SERIOUS INCIDENT

Aircraft Type and Registration:	MBB-BK 117 C-2, G-MPSB
No & Type of Engines:	2 Arriel 1E2 turboshaft engines
Year of Manufacture:	2005 (Serial no: 9068)
Date & Time (UTC):	12 March 2021 at 1150 hrs
Location:	North Weald Airfield, Essex
Type of Flight:	Private
Persons on Board:	Crew - 2 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Distorted aft crosstube between skids
Commander's Licence:	Airline Transport Pilot's Licence (Helicopters)
Commander's Age:	52 years
Commander's Flying Experience:	7,170 hours (of which 2,196 were on type) Last 90 days - 28 hours Last 28 days - 14 hours
Information Source:	AAIB Field Investigation

Synopsis

This serious incident occurred during the demonstration of an engine failure after takeoff emergency procedure on a revalidation flight for the commander's type rating instructor qualification. The engine failure was simulated by the commander reducing Engine No 1's throttle to IDLE. Shortly afterwards the commander increased the throttle setting, but Engine No 1 did not respond. During attempts to resolve the problem, the throttle setting for Engine No 2 was inadvertently reduced, resulting in insufficient power being available for continued safe flight. The commander rejected the takeoff and executed a firm landing within the airfield boundary.

While the aircraft's skid assembly was deformed as a result of the landing, the touchdown forces did not exceed the manufacturer's threshold for it to be classified as a 'hard landing.' The subsequent engineering investigation did not find any evidence of malfunction in the engine control systems. Engine No 1 probably did not respond because the rotor rpm droop compensation had been inadvertently trimmed in the wrong direction.

History of the flight

The incident flight was a type rating instructor (TRI) revalidation event for the left seat pilot who was also acting as commander. The examiner occupied the right seat and acted as the simulated student. After completing three training autorotations, one demonstration by the commander and two practises by the examiner, the helicopter was positioned to a low hover at the northern end of the mown helicopter takeoff strip adjacent to the runway intersection at North Weald (Figure 1).

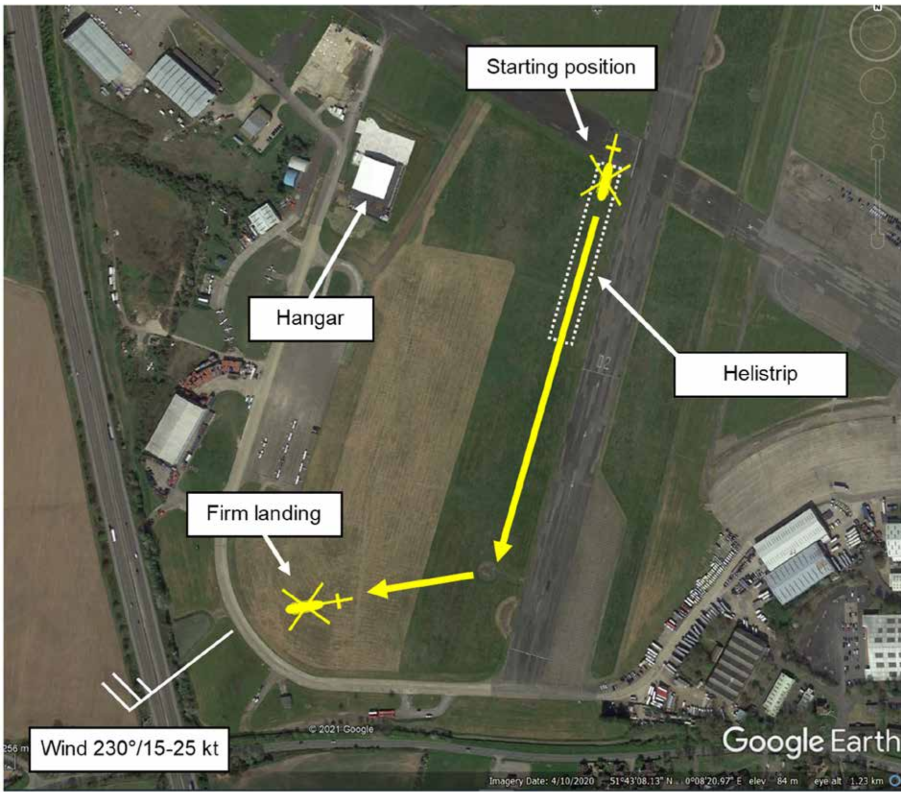

Figure 1

Approximate track of G-MPSB from Cat A takeoff to firm landing (satellite imagery courtsey of Google Earth ©2021 Google)

The intention was for the commander to demonstrate a Category A (Cat A) Clear Heliport takeoff procedure with a simulated engine failure after the takeoff decision point (TDP) and a continued takeoff (Figure 2). This was to lead into a single-engine circuit to Runway 20.

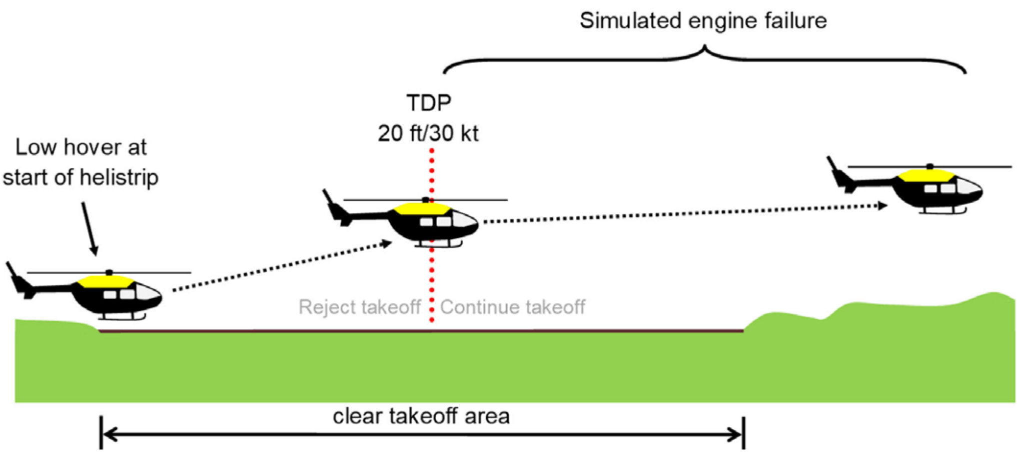

Figure 2

Overview of Cat A Clear Heliport takeoff profile with simulated engine failure after TDP

When established in a low hover at the threshold of the helicopter strip, the commander noted that the first limit indicator (FLI)[1], an analogue representation of the instantaneous power being used and the excess power available to the pilot, was indicating approximately 7.5 (non-dimensional units). He then increased power to FLI 8 to start the takeoff. After assessing that the TDP parameters of a height of 20 ft agl and airspeed of 30 kt had been achieved, the commander closed Engine No 1's throttle to simulate an engine failure. As he continued with the takeoff, the commander saw that the power required from Engine No 2 to execute the flyaway manoeuvre had exceeded the training maximum target figure of FLI 11[2]. Accordingly, he attempted to increase the throttle setting on Engine No 1 by approximately 15% to reduce the power requirement from Engine No 2 to below FLI 11.

Despite increasing Engine No 1's throttle setting the commander did not detect a corresponding engine response. He reported attempting to cycle the Engine No 1 throttle between IDLE and 15% a further "one or two times" with no effect. While manipulating Engine No 1's throttle the commander noticed the Engine No 2 rpm starting to decay. At the same time, he became aware that the main rotor rpm (N_R) was decreasing and there was insufficient power available to establish a positive rate of climb as required by the continued takeoff profile. With obstacles and rising ground ahead, the commander rejected the takeoff and turned right to land on grass close to the south-western perimeter of the airfield. As he did so, he saw that the N_R was close to its lower '*power on*' limit of 85%, giving little performance available to cushion the touchdown. He executed a running landing, which both pilots described as being firm but not dissimilar to what might be experienced with trainee pilots carrying out running landings in simulated one engine inoperative (OEI) scenarios. Shortly after the helicopter came to a halt, both engines accelerated to normal FLIGHT rpm and the N_R increased to approximately 100%. FDR data showed that the engines began accelerating after their engine twist grips were returned to the FLIGHT detent, as indicated by the associated TWIST GRIP caution extinguishing.

While stationary on the grass, the pilots noted that the helicopter was sitting right skid low but attributed that to the ground sloping from left to right. With both engines running normally, the pilots discussed the incident between themselves and, having reviewed the status of the helicopter's systems, elected to reposition the helicopter to a taxiway close to the hangar before shutting it down. When parked on a level surface it became apparent that the aircraft was still sitting abnormally right skid low. After vacating the helicopter, the pilots saw that the skid assembly was deformed.

Incident site

The helicopter landed on an area of grass to the north of the south-western taxiway. Ground marking caused by both skids extended for approximately 17 metres in a westerly direction. The initial landing point was identified by deep furrows which were left in the turf by the helicopter's skids. The markings indicated that the right skid bounced after the initial contact with the ground before it slid and came to rest (Figure 3). The ground marking became less visible as the ground slide progressed.

Footnote

[1] See *FLI description.*

[2] The maximum continuous power (MCP) setting with one engine inoperative (see *Table 1*).

Figure 3
Ground markings from right skid

Helicopter information

The BK 117 C-2 is a multi-purpose twin engine helicopter powered by two Safran Helicopter Engines (formerly Turbomeca) Arriel 1E2 turbo shaft engines. Following the joint venture between MBB & Aerospatiale which led to the creation of Eurocopter, the type was rebranded as the EC145 (type certified as the EC145 / BK 117 C-2).

The two engines drive the main rotor, tail rotor and accessories via the main transmission gearbox, which is in the transmissions compartment on top of the cabin roof. The main rotor system is a rigid head system with four fibre-reinforced plastic blades.

The helicopter's landing gear consists of two crosstubes and two skids. The crosstubes are designed to flex during touchdown to absorb vertical forces.

Engine fuel and control system

The helicopter fuel system provides fuel to the fuel control units (FCUs) on each engine. These FCUs are linked to two twist grip throttles on the collective pitch lever(s) (Figure 4) and the collective output of the hydraulic flight control actuator[3]. The FCUs hydromechanically control the fuel flow to the engine combustion chambers.

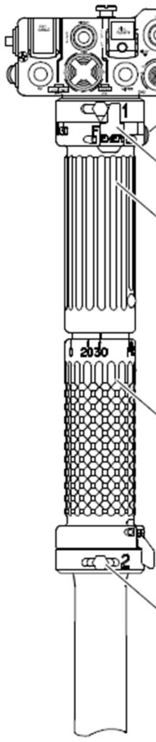

Figure 4

BK 117 C-2 collective pitch lever showing twist grip positions

The twist grips can be turned to set their respective engine in the start position, set it to IDLE, to FLIGHT and, if necessary, operate it in the emergency range. Each twist grip has five markings identifying its angular position as follows:

"0" – The engine is off. The main valve in the FCU is closed. The twist grip has been turned fully to the right.

"20" – Engine start position. The FCU main valve is partially open.

"30" – IDLE. The engine N_1 is approximately 70±2%. An idle stop prevents the twist grip moving from "30" towards "20" if approached from flight. An unlock button on the P1 collective must be depressed to pass the idle stop.

"F" – FLIGHT position. The twist grip has been turned to the left until the stop. This is the position for normal flight operations. The main valve in the FCU is fully open and the fuel flow is controlled automatically to keep the N_2 speed constant. The flight detent on the twist grip has a sprung ball into a notch to give tactile feedback to the pilot when entering and moving from FLIGHT.

Footnote

3 To maintain rotor speed when collective pitch inputs are applied, a signal from the collective pitch actuator is fed into an anticipator which increases the fuel flow to the engines via the engine trim actuators.

"EMER" range – Used in the case of automatic engine control failure. An emergency guard needs to be flipped open to allow further twist grip operation beyond FLIGHT position. In Emergency range, N_2 speed control is manual.

Each twist grip throttle has a different surface texture and they are also differentiated by position. This provides tactile feedback to pilots for non-visual identification of the throttle being manipulated. The investigation heard evidence from several EC145 type rating examiners who had experienced situations where trainees in stressful or high workload situations had inadvertently taken one throttle out of the FLIGHT detent while manipulating the collective on the BK 117 C-2 variant. It was hypothesised that this was likely due to them unintentionally gripping the collective more tightly than usual, in response to the perceived stress level.

A microswitch on the FCU throttle quadrant is closed when the twist grip is positioned into FLIGHT. When a twist grip is not in FLIGHT or in the emergency range, a TWIST GRIP caution is displayed on the Caution and Advisory Display (CAD) for the relevant engine.

In normal operation, when the engines are selected to FLIGHT, the engines are controlled to a constant output speed (N_2). As the collective pitch is raised the load on all the blades increases, thus fuel flow must also increase. A control rod which is attached to the collective axis hydraulic actuator connects to the left and right engine trim actuators. These actuators are connected, via levers and Teleflex cables, to the N_2 control inputs on the engine FCUs. As the collective lever is raised, the system anticipates the load and requests additional fuel to maintain the engines at the constant N_2. This system is referred to as the droop compensation control system.

In addition to the droop compensation system the engines can be trimmed using a four-way beep trim switch located on the collective pitch lever (Figure 5). This allows the pilot to match engine torque output when in manual control. In an OEI situation trimming forward on both engines will increase the torque output of the operational engine irrespective of which engine has become inoperative. The engines can be trimmed in four ways using this switch:

Forward: the power of both engines is increased simultaneously. Rotor speed is increased.

Backward: the power of both engines is decreased simultaneously. Rotor speed is decreased.

Left: the power of Engine No 1 is increased, while the power of Engine No 2 is decreased. Rotor speed remains constant.

Right: the power of Engine No 2 is increased, while the power of Engine No 1 is decreased. Rotor speed remains constant.

The beep trim switch axis is offset approximately 30° clockwise to align with the natural direction of thumb movement when pushing forward with the pilot's hand on the collective.

The switch will return to centre once thumb pressure is released and is gated so that it cannot be moved from one position to another without first being centred.

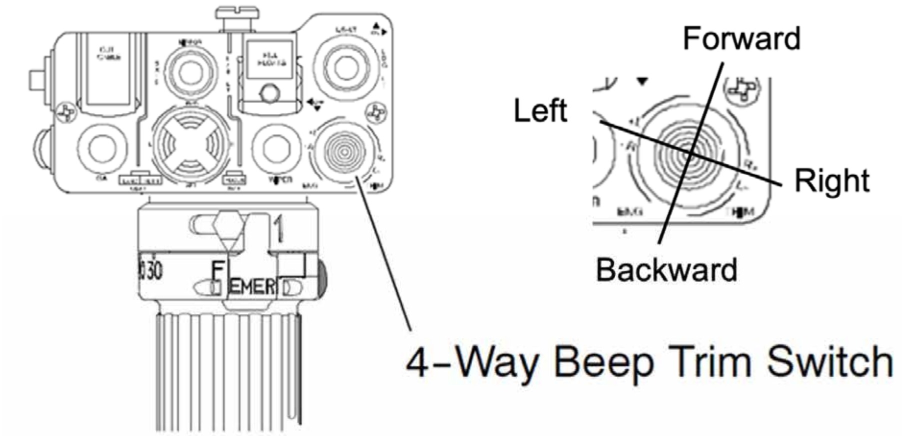

Figure 5

Four-way beep trim switch (with beep trim axis inset)

In addition to the N_2 droop compensation and trim function, the aircraft has a VAriable Rotorspeed control and TOrque Matching System (VARTOMS) which automatically controls the main rotor rpm between 96.5% and 103.5% and matches the torque of the two engines. A VARTOMS control panel (Figure 6) is located on the helicopter instrument panel. This allows the pilot to select VARTOMS to MAN (VARTOMS off) or NORM (VARTOMS on) modes, the button illuminates yellow when the system is in MAN mode.

Another mode button allows the pilot to select Cat A, N_1 or Cat A/N_1 modes. A single push activates Cat A mode, which automatically maintains the rotor rpm at 103.5% when the airspeed is below 55 kt.

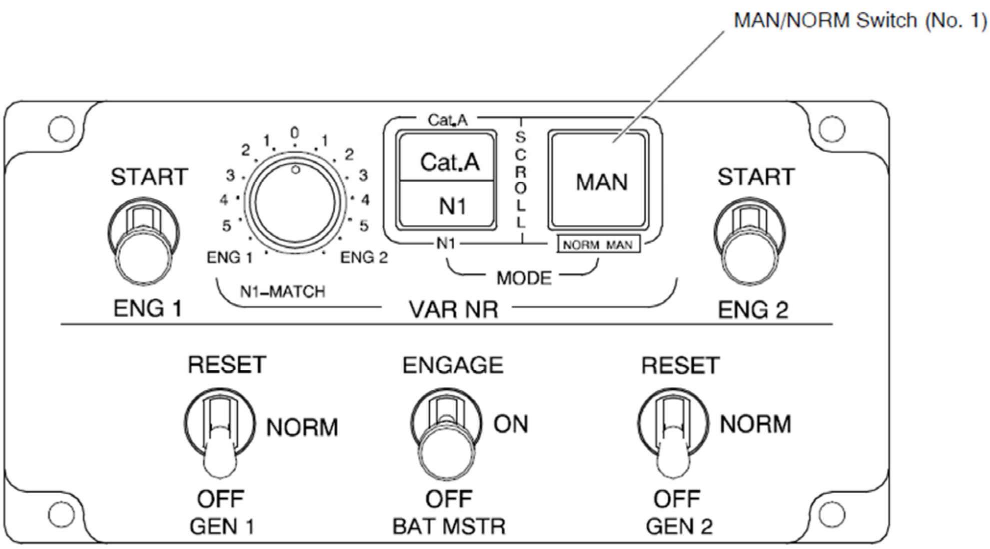

Figure 6

VARTOMS control panel

If the VARTOMS identifies that there is an engine torque split of greater that 15% the system will automatically switch to manual mode and the MAN button will illuminate yellow. If a VARTOMS failure is detected a caution will be illuminated on the CAD.

FLI description

While operating, the engines and transmission system are subjected to loading which, when kept within normal operating limits, incurs no significant damage to the components. If the loading is increased above a threshold the components can start to accrue damage. To allow the pilot to monitor the engine and transmission, an analogue display of the FLI is provided on the vehicle and engine multifunctional display (Figure 7). White rectangles displayed on the FLI adjacent to the most limiting parameter for each engine enable the pilot to determine which engine/transmission limit (N_1, turbine outlet temperature (TOT) or torque) the FLI is representing. FLI indications are non-dimensional, thus pilots can use one set of power limit figures regardless of which parameter is limiting at any given stage of flight (Table 1).

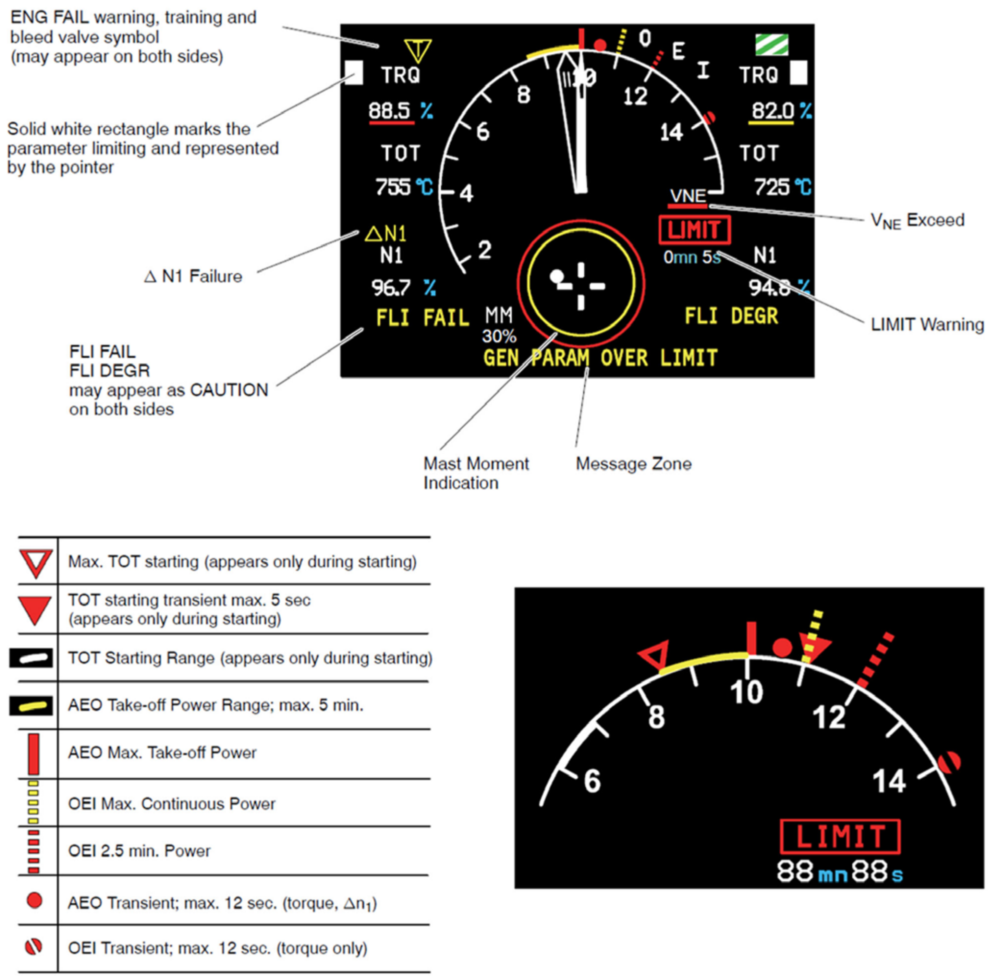

Figure 7

FLI indications and legend (CPDS[4] V2006 Software as installed in G-MPSB)
(images courtesy of the manufacturer)

Footnote

4 Central Panel Display System.

Condition	FLI marking	Transmission (helicopter) limits max torque %	Engine operating limits	
			Max N1 %	Max TOT °C
Starting				
Transient (max 5 sec)	11.0	-	-	865
Starting	8.5	-	-	785
All engines operating				
Takeoff power (5 min when $V \le V_Y$)	10.0	2 x 88	100.2 – 101.9	845
Maximum continuous power (MCP)	9.0 (8.5[1])	2 x 71	98.8 – 100.0	
Transient (12 sec when $V \le V_Y$)[2]	10.5	2 x 97	103.3[1]	-
One engine inoperative[3]				
MCP	11.0	91.5	100.2 – 101.9	845
2½ minute power	12.0	125	101.8 – 103.3	885
Transient (12 sec when $V \le V_Y$)[2]	14.0	140	107.5[1]	-

Notes:

1. When CPDS software V2006 or subsequent installed.
2. '*Unintended use*' only.
3. OEI power ratings are limited to use only after the actual failure of an engine, except for the MCP values, which may also be used for training if the manufacturer's OEI training device is not installed.

Table 1
Engine and transmission power limits specified in the flight manual

If the FLI exceeds 11 for more than 10 seconds there is an associated maintenance activity required.

G-MPSB

When the incident occurred G-MPSB was configured for training operations with removable left seat cyclic and collective controls installed. In this configuration the left collective is identical to the right collective except that the left collective twist grips do not have idle stop buttons so the right collective must be used to shut down the engines.

At the time of the incident G-MPSB had completed 11,038:50 flying hours. At 15 hours 35 minutes before the incident the helicopter had been subject to heavy maintenance which included its annual, 5,600 hour and 400 hour inspections. The helicopter's Certificate of Airworthiness was valid and its Airworthiness Review Certificate was in date.

Recorded information

The helicopter was fitted with a Combined Voice and Flight Data Recorder and two Airborne Image Recorders (AIRs) which recorded footage from two cockpit-mounted cameras. The recorders were downloaded at the AAIB and captured the event flight.

The AIRs were fitted to G-MPSB in April 2019 in response to CAA requirements to fit them to helicopters engaged in State and search and rescue operations[5]. Compliance with these requirements was required by 31 July 2021. One camera faced the overhead panel, allowing a view of the switch positions in this panel. The second camera was mounted behind the flight crew, facing forwards to provide a view of the pilot's displays.

The FDR recorded a number of relevant parameters including engine speeds, torque and FLI, along with the Caution and Advisory Unit (CAU) TWIST GRIP caution. This caution is the same as that displayed to the pilots on the CAD and is triggered when the engine throttle is out of the FLIGHT position. Engine trim, throttle position and fuel flow were not recorded and the CAU TWIST GRIP caution was only recorded every four seconds.

The CVR was reviewed. Throughout the flight, each exercise was briefed and both pilots sounded professionally engaged in the training task.

At 1159:13 hrs, while climbing through 16 ft agl at an IAS of 43 kt, Engine No 1 FLI began to reduce, signifying the point at which the Engine No 1 throttle was reduced. This was confirmed by the CAU TWIST GRIP parameter (Figure 8). The position of the Engine No 1 throttle was not recorded but within 3 seconds, Engine No 1 torque had reduced to less than 3%.

The IAS increased to 47 kt and the aircraft climbed to a maximum of 39 ft with the CVR recording the commander talking through the simulated engine failure. Eighteen seconds into the exercise, the CVR recorded the commander stating "AND WE'VE GOT A TINY RATE OF CLIMB… HARDLY ANYTHING THERE ARE WE". The examiner replied "NO", to which the commander stated "A BIT MORE". At this time, the FDR recorded an increase in the Engine No 1 FLI but also a decrease in the Engine No 2 FLI and the Engine No 2 CAU TWIST GRIP caution was triggered.

Two seconds later, the CVR recorded an audible low rotor rpm warning as the N_R dropped below 95%. The examiner stated "JUST WATCH YOUR N_R", which the commander acknowledged. The examiner stated "PUT THE THROTTLE BACK IF I WERE YOU". However, as this exchange was taking place, the Engine No 2 FLI reduced further and the Engine No 1 FLI increased.

Footnote

[5] CAA Safety Directive SD 2020/001.

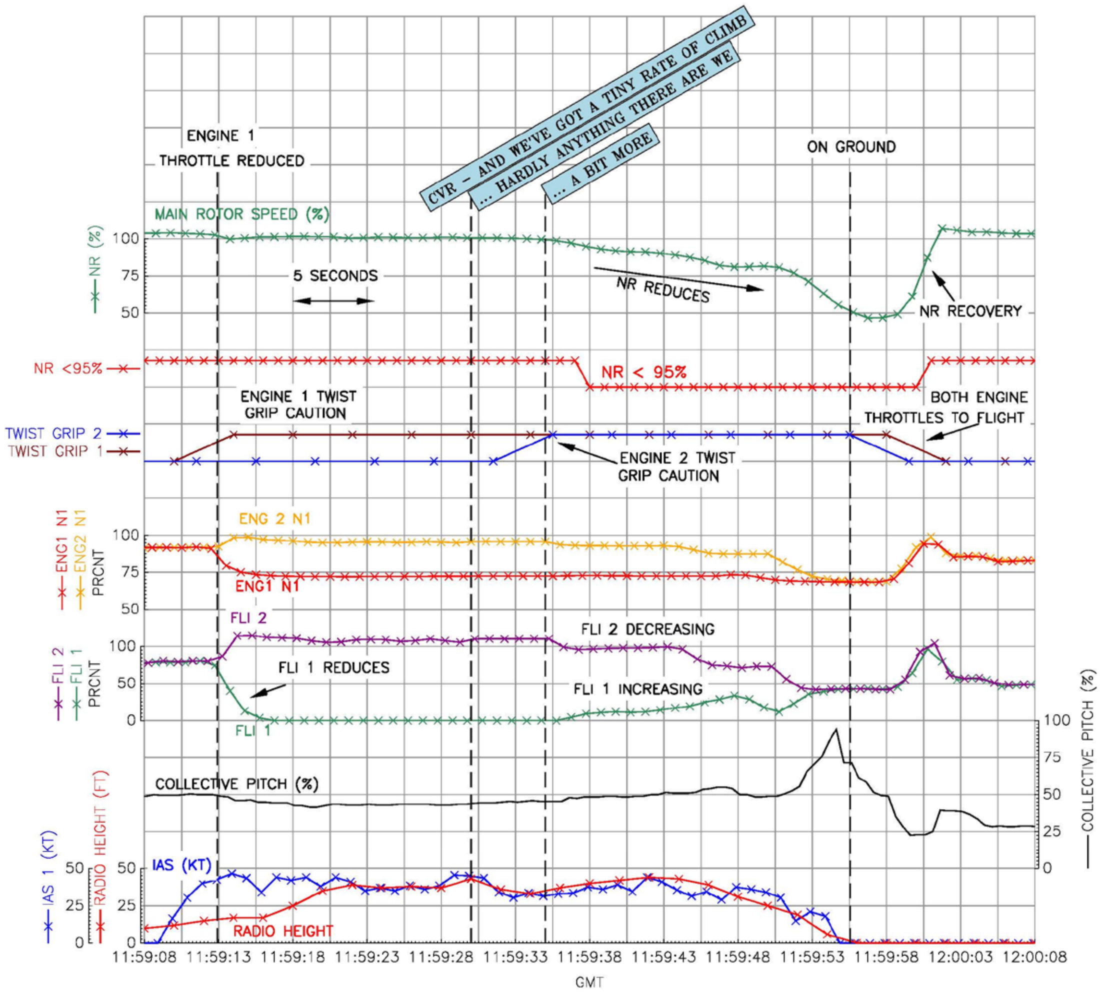

Figure 8

G-MPSB FDR parameters
NOTE FLI is recorded as percentage on the FDR

At 19 ft agl and an IAS of 15 kt, the collective was raised to cushion the landing. At touchdown, both recorded FLI were the same at 43%. After landing, the collective was lowered and a few seconds later, both engine throttles were returned to the FLIGHT position. As a consequence, both engines spooled up and the main rotor rpm recovered.

AIR camera footage

Each cockpit video camera had its own dedicated AIR and the footage from the overhead panel camera was successfully recovered. However, it was discovered that the AIR for the forward-facing camera had failed during the incident flight. The AIR maintenance data was downloaded which indicated that five minutes after power-up, a fault was logged.

The rotorcraft flight manual (RFM) supplement for the AIR installation required a pre-flight check of the system by pressing and holding the REC TEST button on the AIR control panel, with a successful test confirmed with a green light. Anything other than a solid green light indicated a fault within the system, with the colour and/or flashing of the light identifying the magnitude of the fault.

Discussion with the flight crew revealed that during the pre-flight checks, the AIR check was performed and they noticed a flashing green light on the control panel. The flight manual supplement defined a flashing green light represents "*System Operation / No Faults – NOT RECORDING"*.

Data for the previous flights was recovered from this AIR which revealed that the forward-facing camera footage was not stable, with the camera vibrating to the extent that the cockpit displays could not be read. The Instructions for Continued Airworthiness for the AIR system required an inspection every 1,000 hours or three years and an AIR replay every two years. The inspection was performed in September 2020 with no issues found, and an AIR replay was conducted in February 2021. This replay failed and a replacement AIR was installed in February 2021 with no reported issues between then and the incident flight.

The operator had three additional aircraft of the same type and was requested to review other downloaded camera footage. The same problem was evident and was attributed to a camera mounting issue, which the company intended to rectify ahead of the CAA's installation deadline of 31 July 2021.

Aircraft examination

The helicopter was moved to a hangar after it had landed. External examination identified significant deformation of the aircraft landing gear (Figure 9). The aft crosstube had bowed, resulting in both skids moving outboard. The right skid had deflected further than the left. Other than the aft crosstube damage, no other physical damage was identified with the aircraft.

Figure 9

G-MPSB landing gear (viewed from front looking rear)

Assessment of the flight data by the operator and helicopter manufacturer determined that the loads associated with the landing were below the threshold to require heavy landing checks to be completed. The loads were likely to have been attenuated by the deformation of the crosstubes and furrowing of the soft ground.

Both engines were in good condition. Their control systems were correctly installed and connected with continuity from the twist grips on both collectives to their associated FCUs. The microswitches on each FCU throttle quadrant (which, when opened, indicated that the twist grip was not in FLIGHT) functioned correctly. Manipulation of the engine trim function for both engines also confirmed correct functionality.

A ground run of both engines showed full and normal operation of both engines and that the engine trim VARTOMS were setup correctly.

Laboratory assessment of fuel samples taken by the operator immediately after the incident revealed them to be satisfactory.

Weight and balance

The pilots completed pre-flight weight and balance calculations using the '*Easyweigh*' software application. With 495 kg of fuel on board at start up, the calculated initial takeoff gross mass of the helicopter was 3,299 kg. Based on the fuel recorded at shutdown, 394 kg, the gross mass of the helicopter at the time of the incident was approximately 3,200 kg. The helicopter remained within the operational CG envelope throughout the flight.

Helicopter performance

The Cat A Clear Heliport profile is designed such that the helicopter can either land safely or climb away should one engine fail during the takeoff. Between starting the takeoff acceleration and reaching TDP[6] the helicopter can decelerate and land within the clear takeoff area remaining ahead. After TDP a rejected takeoff within the available clear heliport area is no longer assured and the pilot is required to fly a continued takeoff (CTO). For a CTO, the pilot accelerates the helicopter to 45 KIAS (V_{TOSS}[7]) while climbing to 35 ft before then climbing away with due regard to obstacles on the planned departure track (Figure 10).

Calculating the maximum mass for simulating OEI conditions during Cat A Clear Heliport training with one engine at IDLE[8] requires interpolation of the corresponding RFM performance chart[9] (Figure 11). Using the environmental conditions at the time of the incident, the maximum training gross mass (MTGM) for G-MPSB was approximately 3,320 kg.

Footnote

[6] TDP is the first point from which a continued takeoff capability is assured and is the last point in the takeoff path from which a rejected takeoff is assured within the available rejected takeoff distance.
[7] Takeoff safety speed.
[8] RFM Section C.2.1. Mass Limitations.
[9] Fig. C1 Training takeoff and landing gross mass category a [sic] (clear heliport)

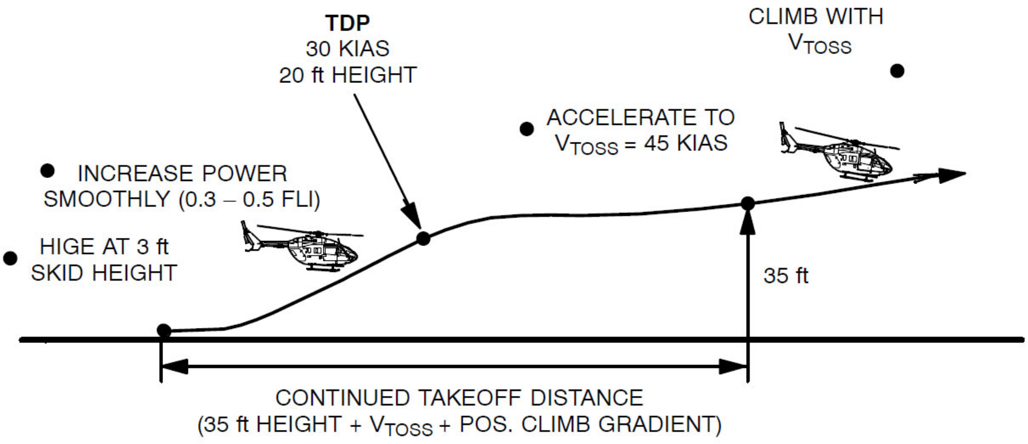

Fig. B5 OEI Continued Takeoff Profile – Clear Heliport

Figure 10

RFM Cat A Clear Heliport initial climb profile for single engine failure after TDP
(RFM Fig.5B courtesy of the manufacturer)

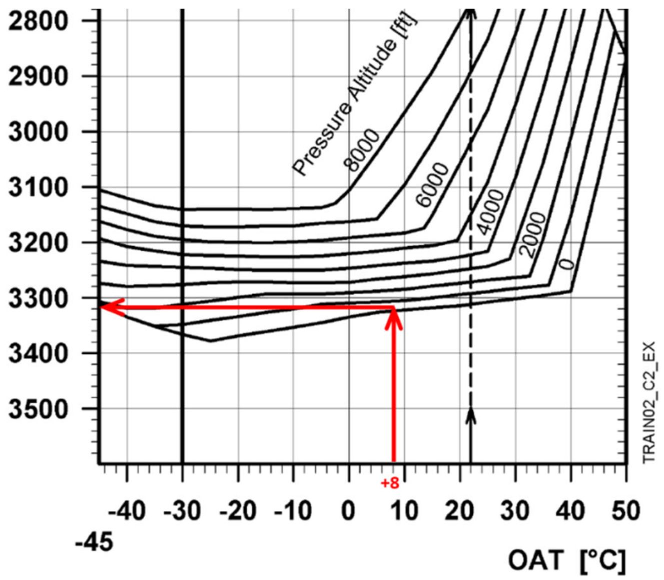

Fig. C1 Training takeoff and landing gross mass category a (clear heliport)

Figure 11

Interpolation of RFM Figure C1 using 8°C and 364 ft pressure altitude
(RFM Fig.C1 courtesy of the manufacturer)

OEI training

The operator had previously sought to establish a flight simulator training contract in support of its BK 117 C-2 training, including instructor revalidation events, but the procurement process had failed when no acceptable tenders were received. In the absence of a suitable flight simulator, TRI revalidation fights were conducted in the helicopter. Dual controls were fitted to helicopters being used for this training.

Rather than attempting to immediately diagnose which engine has failed and selectively trim the other engine's power to maximum, BK 117 C-2 pilots are trained to respond to any OEI situation by pushing forward on the engine trim button. Trimming the live engine (for real or simulated OEI conditions) to maximum power[10] is necessary to guard against N_R droop at power levels lower than OEI MCP.

With no suitable flight simulation training device (FSTD) available or accessible to the operator, there were three options open to their pilots for generating a simulated OEI condition for training on the BK1 17 C-2. The choices were.

Manufacturer's OEI training device. The manufacturer's training device system[11] employs collars to restrict throttle movement, which can be affixed to either twist grip throttle, and training switches on the overhead console (Figure 12) which modify the FLI display to simulate the OEI condition. The system can be used at gross weights at or below MTGM, but the BK 117 C-2 RFM only explicitly requires it to be used for Cat A OEI training when at MTGM[12]. Opinions varied, across the BK 117 C-2 user groups consulted by the investigation, as to the merits of using the training device system. The investigation heard that the manufacturer, and at least one other large helicopter training organisation, exclusively used the training device for OEI training. G-MPSB's operator had previously experienced engine overtorque incidents when using this system and their training manual[13] explicitly prohibited its use. Several pilot witnesses who spoke to the investigation stated that fitting the collars and the associated throttle '*tuning*' procedure was "fiddly" and wasted valuable rotors-running training time[14]. A manufacturer's OEI training report[15] provided to the investigation stated that '*experience has shown that the estimated time to set up the collar is about 2 minutes on the ground.*' Some pilots reported that, once configured, there was no guarantee that the engine setup would not drift in a very short time.

Both engines at FLIGHT setting. When employing this method both engines are left at the FLIGHT detent and an artificially low FLI target is used. The benefit of leaving both engines at FLIGHT is that, should it be required, full power is immediately available by raising the collective lever. A reported drawback of this technique was that trainees would not experience simulated OEI flight in true power-limited scenarios close to the ground, meaning they were not necessarily exposed in a training environment to the handling demands of a real engine failure.

Footnote

10 *See Engine fuel and control system*.
11 Manufacturer's part number B032M0820101.
12 Approved Rotorcraft Flight Manual BK117 C2 Section 9.1-3.C.2.
13 Operations Manual Part D (OMD).
14 Reportedly between 5 and 15 minutes each time the OEI throttle setting needed to be tuned.
15 AHI/19R-E-184: Helicopter Limitations and OEI Training on BK117-C2.

Figure 12

Manufacturer's training device (collars and overhead switches)

One engine at IDLE. Using this technique, engine failure is simulated by moving one engine throttle to the IDLE position while leaving the other in the FLIGHT detent. A pilot-reported benefit of using this technique for OEI simulation was that it reinforced the need to use the engine trim button and gave pilots exposure to the handling demands of staying within the engine and transmission limits while still achieving the required OEI flight profile. Pilots stated that a drawback was that "often" with one engine at IDLE the power requirement from the remaining engine exceeded the OEI MCP limit of FLI 11. The incident pilots reported that common practise was to roll one throttle to IDLE and then, if necessary, increase engine rpm by approximately 15% to offset the power demand on the engine set to FLIGHT to avoid exceeding the OEI MCP limit. One experienced BK 117-C2 instructor explained that, when using the engine to IDLE technique, he found it safer and more reliable to incrementally reduce the throttle towards IDLE to achieve the desired engine power disparity rather than reducing immediately to IDLE. His reasoning was that he then always had power in hand and was not reliant on the engine responding to a subsequent increased throttle demand. The manufacturer publishes guidance for flying Cat A takeoffs with engine failure for real but does not include throttle handling guidance in the RFM for instructors or examiners simulating OEI for training purposes. The investigation noted that the RFM describes simulating OEI operation with one engine at IDLE[16] but does not mention the use of a fixed intermediate throttle setting between IDLE and the FLIGHT detent for the simulated failed engine.

Procedures for training and testing conducted by an AOC holder as required by Part Ops, for example Operator Proficiency Checks, are contained within the operator's Operations Manual Part D[17] (OMD) and are to be followed by examiners conducting such activities. TRI revalidations are a licensing requirement which sits outside of Part Ops and are, therefore, subject to RFM rather than OMD limitations. For the OEI serial being flown on the incident flight, the only material difference between OMD and RFM limitations was that the latter were less-restrictive in allowing, but not requiring, use of the OEI training device system. The regulator does not specify how OEI conditions are to be simulated, other than requiring the procedure to be RFM-compliant. Based on their prior experience of using the manufacturer's training device, both pilots reported that, although allowed to when flying under RFM limitations, they would not choose to use it for OEI simulations.

OEI training risk

Training for emergencies is a balance of risk. The regulatory expectation was that simulated higher risk emergencies, such as engine failures, should be conducted in an appropriate FSTD, unless one was unavailable or inaccessible. Exemplar risks for the three 'live aircraft' OEI training options are outlined below.

Training Mode. Operator identified risks were the loss of rotors-running training time when setting up the training device and maintenance penalties from inadvertent engine overtorque events. The operator had prohibited the use of the manufacturer's device for their routine training to mitigate against engine overtorque situations previously encountered. They also found the setup procedure could take ten or more minutes of rotors-running training time and the collar would need to be reset regularly because the setting would 'drift'. The abstract to the manufacturer's OEI training report[18], however, concluded that '*the use of* [the] *OEI training device provides more realistic training…and does not cost overtime* [sic] *to the training session.*'

Training with both engines in the FLIGHT detent. The key operator-perceived risk was pilots not gaining and/or being able to demonstrate confidence and competence in safely controlling the helicopter with limited power margins as might be experienced following a real engine failure during Cat A operations.

Footnote

16 RFM Section 9.1-3 C.1. General.
17 Operator's training manual.
18 AHI/19R-E-184.

> **Training with one engine at IDLE.** The operator identified as a significant risk a maintenance penalty if OEI training engine limits were exceeded. As highlighted by this incident, continued safe flight was also at risk if the engine left at FLIGHT subsequently suffered a power loss.

Immediately following this event, the operator suspended training with one engine at IDLE until the circumstances of the incident were more fully understood. It also raised a technical request with the manufacturer to clarify procedural elements of OEI training with one engine retarded to IDLE. Pending the outcome of the investigation, the operator elected to only conduct OEI training with both engines at FLIGHT. The operator also pursued a new contract to provide simulator-based OEI training for their BK 117 C-2 pilots and this became fully established by the end of Autumn 2021.

Meteorology

The reported weather at the time of the incident was a south-westerly wind of 10-15 kt with gusts to 25 kt, good visibility under a 2,500 ft cloud base, temperature of 8°C and a QNH of 1,000 HPa.

Airfield information

In addition to the helicopter operating strip used on the incident flight, North Weald Airfield has a grass runway adjacent to the northern end of Runway 02/20. For noise abatement reasons, the operator does not conduct routine training on the grass runway.

Personnel

The pilot occupying the left seat was revalidating his TRI qualification and was being assessed by the examiner who was flying from the right seat.

Both pilots were qualified as BK 117 C-2 type rating examiners, each with approximately 7,170 total flying hours. The commander had 2,200 hours on type and was also qualified on the EC135 helicopter. The examiner had flown 2,600 hours on BK 117 C-2 helicopters. They were both familiar with the training profile being conducted and reported having conducted Cat A Clear Heliport OEI training using the one engine at IDLE technique "over a hundred times." The crew explained that the pilot revalidating his TRI qualification was nominated as aircraft commander because he would be manipulating the throttles during the engine failure training scenarios.

Earlier in the year, the examiner had taken on additional managerial and strategic responsibilities including the Head of Flight Operations role. As a result, he had a higher workload and had been flying less than in previous years.

Neither pilot reported any personal or work-related factors that they felt affected their performance.

Organisational information

The operator was in the process of a significant national programme of organisational change that included changes of location, job roles and working pattern for some pilots. The programme of change was being managed through the operator's Safety Management System (SMS). In October 2020, the operator identified the start of an increasing trend of fatigue and distraction due to the uncertainty associated with the changes. The operator was attempting to manage these hazards while recognising that they are an inevitable consequence of some types of organisational change and that there are limited options for reducing them while uncertainty continues. Some of the role changes had resulted in additional workload. The operator recognised the potential for this to affect pilot performance and took safety action in this area.

Tests and research

Following the occurrence and subsequent aircraft examination, a rotors-running ground check confirmed the correct operation of the VARTOMS and trim system. Tests to assess the authority of the engine trim system were made by a test pilot from the helicopter manufacturer and were overseen by AAIB.

Trim authority was assessed by setting VARTOMS to MANUAL, manipulating the trim function and assessing the engine speeds when the twist grips were set to IDLE and FLIGHT. The results are shown in Table 2. Collective pitch remained at zero throughout the testing.

Test number	Trim position	No 1 Twist Grip position	No 2 Twist Grip position	No 1 N1 (%)	No 2 N1 (%)
1	Neutral	FLIGHT	FLIGHT	80.1	79.1
2		IDLE	IDLE	69.6	70.9
3	Fully forward	FLIGHT	FLIGHT	79.1	82.0
4		IDLE	IDLE	70.0	71.1
5	Fully backward	FLIGHT	FLIGHT	79.1	77.1
6		IDLE	IDLE	70.5	71.2
7	Fully left	FLIGHT	FLIGHT	83.9	73.1
8		IDLE	IDLE	70.5	70.9
9	Fully Right	FLIGHT	FLIGHT	69.8	85.9
10		IDLE	IDLE	69.8	71.6

Table 2

Engine speeds at Idle and Flight when trimmed using engine trim function

These tests revealed that when the engines were set to FLIGHT and then trimmed fully right, Engine No 2's N1 increased and Engine No 1's N1 reduced. Engine No 1's N1 settled at approximately 70% and when the throttle was moved to IDLE and back to FLIGHT the engine speed remained at approximately 70% N1. A similar but opposite result was observed when the engines were trimmed to the left; as shown in the results of tests 7, 8, 9 and 10.

Analysis

Examination and ground running revealed no technical malfunction with the helicopter that would have prevented Engine No 1 from responding to the twist grip as it was moved from IDLE toward FLIGHT during the initial phase of the OEI manoeuvre, or to cause the twist grip for Engine No 2 to come out of the FLIGHT detent during the latter part of the manoeuvre. Ground running did, however, identify that if the engines were fully trimmed right, ie the No 1 engine trimmed down, Engine No 1's response was similar to that in the event flight.

Operation of the trim switch

Without a trim parameter or twist grip position recorded on the FDR, it was not possible to confirm whether the trim was inadvertently moved to the right, instead of trimming both engines forward. From the pilot's recollection of advancing the Engine No 1 twist grip without response it is likely that when he applied forward trim, as trained to do in OEI situations, the four-way trim switch was inadvertently moved to the right trim position.

By trimming Engine No 2 up and Engine No 1 down while Engine No 1 was set to idle, the engine response would initially have been the same as if the trim had been pushed forward. Engine No 2 would have increased torque with Engine No 1 remaining at a low torque output. Only when the Engine No 1 twist grip was advanced would the engine trim split manifest itself.

The trim switch is offset to align with the pilot's thumb when holding the collective so that movement forwards (power of both engines is increased simultaneously) is the easiest action. The offset alignment makes inadvertent movement to the right less likely compared to a straight alignment because movement to the right position requires a slight rearward movement, but it is still possible. If the switch is inadvertently moved into the right gate, any forward pressure moves it against the side of the gate, feeling similar to when the switch is positioned against the forward stop. There is no feedback to the pilot to indicate the location or direction of trim, so if this occurs there is little opportunity to recognise and correct it.

OEI training risk

Having previously been unable to establish an appropriate simulator training contract, the operator was required to choose between the three options available for live emergency training in the helicopter. Balancing the risk factors for the various options, the operator chose to use the 'one engine at IDLE' method to train pilots for OEI conditions.

Incident event

The CVR evidence suggested a relaxed professional atmosphere in the cockpit with both pilots focused on the exercises that were being flown. Accordingly, it is unlikely distraction or interpersonal factors contributed to the occurrence.

For the incident event, the commander was using a technique specified in the RFM to simulate an engine failure on a Cat A Clear Heliport takeoff. The helicopter was below the maximum gross mass for simulating OEI conditions with one engine at IDLE so there was no RFM requirement for it to be fitted with the manufacturer's OEI training device. The investigation observed that the RFM limitation requiring the device to be fitted for training at MTGM was of limited value; training could not be conducted above MTGM and at 1 kg below that mass use of the device was not required. The manufacturer undertook to review the appropriateness of this limitation.

During the takeoff acceleration the commander was judging his height and airspeed by looking across the cockpit to the examiner's flight instruments. He recalled announcing "flyaway" when he saw they were above 20 ft and 30 kt based on the examiner's displays, he then retarded Engine No 1's throttle to initiate the simulated engine failure. The FDR trace showed the helicopter at 16 ft radio height and 42 KIAS when the throttle came out of the FLIGHT detent. The helicopter maintained a shallow climb and passed through 20 ft radio height approximately 3-4 seconds after the throttle had been closed, the recorded IAS at that point was close to 43 kt. The reason for the apparent discrepancy between the commander's interpretation of the examiner's altimeter display and the recorded radar altimeter height was not identified. While the helicopter might possibly have been below the target TDP height parameter when the engine failure simulation was initiated, the excess speed meant that less power would have been required to maintain level flight or fly away than at the nominated TDP parameters of 20 ft and 30 KIAS. Given the energy state of the helicopter, the investigation assessed that continuing the takeoff was a reasonable course of action.

During the OEI demonstration, the power required from Engine No 2 to execute the flyaway manoeuvre exceeded the training limit, therefore the commander increased the throttle setting of Engine No 1. Then, while the commander was manipulating Engine No 1's throttle in reaction to its lack of response, Engine No 2's throttle moved out of the FLIGHT detent, thereby putting the engine into manual control. The evidence supported the commander's theory that, if his hand had overlapped both twist grips (Figure 13) while adjusting Engine No 1's throttle, it could account for FLIGHT being deselected inadvertently on Engine No 2. The commander also reported that the breakout force from the FLIGHT detent was relatively low compared with other helicopter types he had flown. The TWIST GRIP caution for Engine No 2's throttle would have been displayed on the CAD, but it did not have any attention getting properties. The commander's attention would have been focused on other indications and there was limited time for diagnosis.

In a rapidly deteriorating situation, the commander made an appropriate decision to reject the takeoff and managed the collective effectively to maintain minimum N_R and achieve a firm touchdown that resulted in some damage to the helicopter but no injuries. Although using the more-northerly grass runway could have given the pilots more obstacle free distance to diagnose and resolve the throttle handling issues, noise abatement considerations precluded its use.

Throttle handling technique

While the commander had no reason to suspect that Engine No 1 would not respond to his increased throttle demand, had he used the alternative technique of initially reducing to an intermediate throttle setting, rather than IDLE, the encountered problems might not have occurred. The subsequent inadvertent deselection of FLIGHT on Engine No 2 probably resulted from the commander's hand accidentally overlapping its throttle as he tightened and/or moved his grip on Engine No 1's throttle while manipulating it in response to the unfolding emergency. The investigation heard that inadvertent manipulation of the throttles during high stress/workload situations was an uncommon, but not unknown occurrence on this type of helicopter. The helicopter manufacturer undertook to review their handling guidance for pilots employing the one engine to IDLE technique for simulating engine failures during Cat A Clear Heliport takeoffs.

Figure 13

Pilot's hand overlapping both throttle twist grips

Throttle and trim switch design

The throttle control incorporates several tactile features to aid non-visual operation and reduce the chance of inadvertent movement of the throttles. The investigation did not identify any design features that could have increased the likelihood of inadvertent right trimming or inadvertent movement of the throttle out of FLIGHT mode.

Organisational change

There was no indication the pilots' performance was affected by the scale of organisational change. They did not report any adverse effects on them that were relevant to the incident. The operator was managing the process in the SMS. The SMS was effective in that it had identified an increasing trend of distraction and fatigue and the operator attempted to minimise this as far as possible.

Conclusion

This serious incident occurred in a serviceable helicopter while the pilots were following an RFM-approved training procedure. While FDR data indicates that the helicopter was slightly below 20 ft when the simulated engine failure was introduced, the excess speed at that point meant it did not materially affect the outcome.

Ground running trials conducted on behalf of the AAIB indicated that, with no faults detected in the helicopter's engine control systems, the most likely cause of Engine No 1 failing to respond to the commander's increased throttle demand was an inadvertent initial RIGHT, rather than FORWARD, trim selection on the 4-way beep trim switch. There was no evidence the incorrect selection was caused by the design of the switch.

The actions taken when Engine No 1 did not respond to the commander's inputs led to Engine No 2's throttle being inadvertently moved out of the FLIGHT detent, which exacerbated the situation. The subsequent landing was firm and caused damage to the helicopter's skid assembly.

The event could possibly have been avoided by using a different throttle handling technique when simulating the engine failure. This incident reinforces the benefit of using flight simulators wherever possible to de-risk training, thus avoiding the requirement for live emergency training in the helicopter.

Safety action

The helicopter's operator has:

- issued a temporary Flying Staff Instruction prohibiting engines being retarded to idle in flight during BK 117 C-2 training and checking.
- raised a technical request with the manufacturer to clarify procedural elements of OEI training with one engine retarded to idle.
- initiated a review of workload at all management levels where change was occurring, including the Head of Flight Operations role.
- introduced simulator training, including OEI serials, for BK 117 C-2 pilots.

The helicopter manufacturer reported that it intended to:

- develop formal guidance to pilots delivering simulated OEI training in the helicopter using the one engine at IDLE technique, and
- review the appropriateness and scope of the RFM limitation requiring the use of the manufacturer's training device when conducting OEI training at MTGM.

Published: 3 February 2022.