Schweizer 269C, G-TASS

AAIB Bulletin No: 10/2004	Ref: EW/C2004/05/02	Category: 2.3
Aircraft Type and Registration:	Schweizer 269C, G-TASS	
No & Type of Engines:	1 Lycoming HIO-360-D1A piston engine	
Year of Manufacture:	1992	
Date & Time (UTC):	10 May 2004 at 1425 hrs	
Location:	Near Bowscale Tarn, Cumbria	
Type of Flight:	Training	
Persons on Board:	Crew - 2	Passengers - None
Injuries:	Crew - 2 (Serious)	Passengers - N/A
Nature of Damage:	Helicopter destroyed	
Commander's Licence:	Private Pilot's Licence (Helicopter)	
Commander's Age:	35 years	
Commander's Flying Experience:	270 hours (of which 88 were on type)	
	Last 90 days - 20 hours	
	Last 28 days - 13 hours	
Information Source:	AAIB Field Investigation	

Synopsis

The aircraft was engaged on a mountain flying instructional flight when it suffered an engine failure at a point where there was insufficient height to allow a safe landing to be made on the valley floor. During the attempted landing the tail rotor struck the ground; this was followed by a heavy impact with the hillside and the aircraft rolled over onto its right hand side. The crew suffered serious injuries in the accident.

The cause of the engine failure was not positively identified, although there was a possibility that the mixture control cable may have become disconnected from the mixture lever on the fuel injector servo. It was found that the attachment of the cable to the lever had been made in such a manner that rendered it susceptible to release under the action of relatively light loads.

History of flight

The helicopter owner was undertaking mountain flying training and had employed an experienced helicopter pilot to provide instruction over a planned two day period. Their first flight, from Leeds to Carlisle Airport through the Lake District, proved uneventful. A number of practise forced landings were initiated by the instructor and successfully executed by the owner within the mountainous area, but the instructor reported that although there was little cloud and excellent visibility the light winds at low level reduced the overall training value of the mountain flying exercise. After landing at Carlisle Airport the aircraft was refuelled to full and, following a break for lunch, they flew back towards the Lake District with the intention of landing at Newcastle Airport. Approximately 20 minutes after departure, whilst flying along a shoulder of high ground, the owner asked the instructor what they would do in the event of engine failure. The instructor replied that they "would not make the valley floor". The owner, who was flying at the time, then started a gentle right hand turn towards the valley floor and began a gradual descent by lowering the collective lever: he cannot recall if any throttle adjustment was made at this time. Shortly after commencing the turn the engine RPM fell rapidly to zero, coincident with the engine noise ceasing, and it became rapidly apparent that the engine had failed. They were flying at between 65 and 75 kt at the time but their exact position and height is unclear. The instructor immediately took control and set the helicopter into a range autorotation profile. He continued the turn towards the valley floor as there was no other obvious landing site but believed that there was little chance of reaching it, hoping at best to be able to 'toboggan' down the grassy slope. The owner attempted to restart the engine using the starter button on the end of the collective lever, but to no avail. After less than 10 seconds in autorotation, they realised they were going to hit a bracken covered protrusion and the instructor pulled fully up on the collective lever to reduce the rate of descent at impact.

The aircraft come to rest on its right side; the owner was able to unfasten his harness and climb out of the wreckage. The instructor was more seriously injured; he was lying underneath the wreckage and some passing hill-walkers assisted the owner in extricating him. This was made easier because the right side of his lap strap attachment had failed in the impact.

Witnesses

It was difficult to determine the exact position of the helicopter when the engine failure occurred and neither occupant was able to recall the height. An eye witness from the other side of the valley observed a level portion of flight and then lost sight of the aircraft behind trees before hearing the accident impact. Using visual features on the mountain behind them, the height of the helicopter was estimated by the eye witness to be 100 metres above the valley floor but their lateral distance from the mountainside could not be determined.

Autorotation

Without knowing the helicopter's exact position and height an accurate construction of their autorotation profile cannot be produced. It is estimated that the all up weight at the time was approximately 1,700 kg; in calm winds this would equate to an engine failed autorotation rate of descent between 1,500 and 2,000 feet per minute. With an airspeed in the order of 60 kt this would give a descent angle of between 14° and 18°. Consideration of the terrain shows that from their likely position, there were no suitable landing sites available to them when their engine failed apart from the valley floor.

Mountain Flying Instruction

The helicopter owner, although less experienced than the instructor, was the commander of the aircraft on this flight. Instruction was provided by a 57 year old Qualified Helicopter Instructor (QHI) who had a total of over 16,000 hours helicopter flying experience of which approximately 150 hours were on this type.

Accident site details

The aircraft had been flying along the valley in a westerly direction, close to the north-facing slope when the engine failure occurred. The marks observed on the ground indicated that the aircraft had turned onto a track of about 040° (ie facing downhill), with the initial contact being made by the tail rotor. Flakes of paint were found on the ground in this area, and it was later determined that this was the result of a main rotor strike on the tail boom, suggesting a large amount of aft cyclic control had been applied at the time. Approximately two metres further on there was a scar in the ground thought to have been made by the vertical stabiliser. Additional tail rotor marks were also found here, together with an impression attributed to the tail rotor guard, or 'stinger', which subsequently broke away from its mounting on the tail rotor gearbox.

The aircraft had then skipped some 16 metres further down the hill, where a substantial impact had occurred. A left skid imprint indicated that the aircraft was yawed slightly to the left compared to the earlier ground contact. Some fragments from the underside of the aircraft, including engine parts, were found here and it was apparent that most of the cockpit glazing structure had become detached at this time. The aircraft had become airborne again before landing some 10 metres further on at the bottom of a steeper section of the slope in soft, marshy ground. The absence of main rotor strike marks on the ground suggested that that the aircraft had remained upright up to this point, although it then rolled over, coming to rest on its right hand side, having sustained extensive damage, see Figure 1.

Figure 1 General view of the wreckage

Figure 1. General view of the wreckage

All three main rotor blades were found to be intact, with no evidence of high-speed impacts with the ground. In addition, all were found at a high flapping angle, indicating significant 'coning' prior to impact. It was also noted that the collective control setting was at maximum pitch angle. Thus the overall impression was one of low rotational energy, which accorded with the pilots' account of an engine failure.

The wreckage was recovered to the AAIB's facility at Farnborough for a detailed examination. During the recovery process, it was observed that a considerable quantity of fuel remained in the tanks, and that the fuel lines around the engine appeared to be primed with fuel.

Detailed examination of wreckage

i) Mixture control

During the on-site phase of the investigation it was observed that the mixture control lever on the injector servo had become disconnected from its control cable, without apparently causing any distress to the bolt hole within the lever, see Figure 2.

Figure 2 View of injector servo as found, showing apparently disconnected mixture lever

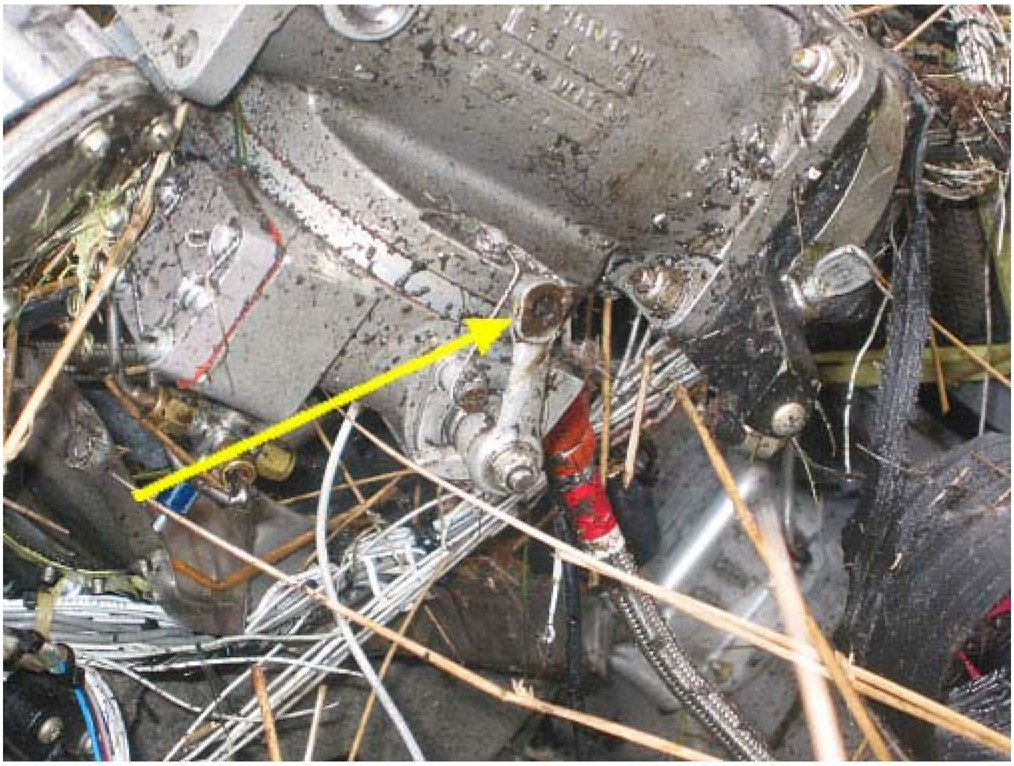


Figure 2. View of injector servo as found, showing apparently disconnected mixture lever

The engineering investigation focused mainly on the potential causes of the engine failure, and paid particular attention to the disconnect of the mixture control cable. This had been attached to the lever by means of a stud, cup, washers, nut and split pin, with the cable passing through a hole in the head of the stud. The Maintenance Manual illustration is shown at Figure 3a, where it can be seen that the head of the stud is wider than the shank.

Figure 3a Maintenance Manual diagram of typical cable attachment

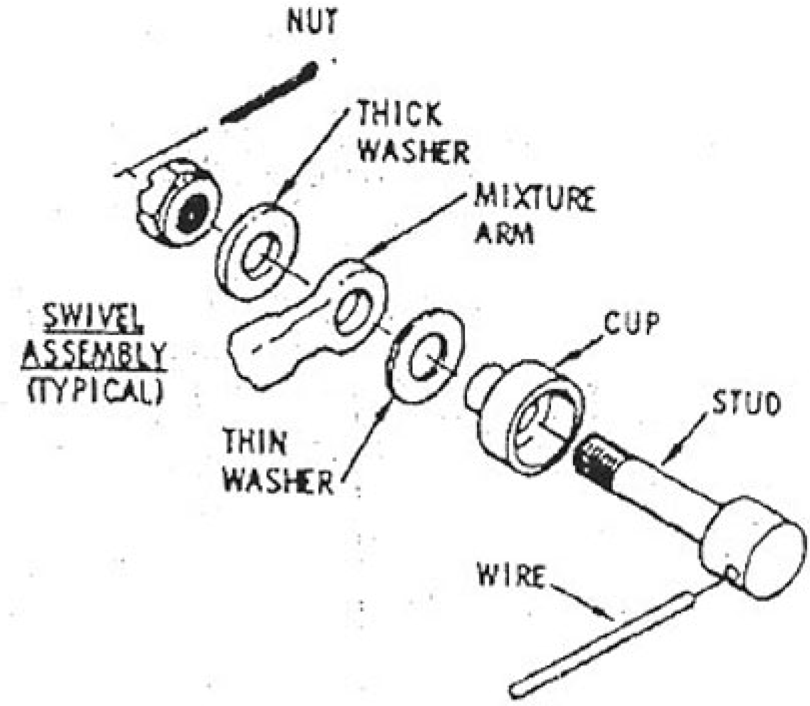


Figure 3a. Maintenance Manual diagram of typical cable attachment

The joint is effected by tightening the nut which draws the head of the stud into the cup, thereby creating a 'joggle' in the cable. Thus, in the event of a failure of the cable within the stud, or if it simply pulled through, the stud and nut assembly would be retained in the lever. This was patently not the case, and a subsequent inspection of a number of intact aircraft revealed that the design had changed such that the 'stepped shank' stud had been replaced with one where the head was the same diameter as the shank. According to the manufacturer, this design was introduced in 1995.

Clearly, in the event of a cable failure or pull-through with the modified design, the stud, together with the cup, nut, washers and split pin would not be retained in the lever. These items were not recovered from the accident site, although there was ample scope for them to have been lost between the grass tussocks in the marshy ground. Thus, the fact that they were not recovered did not help to determine whether the disconnect occurred in the air or as a result of the ground impact.

The fuel shut-off control utilised a similar cable to that of the mixture control, and was attached to the valve operating lever by means of the 'step-less shank' stud design, as shown at Figure 3b.

Figure 3b Current method of attachment, using "stepless shank" stud design. Split pin not shown

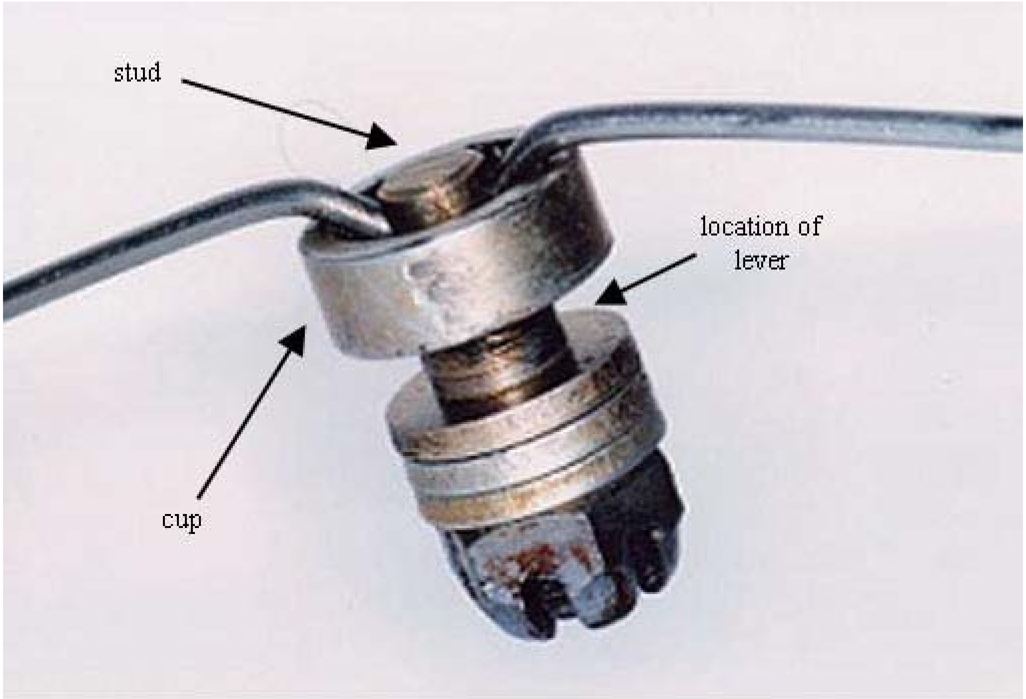
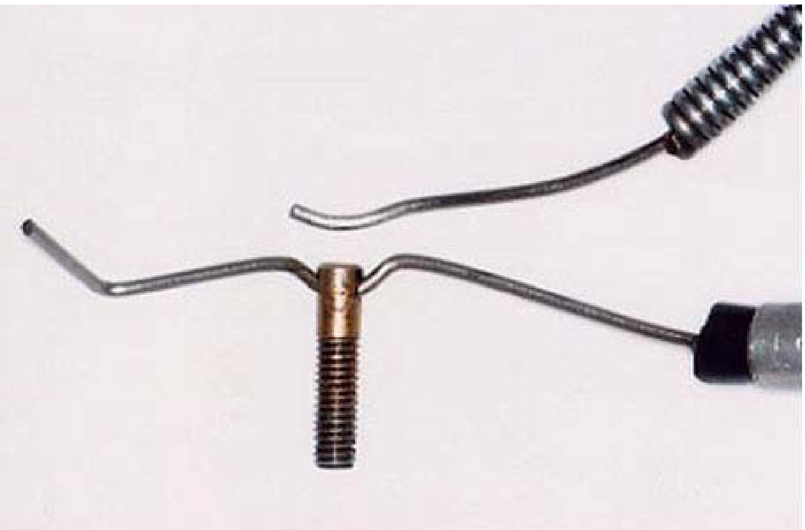


Figure 3b. Current method of attachment, using "stepless shank" stud design. Split pin not shown

This was disassembled for examination and comparison with the mixture control cable, see Figure 4. It was immediately apparent that the mixture cable terminated very close to the stud, whereas the fuel shut-off cable extended several inches beyond it, with the final half-inch being bent at right angles. The latter style was similar to mixture controls cables seen on a number of intact aircraft that were examined during the course of the investigation.

Figure 4 Comparison of mixture cable (top) and fuel shut-off cable



Cut end of mixture cable, showing low cycle fatigue band

Figure 4. Comparison of mixture cable (top) and fuel shut-off cable

A microscopic examination of the end of the mixture cable (see inset in Figure 4) revealed a central band containing evidence of low cycle fatigue, flanked by smooth, sloping surfaces, together with an area of overload. This was consistent with the action of a set of wire cutters, with the loose end being repeatedly moved up and down until it broke away. It was thus concluded that the end of the cable had been cut during the attachment process, as opposed to failing in the accident.

The fact that the mixture cable had been cut so close to the end of the lever meant that the final bend in the joggle contributed nothing to the strength of the joint. In a test on the fuel shut-off cable, a force of 25 lbs failed to pull the wire through the stud/cup/nut assembly. In contrast, the mixture cable required only 5 lbs force to pull it through. In both cases, the nut was finger tight. Whilst this may seem very little, it was observed, during a separate test on a piece of wire, that less than 10 lb ins of torque was required on the nut in order to draw the stud into the cup, in order to create a joggle.

Figure 5 shows a close-up view of the end of the mixture cable. Two indentations can be seen, which lined up with the edge of the cup. In the pull-off test described above, two similar marks were made, which were immediately adjacent to the existing ones.

Figure 5 "Joggle" area of mixture cable, showing indentations from cup rim

Figure 5. "Joggle" area of mixture cable, showing indentations from cup rim

ii) Engine and ancillaries

The engine was subjected to a strip examination at a Lycoming overhaul facility, under AAIB supervision. No mechanical defects were found, and the condition of the internal components was judged to be excellent; this was attributed to the owner's practice of changing the oil at 25-hour intervals instead of the 50 hours specified in the Maintenance Schedule. Some oil had pooled in the right hand cylinder heads as a result of the aircraft having come to rest on its right side. This had caused the spark plugs to be contaminated with oil, although the ones on the other side were noted to be dry in appearance, ie with no visible oil or fuel.

The accessory gearbox had been damaged in the accident, causing the oil filter and engine driven fuel pump to break off. The internal components of the gearbox were intact, and the oil was clean and free from metal flakes.

The ignition harness had been broken in a number of places as a result of the accident and so could not be tested. However, the technical records indicated that this had been renewed in January 2004. The magnetos functioned satisfactorily on a bench test. No loose components were found in the ignition switch, nor was there any evidence of pre-impact chafing or disconnect in the associated wiring.

The fuel gascolator was free of debris, and an internal examination of the engine driven fuel pump revealed no defects. The fuel tank vent system, which included a check valve, was found to be free from obstructions. The fuel boost pump, the cockpit switch for which was found selected to the ON position after the accident, functioned when connected to an electrical supply.

The fuel injector servo had suffered some damage in the impact such that the throttle butterfly would not close completely. This meant that the idle fuel flow could not be measured during the bench test. Information from the aircraft manufacturer indicated that engine failure can result following sudden throttle closure in the event that the idle fuel flow is set too low. This can be varied by means of an adjustable rod connected between the butterfly operating lever (connected to the throttle) and the fuel metering section on top of the servo. In all respects other than the idle fuel flow, the unit performed satisfactorily on test. This included checking the operation of the automatic mixture control, which used a bellows assembly to lean the mixture at high altitudes.

The fuel flow was measured throughout the approximate 80° range of movement of the mixture lever; from the fully rich position, it remained at maximum for the first 20% of travel, before decaying linearly to zero just before the idle cut-off position. The lever itself could be rotated easily under finger pressure, although it could not be described as "sloppy". A subsequent test revealed that approximately 2.5 lb ins of torque was required to produce movement.

Finally, the fuel injectors were placed on a test rig, with satisfactory results in terms of flow rates and spray patterns.

Previous incident

The owner had occasionally leased this aircraft to a local training organisation. There is anecdotal evidence that on 9 June 2003, whilst one of their instructors was flying in autorotation, the engine failed. The instructor reported that he had twisted the throttle to idle just prior to failure and was able to execute a forced landing with no damage to the airframe. During the subsequent investigation the idle fuel flow was reportedly adjusted. However, there was no entry in the technical log or aircraft log books that the incident had occurred; neither was there any paperwork that reflected the remedial action. The organisation that was responsible for most of the maintenance on the aircraft also denied all knowledge of the event.

Discussion

The crew statements, together with the on-site evidence, suggested an engine failure having occurred whilst the aircraft was unable to effect a landing on the valley floor. It is accepted that whilst flying this type of helicopter in mountainous areas, there will be times when a successful forced landing on a suitable site is not possible. Mountain flying training would lose much of its purpose if the helicopter was always flown within autorotative range of such a site.

Contaminated fuel was ruled out as a potential cause, as the elapsed time at Carlisle between refuelling and the subsequent takeoff would have allowed any contaminant to settle, leading to engine problems soon after start-up. The fuel lines around the engine appeared to be primed with fuel, although the dry appearance of the plugs might suggest fuel starvation. An exhaustive examination of the engine and fuel system revealed no irrefutable evidence of what could have been responsible for the power loss, although suspicion must inevitably fall on the attachment of the mixture control cable to the lever on the injector servo.

For the cable to become detached from the mixture lever, it would need to be loaded in *tension*, ie by *pulling* the cockpit control knob towards the idle cut-off position. The engine start procedure on this type of aircraft calls for the mixture initially to be set to the rich position whilst the boost pump is switched on; it is then returned to the idle cut-off position. The starter is then operated, with the mixture control being moved to the rich position as the engine fires. Thereafter, there is no need to touch the control knob, even at high altitudes, due to the automatic mixture control in the injector servo. Thus the mixture control knob can effectively be regarded as a low pressure fuel cock. If the cable had become detached prior to the starter being engaged, it is likely that the engine would not have started. If any such disconnect occurred subsequently, the mixture lever on the injector servo would have had to move, possibly under the influence of vibration, to a position where the fuel flow was insufficient to maintain engine operation at that throttle setting.

The injector servo was bolted directly onto the engine, and as such would be subjected to significant vibration, the amplitude of which may have varied with engine RPM. It is also possible that airframe vibration affected the unit. Whether vibration forces alone could have caused a disconnect is a moot point. It also debatable whether the same vibration, acting on the mass of the mixture lever, could have subsequently overcome the torque necessary to move it.

Although it could not be established whether the cable had become disconnected from the lever prior to the accident, there was no doubt that the cable had been cut too short, thus reducing the strength of the attachment such that a force of only a few pounds could release it. The nature of the attachment was inconsistent with a similar cable attachment on the aircraft, and with those observed on other aircraft. This posed the question of whether there was any truth in the anecdotal report of an engine failure a year earlier, with the defective cable union being made in the subsequent, undocumented maintenance activity.