SERIOUS INCIDENT

Aircraft Type and Registration:	EC135 P2+, G-POLA
No & Type of Engines:	2 Pratt & Whitney Canada PW206B2 turboshaft engines
Year of Manufacture:	2010 (Serial no: 0877)
Date & Time (UTC):	5 April 2018 at 1040 hrs
Location:	Morpeth, Northumberland
Type of Flight:	Flight test
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	None
Commander's Licence:	Commercial Pilot's Licence
Commander's Age:	49 years
Commander's Flying Experience:	6,200 hours (of which 2,400 were on type) Last 90 days - 16 hours Last 28 days - 7 hours
Information Source:	AAIB Field Investigation

Synopsis

During a maintenance flight to adjust engine speed, main rotor rpm varied between its maximum and minimum continuous limits. A mechanical stop within the adjusting potentiometer had failed in such a way that main rotor speed could not be controlled accurately, putting the helicopter at a significant risk. The pilot had not been specially trained to carry out the flight test but his actions in flight prevented rotor speed exceeding its limits and a more serious outcome. The manufacturer and operator have taken safety action regarding the conduct of airborne engine speed adjustments.

History of the flight

In November 2017, after an engine change, a deferred defect log (DDL) entry restricted the helicopter to 4,500 ft density altitude[1] (DA). To remove this restriction the helicopter required an N_2 adjustment flight at 9,500 ft DA. The pilot indicated that because the DDL had been present for some time, he planned to use the opportunity of good weather at his base of Newcastle Airport to perform the flight test with appropriate engineering support.

Footnote

[1] Density Altitude – Pressure altitude corrected for non-standard temperature variations.

The pilot arranged for the helicopter to be left with the appropriate fuel onboard. He and the engineer reviewed the relevant procedure in the Aircraft Maintenance Manual (AMM)[2]. The pilot then calculated the DAs, because the helicopter would be required to climb from below 4,000 ft DA to at least 9,500 ft DA. This process also established the expected engine torque at the pitch stop.

The pilot started both engines, carrying out a five-minute drying out run after the cold rinse, followed by a hover check. The helicopter then departed the airfield. The pilot initiated a climb in accordance with the AMM procedure and called out the heights and temperatures for the engineer to record. They determined a pitch stop torque value at 9,500 ft DA of 67%, with an associated N_2 of 103.2%. This was slightly lower than the required 103.8% N_2. The pilot asked the engineer to make an adjustment on the N_2 adjuster, which he did. Initially there was no increase. However, after further adjustment, the N_2 slowly increased at a constant rate.

As the N_2 reached 103.8% the pilot advised the engineer to stop the adjustment, and he did so. However, the N_2 continued to increase through 104% and the N_R began to increase at the same time. The pilot arrested the rising N_R at 106% (the maximum continuous power-on N_R allowable) by raising the collective lever to full travel with a torque of 69%. At this point the N_R overspeed warning light illuminated and the associated aural alert sounded. To contain the now increasing airspeed and resulting airframe vibration, the pilot adjusted the helicopter attitude and initiated a moderate climb. The pilot asked the engineer to reverse the adjustment as soon as possible, which he did, but with no effect.

The helicopter had climbed approximately 1,000 ft and the pilot advised the engineer that he would have to manually retard the engines if the N_2 could not be reversed using the adjuster. The pilot stated that he was reluctant to do this because he considered it would result in either a double manual throttle approach[3], or a double manual throttle transit to a double engine shutdown and associated auto rotation forced landing at the airport. However, as the engineer continued adjusting, the N_2 started to reduce. The pilot advised the engineer to stop the adjustment as the N_2 reduced towards the target figure. Despite this, the N_2 continued to reduce past the target figure down to 98% which had a "dramatic effect" on the N_R. The pilot then lowered the collective to 20% torque and the N_R stabilised at 97%, the minimum continuous N_R, power-on allowable.

The helicopter was now in a moderate descent with an increasing airspeed, so the pilot adjusted the pitch the attitude and lowered the collective lever to increase the N_R. At this point the torque reduced to around 10% and the FADEC 1 & 2 FAIL (Full Authority Digital Engine Control) caution indications illuminated. By lifting the collective lever, the pilot increased the torque to 25% and the captions went out. In an attempt to recover N_R, the engineer made additional N_2 adjustments.

Footnote

2 AMM Section 05-60-00, 6-4 *'Ground Check Run and Functional Check Flight – EC135 P2 / P2+ Ground Check Run and Functional Check Flight'*, section F10 *'Adjust / check N2 in or above 9500 ft density altitude (only to be performed if the helicopter is operated above 4500 ft density altitude'*.

3 Whereby the pilot, not the FADEC, regulates engine speed.

The pilot began to revert to manual throttle but had difficulty lifting the associated catches until he removed one of his flying gloves. Just as he lifted one of the catches, the N_2 rose to 105% and eventually, with further adjustments, the engineer stabilised the N_2 at 101%. No further attempts were made to adjust the N_2 setting.

The pilot started a gentle descent. Aware that both engines were in an "under-trimmed" N_2 state, he performed power checks and a simulated approach to the hover at 2,000 ft agl. whilst maintaining a stabilised N_R of 101%. Therefore, the pilot elected to fly a normal approach to his base helicopter landing site at Newcastle, using a shallow descent profile to the hover. The pilot stated that he had been prepared to engage manual throttle on the No 1 engine and increase power, or commit the aircraft to a running landing[4], should the N_R decay dangerously on the approach.

After confirming that the N_R was sufficient, the pilot hover taxied the helicopter to the parking area and landed. As he fully lowered the collective lever, the pilot observed the N_R to rapidly drop to below 96%. The helicopter was then shutdown normally.

Weather

The pilot reported the weather on the ground as CAVOK, with a wind of 14 kt from 280° and air temperature of 6°C.

Personnel

The pilot was a "line"[5] pilot for the operator. He reported that of his 6,200 hours flight experience, 2,400 hours were on the EC135; mostly on the T2 variant. He had previous experience as a military "air-test" pilot.

The engineer was an experienced B1 licenced engineer who had carried out similar flight tests on previous occasions.

Aircraft description

General

The EC135 P2+ is a twin-engine, lightweight utility helicopter fitted with a four-blade rigid rotor. Yaw and anti-torque control is provided by a Fenestron[6]. It is fitted with two Pratt and Whitney Canada PW206B2 free turbine, turboshaft engines[7] with FADEC[8]. Input from the engines into the main rotor gearbox is via two main drive shafts with freewheel units. Inputs from sensors within the engines, main rotor gearbox and airframe are converted to digital control outputs from the FADECs into the engine fuel control units to control fuel to the

Footnote

4 Running landing – Helicopter landing made into wind with groundspeed and/or translational lift at touchdown.
5 Line pilot – common term for those of the front-line pilot workforce, who have no additional management or training functions within an organisation.
6 A ducted fan system providing yaw control in the manner of a tail rotor.
7 EC135 helicopters fitted with Pratt and Whitney engines are designated as EC135 P variants and those fitted with Turbomeca engines are designated as EC135 T variants.
8 Full authority digital engine control.

combustion chambers. Power output is varied automatically to maintain the rotor N_R within its design limits throughout the flight envelope. The FADECs are linked, known as 'cross-talk', to automatically match each engine as collective demands are made by the pilot.

N_2 description

After installation of a replacement engine or FADEC unit the N_2 speed is set by adjustments made to the N_2 ADJUST control installed in the lower part of the overhead panel.

On the earlier P1 variants of the EC135 there was no cross-talk between the engines which therefore required an individual adjuster for each engine. In the P2 variants of the EC135 the cross-talk facility means that it is possible for one adjuster to set N_2 in both engines simultaneously. When a replacement engine is fitted, the cross-talk facility automatically matches both engines. Normally the remaining, and already correctly set, engine would cross-talk to the replacement engine and N_2 would be correct. However, occasionally adjustments are required to ensure that when the engine start switch is in the FLIGHT position, the N_2 speed is maintained at 100% in normal flight conditions. This also ensures that the N_2 speed is automatically increased to between 100% and 104% when DA is between 4,000 ft and 9,000 ft.

N_2 adjuster

The N_2 adjuster is a small rotary switch set into the overhead panel (Figure 1) alongside the ENG I and ENG II MODE and VENT selection switches just behind the rotor brake lever. To operate the adjuster, a small flat-bladed screwdriver must be inserted which then enables it to be turned clockwise or anticlockwise. Within the switch there are a series of radially spaced contacts which are brought into alignment in various combinations as the spindle is rotated. In the switch casing there are 12 detent slots which engage a spring-loaded plunger held in the spindle designed to assist in the accurate alignment of the contacts. The detents give the switch a distinctive but light 'click' as the switch is rotated. There is also a fixed limit stop within the switch casing. However, in this application, it is required to work in a similar way to a three-position switch that can be rotated left or right 45° either side of the neutral setting. This range of movement is set by a stop ring fitted around the spindle of the rotary switch. The stop ring has a tang which protrudes through the switch casing into the path of a moulded lug, thus restricting spindle rotation to between the lug and limit stop. Figure 1 shows the N_2 adjuster location within the overhead switch panel of an example EC135. Safety lacquer (highlighted in Figure 1) is applied after adjustment in accordance with the AMM.

If the adjuster is turned anticlockwise against its stop the N_2 will gradually decrease until the adjuster is returned by the operator to its neutral position. Similarly, if rotated clockwise against the stop it will gradually increase until returned to the neutral position. The N_2 figure is shown as a percentage on the Vehicle and Engine Monitoring Display when the FADEC status page is selected. The gradual rate of response of N_2 allows accurate adjustments to be made.

Figure 1

Pratt and Whitney engine EC135 N_2 adjuster location

Maintenance history

The helicopter was maintained in accordance with the AMM and had recently undergone an engine change, which was not relevant to this occurrence other than it required the flight test to adjust and set the $N_{2.}$

Flight test procedure

The procedure in AMM Section 76-10-00, 5-5 - *'Setting N2 Speed',* describes how the N_2 adjustment is carried out and how to use both types of adjuster in the P2 and T2 series EC135 helicopters.

The flight test schedule for this task is set out in AMM Section 05-60-00, 6-4 *'Ground Check Run and Functional Check Flight…'*, as item F10 *'Adjust / check N2 in* [sic] *or above 9500 ft density altitude…'*. This describes how the helicopter should be flown and the altitudes at which this adjustment should be made to achieve the correct N_2 setting. It is laid out such that the pilot and engineer can record the readings at each stage of the step by step process.

In its internal report into the serious incident, the manufacturer stated that the correct procedure had been followed.

The operator indicated that, at the time of the occurrence, line pilots were permitted to perform the N_2 adjustment flight. The manufacturer stated that it is for an operator to decide which of its pilots qualify for maintenance activities. However, the manufacturer indicated that this flight test should be restricted to specially trained pilots, commenting that its own pilots undertake in-house training and would not carry out this flight test until they had seen it performed by another pilot. The manufacturer highlighted the importance of briefing what might happen on such a flight test, a process known as Threat Error Management (TEM)[9].

Footnote

[9] TEM – To plan, direct and control an operation or situation.

As an immediate response to this serious incident, the operator restricted the N_2 adjustment flight test to its maintenance test pilot only. It subsequently sought advice from the manufacturer and categorised all flight tests according to which of its pilots should perform them. Level 1 tests may be performed by line pilots without specific training; Level 2 tests require pilots to undertake a briefing; and Level 3 tests may only be conducted by specially trained type rating instructors and examiner pilots[10]. The N_2 adjustment flight test was categorised as Level 3, and the required training was modelled on that provided by the manufacturer to its pilots.

Investigation by the manufacturer and operator

N_2 adjuster

During the subsequent investigation by the operator and the helicopter manufacturer, the adjuster was found to be faulty. The adjuster spindle rotated freely through approximately 330° so was only being restricted by its fixed internal stop.

Pictures supplied by the manufacturer of the faulty switch showed no outward evidence of damage. However, the small screwdriver slot at the end of the spindle showed some evidence of wear marks left by screwdriver blades in the past (Figure 2).

The metal stop ring tab engages in the plastic components within the switch. The helicopter manufacturer issued a Technical Information Notice in 2010 drawing attention to the delicacy of the N_2 adjuster in the P2 variants of the EC135 helicopters. It also described the differences between the adjusters and how they operate to adjust the N_2.

Actions by the engineer

Prior to the flight, the engineer and pilot briefed the AMM procedure. During the flight, when the helicopter had been correctly configured for the first adjustment, the pilot noted the first N_2 figure and asked the engineer to increase it. This meant turning the adjuster clockwise, which he did. At first there was no reaction, so the engineer turned it a little further. The N_2 then continued to rise past the desired figure and so the engineer stopped adjusting. Then, as requested by the pilot, he turned it back anticlockwise and again, after a delay, the N_2 reacted, this time reducing. After his first adjustments he no longer knew the orientation of the N_2 adjuster relative to its neutral datum. The engineer was now “very concerned” about this and felt that he had completely lost control of the N_2.

Although the engineer was expecting the stops to limit his adjustments, he was not aware of them having done so. He did, however, observe evidence of a previous application of safety lacquer.

Investigations by the manufacturer

The adjuster was removed from the helicopter and was returned to the helicopter manufacturer for further investigation. After removal of the adjuster the stop ring could not be found. Tests carried out on the adjuster using a spare stop ring showed that the adjuster worked correctly, with the stop ring and fixed stop restricting rotation either side of its neutral position.

Footnote

[10] Pilots with a formal training function.

Additional tests were carried out on another adjuster and stop ring combination. During this test the adjuster was forcibly over-driven using a screwdriver in the spindle slot. This had two effects: the screwdriver slot became misshapen and burred on the slot faces; and the lug on the plastic rotating part of the adjuster, which limits its travel against the stop ring tang, was damaged with a distinctive 'cut' through the lug.

These effects were compared to the original adjuster removed from G-POLA. The screwdriver slot showed superficial wear and the lug on the rotating part of the adjuster was undamaged (Figure 2).

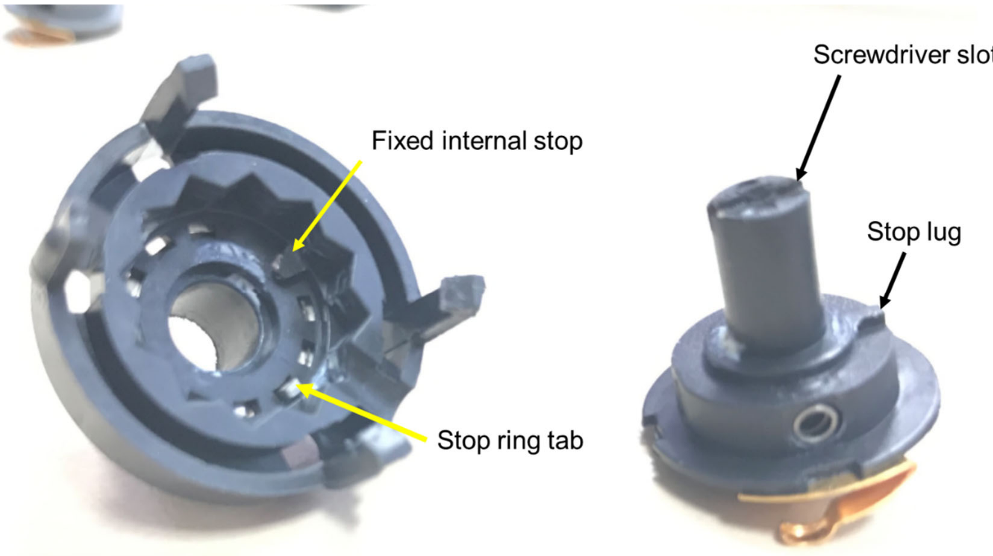

Figure 2

N_2 adjuster fixed casing and spindle.
Note the stop ring tab, fitted to show how it controls the range of spindle rotation

As a result of this serious incident the manufacturer released a Safety Information Notice (SIN), which stated:

> *'During an engine power turbine speed (N_2) adjustment flight of an EC135, P2+, the N_2 had been unintentionally adjusted up to 106% N_R. In the subsequent attempt to reduce N_2 speed again, N_2 reduced to 98% with a corresponding effect on the rotor speed N_R. For safety reasons, the pilot then aborted the flight and landed.*
>
> *Therefore, Airbus Helicopters Deutschland (AHD) wants to highlight that – depending on the engine variant – there are different procedures for adjusting the power turbine speed (N_2). These are described in AMM 76-10-00-5-5 (setting – N_2 speed). Additional information can be found in TIL EC135 033-2010.*
>
> *Applying the wrong adjustment procedure could result in an incorrectly adjusted N_2'.*

The SIN did not refer to the faulty adjuster or offer advice on how pilots should prepare for carrying out the flight test.

Comments by pilot

The pilot and engineer found the occurrence disconcerting because they were faced with several emergencies in a short space of time.

The pilot believed he had been assisted by his previous military training, during which he encountered similar malfunctions to those in the incident flight in a full motion simulator.

Most of the pilot's EC135 experience had been on the T series. In his opinion, manual throttle control on the P series is more difficult because it is more "sensitive" and the pilot's inputs control[11] the engine directly. He stated that he had not had the opportunity to practice a double manual throttle emergency on either series but had previously developed a plan for dealing with one, which he believed was crucial in his handling of this emergency. He stated that he had "meticulously planned" the logistics of the incident sortie, but that he had not specifically briefed the "what if's" of the flight.

The pilot wore thick gloves because he had calculated the OAT during the flight test would drop to around -15°C. However, these impeded his ability to lift the manual throttle catches, which he reflected could have been problematic had it happened close to the ground.

The pilot suggested that an N_2 adjustment flight should be performed by specially trained pilots and conducted in smooth air conditions. Pilots should be prepared for uncommanded changes in N_2 and a double FADEC failure.

Additional information from the operator

The operator stated that at the time of the serious incident it was in the process of introducing simulator training for its pilots. This training began in September 2018, after this serious incident. The operator has incorporated what it considers "high risk" scenarios in the simulator syllabus and intends to mimic the occurrence as closely as possible in training.

Analysis

The helicopter had been correctly prepared and configured to carry out the flight test. The engine change was not related to the occurrence other than to have created the requirement to undertake an airborne test to adjust and set up the N_2.

Actions by the pilot and engineer

At the time of this serious incident, the operator had not prohibited line pilots without specific training from performing the N_2 adjustment flight test. The pilot chose to perform the flight test in order to clear the associated DDL. The pilot and engineer did not specifically brief the possible hazards of performing it.

Footnote

[11] The pilot explained that the T series' manual throttle mode retains an element of FADEC control.

During the flight, the engineer was unable to control N_2 and the pilot made large control inputs to control N_R. High and low N_R values had the potential to have a catastrophic effect on the helicopter in flight but by working together and using the effects of the helicopter dynamics, the pilot and engineer were able to stabilise the N_R, albeit lower than normal, and recover the helicopter to land safely.

Effect of the faulty N_2 adjuster

N_R variation was consistent with N_2 changes made using the faulty adjuster. In the absence of the stop ring there was no means to ensure correct alignment of the contact combinations within the rotary switch. This meant the switch did not have a reliable effect on N_2. The engineer making the adjustments could not determine which contacts were made and was no longer confident in the neutral position. The gradual N_2 change rate also made it difficult to establish what was happening with the adjuster, which appeared to be having an unexpected effect. Despite the residual safety lacquer on the adjuster, the engineer was not able to establish a neutral position or judge its extremes of range, so was therefore quite correct in his feeling that he had completely lost control of the adjuster.

N_2 adjuster

The manufacturer found the adjuster to be undamaged and, when combined with a spare stop ring, it worked correctly. The description of the action of the adjuster by the engineer during the flight test indicated that there was no restriction, apart from the detent clicks, in the rotation of the adjuster. The feel of an adjuster that has been forced is distinctive and was not present on the adjuster removed from G-POLA. Discussions with the manufacturer indicated that despite the delicate construction of the switch, considerable force would be required to overcome the stop ring. This verifies the finding that after removal of the adjuster the stop ring could not be found and therefore it was not present during the test flight.

From the description of the event by the engineer it appears that the initial adjustment would have been a clockwise rotation to increase the N_2. Without the stop restricting movement there is a risk of rotating the adjuster too far.

However, it is possible that on previous occasions the detent 'clicks' were enough to have prevented over- or under adjustment by other engineers.

Once the N_2 is set, in normal circumstances the N_2 adjuster does not have a dynamic effect on the helicopter in flight. However, it is only when it is adjusted in flight that it becomes apparent whether it is working correctly. Unlike the N_2 adjuster in the T series EC135, which is of a different design and is a more traditional potentiometer, it is possible to establish the integrity of the stops of the adjuster in the P series helicopters on the ground with power-off before a flight test is carried out.

Training and preparation

Although operators decide which pilots may perform the N_2 adjustment flight test, the manufacturer indicated that it should be restricted to specially trained pilots. The operator now intends that only nominated and trained pilots should perform it, and intends to incorporate the event in to its simulator training.

SIN 3254-S-76, released by the manufacturer after this serious incident, only focussed on the differences between the two types of N_2 adjusters. The AAIB discussed with Airbus Helicopters Deutschland the possibility of it informing all EC135 operators of the circumstances of the occurrence to G-POLA, advising them to use appropriately trained pilots to conduct N_2 adjustment flight tests, and explaining the importance of conducting a threat and error management briefing before performing it. Airbus Helicopters Deutschland has undertaken to action those suggestions, which it intends to extend to all AMM post maintenance tasks for all of its helicopter types, reminding operators of the importance of the specific pilot skills required by post maintenance flying activities.

It is likely that the hazards related to post maintenance flying highlighted by this event are relevant to helicopters from other manufacturers.

Conclusion

The loss of control of $N_{2,}$ and therefore of N_R, was caused by the absence of the stop ring mechanism within the P2 series EC135 N_2 adjuster, which risked a loss of control of the helicopter. The pilot had not been trained to carry out the procedure but his actions in flight prevented a more serious outcome.

Several safety actions have been taken by the manufacturer and the operator in relation to the related AMM procedure, pilot suitability for conducting post maintenance flying tasks, and pilot training.

Safety action

The manufacturer has:

- Issued an AMM amendment regarding the N_2 adjuster installation procedure (76-11-00,8-4), a caution to install the stop ring correctly / take care that the ring is not forgotten.
- Issued an AMM amendment regarding N_2 adjustment maintenance flights (05-60-00, 6-4), to check, prior to flight while on ground without power, that the N_2 adjustment switch works properly (only three switch positions are possible - decrease, neutral, increase). After successful check the switch must be turned into the neutral position.
- Issued Safety Information Notice AH 3254-S-76: *'Engine Controls – Engine Power Turbine Speed (N_2)'* to draw attention to this occurrence, remind operators of the procedure, and to highlight the difference in N_2 adjustment procedures between the P2 and T2 Series EC135 helicopters.

- Has undertaken to inform operators of all its helicopter types of the circumstances of the occurrence to G-POLA, reminding them of the importance of the specific pilot skills required by all AMM post maintenance flying tasks.

The operator:

- Has categorised its flight test activities according to which of its pilots should perform them. It has restricted the N_2 adjustment flight procedure to the remit of specially trained type rating instructor and examiner pilots.
- Intends to incorporate the incident scenario in to its newly established simulator training package.

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