction and additional pressure whilst they performed their roles as certifying engineers. Without a documented handover they did not have a full understanding of the outstanding tasks on the input. After the installation of scissor link B, the duplicate inspection process, designed to identify such errors, failed to identify the incomplete installation of scissor link A. It was clear from the interviews, that all the personnel involved felt that they had carried out the inspection, yet the error went unidentified. Both the subsequent Check A's also failed to identify this situation.

Conclusions

The scissor link assembly requiring rectification work was not clearly identified in the input work pack. Also, the incomplete repair scheme, provided by the aircraft manufacturer for the replacement of the bushes on scissor link B, resulted in a delay to the maintenance input which, due to other commitments, prevented LAE1 from completing the rectification work.

The removal and subsequent incomplete refitting of scissor link A for comparison with scissor link B was not recorded in the work pack. Nor was there evidence to suggest that the nut securing the helical lever of scissor link A to the rotating swash plate had been torque-loaded or secured with a split pin after being refitted. The nut used appeared to have been previously installed; had a new nut been used, its incomplete installation may have been more apparent.

The use of a verbal handover between LAE1 and

LAE2 could have resulted in a misunderstanding of the status of the helicopter. The organisation's policy for providing 'in field' support resulted in a further discontinuity in the management of the input and the lack of a documented handover then prevented subsequent certifying staff from fully understanding the status of the helicopter. All the personnel involved with the helicopter from 1 December onwards were under the impression that the only outstanding task was the refitting of scissor link B. The reinstallation of the main rotor blades and pitch control rods seems to have reinforced that belief.

The use of hangar supervisors to carry out certification tasks in addition to their normal duties may have introduced additional distractions during these tasks. After the reinstallation of scissor link B, five further inspections of the scissor link assembly failed to identify the situation.

Safety actions taken

In addition to the investigation conducted by the AAIB, the maintenance organisation conducted an internal investigation using the Boeing Maintenance Error Decision Aid (MEDA) tool. As a result, the maintenance organisation introduced the following changes to minimise the possibility of a similar event occurring again:

1. All engineering staff received additional training on the importance of identifying the status of all tasks within a work pack. This included the need to record accurately the partial assembly/disassembly of components and systems, the use of high visibility labelling to be attached to partially assembled items and the need to identify identical and interchangeable components clearly.

2. An internal engineering notice (EN323) was circulated reminding all staff of the standard practices involved in the use of self-locking nuts.

3. A redesign of the work card layout and procedures was carried out to improve the method of assessing, recording and certifying a task.

4. A redesign of the duplicate inspection process was carried out. This included additional training and guidance for all certifying staff in how to assess, scope and certify a task, how to identify possible areas of ambiguity and the consideration of external factors, such as lighting and use of maintenance platforms.

5. Hangar supervisors were no longer required to supervise inspections in a certifying role.

6. Certifying engineers acting in the role of 'crew chief' would be assigned to a single airframe and not distracted or expected to certify additional airframes.

7. Certifying staff completing critical inspections were required to wear a red waistcoat to signify that they were completing such a task and should not be distracted.

8. An amended handover procedure was introduced. This required that a documented handover be produced for every crew/shift change. These handovers would form part of the aircraft work pack.

9. A review and amendment of the content and scope of the current Human Factors training undertaken by the company was carried out, to ensure that the areas of concern identified in the investigations were addressed.