Sikorsky S-61N, G-ATBJ

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Aircraft Type and Registration:	Sikorsky S-61N, G-ATBJ
No & Type of Engines:	2 General Electric CT58 turboshaft engines
Year of Manufacture:	1965
Date & Time (UTC):	26 August 1998 at 0925 hrs
Location:	Dyce Airport, Aberdeen
Type of Flight:	Public Transport
Persons on Board:	Crew - 2 - Passengers - 8
Injuries:	Crew - None - Passengers - None
Nature of Damage:	Damage limited to tail rotor control system
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	54 years
Commander's Flying Experience:	15,486 hours (of which 5,168 were on type)
	Last 90 days - 71 hours
	Last 28 days - 17 hours
Information Source:	AAIB Field Investigation

History of flight

The helicopter was returning to its base at Aberdeen after an uneventful flight with passengers from a North Sea platform. The crew's intention was a 'run-on' landing on Runway 32 and the base leg and final approach were normal, with a slight crosswind of 350°/10 kt.

As the aircraft slowed in the flare, the first officer, who was the handling pilot, applied collective pitch and found that, with increasing left pedal input, he could not prevent the helicopter's nose swinging to the right. As he reached full left pedal he commented, "Why have I got full left rudder?" to which the commander responded, "Oh dear ..... better put it down". By this time the handling pilot had realised that he had lost control of the tail rotor as the rate of rotation increased: he briefly considered a 'fly-away' manoeuvre but could not generate the necessary forward airspeed.

The helicopter continued to yaw rapidly to the right for what appeared to the crew to be two or three rotations before the handling pilot, using collective and cyclic controls, was able to put the

helicopter on the ground. By this time the helicopter was no longer over the runway and the touchdown itself was a skidding manoeuvre on the grass, confirmed by the ground marks. The aircraft remained upright. The crew rapidly shutdown both engines and further advised ATC of their problem with tail rotor control.

It had seemed to the crew that the helicopter's tail rotor control system had failed and this was confirmed during initial inspection when it was found that one of the two tail rotor control cables had separated in the tail cone.

Flight recorders (Figure 1)

During the final approach to Runway 32 the aircraft was descending on a heading of 321°M and decelerating, with pedal position approximately neutral. By 33 feet agl the airspeed had reduced to 23 kt and, with collective increasing, the aircraft began to yaw slowly to the right. From this point, increasing left pedal was applied, reaching full travel within 10 seconds, but the yaw to the right continued and the yaw rate increased. The handling pilot commented that he had full left pedal applied, and was told to put the aircraft down.

At 9 feet agl the aircraft started to pitch nose-down and reached a 14o nose down attitude before the cyclic was moved fully aft, arresting the forward pitching moment and bringing the aircraft attitude back to between 5o and 8o nose-down. With collective still increasing, it began to climb and reached a maximum height of 51 feet agl as the commander made a brief radio transmission to advise that they had a problem. By this stage the yaw rate had reached a stabilised maximum of 59° per second to the right and the aircraft had made one complete revolution. It then started to roll erratically to the left with rapidly varying roll angles of between 5o and 22o.

The aircraft completed a second revolution as it descended and as it began to roll towards 'wings level' the commander made a MAYDAY call. At touchdown, which registered a value of 1.43g on the normal accelerometer, the aircraft was in an attitude of 10o left roll and 5o nose down pitch. Collective was lowered immediately but the aircraft continued to rotate to the right a further three-quarter turn, eventually coming to rest on a heading of 268°M.

Technical examination

Further examination of the helicopter was conducted with AAIB present and it was clear that the only discrepancy in the flying control system was the failed tail rotor cable, which had failed in the vicinity of a pair of pulleys in the tail cone. This arrangement is shown in Figure 2. In the S-61 design, very similar to the Sea King/SH-3 design, the two tail rotor cables are routed around pulleys along the roof of the cabin. The cables then pass over the pair of pulleys mounted at the top of the tail cone, turning 90° downwards before connecting to a quadrant mounted at the floor of the tail cone.

The tail rotor cables in this case are of the conventional construction, where a number of individual steel wires are wound into strands and these strands are themselves helically wound around a core strand, forming the completed cable. In this case the diameter is 1/8" with 7 strands, each of 19 individual wires.

The cable fracture was examined in detail, together with the pulley and its associated 'guard' pins, which are positioned to ensure that each cable remains located within its groove on the rim of the pulley. There was no deficiency in the cable material itself and many of the strands had apparently

failed in fatigue, others due to overload. Many of the wires adjacent to the fracture had been grossly deformed by being folded back or twisted together and the cable had taken on a 'set' about a diameter much smaller than that of the pulley (2.5").

The 'guard' pin mounted at the rear of the pulley (shown in Figure 3 as 'Guard pin - incorrect installation') had a distinctive area where the cadmium plating had been removed by wear. This suggested that the tail rotor cable had been misrouted over the guard pin during maintenance and that the cable had then proceeded to rub on the guard pin, which is formed of spring steel, until the cable eventually failed.

To test this theory, a new cable was routed in this manner, correctly under the top (0°) guard pin but, incorrectly, over a new aft (90°) guard pin (Figure 3). It was found that the tail rotor cable could still be joined to the next cable at the adjustable turnbuckle and the misrouting still allowed the tail rotor controls to operate. After the correct tension had been applied the tail rotor controls were exercised through the pedals for 'full & free' checks, with the auxiliary servo ON and OFF. The investigators agreed that there was a different "notchy" feel to the controls, particularly with the auxiliary servo OFF, and some additional noise, but neither the 'feel' nor the noise were compelling and both could be missed in a noisy and busy environment. After the test the cable and guard pins were examined and showed damage and burnishing very similar to the failed cable and its guard pin.

Previous maintenance actions

The maintenance organisation for G-ATBJ observes a conservative policy of replacing worn sections of tail rotor cable, including a full check of the cable runs every 300 hours. On 8 August 1998, some 44 flying hours before the incident, a 300 hour check had been performed. A total of 4 sections of cable had been replaced, including the section which later failed.

Interviews of the maintenance engineers by the AAIB and an independent Human Factors specialist did not reveal any particular circumstance to explain the misrouting of the cable and the failure to detect this during the subsequent 'full & free' checks. The engineers were properly qualified and experienced, were not under any particular pressure of time or workload, and appeared to have followed the normal procedure laid down in the maintenance manuals, including the duplicate inspections. The HF specialist had a number of minor suggestions for improvements in working practices but it appeared that this was a maintenance mistake which could, on occasion, recur.

Previous occurrences

During the investigation the AAIB reviewed a number of previous occurrences to similar (S-61/Sea King) commercial and military helicopters in the United Kingdom. In particular, UK military records showed a number of occurrences where, in this design, a section of tail rotor cable had been misrouted and then misrigged. In some cases the mistake had been caught during the maintenance or before flight but a number had caused in-flight cable failures and, in at least one case, this had led directly to an accident.

The design of the Sikorsky S-76 tail rotor system is comparable. There have been at least two accidents to S-76 helicopters attributed to failures of tail rotor cables after misrouting. In September 1983 a US-registered S-76 (N-521AC) ditched in Lake Michigan following loss of tail rotor control and in April 1982 a Canadian-registered S-76 (C-GIMF) had crashed in the Gulf of Thailand, also following loss of tail rotor control.

Following these accidents, two changes were introduced for the S-76. One change was to the Maintenance Manual (MM), changing the process of installation of the tail rotor controls. Previously, the cables would be installed, the guard pins would be installed and then the cables would be correctly tensioned. In the MM revision the cables would be installed, the cables would be tensioned and **then** the guard pins would be installed.

The other change was that, in those areas with limited visibility, the steel guard pins were replaced with a frangible pin so that, in the case of misrouting, the guard pin would fail before the cable. This was promulgated in an Alert Service Bulletin, ASB 76-67-19. Neither of these changes was, however, applied to the S-61 product.

Safety recommendations

In most modern transport aircraft, any cable-signaled flight control system is either duplicated or is not critical to continued safe operation of the aircraft. Cable systems are structurally reliable and highly unlikely to fail for material reasons but in most helicopters the loss of the tail rotor control system is critical and in the S-61 this loss can result from a simple single failure. It is thus crucial that the possibility of such simple failures be reduced to the lowest level possible.

It is, therefore, recommended that the FAA require that S-61 maintenance documentation be changed to minimise the likelihood of tail rotor cable misrouting (Recommendation 98-64).

(The helicopter manufacturer comments that the S-61N Maintenance Manual has been revised to incorporate a cable installation sequence which satisfies this Recommendation 98-64. The changes are found in Revision 43, of October 1998, affecting Chapter 65-40-0 of SA 4045-80, the S-61 MM).

It is also recommended that the FAA require changes to the tail rotor pulley hardware in S-61 helicopters so that, in a case where misrouting has occurred, the tail rotor cables will remain intact (Recommendation 98-65).