INCIDENT

Aircraft Type and Registration:	AS332L2 Super Puma, G-CHCF
No & Type of Engines:	2 Turbomeca MAKILA 1A2 turboshaft engines
Year of Manufacture:	2001
Date & Time (UTC):	20 November 2007 at 2057 hrs
Location:	Aberdeen Airport, Scotland
Type of Flight:	Training
Persons on Board:	Crew - 3 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	None
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	50
Commander's Flying Experience:	13,199 hours (of which 2,040 were on type) Last 90 days - 118 hours Last 28 days - 37 hours
Information Source:	AAIB Field Investigation

Synopsis

A Training Captain was conducting an Operational Proficiency Check (OPC); the pilot under training was required to demonstrate a clear area rejected takeoff. The helicopter was equipped with a Training Idle System (TIS) which was in use to simulate a failure of the left engine. The helicopter took off along Runway 16 at Aberdeen; at about 28 kt the commander simulated a failure of the left engine and the takeoff was rejected. The pilot flared the helicopter to reduce speed and descended towards the runway. As the collective control lever was raised to reduce the rate of descent, the overspeed protection system shut down the right engine. Main rotor rpm (N_r) decayed rapidly and the helicopter touched down firmly before rrpm could be restored.

The right engine freewheel unit had failed causing that engine to overspeed; this was contained by the overspeed protection system shutting down the engine.

Four Safety Recommendations are made.

History of the flight

The purpose of the flight was to conduct standardisation training and OPCs on two pilots who had recently completed their type training and Licence Skills Test. The weather was good with a surface wind from 140° at 5 kt, visibility was in excess of 10 km with a few clouds at 3,700 ft, the temperature was +7°C and the QNH 1010 hPa. The intention was to commence the training by carrying out a maximum performance rejected takeoff. The flight had been fully briefed and the performance, weight and balance calculations had been completed prior to departure. The helicopter performance calculations were based on the training weights permitted in the Flight Manual Supplement relating to the engine TIS. The TIS allows the commander to simulate an engine failure on either engine by reducing its power to a training idle condition. The engine not selected to training idle powers the rotor system and is referred to in this report as the operating engine. Should the operating engine fail, the engine at training idle automatically accelerates to power the rotors.

Following a normal start on both engines a freewheel check was carried out and both freewheel units operated normally. The TIS was tested in accordance with the operator's Standard Operating Procedures (SOPs) and found to be fully serviceable. The helicopter was ground taxied to Runway 16, which is 1,829 m long, 46 m wide and has an asphalt surface. Following two demonstrations of an engine failure in the hover, using the TIS, the commander then demonstrated the rejected takeoff profile using a Takeoff Decision Point (TDP) of 60 kt. Following this demonstration, the helicopter stopped on the runway approximately half way along its length and was then ground taxied back to the threshold of Runway 16.

A rejected takeoff was then flown by one of the pilots under training using the same TDP and, as before, approximately half the length of the runway was used. Since there was sufficient runway length remaining, the pilot repeated the exercise. The helicopter was initially established in a 10 ft hover and then accelerated along the runway. As the airspeed passed through 28 kt at a height of 39 ft, the commander simulated a failure of the left engine using the TIS. The pilot lowered the collective control lever and pitched the nose up to 20° in order to reduce speed. As the speed decayed, the nose was lowered and the helicopter descended normally. The collective control lever was raised to cushion the landing, but at about 10 ft the crew heard the sound of an engine running up, accompanied by a loud bang and the sound of the low N_r warning. The commander took control of the helicopter, adopted the landing attitude and raised the collective control lever to its maximum limit. The helicopter continued to descend and touched down firmly with the left engine accelerating. The N_r which had decayed to 68% just prior to the touchdown began to increase and eventually stabilised at 90%.

The crew noted what appeared to be smoke or vaporised fuel on the right side of the helicopter and requested the attendance of the Airport Rescue and Fire Fighting Service (ARFFS). The crew identified from the cockpit indications that the right engine had suffered an overspeed condition and carried out the engine shutdown drill in accordance with the emergency checklist. Following confirmation from the ARFFS that there were no signs of fire, and noting that all other helicopter systems were normal, the commander taxied back to the operator's parking area. After a discussion with engineering control, the helicopter was shut down.

The helicopter was examined in accordance with the requirements of the engine overspeed inspection, after the removal of the right engine, at the operator's maintenance facility. The main rotor gearbox right freewheel shaft was found to rotate freely in both a clockwise and an anti-clockwise direction. The gearbox was removed for investigation.

Weight and balance

The maximum permitted takeoff training weight for the ambient conditions was 8,880 kg, with a maximum permitted landing weight of 8,450 kg. The actual takeoff weight at the commencement of the takeoff was 8,261 kg. The CG limits for the AS332L2 helicopter at this weight are 4.5 m to 4.95 m aft of the datum; the CG position of G-CHCF at the time of the incident was 4.67 m.

Main rotor gearbox

The AS332L2 is fitted with Makila 1A2 engines, which provide an additional 132 shp for single engine operation compared to the Makila 1A1 engine fitted to the AS332L1. Power from each of the engines is transmitted to the main rotor gearbox, which is common to all AS332 variants, through two input drive gearboxes fitted to the forward face of the main rotor gearbox. In the event that an engine fails or is shut down, a freewheel unit within the input drive gearbox prevents the engine being back driven through the gearbox by the remaining operating engine. The freewheel is a 'ramp and roller' unit, see Figure 1. The rollers are positioned on the engine driven 'ramped' freewheel shaft by a cage. As torque is applied to the freewheel shaft, the rollers are forced up the ramps locking the freewheel shaft to the gearbox input shaft allowing the engine to 'drive' the gearbox. In the event that engine torque is lost the rollers move down the ramps due to the relative rotation of the freewheel shaft and the gearbox drive shaft, disengaging the engine from the gearbox. The roller cage is fitted with a spring which holds the rollers towards the upper end of the ramps to minimise roller slip during engagement.

Engineering investigation

Main rotor gearbox

The main rotor gearbox was disassembled at the operator's overhaul facility under AAIB supervision and in the presence of the manufacturer's representative. No mechanical defects were found within the gearbox with the exception of the right engine freewheel unit which had been severely damaged. Examination of the freewheel unit showed that the roller cage had rotated to a point where the rollers had overridden the freewheel ramps, and moved into the adjacent 'trough' in the freewheel shaft disengaging the engine output shaft from the gearbox.

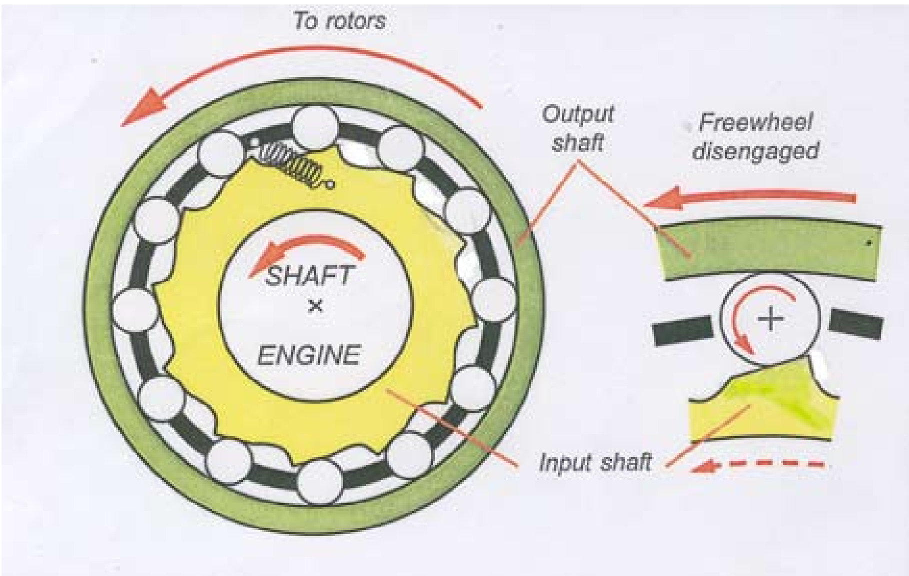


Figure 1

'Ramp and roller' freewheel unit

The freewheel anti-rotation stops had failed as a result of the roller cage rotating into them with significant force and all the rollers showed signs of deformation and mechanical damage. The shaft exhibited signs of significant mechanical wear on the ramps together with some burring of the ramp lips, produced when they had been 'over-ridden' by the rollers. Metallurgical examination confirmed that there were no material abnormalities within the freewheel shaft, the rollers or the roller cage. No evidence of a failure was identified during the inspection of the right engine which may have contributed to the failure of the right freewheel unit.

Manufacturer's experience and actions

Whilst there have been previous failures of the freewheel during engagement, the incident experienced by G-CHCF was the first failure of a fully engaged AS332 freewheel. Prior to February 2007, the allowable wear limits for the freewheel shaft ramps had been the same for both the AS332L1 and L2 gear boxes. During the overhaul of gearboxes, the manufacturer had identified that the wear rate of the AS332L2 freewheel assemblies was higher than that seen on the AS332L/L1 fleet and that the right freewheel shaft was subject to significantly higher wear rates than the left freewheel shaft. Whilst the reason for this higher rate of wear was not fully understood, it was believed to be due to variations in the torsional loading and rigidity within the rotor drive system. The increased wear rate of the L2 freewheel shafts had led to a significant increase in the number of shafts being scrapped due to excessive wear, with most right freewheel shafts being scrapped at the first exposure (3,000 hrs). In order to prevent an 'in service' freewheel failure due to excessive ramp wear, in February 2007 Eurocopter issued Repair Letter (RL) 214, which introduced tighter wear limits for the L2 freewheel shaft ramps. There was no requirement to re-inspect units overhauled prior to the release of RL 214.

As a result of this incident a review of the overhaul records of all AS332L2 main rotor gearboxes was completed by the manufacturer which identified those which may have been exposed to the potential of freewheel failure in operation. These units fell into two groups: those in which both freewheel units may have operated for at least 3,000 hours in the right input gearbox, and those where only one of the freewheel units had operated in that position for more than 3,000 hours. Those units within the first group were exposed to the potential of a double freewheel failure whilst those in the second were exposed to a single failure. On 20 December 2007 the manufacturer issued Alert Service Bulletin (ASB) 01.00.74 to require the removal and inspection of the first group of gearboxes within 40 hours or before 31 December 2007 (whichever was the earlier) and the second group within 100 hours and before 31 January 2008. This action was mandated by the publication of EASA Airworthiness Directive 2007-0312-E on 21 December 2007.

Maintenance records

The published overhaul life of the AS332L2 main rotor gearbox is 3,000 hours. The operator's records confirmed that the gearbox fitted to G-CHCF had operated for 2,644 hours since its last overhaul in November 2005. It was confirmed that the right freewheel shaft had been installed for a total of 8,942 flying hours and the left shaft for 5,652 hours at the time of the incident. A review of the records showed that the failed freewheel unit had been installed in the right input gearbox for 5,652 hours. They also confirmed that both the left and right freewheel shafts had been inspected and found within the published limitations applicable at the time of the last overhaul. Tooling calibration records confirmed that all the tooling used had been correctly calibrated at the time of this inspection.

Recorded information

Flight Recorders

The helicopter was equipped with both a Combined Voice and Flight Data Recorder[1] (CVFDR) and a Health and Usage Monitoring System (HUMS). The CVFDR was capable of recording just over eight hours of data and 90 minutes of audio respectively. Parameters pertinent to this investigation were the main rotor speed, engine free power turbine speed (N_f), gas generator speed (N_g) and engine torque. A time history of the relevant parameters recorded during the incident is shown in Figure 2. The HUMS, and its associated data, is discussed later.

CVFDR Recorded Information

The CVFDR was removed from the helicopter and replayed at the AAIB. Data indicates that the right engine (No 2 engine) was started at 1909 hrs and the left engine (No 1 engine) five minutes later. Both the engine start and subsequent pre-flight checks were normal and the commander confirmed the TIS was operating correctly. At 1952 hrs the helicopter entered Runway 16 with the pilot in the first officer position (FO) as the handling pilot. The FO flew the helicopter into a 10 ft hover, before the commander simulated the failure of the left engine, using the TIS, and the helicopter slowly descended to the ground. This exercise was repeated from the same height, before the commander demonstrated a rejected takeoff, with the TIS being used to simulate the failure of the left engine as the helicopter approached 60 kt at a height of 40 ft.

About three minutes later, the helicopter was cleared to re-enter Runway 16, the FO flew the helicopter into the hover and the commander briefed him as to when he would activate the TIS. The helicopter then transitioned into the climb and at about 50 kt and 50 ft, the commander activated the TIS. The helicopter landed without incident and came to a stop on the runway. The commander confirmed that they would perform a further rejected takeoff.

During the transition, the commander activated the TIS to simulate the failure of the left engine when the helicopter was at 39 ft, at which time the airspeed was about 28 kt. Initially everything appeared normal, but at a height of about 10 ft, the right engine N_f speed rapidly increased to 115%, before the engine was automatically shutdown and the main rotor speed started to decay. (See points A and B, Figure 2). Almost immediately, the low rotor speed aural warning activated and the commander took control of the helicopter, just before it landed firmly. As the right engine had started to run down, the left engine responded with an increasing N_g speed. By the time the left engine had reached its normal operating speed, the helicopter had already landed. From the point at which the right engine had started to rundown, the left engine had taken about three seconds to increase from the TIS setting of 69% to 91% N_g. The main rotor speed had decayed from about 97% to about 73% in two seconds.

When the right engine had started to rundown, the engine torque indication had rapidly decreased and increased twice (See point C, Figure 2). The indications were later attributed to a misalignment of the torque sensing components, which had become misaligned as a result of the freewheel unit failure.

Analyses of the CVFDR data did not identify any abnormalities in either the operation of the helicopter or the characteristics of the freewheel unit. However, it did identify one defect in the recording of data from

Footnote

[1] Penny and Giles manufactured CVFDR, part number 900/51508, serial number 1030/10/93.

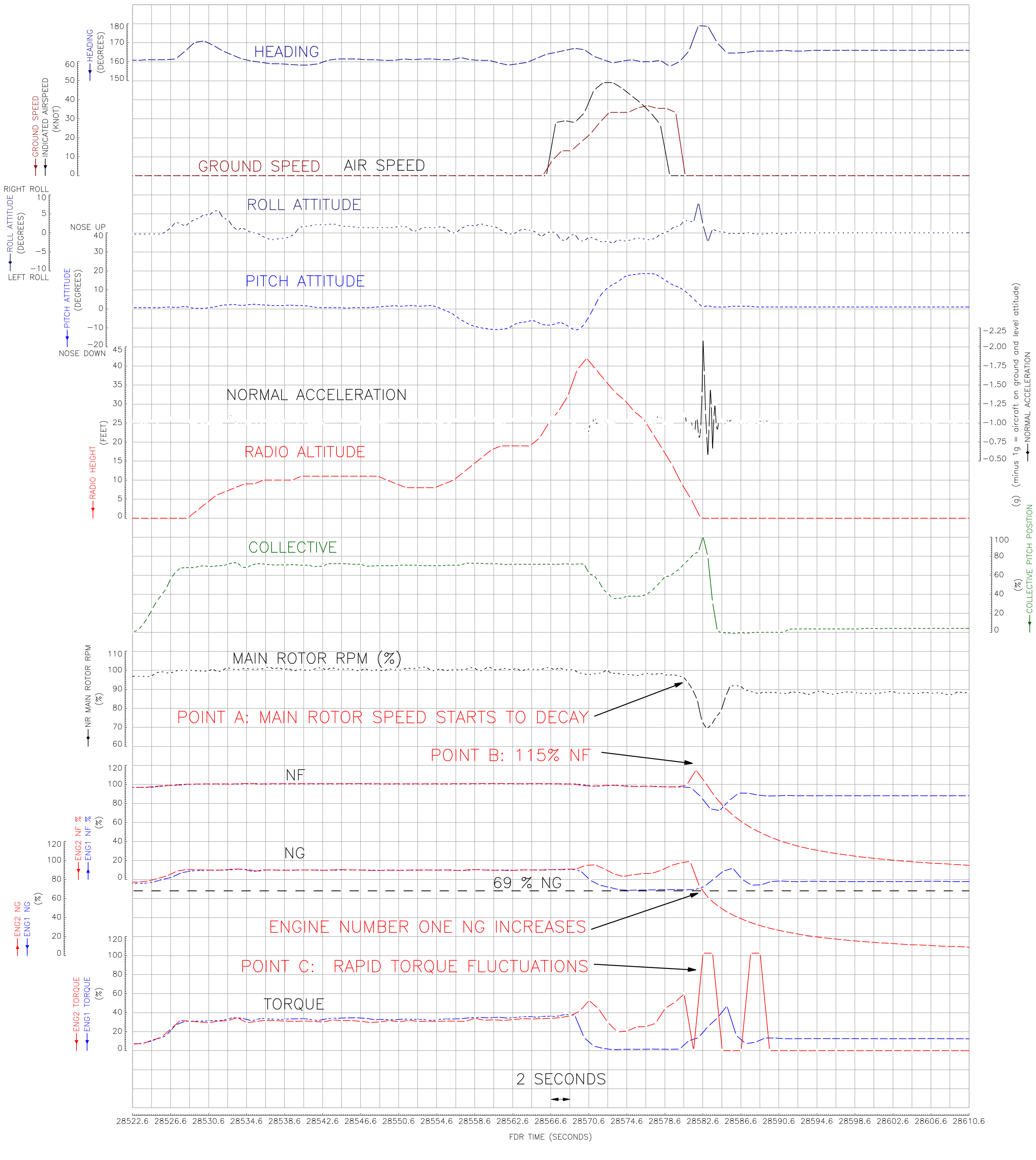


Figure 2

Salient FDR Parameters

the FDR systems mandatory tri-axial accelerometer[2]. The defect did not affect the operation of the HUMS or any other helicopter system. It was found that rather than the normal acceleration parameter quiescent value indicating +1g, it indicated -1g. A check by the operator on 27 November 2007 found that the tri-axial accelerometer had been incorrectly installed. Maintenance records indicated that the accelerometer had last been removed and replaced during July 2007. A fleet-wide check was carried out and no further helicopters were affected. The incorrect installation of the sensor had the effect of inverting the sense of the normal acceleration parameter and also reversing the operation of the lateral acceleration parameter. The operating range of the lateral acceleration parameter was not affected; however, that of the normal acceleration parameter was no longer compliant with the legislative requirement. Instead of having an operating range of between +9g to -3g, this was reversed to +3g to -9g. Although the Aircraft Maintenance Manual (AMM) installation procedure provided a diagram of the correct orientation of the sensor, there was no requirement to carry out a post-installation test. On this occasion, the incorrect installation of the tri-axial accelerometer did not result in a loss of information, although under different circumstances, information from a mandatory parameter could have been compromised. The helicopter manufacturer has responded to the installation error by confirming that it will be carrying out a review of the AMM procedure.

Footnote

2 The FDR system is equipped with a dedicated tri-axial accelerometer, which provided normal, lateral and longitudinal acceleration data.

Health and Usage Monitoring System

Overview and system description

In accordance with legislation[3], the helicopter was equipped with a Health and Usage Monitoring System (HUMS). The system is designed to record vibration data from sensors that are strategically placed around the helicopter. Data can then be analysed to detect incipient defects in the major components of the helicopter, before they can become a hazard to flight. The system may also be used to improve the reliability of the airframe and its components by identifying sources of abnormal or increasing vibration. HUMS data trending is predicated on the comparison of data that has been obtained during as stable and as consistent a period of flight as practicable. For this reason, data is most typically recorded when either on the ground or in the cruise.

First generation systems, such as North Sea HUMS and Integrated HUMS (IHUMS), were developed in the late 1980s and early 1990s during North Sea helicopter operations. These early systems were installed, developed and supported by the helicopter operators and HUMS equipment manufacturers, with approval from the CAA. G-CHCF utilised a later generation system known as EUROHUMS. This differed from the first generation systems by being developed and supported by the helicopter manufacturer.

In common with the design philosophy of other rotary wing health monitoring systems, EUROHUMS does not record data continuously in flight. At pre-defined

Footnote

3 The Civil Aviation Authority (CAA) issued AAD 001-05-99, which became effective on 7 June 1999. The AAD made the installation and use of health monitoring systems mandatory for United Kingdom registered helicopters issued with a Certificate of Airworthiness in the Transport Category (passenger), which had a maximum approved seating configuration of more than nine passengers.

time intervals, during either the ground or cruise phase, snapshots of vibration information specific to particular engine or drive train components are recorded. Components with high rotational speeds, such as the engine input shafts, would be recorded more frequently than lower speed components, such as those within the main gearbox. At the time of the incident, data pertaining to the engine input shafts were recorded once every 20 minutes when the helicopter was in the cruise phase. The engine input shafts were not recorded during any other phase of flight. Recording intervals for components had been refined over a number of years and had been demonstrated as providing suitable levels of detection by the helicopter manufacturer.

In accordance with UK legislative requirements, HUMS data is downloaded and analysed once per day. Data is downloaded into a ground-based analysis tool which detects any imbalance; misalignment; damaged, eccentric or cracked gears, or bearing wear within the main rotor gearbox and engines. An indication of the health of important components is thus provided and caution or warning indications can be provided if predefined limits are exceeded. If a caution or warning for a component is generated, or an adverse trend is identified, the ground-based system is able to provide the operator with details of corrective maintenance action. After maintenance, ongoing HUMS monitoring and in-service inspections are used to ensure that any corrective action was successful.

Although HUMS has demonstrated that it provides an effective means of monitoring, there are certain components, such as freewheel units, which may not exhibit any detectable levels of vibration during normal operation and, as such, cannot be monitored effectively by a vibration monitoring system.

HUMS data

Prior to the incident, the operator had been monitoring a progressive increase in the right engine input shaft vibration level. On the 18 November 2007, two days before the incident, the operator replaced the right engine. In the following two days, a small number of data points were recorded by the HUMS. These points indicated a reduction in vibration for the right engine input shaft. However, results from the subsequent stripdown did not identify any keys areas of damage and the operator and helicopter manufacturer discussed whether the increasing trend may have been due to wear of the freewheel unit.

The helicopter manufacturer reviewed the HUMS data and confirmed that a progressive increase in vibration levels relating to the right engine input shaft had been detected and that, following engine replacement, the vibration levels had reduced. They confirmed that vibration levels recorded prior to the engine replacement had been at a low level and that the subsequent stripdown findings were not unusual considering these low levels. Both the helicopter manufacturer and operator concluded that the increasing vibration trend had been as a result of normal wear within the engine or its coupling to the main rotor gearbox and was not related to vibration of the freewheel unit.

Operational aspects

Takeoff and landing profiles

The AS332L2 has takeoff and landing profiles for both clear area and helipad operations. These profiles ensure that the helicopter complies with Performance Class 1 requirements when operated at a weight appropriate for the ambient conditions.

In order to ensure that the helicopter can either land or fly away in the event of an engine failure the profiles have Takeoff Decision Points (TDPs). During a clear area takeoff the TDP is calculated on the distance available for landing should the helicopter have to abandon or reject the takeoff and/or the maximum weight, whichever is the more limiting. The TDP is based on Indicated Airspeed (IAS) and an associated height. The TDP may be varied between 20 kt and 60 kt at 10 kt increments and associated heights of 20 ft to 40 ft in 5 ft increments. The heavier the helicopter, the higher will be the IAS and height that define the TDP. With a limiting reject distance, the TDP IAS and height will be lower. If an engine fails prior to TDP the takeoff is rejected and the helicopter should stop within the pre-determined distance. Should an engine fail after the TDP, the helicopter can be flown away providing a target IAS is maintained and the correct power is set on the operating engine.

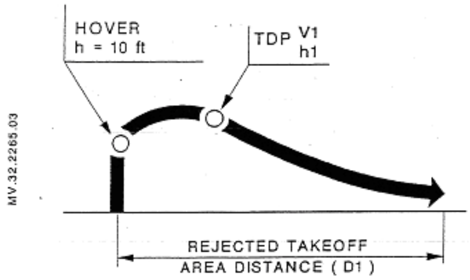
The Landing Decision Point (LDP) for a clear area landing profile is a fixed height of 100 ft and requires an IAS of 35 kt at that height with a rate of decent less than 400 fpm at the LDP. In the event of an engine failure before LDP the helicopter may continue to land or the pilot may go around and climb away. After LDP the helicopter must be landed and should stop within the promulgated landing distance.

When operating at a helipad the profile requires that the helipad must have a minimum diameter of 24 metres. The TDP is then a fixed point, 130 ft above the pad and with a horizontal back up distance from the pad of 125 m. LDP is the same as for a clear area but the approach is steeper. The takeoff, landing and rejected takeoff profiles are set out below.

Clear area profiles

Takeoff with Single-Engine Failure recognised at or before the TDP

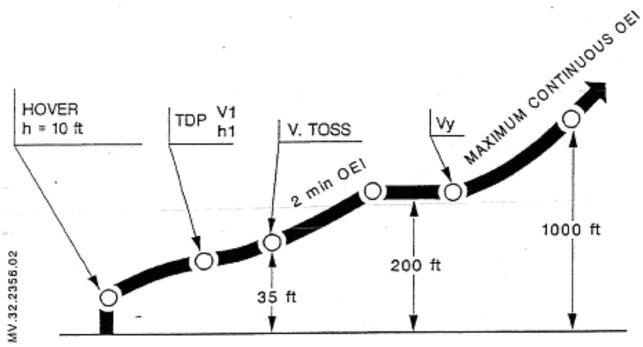
Abort takeoff as soon as engine failure occurs.



- Simultaneously reduce the collective pitch while maintaining a rotor speed of at least 250 rpm (94%), and adopt a nose-up attitude of 10° to 20°, allowing the aircraft to climb slightly.
- As aircraft begins to sink, control attitude and cushion touchdown.
- On the ground, reduce collective pitch to minimum and use wheel brakes to stop the aircraft.

Takeoff with Single-Engine Failure at or after the TDP

Continue the takeoff procedure.

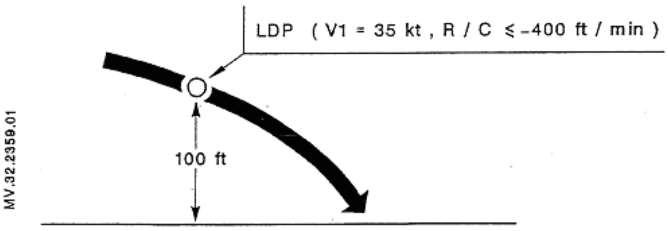


VI (IAS) = V.TOSS (IAS) - 10 kt [where V.TOSS is the Takeoff Safety Speed]

- Control N_r
- Accelerate to or maintain V.TOSS.
- At V.TOSS reduce collective pitch to 2-minute One Engine Inoperative (OEI) rating and simultaneously shift N_g stop to 2-minute OEI rating position.
- At a height of 200 ft, level off and accelerate from V.TOSS to V_y (best rate of climb airspeed).
- At 200 ft but no later than when the OEI LO caption flashes, adjust collective pitch to maximum continuous OEI rating.
- Retract landing gear and continue climbing at V_y.

NOTE: If landing gear is retracted below 60 kt, then red L/C caption will flash.

Normal Landing

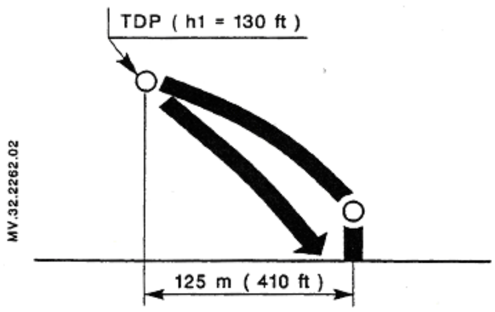


- After reaching LDP, proceed with a straight-in approach, reducing speed regularly to enter hover IGE at a height of 10 feet.
- Proceed with normal landing.

Helipad profiles

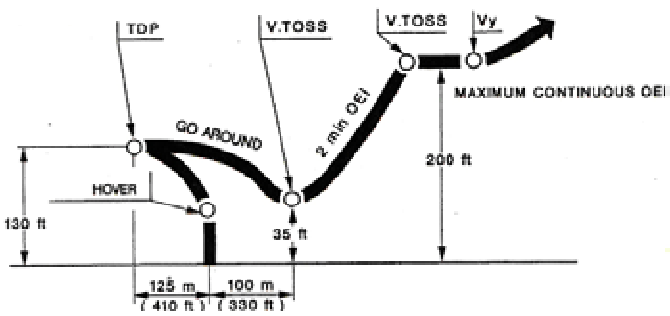
Takeoff with Single-Engine Failure at or before the TDP (before aircraft rotation)

Abort takeoff as soon as engine failure occurs.



Takeoff with Single-Engine Failure at or after the TDP (aircraft rotation started)

Continue flight



Training idle system

The maximum OEI limits cannot be used unless an actual engine failure occurs. The TIS enables OEI flight training to be conducted using non-damaging power levels, provided that the helicopter weight has been reduced to the associated training limit.

A guarded switch, associated with each engine, is provided on the overhead control unit. This switch is used to perform the following actions simultaneously:

1. Simulation of an engine failure by reducing the power of that engine to idle rating, with N_f being governed at a value slightly lower

than 245 rpm, equivalent to 92.5% Main Rotor Rotation Speed (N_r).

2. De-rating the OEI stops of the other engine by approximately 1665 rpm (5%) in order to limit the N_g to a value not exceeding the takeoff power rating.

The Flight Manual Supplement contains the following information regarding safety devices associated with the TIS:

> *'Function Safety Devices*
>
> *In addition to limiting the power to non-damaging ratings, the following safety devices are provided when using the TRAINING function:*
>
> - *In the event of an incorrect training manoeuvre or an actual failure of the engine supplying the power, the required power can be obtained from the idling engine simply by pulling the collective pitch lever. The principle is as follows: as soon as the NR drops below 240 rpm (90.5%) the idling engine supplies the amount of power required until the actual 30-second OEI rating is reached (at NR = 220 rpm (83%)), using static droop effect.*
> - *There is no risk of a false manoeuvre with the fuel flow control levers, since these levers remain in flight position; the OEI is simulated using specific controls.*
> - *In the event of unintentional action on more than one TRAINING IDLE control, the function is inhibited and a minor governing fault is indicated. The function will be re-established after landing, shutting down both engines and re-starting the engines according to the standard procedure.*
> - *Should the engine running in TRAINING IDLE mode fail, the procedure can be continued at the actual OEI rating (i.e. with a larger power margin) by setting the TRAINING IDLE control forward (switch guard down).*
> - *Return to twin-engine flight is possible at any time by setting the TRAINING IDLE control forward (switch guard down).'*

The Engine Monitoring Display (EMD) for the operating engine changes to the indications that the pilot would read in true engine failure condition. A letter 'T' appears in an inverted triangle to indicate to the pilot that the training mode is in operation.

Helicopter certification

The initial certification of the helicopter was carried out by the French, Direction Generale de l'Aviation Civile (DGAC). The UK CAA conducted a validation of that certification in 1991/92. No specific requirements were in place to establish the helicopter performance with the TIS selected and a subsequent failure of the operating engine. A requirement was in place which ensured that any 'Option' such as the TIS should not introduce an increased hazard.

Prior to the introduction of the TIS, the only method of simulating a single engine failure was to retard a Fuel Flow Control Lever (FFCL). In the event of the operating engine failing that FFCL would then have to be advanced to reinstate the power available from that engine. This would have to be combined with a lowering of the collective control to prevent loss of N_r. If the FFCL were advanced too rapidly, the possibility of engine surge, flame-out or an overspeed shutdown of that engine was possible.

By introducing the TIS both FFCLs remained in the flight position and the decaying N_r, resulting from a failure of the operating engine, was used to trigger the acceleration of the engine at idle. The Digital Engine Control Unit (DECU) optimised the acceleration to restore safe flight.

There was no record or data available of any tests carried out during development by the manufacturer or certification authorities to simulate the failure of an operating engine whilst the TIS was in use. The UK validation did not call for any testing of a failure of the operating engine but satisfactory flight tests of the TIS in operation were conducted.

Operator's safety actions

General

Following the incident involving G-CHCF, the operator ceased training and testing on the AS332L2 using the TIS. This was followed by a ban on using the TIS, which was imposed by the UK CAA for all operators.

Tests and evaluation

In order to understand the potential hazards which may arise when using the TIS the operator evaluated a number of test conditions in the AS332L2 flight simulator based in Marseille, France. The test points were identified within the takeoff and landing profiles for both clear area and helipad operations. The tests were based on the operating engine failing whilst the other engine was in the training idle mode. The test pilot then attempted to preserve N_r and safe flight whilst the other engine accelerated to the extent that the helicopter could either be landed or flown away.

The Flight Simulator

The flight simulator was a level D Synthetic Training Device (STD) with motion and visual display. The data on which the simulator was modelled was derived from the manufacturer's AS332L2 flight test and certification programme. The certification programme confirmed the helicopter performance when using OEI 30-second power but a failure of the operating engine, with the other engine in the training idle mode, was not carried out. Although the modelling of the TIS was not derived from flight test data, it was considered that the simulator offered a reasonable indication of the likely outcome of the event being simulated.

Test conditions

The simulator was representative of the operator's standard AS332L2 configuration. The conditions were set to sea level standard (1013 hPa, +15°C) with no wind. The runway at Hong Kong was used as it is at sea level and the model database gave good visual cues throughout the tests. Helicopter mass was set at 8,600 kg for the clear area work and 7,500 kg for the helipad exercises. These weights were representative training mass values (maximum training mass for the conditions would have been 8,900 kg and 7,600 kg respectively).

Tests made

Failures of the operating engine were investigated before and after TDP, and before LDP on a clear area, as well as before TDP on a helipad. Failures were initiated by selecting the left engine to training idle, at the target speed, using the TIS, followed one second later by injecting a failure into the operating engine. The operating engine was initially failed by introducing an N_f overspeed condition, but there was a marked delay in the left engine accelerating. By using the FFCL to stop the right engine the time delay was reduced. The right engine failure was activated as the pilot flying (PF) was commencing the required recovery manoeuvre. The inherent delays in the simulation and the inertia of the helicopter meant that the actual failure of the operating engine during the takeoff exercises occurred at between 5 kt and 10 kt above the target speed. Each test point was recorded and the relevant data (N_r, N_g and radio height) could be noted.

Findings

The behaviour of the simulator was considered against the Flight Manual Supplement (FMS), Supp 3 (One Engine Inoperative (OEI) Flight Training Procedures), which contains the limitations, procedures and performance data for use of the TIS. It makes the following statement:

> *'In the event of an incorrect training manoeuvre or an actual failure of the engine supplying the power, the required power can be obtained from the idling engine simply by pulling the collective pitch lever. The principal is as follows: as soon as the* NR *drops below 240 rpm (90.5%), the idling engine supplies the amount of power required until the actual 30-second OEI rating is reached (at* NR *=220 rpm (83%)), using the static droop effect.'*

The tests revealed inconsistencies in the simulator modelling, not only in the response to low N_r and variation of collective movement, but also in the different responses depending on how the engine failure was initiated. The low N_r trigger at 220 rpm and removal of the training idle stop (release of real OEI 30-second power) were consistent, and appeared to be in accordance with FMS Supp 3 if the failure was introduced using the FFCL, but inconsistent if the failure was introduced via the N_f overspeed. This could be assessed in the helicopter without going to the actual OEI; it would be sufficient to see the release of the real OEI rating and an N_g increase through 90% in response to N_r decay.

It was evident from the tests performed in the simulator that clear area rejected takeoffs, with failure of the operating engine during the reject (ie failures before TDP), could be recovered and the helicopter could be landed safely; this was the case relating to the incident with G-CHCF. It was also evident that failures just after TDP (with the intention to continue the takeoff) would result at best in a rejected takeoff, depending on the distance of suitable landing surface remaining. Any failure of the operating engine in the first segment (ie below 200 ft) would result in the helicopter either making a forced landing or descending to or below 35 ft in the flyaway. A similar conclusion could be drawn for failures before LDP, because the failure simulated at 150 ft resulted in a controlled forced landing with insufficient height to recover N_r or N_g to the extent that a safe go-around could be considered. It is probable that at least 200 ft would be required (possibly more because the helicopter is already descending at the moment of failure). Furthermore, real intervention times are likely to be greater and this can only have a detrimental effect on the potential outcome.

Conclusions

From the simulator tests, the Flight Manual Supplement, Supp 3, statement set out above does not accurately reflect the behaviour of the helicopter or the technique that the pilot should adopt. Simply pulling the collective lever did not restore N_r but caused it to decay into an over-pitching condition unless the collective lever was first lowered positively to prevent this. The helicopter also touched down beyond the rejected takeoff distance following a failure of the operating engine after TDP and in the undershoot with the operating engine failing just before LDP. It was not possible to land or fly away safely during the helipad profile.

Recommendations

On the basis of the simulator test results, the operator considered that the TIS should not be used to simulate engine failures in the following cases:

- On clear areas during continued takeoffs in the first segment (ie below 200 ft)
- On clear areas during landing not below a height agreed with, and authorised by, the authorities
- On helipads at any time

This restriction would remain in force until a risk assessment of engine failure training on the AS332L2 had been carried out.

Analysis

Engineering

Excessive wear to the freewheel shaft ramps resulted in the freewheel rollers overriding the ramps, disengaging the engine from the main rotor gearbox. No metallurgical defects were identified within the freewheel unit. The gearbox had been overhauled in November 2005, prior to the release of Eurocopter RL 214, in accordance with the applicable limitations and procedures in force at that time. The possibility of an in-service freewheel failure has been significantly reduced by the introduction of RL 214. Eurocopter, in Alert Service Bulletin 01.00.74, identified all the AS332L2 main rotor gearboxes which were exposed to a potential freewheel failure with a defined timescale for removal and this was mandated by the publication of EASA Airworthiness Directive 2007-0312-E on 21 December 2007. All of the affected gear boxes were removed from service and are now compliant with EASA AD 2007-0312-E.

Operations

The crew were properly qualified to conduct the flight and the helicopter was being operated within the weight and the C of G envelope for the manoeuvre being flown. The training exercise had been fully briefed.

The failure of the operating engine freewheel unit, as the collective control was being raised, occurred in an area of the takeoff profile where recovery was possible, and this was achieved through the prompt action of the helicopter commander in taking control and performing a safe landing. From the evidence provided by the FDR, the helicopter touched down before the left engine accelerated. Once on the ground the N_r was restored. There was no test data from the flight test or certification programme with which the TIS operation could be compared to establish whether it had operated correctly.

The test points carried out in the simulator flying the clear area profile with a failure of the operating engine at or just before TDP showed that a rejected takeoff could be performed successfully. This relied on the prompt reaction of the pilot and demonstrated the need for the pilot to lower the collective control, if possible, to assist with restoring N_r. This action, combined with flaring the helicopter, would assist in reducing N_r decay and providing the accelerating engine with the best conditions for restoring N_r. It also showed that the action required in the Flight Manual Supplement, Supp 3, that '*the required power can be obtained from simply by pulling the collective pitch lever'* is incorrect.

If an operating engine failure occurs at or after TDP, or just before LDP, attempting to fly away using the technique described in the Flight Manual Supplement, Supp 3, could result in significant over-pitching with the associated build-up in the rate of descent. The simulator modelling was not sufficiently reliable in the scenario being tested to identify an exact outcome. It is, however, probable that the helicopter would touch down or descend below the 35 ft minimum height required. The point of touchdown may be beyond the rejected takeoff distance available.

Using the helipad profile, with an operating engine failure before or just after TDP or just before LDP the loss of N_r and high rate of descent may make the situation irrecoverable. The point of touchdown would be short of the pad in the early stages of the profile and beyond the pad if positive airspeed was achieved. It was considered highly unlikely a successful safe landing on the pad would be achieved.

Conclusions

The safe outcome of this incident was dependant upon a combination of the point at which the failure of the freewheel unit occurred and the prompt corrective action taken by the commander. The information presented in the Flight Manual Supplement, Supp 3, does not appear to accurately reflect the behaviour of the helicopter or the technique to be employed following a failure of the operating engine and may provide a false sense of security if using the TIS. The principle of having a system to accelerate an engine from a training idle position, following a failure of the operating engine, is a positive safety enhancement and avoids a rapid movement of the FFCL introducing an overspeed shutdown. However, the Flight Manual Supplement, Supp 3, should alert the pilot to the limitations of the system and in particular the technique to be used should the operating engine fail. Therefore:

Safety Recommendation 2009-003

It is recommended that Eurocopter should review the operation of the Training Idle System on the AS332L2 helicopter in the event of the failure of the operating engine. Eurocopter should ensure that the behaviour of the helicopter in terms of N_r recovery and any height loss are included in the Flight Manual Supplement, Supp 3. The correct pilot technique for managing such an event should also be included. This information should be based on flight test data.

Furthermore, the AS332L2 is one of a number of helicopters fitted with a Training Idle System, or similar system. As no certification requirements are stipulated for such systems, there may be other helicopters where the operation of the TIS is not accurately documented. Therefore:

Safety Recommendation 2009-004

It is recommended that the European Aviation Safety Agency should review the accuracy of Flight Manual information covering Training Idle Systems fitted to all helicopter types or models. They should ensure that the information on the system, the behaviour of the helicopter and the correct pilot technique to be employed in the event of the operating engine failing are correctly documented.

Moreover, there is no current requirement within the certification process for the Training Idle System to be evaluated with a failure of the operating engine. Data derived from such tests would ensure that the correct information was included in the Flight Manual and that accurate data was used for the modelling of flight simulators. Therefore, the following two Safety Recommendations are made:

Safety Recommendation 2009-005

It is recommended that the European Aviation Safety Agency should require that when a helicopter is fitted with a Training Idle System, or similar system, the effects of a failure of the operating engine are determined during the flight test and certification process.

Safety Recommendation 2009-006

It is recommended that the European Aviation Safety Agency should ensure that where a Training Idle System is fitted to a flight simulator the handling qualities and performance of the helicopter, following the failure of the operating engine, are accurately modelled.