ACCIDENT

Aircraft Type and Registration:	Schweizer 269C-1, G-CEAW
No & Type of Engines:	1 Lycoming HIO-360-G1A piston engine
Year of Manufacture:	2006
Date & Time (UTC):	22 May 2010 at 1150 hrs
Location:	Liverpool Airport, Merseyside
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - 1 (Minor) Passengers - N/A
Nature of Damage:	Extensive
Commander's Licence:	Commercial Pilot's Licence
Commander's Age:	51 years
Commander's Flying Experience:	370 hours (of which 230 were on type) Last 90 days - 1 hour Last 28 days - 1 hour
Information Source:	AAIB Field Investigation

Synopsis

The pilot was performing takeoffs and landings at Liverpool Airport when the helicopter entered ground resonance while landing. The rotor rpm (N_R) was too low for flight but, instead of closing the throttle, the pilot attempted to restore the N_R to the normal speed. The ground resonance increased rapidly and the aircraft was damaged beyond economic repair. The pilot recalls losing control; his next recollection is receiving medical treatment 40 m from the helicopter. His injuries were classified as minor.

The helicopter's landing gear dampers were subjected to several tests, but with inconclusive results.

History of the flight

The pilot was carrying out some general handling manoeuvres around Taxiway Y at Liverpool Airport. The weather conditions were good, with a light and variable wind, and the temperature was 24ºC. The pilot completed a landing on the shoulder of the taxiway, facing west, which gave him a lateral slope of about 3°. He then lifted the aircraft back into the hover, carried out a 180° turn and landed again, this time facing east. As the pilot lowered the lever, he experienced a violent and divergent vibration. Suspecting ground resonance, the pilot decided to lift back into the hover, but, on checking the N_R he realised that it was below the green arc (the operating range for flight). He opened the throttle to increase the N_R but was unable to lift to the hover because the increasing vibration made the aircraft uncontrollable.

This was the pilot's last recollection. The next thing he remembered was sitting on the ground, approximately 40 m from the helicopter, being treated by the emergency services. The pilot was taken to the local hospital where he received 20 stitches to the back of his head. The aircraft was damaged beyond economic repair but there was no fire (Figure 1).

Figure 1

Ground resonance

All fully articulated helicopters are susceptible to ground resonance with, according to the manufacturer of G-CEAW, three-bladed aircraft more susceptible than those with more blades. Ground resonance is a condition which can occur when the relatively equal angular spacing between the main rotor blades is not maintained, due to movement permitted by the lead-lag dampers, whilst operating on the ground. This results in an out of balance condition in the main rotor, creating a lateral oscillation of the aircraft. This is normally damped by the landing gear oleos and tyres or, in the case of the Schweizer 269C, the landing gear dampers and struts. When one or all of the landing gear damper pressures differ from the design values, they may not attenuate the lateral motion and the subsequent divergent oscillation can increase to the point of breaking up the aircraft.

The flight manual for the helicopter contains the following caution when performing the external check of the landing gear.

> *'Ground resonance can result if the helicopter is operated when landing gear damper extension, oil type, and/or oil to air proportions are incorrect.'*

The manufacturer examined photographs of the helicopter and of relevant components, which were taken after the accident and confirmed that the damage to the aircraft was consistent with ground resonance.

Once ground resonance starts it can develop very quickly. The FAA Basic Helicopter Handbook contains advice for pilots who experience ground resonance. It states:

> *'Corrective action could be an immediate takeoff if RPM is in the proper range, or an immediate closing of the throttle and placing the blades in low pitch if RPM is low.'*

Landing gear damper description and maintenance history

The dampers are fixed-orifice type hydraulic units, filled, to a specified level with hydraulic oil and charged with nitrogen gas. The rear dampers have a higher charge pressure (725 psi) and lower fluid level than those at the front (350 psi). Thus the effective spring stiffness is determined by the gas pressure whilst the damping is governed by the rate at which the fluid is transferred through the internal orifices.

The pressure in the dampers can only be set at manufacture and subsequent overhaul; there is no provision for checking or topping up the pressure during service due to the small volumes of gas involved. The condition of the units is assessed by means of a pre-flight visual check of the aircraft stance, together with a dimensional check of the dampers at the 100 hour inspections.

The helicopter underwent a 1,200 hour check in November 2009 at 1,172 flight hours. The work carried out included sending the landing gear dampers, for resealing and recharging, to a small component maintenance company that is familiar with the units and has a long experience of servicing them; they were thus aware of the different charge pressures between front and rear. The recharging process was conducted using a dedicated rig in which the damper was connected to a nitrogen supply: the rig's pressure gauge was subjected to an annual calibration check. The helicopter maintenance company had requested that the pressures were set to the lower limits, as the flying instructors had stated that doing this tended to lessen any vibration. However, the component maintenance company misinterpreted this request and set them to the upper limits. When the helicopter maintenance company realised this (via a telephone conversation, before the dampers had been refitted to G-CEAW), the units were sent back again and recharged to the lower pressure limit on 26 November 2009. The worksheets relating to this activity were made available to the investigation; these indicated that the pressures were set in accordance with the values stipulated in the associated Maintenance Manual. Only after this second visit to the component maintenance company were the dampers finally reinstalled on the aircraft.

Other work conducted during the 1,200 hour check was a dynamic balance of the main rotors. This resulted in an adjustment to two of the lead-lag dampers; the adjuster nut on one of them was turned 3.875 flats, with the maximum allowed by the Maintenance Manual being 4 flats. Changing the damper length in this way results in a small change in the angular displacement of the main rotor blades, with an attendant possibility of altering the magnitude of the lateral oscillations. The helicopter maintenance organisation stated that they keep a record of successive adjustments to ensure that the totals do not exceed the 4 flats limit.

The next maintenance activity on the aircraft was a 50 hour check on 30 April 2010 at 1,264 flight hours. This included a visual inspection of the landing gear dampers. At the time of the accident the helicopter had flown 121 hours, without incident, since the 1,200 hour inspection in November 2009.

Examination of components

Photographs taken after the accident showed that all three lead-lag dampers were broken. Unfortunately, these were not available for examination as the wreckage was disposed of shortly afterwards. The only components that were retained were the landing gear dampers, which appeared to be undamaged, with no fluid leakage. In view of their potential to cause ground resonance, it was decided to send them to the helicopter manufacturer for testing.

It was not possible for the charge pressure to be measured directly, for the same reasons noted above. The tests involved subjecting the units to a compression load/deflection test and comparing the results with those from serviceable dampers. It was found that, for a given load, the forward dampers were compressed by a smaller amount than with a serviceable unit.

Similar results were obtained with the rear dampers, although the differences were much smaller. Overall, these results suggested that the forward landing gear dampers were significantly overcharged, and the aft dampers were slightly overcharged. The helicopter manufacturer concluded that this condition did not allow the dampers to stroke sufficiently to attenuate the normal oscillating motion of the aircraft, thus resulting in ground resonance.

The dampers, which had not been opened or otherwise tampered with during the tests, were then returned to the UK, where they were subjected to additional tests, under AAIB supervision, at the component maintenance company where they were serviced. These tests were aimed at estimating the charge pressure and utilised the same rig that was used for charging the units during servicing. In this process, the damper was mounted in a specially designed fixture, with the piston ram end screwed into an integral fitting that was pressurised from a nitrogen supply. A charging plug on the end of the ram could be unscrewed by means of a handle and operating spindle that was located within the fitting and which was equipped with gas-tight seals. The process of partially unscrewing the plug exposed a hole in the threads that linked the gas chamber within the ram to the pressurised supply. Thus, by reference to the gauge, the damper could be charged to the required pressure before re-tightening the plug.

The test involved pressurising the supply line to the approximate charge pressure and then closing an isolating valve immediately upstream of the gauge, thereby trapping the gas in the short length of tubing between the damper and the isolating valve. Unscrewing the damper plug allowed equalisation of the pressures in the damper and tubing, which resulted in a change in the gauge reading. In the case of the forward dampers, the lines were charged to approximately 340 – 350 psi (it was noted that the combination of small gauge size and parallax error realistically limited the accuracy of the reading to ± 10 psi). Opening the damper plug caused the indication to drop to around 320 psi in both cases. If it is assumed, for a first approximation, that the gas volumes in the damper and charging lines were similar, then the gauge would indicate an average of the two pressure values. Thus the damper pressure would have been in the region of 290 - 300 psi. Whilst this figure does not represent an accurate assessment, the fact that the needle dropped confirmed that the damper pressure was lower than the specified value, albeit by a small amount.

The aft dampers were subjected to the same test. In the case of the right hand unit, the gauge reading increased slightly when the damper plug was loosened, indicating that the internal pressure was around 720 psi. The left unit was found to be low, probably below 600 psi.

The overall conclusion was that three of the dampers were likely to have been below their specified charge pressures, with the left rear unit approximately 14% down. These results were thus in complete disagreement with the conclusions drawn from the tests at the helicopter manufacturer.

An additional test was conducted in which a damper was placed in a fixture that was equipped with a hydraulic jack, a gauge and a hand pump; operating the pump caused the damper to compress. The internal dimensions of the jack were not known, although a pressure of 100 psi would have generated a load of between 500 and 1,000 lbf. A serviceable front damper (no rear ones were available) was installed in the fixture and the jack pressurised to 50 and 100 psi, and the compression of the damper was measured.

The process was repeated for one of the front dampers from G-CEAW, using the same applied pressures. The deflections were found to be nominally the same for both units.

Discussion

The available evidence indicated that the helicopter entered a ground resonance condition while landing. The N_R was too low for the pilot to lift into the hover and he did not close the throttle. The ground resonance rapidly increased in severity and the helicopter broke up. The helicopter manufacturer's tests suggested that the forward landing gear dampers were out of limits, in that the internal gas pressures were too high. However, subsequent tests in the UK suggested that the pressures in three of the units were slightly below the specified value, with one of the rear units being more significantly (possibly around 14%) below. It was not possible to reconcile this contradiction in the conclusions of the two series of tests.

The helicopter had successfully completed 121 flying hours since the 1,200 hour inspection, when the landing gear dampers had been recharged and the main rotor dampers adjusted. The operator experience suggests that some aircraft have a greater tendency than others to display symptoms of ground resonance. It is likely that changes to the landing gear and main rotor dampers, either singly or in combination, could account for such tendencies.