Investigation report

L2013-01

Helicopter accident on a heli-sawing flight near the city of Tampere on 10 January 2013

Translation of the original Finnish language report

OH-HNP

Hughes 369D

According to Annex 13 to the Convention on International Civil Aviation, paragraph 3.1, the sole objective of the investigation of an accident or incident shall be the prevention of accidents and incidents. It is not the purpose of this activity to apportion blame or liability. This basic rule is also contained in the Safety Investigation Act (525/2011) and European Union Regulation No 996/2010. Use of the report for reasons other than improvement of safety should be avoided

Due to the nature of this occurrence the format of this investigation report diverges from that defined in Annex 13 to the Convention on International Civil Aviation.

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INVESTIGATION REPORT: L2013-01 **INVESTIGATION COMPLETED ON:** 20.9.2013
Investigator-in-charge: Ismo Aaltonen
Investigation group: Kalle Brusi, Ari Anttila
On-scene investigation expert: Esko Lähteenmäki
Sweden (State of Maintenance Organisation) and the United States (State of Manufacture) designated their accredited representatives to the investigation.

Helicopter type and registration	Hughes 369D, OH-HNP Serial number: 1260066D
Year of manufacture	1976 Total flying hours: 10797 hours
Powerplant	Rolls Royce (Allison) 250-C20B Serial number: CAE-832465 Total hours: 13417 hours
Weight	MTOW 3000 lbs Approximately 2760 lbs at the time of the accident
Heli-saw	Super Cut. Massa 743 lbs (337 kg).
Operator	Heliwest Oy
Continuing Airworthiness Management Organisation	Malmskogens Aerocenter AB
Time	10.1.2013, 8:45 (UTC)
Place	Teisko, Tampere. N 6835162 E 330436. Elevation: 103 meters
Meteorological information	-5 °C, wind NNE 3–4 m/s, overcast at 800–900 ft, no precipitation, daylight conditions.
Type of flight	Aerial work. Branch trimming (power line clearing flight)
Number of persons on board	1
Injuries to persons	The helicopter pilot sustained minor injuries
Damage to the helicopter	Substantial damage.
Licences	Airline Pilot Licence Helicopter. Licence was valid.
Pilot	Pilot in-command: Age 42.
Flight experience	4905 hours (810 hours on this specific type) Approximately 300 hours of heli-sawing flights Last 90 days 70 h (45 h on this type) Last 30 days 30 h (20 h on this type)

Figure 1. The accident site.

SUMMARY

On Thursday, 10 January 2013 the helicopter pilot was on a branch trimming flight near power line wires in the city district of Teisko in Tampere. Following a malfunction of the helicopter's powerplant the pilot made an emergency landing on a field.

The malfunction was caused when a B-nut downstream of the Pc filter on the compressor delivery air pressure sensing line became completely unscrewed, which resulted in the loosening of the coupling and, consequently, in a loss of pressure in the engine's power control system. The pilot suffered minor bruises but the helicopter sustained substantial damage. The occurrence was caused by an imprecise daily inspection prior to the flight as well as non-standard practice or error in previous maintenance.

Several heli-sawing accidents have occurred in Finland. In these accidents the pilots have not managed to carry out the emergency release of the heli-saw. The heavy sawing unit, assembled in a long tubular frame (suspension bar), poses a specific challenge to the pilot and the helicopter during emergencies.

The investigation group comprised Mr Kalle Brusi, the team leader, accompanied by Mr Ari Anttila. Chief Air Safety Investigator Ismo Aaltonen was appointed as investigator-in-charge. Mr Esko Lähteenmäki provided his expert assistance to the investigation group in the on-scene investigation. Also Mr. Oskari Työppönen provided his expert assistance to the technical inspection. Utti Jaeger regiment assisted with the technical inspections.

Four safety recommendations were made. The recommendation to MD Helicopters Inc concerns the instruction for the daily inspection of the helicopter. The safety recommendation issued to the supervisory Finnish and Swedish aviation authorities, i.e. the Finnish Transport Safety Agency and *Transportstyrelsen*, respectively, pertains to maintenance organisation regulations and maintenance procedures. In addition, the recommendations directed at the Finnish Transport Safety Agency dealt with the safety of heli-sawing operations.

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1 HISTORY OF THE FLIGHT

The helicopter was on its first flight of the day. The flight commenced at 8:25 (UTC). Prior to the flight the pilot carried out the daily inspection. Once airborne, the pilot started out by trimming a couple of solitary trees, after which he began to clear branches along the edge of power lines. Approximately 20 minutes into the flight, while over a knoll (Fig. 2) and immediately in front of a field directly ahead, the helicopter's engine lost its power and, apparently, flamed out. Low main rotor rpm and automatic relight cautions annunciated. The pilot fully lowered the collective lever and pushed the nose down, steering the helicopter towards the field. As the emergency landing site approached he momentarily flared the helicopter. Before the ground impact he righted the helicopter and lifted the collective lever so as to soften the touchdown. The helicopter was at an approximate height of 60 m above the landing site when the engine failure occurred. The pilot tried to use the mechanical release handle of the cargo hook to release the saw, but to no avail. Apparently the sawing unit got tangled up in a tree, which broke its suspension bar. The helicopter suffered substantial damage in the emergency landing. Prior to the malfunction the engine had been operating normally.

It was -5 °C and the wind was light: 3–4 m/s. At the time of the accident the wind was blowing from the left of the helicopter. There was no fire. The helicopter pilot suffered minor injuries. There was no other damage.

Figure 2. The accident site photographed from the top of the knoll.

The pilot immediately reported the accident to the aviation authority and called the emergency number 112. The first rescue unit arrived at the site within 10 minutes of the alarm issued by the Emergency Response Centre, i.e. just under 15 minutes after the accident occurred. The area is sparsely populated and accidents are infrequent. Therefore, the readiness risk class for that area is 4. This means that the regulations[1] allow for more than 30 minutes for rescue squads to arrive at an accident site.

[1] Preparedness Instructions. 2003. Ministry of the Interior, Department for Rescue Services publications.

2 ACCIDENT INVESTIGATION

Figure 3. The broken saw suspension bar, photographed from the direction where the helicopter came from.

2.1 On-scene investigation

The last tree that was trimmed was on the slope of a ridge, at the edge of a field. The helicopter lay approximately 35 m from the tree on the field along the track which it had been maintaining at the time of the accident. On the power lines' side one large branch remained untrimmed from the tree, a 20 m tall aspen. The heli-saw, consisting of 10 rotating blades, lay approximately three metres from the tree along the original track of the helicopter. The saw was approximately seven metres long.

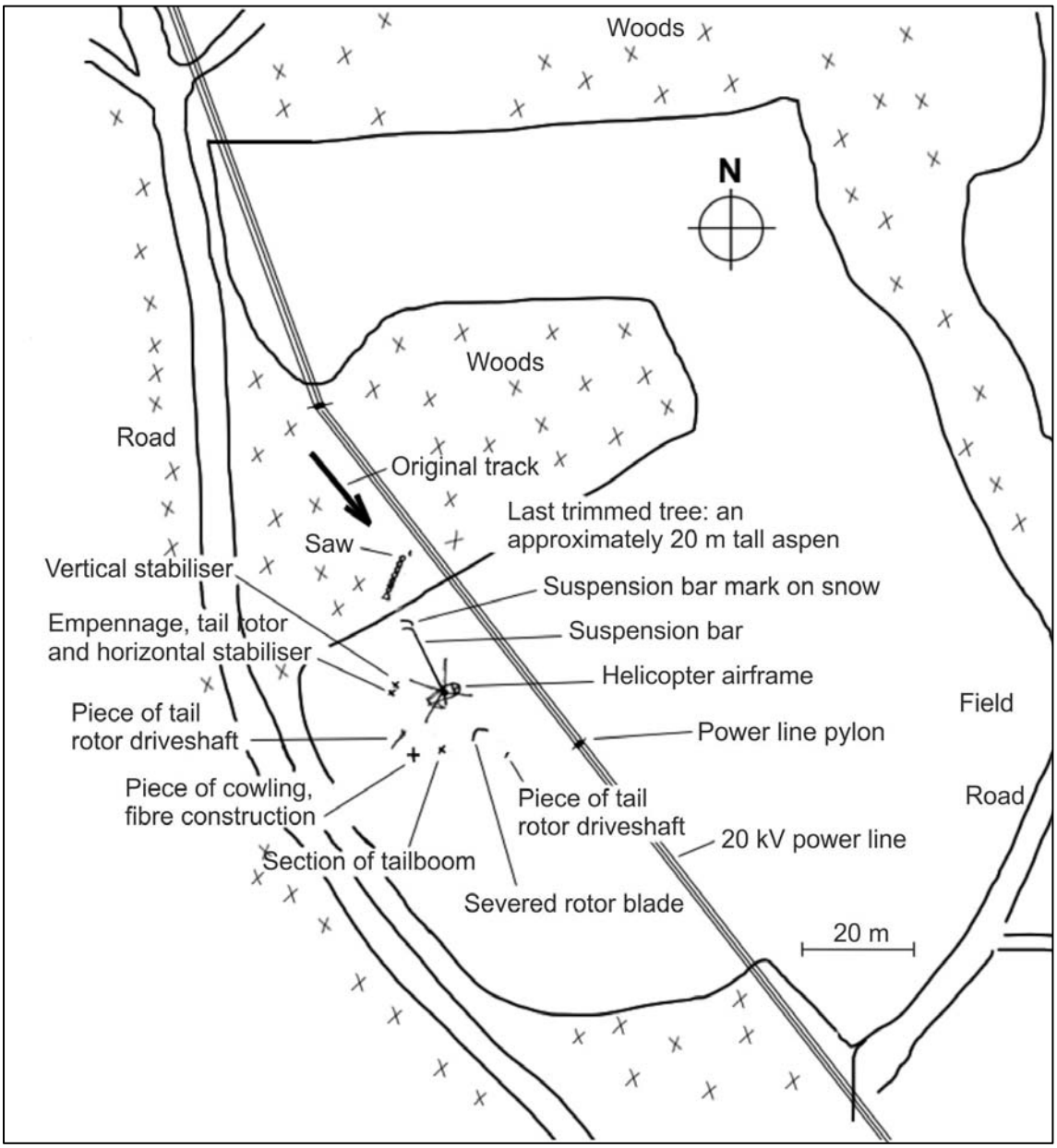


Figure 4. A sketch of the accident site.

The roughly 18 m long suspension bar of the saw, having separated from the sawing unit, lay approximately 10 m from the saw on the field. The bar was bent at approximately two metres from the place where it broke off. The bent suspension bar had left a mark on the snow at approximately two metres before the place where it lay. One end of the bar was still attached to the bottom of the helicopter, to the external cargo hook. The original track of the helicopter was approximately 145 degrees but the airframe veered approximately 90 degrees to the left once it collided with the ground. The magnetic compass was pointing towards 55 degrees. There was a power line 16 m from the nose of the helicopter; the closest power line pylon was 21 m from the airframe. The local road was approximately 40 m behind the helicopter. The snow layer was approximately 30 cm thick.

Both of the helicopter's skids broke off in the collision with the ground. The airframe was lying on its bottom on the ground. The lower section of the left windshield was shattered next to the antitorque pedals. One of the main rotor's five blades was broken off close to the root of the blade. Another blade was bent downward and its leading edge was crushed. The third blade was bent upward and the remaining two blades seemed intact. The rotor blades had struck the tailboom, slashing it into three separate sections. The root of the tailboom was bent towards the right side of the airframe and the middle part lay approximately eight metres from the airframe, in front of the helicopter in its original heading. The empennage section, including the tail rotor, the tail rotor gearbox and the horizontal stabiliser, which were still attached to the empennage, lay approximately seven metres to the right of the airframe in relation to the track of the helicopter. The vertical stabiliser lay next to them. In addition, two pieces of the tail rotor's driveshaft and a fibre cowling from above the engine's compressor were close to the airframe. The stabilisers and the driveshaft parts had rotor slash marks on them. The tail rotor was intact. The helicopter's seats had maintained their integrity.

Figure 5. A B-nut downstream of the Pc filter on the compressor delivery air pressure sensing line, photographed after the accident.

2.2 Technical inspection

The helicopter's technical inspection revealed that a B-nut downstream of the Pc filter on the compressor delivery air pressure sensing line and the coupling had become loose (Fig.

5). The line loosening results in an air pressure drop in the engine's power control system and, consequently, the loss of engine power or a flameout.

The coupling, the filter and the line were all intact. The condition of the air pressure sensing line parts were also tested, using a pressure test in accordance with maintenance instructions, and no other leaks in the lines were discovered. The technical inspection found no other damage or fault in the helicopter which could have contributed to the onset of the accident.

Once the line's nuts are tightened to the correct torque the couplings are marked with torque paint so as to make it possible to monitor any slippage. Whereas some paint markings had blackened because of heat, some nuts showed no paint markings at all. When the loosening and tightening torques of the B-nuts were tested for the purpose of general estimation, their loosening torques varied quite a lot, from 25 to 125 lb in. The B-nut at the other end of the Pc filter, upstream of the loosened coupling, was remarkably tight. It loosened at 125 lb in. The B-nut on the Pr line loosened at 25 lb in and tightened to its original position at less than 80 lb in.

The air pressure sensing line and the B-nut installed on the helicopter were compared with new, similar parts. Their loosening torques differed insofar as the new parts required approximately 10 lb in of higher torque. The new parts loosened at 70 lb in, compared to 60 lb in, the torque of the parts installed on the helicopter. The testing was done at a tightening torque of 100 lb in. According to the engine manufacturer the two main causes for a leak include loose couplings and worn parts, which may open as a result of vibration. Incorrect tightening torques may also wear the couplings. There were no signs of exceptionally high vibration in the engine or in its immediate surroundings.

2.3 Additional observations

The technical inspection also revealed that the circuit breaker of the engine's automatic relight system was worn and loose. Nonetheless, it functioned properly. During the investigation the engine's igniter was removed and a functional test of the automatic relight system found the operation of the system to be normal. The engine was manually turned at the compressor and the engine rotated freely. The helicopter's fuel tank inspection door was opened and the remaining fuel at the bottom of the tank was tested with water-finding paste. There was no water in the tank. The ice filter in the engine compartment was removed and inspected. A few drops of water came from the filter. The engine fuel pump filter was clean. The fuel nozzle was removed and the operation of the system was checked by turning the starter motor. The check valve and the nozzle functioned normally. The injector spray cone was also normal.

To allow for the heli-saw's controls, the external cargo release handle was installed a bit to the side and farther than normal from the cyclic control (Figure 6). The recording feature on the helicopter's GPS satnav had been turned off. Following the emergency landing the helicopter's ELT transmitter (ACK Model E-01) did not activate.

Neither the helicopter's Flight Manual appendices nor the operator's Operations Manual contained any instructions, limitations or weight and balance calculations regarding the sawing apparatus which was being used. The other heli-saw control unit was hanging freely on the cyclic control (Figure 6). The sawing apparatus mentioned in the Operations Manual was intended for another type of sawing unit than the one installed on this helicopter. The weights of these saws were dissimilar. There were no Hold Item List markings in the helicopter's journey logbook. The investigation could not establish a clear picture of whether there was an alternative method in use as regards managing the deferred fault correction actions list and maintenance work.

During an inspection conducted on 30 March 2011 the Finnish Transport Safety Agency discovered a shortcoming in ground crew instructions. In their feedback to the operator following the inspection, the Finnish Transport Safety Agency required that the material related to corrective action be presented to them no later than 30 August 2011. The Finnish Transport Safety Agency determined that the Operations Manual, revision 4 (16 Nov 2011) resolved the deficiencies. The Operations Manual in the helicopter was a revision 3 (2009); no other documents concerning the ground crew were found in the helicopter. The Operator informed the Transport Safety Agency that the current revision of the Operations Manual was 5. The operator had notified about the introduction of the new revision to the Transport Safety Agency. The Transport Safety Agency has not confirmed the introduction of the new revision.

The helicopter's airworthiness review certificate was valid. The operator's aerial work certificate was valid.

Figure 6. The layout of the sawing unit's controls and the external cargo emergency release handle, photographed from the side and the front.

2.4 Similar accidents

Four heli-sawing accidents have occurred within a decade in Finland. Likewise, the database of the US National Transportation Safety Board (NTSB) lists four accidents in the United States within the same time frame. The numbers are not directly comparable because the hours used in heli-sawing differ from country to country and reliable figures were not available. When it comes to the accidents that occurred in Finland, one accident was caused by a technical fault, another by pilot error (HF[2]) and in the case of this accident being investigated the cause was a maintenance procedure or error (HF). The investigation of one accident is still ongoing. Even though the emergency procedures related to sawing operations and external cargo prioritise an immediate release of external cargo, in none of the Finnish accidents was the external cargo jettisoned.

The loosening of the B-nut in Rolls Royce Allison 250 Series engines has caused several accidents worldwide. As a result of an accident which occurred in 1992 the UK Air Accidents Investigation Branch (AAIB) recommended that the engine manufacturer take action to introduce some form of positive mechanical locking of the B-nuts (AAIB 12/92).

2.5 Maintenance requirements

The engine manufacturer provides detailed maintenance instructions for inspecting and tightening the B-nuts. The EASA's Airworthiness Directive AD 2004-0009 R2 requires inspections of the B-nuts for indication of slippage at intervals not exceeding 100 hours, as well as following maintenance which involves disturbing any control system plumbing. Furthermore, it is stated that the B-nut torque values must be recorded in the relevant aircraft technical records.

The scroll-to-Pc filter on the compressor delivery air pressure sensing line is removed for inspection every 100 flight hours. The Pc filter is removed and cleaned every 300 flight hours. This involves the opening of the coupling which had come loose in this accident. Likewise, the coupling must be opened in conjunction with engine module maintenance or the maintenance of other components. The B-nuts must be torqued down to 80 – 120 lb in (Rolls Royce M250 C20 Maintenance Manual). The engine manufacturer's instructions do not require that the tightening torques be recorded.

The instructions for the daily inspection, which are contained in the flight manual published by the helicopter manufacturer and approved by the aviation authority, call for a check of the engines' air lines. The instruction reads as follows: "Engine oil, air, and fuel lines CHECK". The daily inspection instructions in the engine manufacturer's maintenance manual are more comprehensive: "Visually check for the presence and alignment of slippage marks (torque paint) on all B-nuts" (Rolls Royce M250 C20 Maintenance Manual). In case of a missing paint marking or a loose coupling, the B-nut must be inspected and re-torqued and the slippage mark must be replenished. The operator's chosen method is for the pilot to carry out the checks on each flying day between the 35 flight hour checks.

[2] Human Factors refer to a human's physiological or psychological action in the realm of the aviation environment.

2.6 Maintenance operations

Effective 1 June 2012, the operator outsourced its helicopter's continuing airworthiness management (Part M, CAM, SE.MG.0095) and maintenance (EASA Part-145 Approval certificate SE.145.0113) to Malmskogens Aerocenter AB. The organisation is located at Lindköping, Sweden. The company runs a line maintenance location at Urajärvi, Finland, where Heliwest Oy's helicopters are maintained. The organisation provides the helicopter's maintenance programme and the required maintenance instructions, and keeps the helicopter's technical documentation up-to-date. Information is transferred over the Internet by using tailored software applications.

The line maintenance location has carried out demanding helicopter and engine maintenance work such as main transmission replacements, major periodic inspections and module replacements on engines removed from helicopters.

The previous documented opening of the air pressure line's coupling was done on 2 December 2012 during the 300 hour maintenance (WO: 12-307). The engine's compressor module was also replaced then. At that time the helicopter had 10719.3 total flying hours. Following the maintenance the helicopter had accrued approximately 78 flight hours. The previous 35 flight hour check was carried out on 2 January 2013. Then, the airframe had 10776 flying hours. The last daily inspection took place on the day of the accident, prior to the flight, at 10797 flying hours.

When the investigation evaluated the work procedure, it was discovered that the tools needed for the assembly were not suitable for some tasks. According to the interviews, the maintenance personnel had to torque the nuts, at least to some extent, by feel. The torque wrench's pressure on the palm was compared with its setting and, afterward, the B-nuts were tightened down to the same 'feel'.

The Airworthiness Directive was properly signed during maintenance. Torque values were not recorded and the nuts were reportedly torqued down in the abovementioned non-standard manner. No work instruction existed for the procedure which was being used. The company did not use any lists which included the sign off of individual work tasks. The inspection of B-nut tightening and maintenance work performed on the lines was taken care of at the practical level through unofficial and undocumented inspections. This being the case, no pressure tests following the reassembly of compressor delivery air pressure sensing lines or tightening of couplings were specifically documented although technicians told during hearing that the pressure test was performed (73-00-00, FUEL SYSTEM CONTROL PNEUMATIC LEAK CHECK).

When it comes to important and demanding maintenance work critical to the aircraft, a dual inspection must be used. Under such a system another qualified person checks the correct installation/reassembly of a part. Both persons then sign off the completed work and the inspection in the maintenance documentation. (EC 2042/2003, Part M, subparts C & D)

As regards compressor delivery air pressure sensing line maintenance pursuant to the Airworthiness Directive, neither the maintenance organisation nor the supervisory aviation authority (The Finnish Transport Safety Agency) have instructed or required that a dual

inspection process be used in the helicopter's approved maintenance programme (1st edition 10-10-2012, Rev 0. 18.10.2012). The non-standard work procedure and the unsuitable tools concerning the critical maintenance work were not noticed in the audits (MAC Quality Audit report 4-2012 and TSL 2012-3048) of the line maintenance located at Urajärvi, which were carried out by the maintenance organisation and the supervisory aviation authority (Transportstyrelsen).

3 ANALYSIS

3.1 The accident

The investigation determined that the slippage of the B-nut and the consequent opening of the coupling caused the loss of engine power. Since the control air pressure sensing lines, the filter and the B-nut were intact and there were no signs of abnormal engine vibration, Safety Investigation Authority deems it possible that

1. The B-nut was not tightened to the specified torque due to a maintenance procedure or error. The variation observed in the loosening torques of the other B-nuts implies that the method used in torqueing the nuts occasionally yields unreliable results.

2. The extremely tight coupling upstream of the Pc filter may have contributed to the opening of the coupling which caused the accident, as a tightening or a later check done with a spanner generates a certain amount of torsional shearing stress and spring load. If the manual-specified torqueing was done after the opened coupling was tightened by using, for example, 50% more moment of force, it is possible that the normally torqued coupling is subjected to residual stress which works towards loosening the coupling. The combined effect of temperature changes, vibration and the residual stress eventually loosened the B-nut.

Additionally, a mechanical opening of the coupling following the maintenance conducted on 2 December 2012 cannot be ruled out because the opened coupling showed no residue of slippage marks. This being the case, the opening of the nut could have been caused by a combination of many factors. Appendix 1 shows a Bow Tie graph which the investigation used to analyse the occurrence. It is the opinion of Safety Investigation Authority, Finland that a maintenance nonconformity (alternative 1 or 2) caused the opening of the coupling. Furthermore, the absence of a slippage mark or the fact that the nut was loose was not detected during daily inspections.

According to documents the OH-HNP was airworthy when it took off for the flight. However, from the technical viewpoint it was not flightworthy.

3.2 Maintenance operations

While maintenance operations used the instructions of the maintenance organisation and the manufacturer, there was variance in the implementation of work in accordance with the Airworthiness Directive. The somewhat unsuitable tools and instructions used at the line maintenance location imply problems in the company's work supervision processes and quality assurance.

A correct dual inspection process significantly diminishes the risk of error in maintenance so long as the inspection and maintenance work can be carried out independent of one another and without any distractions. A phase-by-phase work documentation on the assembly of lines and leak testing, for example, would reduce the possibility of error. Thus, systematic maintenance and quality assurance can effectively improve safety. It is the opin-

ion of the Safety Investigation Authority that by not documenting work phases and inspections during demanding and extensive maintenance work such as engine removals, reassembly and engine module replacements, the company's present practice increases the risk of error.

The engine manufacturer has previously decided against making the critical part safer by mechanical locking, for example. At present, the solutions include "soft measures". In other words, there is an attempt to mitigate the problem by making the instructions more specific. Mutually contradictory instructions (Rolls Royce M250 C20 Maintenance Manual and AD 2004–0009 R2) do not support the work process. The presently used method for solving the problem carries a higher risk for error than a mechanical implementation.

The engine manufacturer's daily inspection instruction is more specific than that published by the helicopter manufacturer (FM) and approved by the aviation authority. The engine manufacturer's instruction requires that the couplings in question and their paint markings be checked on every flying day. The maintenance programme approved by the operator used the helicopter manufacturer's manual which did not include this requirement.

The purpose of the daily inspection is to ascertain whether the helicopter is airworthy. In other words, it is the final technical safety net. Had the missing paint marking been detected in daily inspections, the coupling would have been inspected and tightened in accordance with maintenance instructions. No missing paint markings were detected, or at least reported, in the previous 35 flight hour check or in daily inspections. According to the interviews the paint markings come loose repeatedly during flight operations. Safety Investigation Authority considers it likely that there was no paint marking on the B-nut when the daily inspection was being done.

3.3 Sawing operations

The sawing apparatus or the ground crew's insufficient documents were not directly associated with the onset of the accident.

Many accidents have occurred on sawing flights in Finland. The heavy sawing unit, assembled in a long suspension bar, poses a specific challenge to the pilot and the helicopter during emergencies. Heli-sawing flights are also flown in densely populated areas. Light, single-engine helicopters are being used in heli-sawing work.

Heli-sawing operations significantly differ from other flights with external cargo. These flights are flown at a high takeoff weight, at a low height and airspeed or in hover out of ground effect (OGE), i.e. in a range which requires high engine power (Figure 7). More often than not there is a high-voltage power line in the helicopter's immediate vicinity. It is impossible to completely compensate for wind conditions because the requirements of the sawing operation dictate the heading of the helicopter. It is almost impossible to monitor the flight instruments during the operation. Together, these factors create an unfavourable safety environment. As can be seen from the diagram in Figure 7, heli-sawing operations occur in an adverse height-velocity range. Excluding ferry flights, the entire heli-sawing operation occurs in this range. When it comes to external cargo flights such as load lifting and

construction work, helicopters minimise the time flown in the abovementioned range and it is normally possible to allow for wind conditions. This being the case, the risks in heli-sawing operations are higher than normal.

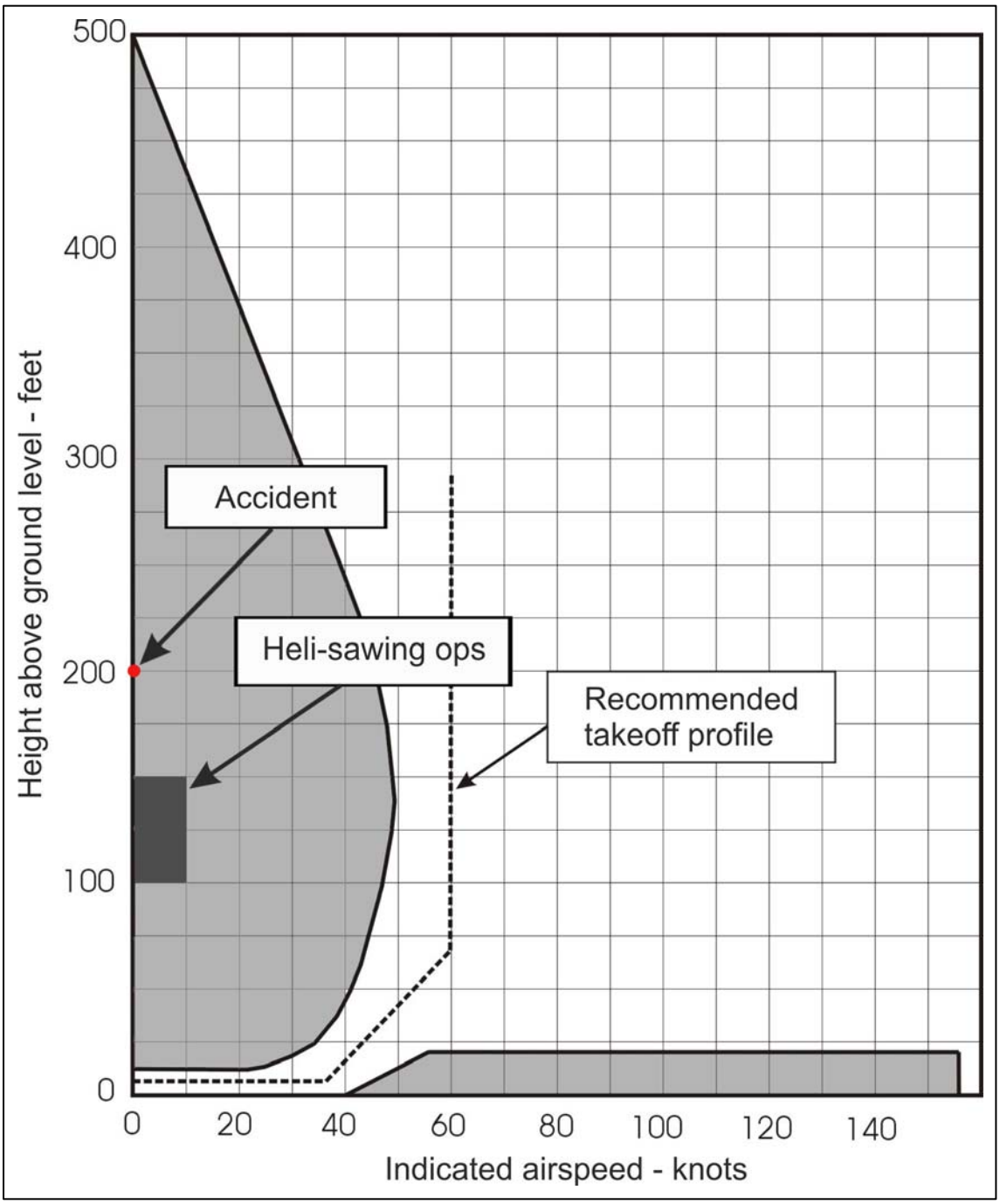


Figure 7. A helicopter's Height-Velocity Diagram. The grey-shaded zone is the so-called 'dead man's curve' which will likely prevent a successful autorotation. One should avoid operating in this height-velocity zone. Heli-sawing operations are normally flown at a very low airspeed and at the height of 30–40 metres or so (dark grey-shaded zone). The helicopter's engine failed as it was flying over a knoll. Therefore, it was flying at approximately 200 ft (red dot) in relation to the emergency landing site.

Challenging operations demand action that promotes the safety of flight. Special attention should be paid to the training of pilots and mechanics. Furthermore, the ground crew should have precise plans, first aid training and rescue equipment in view of a potential accident.

Even though the primary task of the pilot in an emergency is to fly the helicopter, it would be of utmost importance to release any external cargo as soon as possible. It is not possible to convert the helicopter's height into more airspeed so as to aid autorotation if the heavy saw, dangling barely higher than 10 m among obstructions, acts as an anchor. Moreover, a high-voltage power line brings additional risk to an emergency landing. Pilots have not managed to release the heli-saw in any of the accidents that occurred in Finland within an observation period of 10 years. A better positioning of the external cargo release handle as well as training on how to use the electric and mechanical switch would improve the odds for a successful emergency landing. For example, relocating the handle from the cyclic control to the collective lever has recently come up in conversations. In this particular accident the suspension bar broke off almost immediately after the engine failure. Therefore, a release would only have had a marginal effect on the success of the emergency landing.

Judging by the accidents that have occurred, it is the opinion of Safety Investigation Authority, Finland that a dangling sawing apparatus cannot be regarded as normal, jettisonable external cargo. It should be considered as a tool installed on the helicopter which, in some controlled circumstances, can be released. The extra limitations and effects that the sawing apparatus brings to the helicopter's flying mass and centre of gravity as well as to emergency procedures should be clearly explained in an appendix of the helicopter's flight manual. The installation of heli-saw controls should be approved by the authorities if they are installed on the helicopter's type-certified flight controls (Figure 6).

3.4 Rescue operations

The rescue operation was carried out in an excellent manner and the response time was clearly shorter than the requirement. It is advisable to first call the emergency number 112 and only after that contact the supervisory aviation authority. Even if the accident does not seem that serious, the most important task following any accident is to protect human life.

4 CONCLUSIONS

1. The pilot had a valid licence.

2. According to documents the helicopter was airworthy. However, from the technical viewpoint it was not flightworthy.

3. The helicopter pilot was on a branch-trimming flight.

4. The helicopter's engine malfunctioned.

5. The malfunction was caused when a B-nut on the compressor delivery air pressure sensing line became completely unscrewed.

6. The helicopter was substantially damaged as a result of the emergency landing.

7. The pilot suffered minor injuries.

8. The operator has outsourced its helicopter's continuing airworthiness management and maintenance to a Swedish EASA Part-145 organisation.

9. Helicopter maintenance and engine module replacements are produced at a line maintenance location in Urajärvi, Finland.

10. The maintenance instructions and technical records documentation are carried out in Sweden. Information is electronically promulgated.

11. Judging by maintenance documentation the requirement to inspect the torque of B-nuts in accordance with the Airworthiness Directive (AD 2004–0009 R2) had been observed.

12. The company did not carry out extensive reassembly work in phases, which means that installations of the air pressure lines or leak testing, for example, were not specifically documented. Hence, the risk of human error was increased.

13. Inadequate use of instructions and the tools used resulted in an unapproved procedure which may have created divergence between the torqueing of different couplings.

14. A possible divergence in the torqueing of couplings upstream and downstream of the Pc filter may have caused residual stress which acts to loosen the coupling which was earlier tightened to a lower torque setting.

15. The dual inspection process as per Part M was not specified for the helicopter's critical structure.

16. Shortcomings in the details of Airworthiness Directive-specified procedures, unsuitable tools or shortcomings in work processes and instructions were not noticed in the

audits carried out by the maintenance organisation and the supervisory aviation authority.

17. A mechanical opening of the coupling, for some other reason, following the maintenance conducted on 2 December 2012 cannot be ruled out because the opened coupling showed no remainders of a paint marking.

18. Daily inspections did not detect the fact that the B-nut was loose.

19. The engine manufacturer and the EASA share the concern over the accidents that the part in question has caused. This has resulted in the issuance of partly overlapping instructions and directives which may confuse the maintainers.

20. Several heli-sawing accidents have occurred in Finland. Pilots have not managed to carry out any manual-specified emergency releases of the heli-saw.

5 PROBABLE CAUSE

The immediate cause of the accident was a B-nut downstream of the Pc filter on the compressor delivery air pressure sensing line becoming completely unscrewed. The air pressure sensing line came loose, which resulted in a loss of pressure in the engine's power control system at which time the engine lost its power and probably flamed out.

The actual cause of the accident was an imprecise daily inspection prior to the flight and non-standard practice or error in previous maintenance.

6 PLANNED ACTIONS

Malmskogens Aerocenter AB

The company has planned several improvements in tooling, work processes and instructions (Appendix 2).

Heliwest Oy

The pilots will receive annual, extended daily inspection training which also takes into account the problems observed in B-nuts and air pressure sensing lines.

The ground crew will receive first aid training.

A versatile first aid kit will be kept in the vicinity of the helicopter's landing site.

Recurrent operator proficiency check (OPC) training and theoretical instruction will be increased.

7 SAFETY RECOMMENDATIONS

1. The helicopter manufacturer's and the engine manufacturer's daily instruction manuals differ as regards inspecting the paint markings of the compressor delivery air pressure sensing line's couplings. On the basis of previous occurrences, to improve safety, the engine manufacturer decided to introduce comprehensive instructions.

   Safety Investigation Authority, Finland recommends that MD Helicopters Inc review the MD 369D helicopter's compressor delivery air pressure sensing line section in the daily inspection manual in such a manner that it complies with the engine manufacturer's manual by including the paint markings on the B-nuts.

2. Under Airworthiness Directive *EASA AD 2004–0009 R2* the control air pressure sensing lines of Rolls-Royce (Allison) 250 Series engines are critical parts as regards the safety of flight. During maintenance and reassembly it is important to provide for an independent inspection which is signed off in the maintenance documentation. It is also important to meticulously follow the Airworthiness Directive at the practical level.

   Safety Investigation Authority, Finland recommends that Transportstyrelsen and the Finnish Transport Safety Agency make certain that the maintenance organisations' regulations require dual release processes following critical maintenance work (EC 2042/2003, Part M, subparts C & D). At the same time it must be checked that Airworthiness Directive EASA AD 2004–0009 R2 is fully implemented at the practical level as well.

3. If light single-engine helicopters flying at the height and airspeed typical to heli-sawing operations encounter an engine failure or some other serious fault, they will face an emergency landing rather than a controlled autorotation. Several heli-sawing accidents have occurred in Finland.

   Safety Investigation Authority, Finland recommends that the Finnish Transport Safety Agency exhaustively assess the practical procedures of operators that carry out heli-sawing flights. In addition, their regulations and the content and extent of training as well as their safety margins must also be established.

4. Due to the specific features of these operations the helicopter's sawing apparatus should be regarded as a tool, rather than external cargo.

   Safety Investigation Authority, Finland recommends that the Finnish Transport Safety Agency would pay more attention during the inspections to the possible EASA approvals of the changes by sawing apparatus installations (for example equipment's installed to the controls). Potential implications of the sawing apparatus on the maintenance program, operational restrictions, weight and balance calculations and the influences to emergency procedures should be checked. Every used sawing apparatus version should be recorded separately to the manuals.

Helsingissä 20.9.2013

Ismo Aaltonen

Kalle Brusi

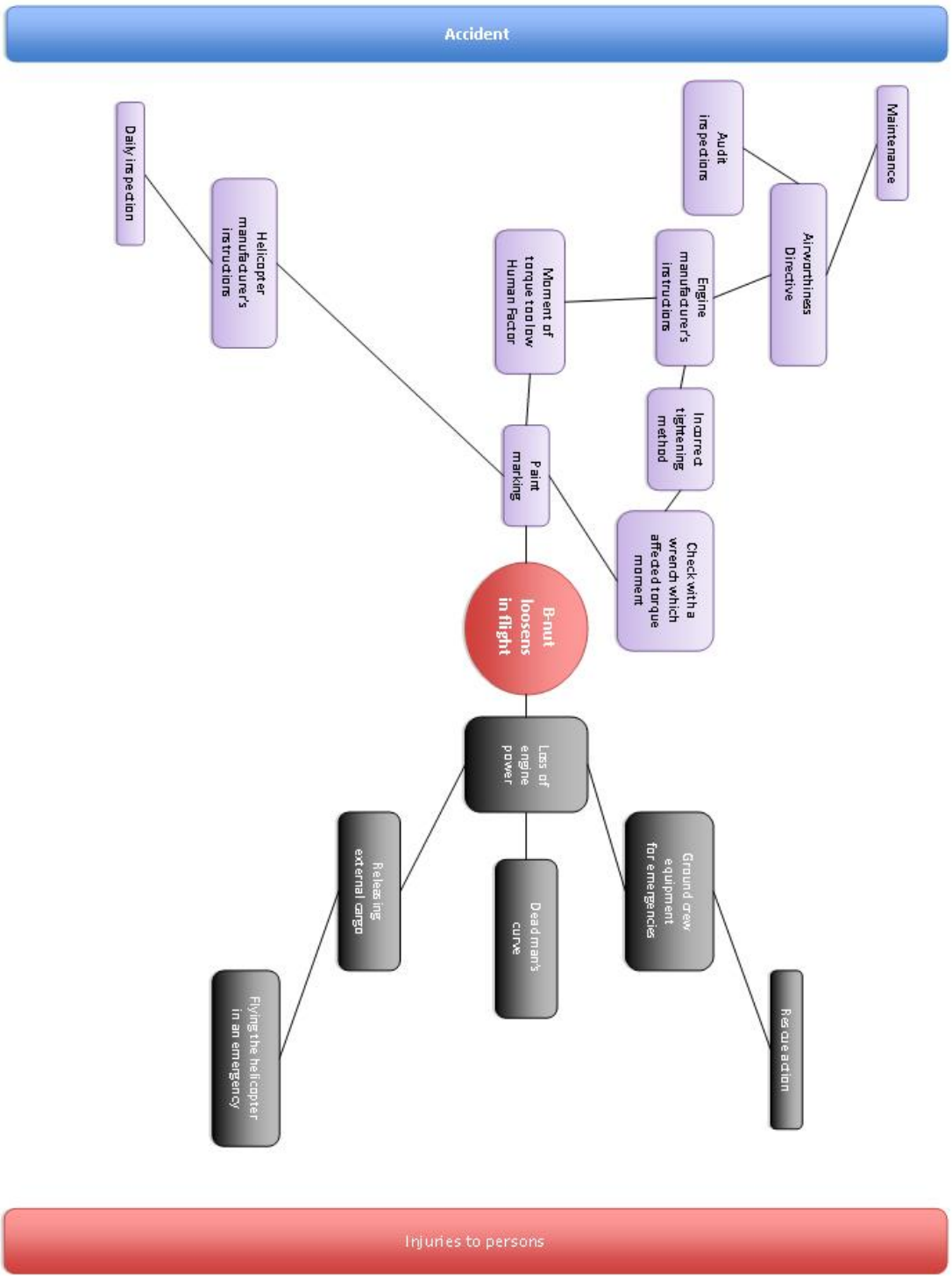
Ari Anttila

REFERENCES

1. Air Accident Investigation Branch. 12/92. ”Bell 206B Jet Ranger III, G-SHCC”.GB. *http://www.aaib.gov.uk/publications/bulletins/december_1992/bell_206b_jet_ranger_iii__g_shcc.cfm* (7.2.2013)
2. The Commission Of The European Community. 1.8.2012. COMMISSION REGULATION (EC) No 2042/2003 Annex 1, Part M.
3. European Aviation Safety Agency. 25.11.2005. EASA AD N: 2004-0009 R2.
4. Rolls Royce Corporation. M250-C20 Maintenance Manual.
5. Transportstyrelsen. 9.6.2012. TSL 2012-3048. Rapport från verksamhetskontroll.
6. Malmskogens Aerocenter AB. April 2012. MAC Quality Audit report 4-2012.

Bow Tie analysis

During the analysis the investigation group drew a Bow Tie graph of the accident



In the Bow Tie graph the Threat is on the left, the (undesirable) Critical Event/Top Event is in the middle and the (undesirable) Consequence is on the right. Several alternative event paths lead from Threats to Consequences.

The analysis also attempts to find Barriers to the event paths so as to prevent the chain of events that follow said paths from happening. Furthermore, the risks associated with each Barrier should also be evaluated: which chain of events could preclude the Barrier from working, and are there any Barriers to be found for that specific chain of events?

Appendix 2

CHECKLIST FOR IMPROVEMENTS OF FUTURE SAFETY IN RELATION TO B-NUTS AND EASA AD2004-0009R2 AT MALMSKOGENS AEROCENTER MAINTENANCE

1. IMPROVING HELICOPTER DAILY CHECKLIST TO GET THE PILOT EYE ON THE TQ INDEX OF EACH TUBE IN VISUABLE AREA USING ONE COLOUR ONLY IN THE FUTURE "ORANGE"

2. ON MD369D/E HELICOPTERS IMPROVING THE TECHNICAL INSPECTIONS PERFORMED AT EACH 35 HRS INSP IN CONJUNCTION WITH THE PLANNED TE BLADE INSPECTION, UPDATE OF THE MP FOR EACH HELICOPTER IS ONGOING, THE FINNISH REGISTRATED HCP MP IS COMPLETED AT THIS DATE

3. UPDATING EACH LINE STATION COMPUTERS, WITH EASY AXCESS TO LIBRARY IN DROP BOX/ CLOUD WITH ACTUAL AD-SB DOCUMENTS INFO WITH SERVICE REQUIREMENT FOR EACH HELICOPTER/ENGINE INVOLVED, AND TRAIN ALL CRS TECHNICIANS HOW TO USE DOCUMENTATION, BEFORE END OF MARCH 2013

4. NEW MAC TI-005 UNDER CONSTRUCTION WITH IMPROVEMENT OF NEW TOOLING EQUIPMENT FROM SNAP-ON TESTED AT MSK 2013-02-08 FOR FUNCTIONALITY, PICTURES TAKEN TO SHOW POSSIBILITIES

5. MAC TI-005 INSTRUCTION WILL BE IMPROVED FOR ALL HELICOPTERS WITH RR250 ENGINES IN MAC SYSTEM TO MAKE SURE ALL OPERATORS I OUR CAMO SUPERVISION WILL BE CONTROLLED WITH THE NEW REQUIREMENTS.

6. NEW TOOLING IS ORDERED FROM SNAP-ON TO MAKE A MORE REALIABLE TQ CHECK, WILL BE DELIVERED IN END OF FEB 2013

7. TI-005 INSTRUCTION INFO WILL BE INCORPORATED AT EACH MAC SERVICE STATION IN MID FEB 2013

8. TI-005 TRAINING FROM EXPERIENCED TECHNICIAN WILL BE COMPLETED AT SOONEST POSSIBLE LATEST MARCH 2013 AT ALL SERVICE STATIONS.

9. ALL HCP / RR250-SERIES ENGINES IN MAC CAMO CONTRACTED OPERATORS SYSTEM ARE TO BE CHECKED LATEST 2013-03-29 WITH THE NEW SYSTEM OF TOOLING AND TQ MARKING.

Comments received from the draft final report:

15 July 2013

MD Helicopters Inc. makes the following comments to the Safety Recommendation contained in draft final report, L2013-01, Helicopter accident on heli-sawing flight near the city of Tampere on 10 January 2013.

Safety Recommendation:
1. The helicopter manufacturer's and the engine manufacturer's daily instruction manuals differ as regards inspecting the paint markings of the compressor delivery air pressure sensing line's couplings. On the basis of previous occurrences, to improve safety, the engine manufacturer decided to introduce comprehensive instructions.

Safety Investigation Authority, Finland recommends that MD Helicopters Inc. review the MD 369D helicopter's compressor delivery air pressure sensing line section in the daily inspection manual in such a manner that it complies with the engine manufacturer's manual by including the paint markings on the B-nuts.

MD Helicopter does not concur with the above draft recommendation. The accident report and previous data presented from a prior UK accident[1] and the issuance of EASA AD 2004-0009R2 indicate "B" nut loosening is the result of improper maintenance practices. The CAA, FAA and Rolls-Royce's (formerly Allison) investigation[2] of "B" nut loosening on 250 engines concluded; "a "B" nut assembly which passes the inspection criteria identified in the maintenance manual and which is properly torqued to the established value will not become loose in service". We do agree that maintenance personnel need to become more aware of the Rolls-Royce maintenance practices concerning pneumatic and fuel system tube assemblies and will issue a Service Letter to emphasize these practices and the requirements of EASA AD 2004-0009R2. However, we do not believe adding a check for slippage marks should be included in the pilot's Daily Preflight Check. A preflight check is meant to note any obvious damage and currently checks for loose attachment of engine oil, air and fuel lines. Adding a check for slippage marks to the control system plumbing connecting the Gas Producing Fuel Control, the Power Turbine Governor, and the Compressor (Pc, Py, Pr, Pg, Po, P1, P2 pipelines) is beyond the scope of the Pilot's Preflight Check requiring the pilot to know which lines require the slippage markings and which ones do not.

Once the proposed Service Letter is in draft form, I will send you a copy for your review.

Regards,

John Hobby
Chief Accident Investigator
MD Helicopters, Inc.
[redacted]

[1] AAIB Bulletin No: 9/94, Ref. EW/C94/1/2
[2] CAP 652, Progress Report 1995

Rolls-Royce

19 July 2013

Rolls-Royce has received and reviewed the subject draft final report and makes the following submissions.

Page 9…

"Torque values were not recorded and the nuts were torqued down in the above-mentioned non-standard manner. No work instruction existed for the procedure which was being used."

Response:

It remains Rolls-Royce's experience and understanding, through extensive operational experience and laboratory testing, that properly-torqued B-nuts will not back off of their own accord during normal operation. Therefore, although a seemingly minor point, we feel that stating that all the B-nuts were, in-fact, torqued down is not a factual statement supported by the evidence. A more-accurate statement would be the nuts "were *reportedly* torqued down".

It is mentioned that no pressure test was performed following the reassembly of the compressor delivery air pressure (Pc) sensing lines.

According to the Rolls-Royce 250-C20 Series Operations and Maintenance Manual, 73-00-00 (page 216): FUEL SYSTEM CONTROL PNEUMATIC LEAK CHECK.

"If any fuel system pneumatic component (including piping) is removed/installed or any pneumatic line is opened during maintenance of the control system, check the pneumatic portion of the fuel control system for leaks as follows…"

Therefore it is Rolls-Royce's position that the Engine Maintenance Manual was not followed, and therefore a critical safety step was missed, when the maintenance documented in the report was performed.

"The extremely tight coupling upstream of the Pc filter may have contributed to the opening of the coupling which caused the accident, as a tightening or a later check done with a spanner generates a certain amount of torsional shearing stress and spring load. If the manual-specified torqueing was done after the opened coupling was tightened by using, for example, 50% more moment of force, it is possible that the normally torqued coupling is subjected to residual stress which works towards loosening the coupling. The combined effect of temperature changes, vibration and the residual stress eventually loosened the B-nut."

Response:

While residual stress could potential contribute to loosening an improperly installed B-Nut, Rolls-Royce has no data to support this theory. Our recommendation is that all B-Nuts be torqued to the requirements of the applicable manuals and the B-Nuts should not be either under or overtorqued. It should be noted that proper technique when torqueing any fastener requires appropriate counter-torque application to avoid the scenario cited.

Rolls-Royce wishes to extend our appreciation to the Finland Safety Investigation Authority for the opportunity to review and make comment to the draft investigation report.

Best Regards,

Jeff Edwards

Jeff Edwards
Senior Manager, Air Safety Investigations
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5601 Fortune Circle S. Drive
Indianapolis, Indiana 46206
USA

FINAVIA

Päivämäärä
25.6.2013

Asia nro
5/070/2013

Onnettomuustutkintakeskus

Onnettomuustutkintakeskuksen lausuntopyyntö 22.5.2013, 151/5L

Finavian lausunto Onnettomuustutkintakeskuksen tutkintaselostuksen L2013-01 lopulliseen luonnokseen

Finavia on tutustunut Onnettomuustutkintakeskuksen tutkintaselostuksen L2013-01 lopulliseen luonnokseen *Helikopterin lento-onnettomuus sahauslennolla Tampereen Teiskossa 10.1.2013*.

Tutkintaselostuksen luonnoksessa ei ollut Finavialle osoitettuja suosituksia eikä Finavialla ole huomautettavaa tutkintaselostukseen.

FINAVIA OYJ
Lennonvarmistusliiketoiminta

Heikki Isomaa
Verkoston päällikkö

Liitteet

Jakelu

Tiedoksi LV-J, Riskienhallinta

Finavia Oyj
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Ohivalinta

Sähköposti

Appendix 3

HÄTÄKESKUSLAITOS
NÖDCENTRALSVERKET

Lausunto

id5960506 1 (1)
00.15.01
HAK/2013/199

Laillisuusvalvontayksikkö

20.6.2013

Onnettomuustutkintakeskus
[redacted]

Viite: Lausuntopyyntö 151/5L

HAK; HÄTÄKESKUSLAITOKSEN LAUSUNTO LIITTYEN TUTKINTASELOSTUSLUONNOKSEEN L2013-01

Onnettomuustutkintakeskus on lähestynyt Hätäkeskuslaitosta viitekohdassa mainitulla lausuntopyynnöllään liittyen tutkintaselostusluonnokseen L2013-01, Helikopterin lento-onnettomuus sahauslennolla Tampereen Teiskossa 10.1.2013. Hätäkeskuslaitos lausuu asiassa seuraavaa:

Tutkintaselostusluonnoksessa ei ole osoitettu suosituksia Hätäkeskuslaitokselle. Hätäkeskuslaitos yhtyy Onnettomuustutkintakeskuksen tutkintaselostuksessa esittämään näkemykseen siitä, että onnettomuuden tapahduttua tulisi ensimmäisenä soittaa hätänumeroon, ja vasta tämän jälkeen ilmailuviranomaisille.

Hätäkeskuslaitoksella ei ole tutkintaselostuksen osalta muuta lausuttavaa.

Johtaja, viranomaisyhteistyö Juha-Veli Frantti

Lakimies Anna Alarautalahti

Asiakirja on sähköisesti allekirjoitettu asiankäsittelyjärjestelmässä. Hätäkeskuslaitos 20.06.2013 klo 11.26. Allekirjoituksen oikeellisuuden voi todentaa kirjaamosta.

Jakelu Onnettomuustutkintakeskus

Tiedoksi

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TraFi Liikenteen turvallisuusvirasto
Trafiksäkerhetsverket

Lausunto

Päiväys/Datum 27.6.2013

Dnro/Dnr TRAFI/787/07.00.01.00/2013

Viite/Referens Lausuntopyyntönne 22.5.2013 koskien tutkintaselostusta L2013-01

Onnettomuustutkintakeskus
Ismo Aaltonen
Ratapihantie 9
00520 Helsinki

Liikenteen turvallisuusviraston lausunto tutkimusselostuksen lopullisesta luonnoksesta L2013-01 "Helikopterin lento-onnettomuus sahauslennolla Tampereen Teiskossa 10.1.2013"

Liikenteen turvallisuusvirasto Trafi on tutustunut lähettämäänne tutkinta-selostuksen luonnokseen ja käyttää mahdolliisuuden antaa luonnoksesta lausunto.

Liikenteen turvallisuusvirasto lausuu tutkintaselostuksen luonnoksesta ja turvallisuussuosituksista seuraavaa:

2. Rolls-Royce (Allison) 250 moottoreiden säätöilmaputkistot ovat lentokelpoisuusmääräyksen *EASA AD 2004-0009 R2* perusteella lentoturvallisuuden kannalta kriittisiä osia. Huollon ja asennuksen yhteydessä on tärkeää järjestää riippumaton tarkastus joka kirjataan huoltoasiakirjaan. Lentokelpoisuusmääräyksen tarkka toteuttaminen on tärkeää myös käytännön tasolla.

   *Onnettomuustutkintakeskus suosittaa, että Transportstyrelsen ja Liikenteen turvallisuusvirasto selvittävät huolto-organisaatioiden ohjeistuksista, että lentoturvallisuuden kannalta kriittisten huoltotoimien jälkeen järjestetään riippumaton tarkastus (*EC 2042/2003, Part M, subparts C & D). *Samalla tulee tarkastaa, että lentokelpoisuusmääräys EASA AD 2004-0009 R2 toteutetaan myös käytännön tasolla kokonaisuudessaan.*

   Trafi pitää suositusta kannatettavana.

3. Sahaustyössä käytettävällä lentokorkeudella ja -nopeudella tapahtuva toimintaan käytettyjen kevyiden yksimoottoristen helikoptereiden moottorihäiriö tai muu vakava vikaantuminen johtaa hallitun autorotaatiolaskun sijaan pakkolaskuun. Suomessa on tapahtunut useita sahaustoiminnassa olleiden helikoptereiden onnettomuuksia.

   Onnettomuustutkintakeskus suosittaa että Liikenteen turvallisuusvirasto selvittää perusteellisesti sahauslentoja suorittavien operaattoreiden käytännön toimintamenetelmät. Myös ohjeistus, koulutuksen sisältö sekä määrä ja toiminnan turvallisuusmarginaalit tulee selvittää.

   Trafilla ei kommentoitavaa.

4. Toiminnan erityispiirteistä johtuen helikopterin sahavarustusta tulee käsitellä työvälineenä ulkoisen kuorman sijasta.

   Onnettomuustutkintakeskus suosittaa Liikenteen turvallisuusvirastolle, että sahauslaitteiston aiheuttamat rajoitukset ja painolaskelmat sekä vaikutukset hätätoimenpiteisiin tulee liittää helikopterin lentokäsikirjaan ja helikopteriin vaaditut laiteasennukset tulee hyväksyttää.

   Muutostyöhyväksynnät kuuluvat EASA:n toimivaltaan. Kansallisessa toimivallassa ovat ainoastaan Liite II –ilma-alukset ja valtion ilma-alukset, joita ei tiettävästi käytetä tällaisessa toiminnassa tällä hetkellä.

Tuomas Routa
Ylijohtaja

Pirkanmaan poliisilaitos 1 (1)

18.6.2013

Onnettomuustutkintakeskus
Ratapihantie 9, 00520 Helsinki

[redacted]

Viite: lausuntopyyntö tutkintaselostusluonnoksesta, Dnro 151/5L.
Helikopterin lento-onnettomuus sahauslennolla Tampereen Teiskossa 10.1.2013

Pirkanmaan poliisilaitoksen lausunto

Pirkanmaan poliisi aloitti asian johdosta onnettomuustutkinnan tapahtumapäivänä 10.1.2013. Asian johdosta on kirjattu ilmoitus 8330/S/487/13.
Asian johdosta poliisi on tehnyt asiassa paikkatutkinnan ja puhuttanut/kuulustellut useita ihmisiä. Poliisi on informoinut ja välittänyt tiedot tekemistään toimenpiteistä onnettomuustutkintakeskukseen.
Tämän hetkisten tietojen perusteella poliisilla ei ole tullut sellaisia seikkoja esille, että tapahtumaan olisi syytä epäillä rikosta. Lopullinen päätös asiasta saadaan onnettomuustutkintaselosteen valmistuessa.
Edellä mainittujen seikkojen perusteella sekä tutkintaselostusluonnokseen tutustuttuaan ei Pirkanmaan poliisilaitoksella ole asiasta tässä vaiheessa erikseen lausuttavaa.

[redacted]

Apulaispoliisipäällikkö Heikki Eronen

Ylikomisario Harri Nojonen

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Transportstyrelsen har inga kommentarer på remissen.

Med vänlig hälsning

Margareta Andersson
Handläggare

[redacted]

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601 73 Norrköping
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