Nose landing gear malfunction in aircraft OH-BEX at Helsinki-Vantaa airport on 26 August 2015

Investigation number: L2015-02

SYNOPSIS

Based on section 2 of the Safety Investigation Act (525/2011), the Safety Investigation Authority, Finland (SIAF) decided to investigate the accident that occurred at Helsinki-Vantaa airport on 26 August 2015 to a Beechcraft King Air C90 aircraft, registered OH-BEX, due to a nose landing gear malfunction. Airline pilot Mr. Hannu Halonen was appointed as team leader for the investigation group, and Mr Tuomas Tuisku, MSc, as an expert member of the group. Chief Investigator Ismo Aaltonen acted as investigator-in-charge.

The accident was reported to the European Aviation Safety Agency (EASA) and to the National Transportation Safety Board (NTSB) of the United States. The NTSB designated an accredited representative to the investigation.

The SIAF investigators made an on-site investigation and examined the damage to the aircraft. The accident site and aircraft damage were photographed. The damaged part was removed from the nose landing gear and sent to the NTSB for examination.

The safety investigation examines the course of events, their causes and consequences and the search and rescue actions as well as the actions taken by the authorities. The investigation specifically examines whether safety had adequately been taken into consideration in the activity leading to the accident and in the planning, manufacture, construction and use of the equipment and structures that caused the accident or incident or at which the accident or incident was directed. The investigation also examines whether the management, supervision and inspection activity had been appropriately arranged and managed. Where necessary the investigation also examines possible defects in the provisions and orders regarding safety and the authorities.

The investigation report includes an account of the course of the accident, the factors leading to the accident and the consequences of the accident, as well as safety recommendations addressed to the appropriate authorities and other instances regarding measures that are necessary in order to promote general safety, to prevent further accidents and incidents, to prevent loss and to improve the effectiveness of the operations of search and rescue and other authorities.

Prior to the completion of the investigation report, an opportunity is reserved for those involved in the accident and to the authorities responsible for supervision in the field of the accident to comment on the draft investigation report. A summary of the comments is included in the investigation report. However, no comments given by private individuals may be included in the investigation report.

The investigation report was translated into English. The report, including summary and appendices, has been published on the SIAF website at *www.turvallisuustutkinta.fi*.

Investigation number: L2015-02
Investigation report 6/2016
ISBN: 978-951-836-479-8 (PDF)

Cover photo: SIAF

TABLE OF CONTENTS

1 FACTUAL INFORMATION

1.1 History of the flight

A Beechcraft King Air C90 aircraft, registered OH-BEX and operated by Scanwings Ltd, departed for a cargo flight from Helsinki-Vantaa airport to Örebro, Sweden, on 26 August 2015. The aircraft had a two-pilot crew and carried four tanks of about 30 kg containing medical substances. There were no other persons on board besides the crew.

The aircraft took off from runway 22L at 07:30. When selecting gear up after take-off, the pilots heard an abnormal crushing sound from the direction of the nose landing gear. An indicator light remained on at the landing gear switch lever, showing that the landing gear was not up as intended.

The pilots selected the gear back down, and the main landing gear was locked down normally. However, the green light indicating that the nose landing gear was down and locked was not lit. The pilots tested the nose landing gear position indicator lamp and found that it was in order. After this the pilots concluded that they had to turn back to Helsinki-Vantaa airport due to a technical malfunction in the landing gear.

The pilots requested an ATC clearance to climb to 3000 ft for further action. ATC cleared OH-BEX to the height of 3000 ft on the northern side of the airport. After flying to the cleared area, the pilots tried to take the gear down using the alternative procedure. The nose landing gear was still not locked down. After this the pilots decided to prepare for landing, knowing that the nose landing gear was likely to collapse during landing.

The pilots went through the emergency procedures for landing when the nose landing gear was not locked down. After this they flew low past the ATC tower. The controllers saw and confirmed that the nose landing gear was out, but not in the normal down and locked position.

The aircraft landed on runway 15 at 08:35. The pilots kept the nose landing gear in the air as long as possible, and then let it gently down. The aircraft nose slid on the ground for about 500 meters before coming to a stop. After touchdown the pilots feathered the propellers and switched power off, as instructed in the emergency checklist. They also closed the fuel taps, although this action was not included in the emergency checklist. After the aircraft had stopped the pilots disembarked normally through the doors.

The airport rescue services were on standby near the runway when the aircraft landed.

1.2 Damage to aircraft

The aircraft was substantially damaged. The aircraft nose and nose landing gear doors sustained damage, and the propellers were bent backwards. The damage did not extend to the cockpit or other locations inside the aircraft. No one was injured in the accident.

1.3 Personnel information

The pilots had valid class and type ratings and medical certificates as required for the flight duty.

The pilot-in-command had a total flight experience of about 4750 hours, and about 1250 hours on type.

The copilot had a total flight experience of about 530 hours, and 54 hours on type.

1.4 Aircraft information

Beechcraft King Air C90 is a low-wing aircraft with full metal construction, equipped with two Pratt & Whitney PT6A-21 turboprop engines. It is manufactured by Beech Aircraft Corporation[1] in the United States. The production of the first King Air versions began in 1964. The aircraft is type certified in accordance with CAR3 and certain FAR Part 23 requirements for the normal category using a single-pilot crew, for VFR and IFR operations, and for flight in icing conditions.

The individual aircraft registered OH-BEX was manufactured in 1981 with serial number LJ-978. Depending on the configuration used, the aircraft has seats for 8 passengers at maximum, and for two pilots. The aircraft maximum take-off weight (MTOW) is 4 762 kg. It is owned and operated by Scanwings Ltd.

The aircraft certificates and documents as required for flight operations were valid. The aircraft had been maintained in accordance with the maintenance requirements in force, and it was airworthy before the accident.

The aircraft mass and balance were in the permissible range.

1.4.1 Description of the nose landing gear system

The aircraft landing gear system consists of the nose gear and two main gears, which are all retractable. The system is mechanic and powered by an electric motor. In case of a power failure, the landing gear can also be extended manually.

The system is normally operated using a selection lever in the cockpit. The selection turns on the electric motor, from which the driving power is conveyed to a thread-based actuator that moves the landing gear (Figure 1). The nose landing gear actuator includes a pinion, a screw assembly and a nut assembly, which convert the rotating motion of the pinion into a pulling or pushing force that moves the gear up or down (Figure 2).

As an alternative procedure in case of a power failure or malfunction in the electric motor, all landing gears can be extended manually using a handle, connected to a ratchet mechanism. The mechanism moves the same landing gear actuators that would be operated by the electric motor. However, if the actuator breaks, the gear cannot be extended and locked for landing using the alternative procedure. The landing gear system is not equipped with a down lock that would cause the gear to be locked in the extended position, but the actuator is intended to ensure that the landing gear is held down. There are separate actuators for each of the three landing gears.

[1] Currently Beechcraft Corporation, former name Hawker Beechcraft Corporation

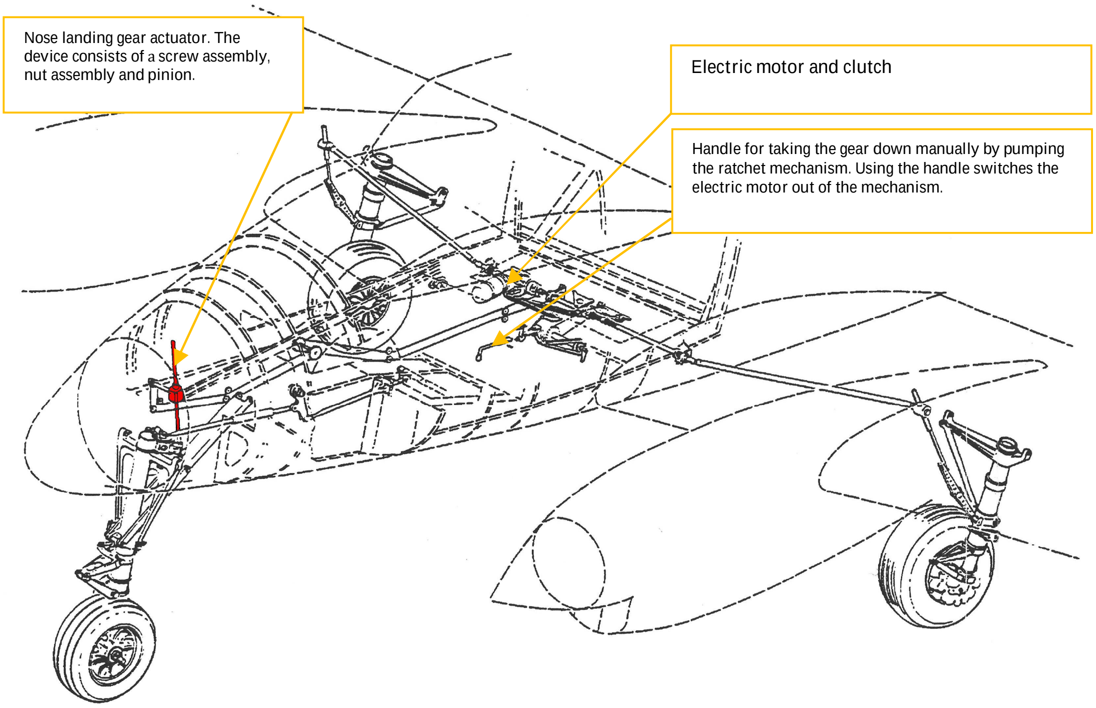

Figure 1. Landing gear system (power driven). The nose landing gear actuator is shown in red colour. (Source: Flight Safety International)

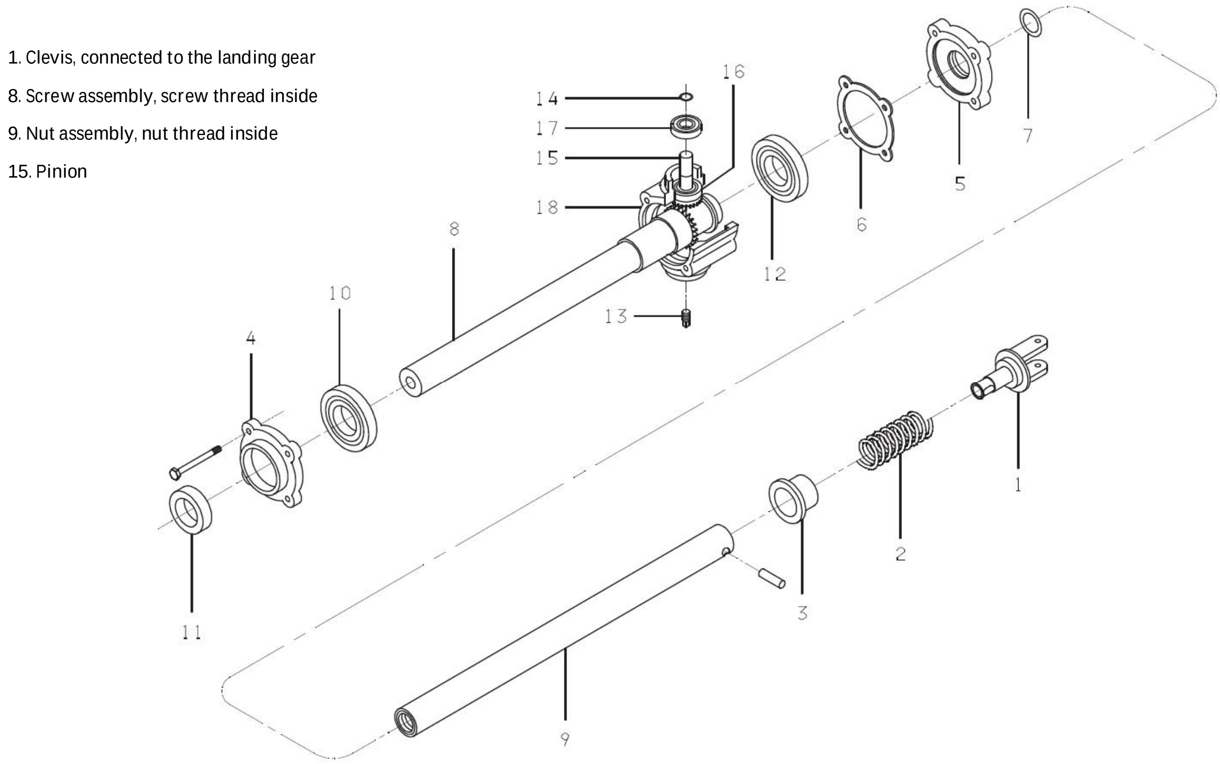

Figure 2. Parts breakdown of the nose landing gear actuator based on a screw assembly. (Source: Hawker Beechcraft Corporation)

1.5 Meteorological information

Visual meteorological conditions (VMC) prevailed at Helsinki-Vantaa airport at the time of the accident.

Aviation routine weather report (Metar) for Helsinki-Vantaa airport at 08:20:

Wind 060 degrees 4 knots, visibility over 10 km. Few clouds at 1000 ft (300 m) and broken clouds at 9000 ft (2750 m). Temperature 19 degrees, dewpoint 16 degrees. QNH[2] 1009 hPa.

1.6 Investigation of the accident site and aircraft

Having reached the accident site, the SIAF investigators carried out an on-site investigation. The aircraft damage was examined and photographed.

The investigation team visited Scanwings Ltd, studying the company operations and maintenance instructions. The team also examined the aircraft damage and reviewed the medical containers used on cargo flights as well as their attachments.

1.7 Medical information

The police made a breathalyzer test to the pilots at the accident site; the result was zero blood alcohol.

1.8 Rescue action and survival aspects

Rescue services at Helsinki-Vantaa airport were alerted of the risk of an aircraft accident, and the rescue unit was near the airport to secure the landing. In accordance with current instructions, the runway was not foamed before landing. There was no fire. Emergency care staff checked the pilots' condition.

1.9 Tests and research

The aircraft was moved to the company hangar at Helsinki-Vantaa airport for technical investigations. To locate the fault, the mechanics removed the nose landing gear actuator (Figure 2) while the SIAF investigators were present. During preliminary investigations, the fault was located in the missing threads of the actuator.

After examination, the component was packed and sent to the NTSB[3] of the United States for analysis and detailed investigations in its materials laboratory on 4 September 2015. Their final report with analysis was received on 29 April 2016.

At the NTSB, the actuator had been disassembled, and the nut assembly sawed lengthwise in two for a more detailed analysis of the threads. In addition to visual inspection methods, a microscope, Scanning Electron Microscope (SEM and EDS), and Fourier Transform Infrared Spectrometer (FTIR)[4] had been used for substance and material determination.

According to the report, there appeared to be a normal amount of lubricating grease inside the actuator (Figure 3). The analysis included a spectrometer inspection (FTIR method) of two lubricant samples, the results of which were compared with the most commonly used

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[2] Altimeter sub-scale setting (hPa) to obtain altitude above mean sea level.
[3] National Transportation Safety Board
[4] SEM, Scanning Electron Microscope; EDS, Energy Dispersive X-ray Spectroscopy; FTIR, Fourier Transform Infrared Spectrometer

lubricating grease products. The spectrum and the color was found to correspond to the quality of lubricants normally used in aircraft constructions, Aeroshell 64[5] which is approved according to MIL-G-21164D. Soot particles and a small amount of water were found in the grease. However, no bronze particles that would have indicated thread wear during use were present in these two samples. Some sand particles were detected in the steel threads of the screw assembly.

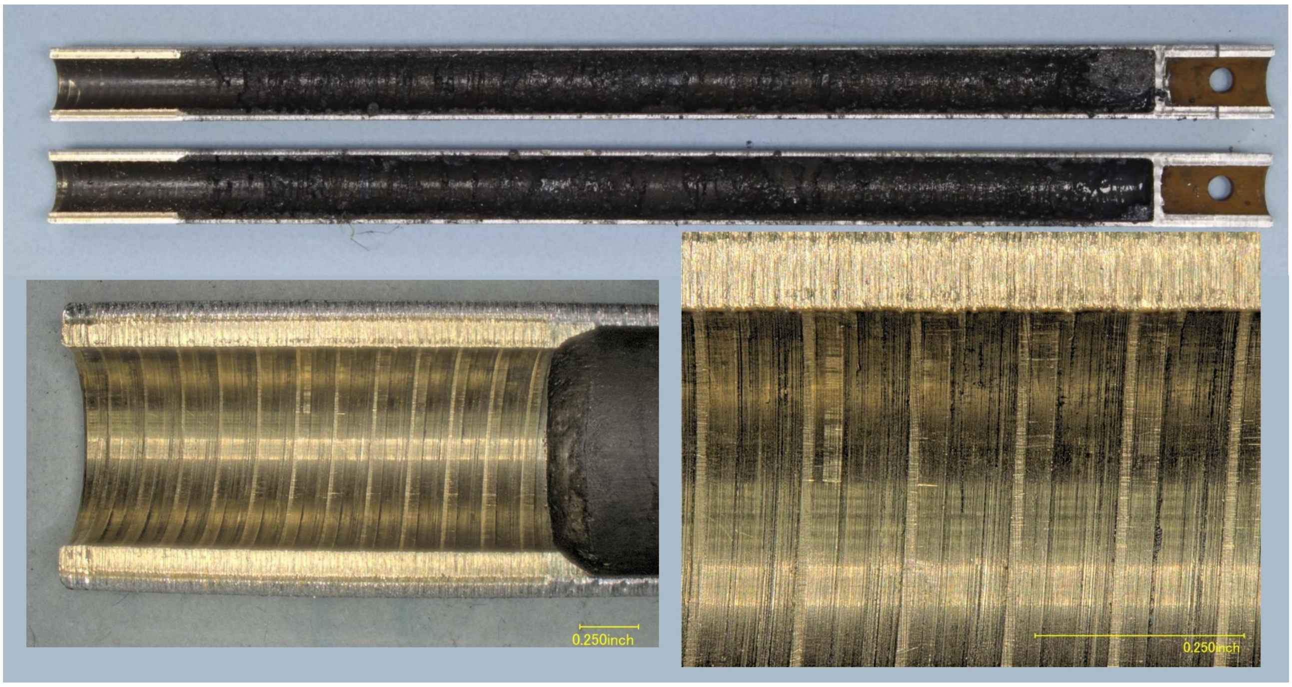

Figure 3. Actuator nut assembly (number 9 in Figure 2) sawn open. The dark substance inside the tube is lubricating grease. After cleaning, a close-up photo of the aluminium bronze part shows that the threads were worn before they were cut off. (Photos: NTSB, Materials Laboratory Report No. 16-020B)

After the component was returned to Finland, investigations continued at the Safety Investigation Authority. The screw assembly housing was cut open so that the whole screw thread could be inspected (Figure 4). Thick lubricating grease and bronze particles were found right at the root of the screw part. Layers of different colour could be discerned in the grease. Right at the dips of the screw threads at the root, a small amount of red grease was found, which indicates that some old grease had been left under the new lubricating grease despite cleaning.

When the grease had been washed away, the loose threads were also found at the screw root. Some of the threads had been broken in parts, while some had maintained their ribbon structure (Figure 5). The fracture surface of the thread was about 0.4 mm wide, which corresponds to the root fracture surface in the bronze nut assembly (Figure 3).

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[5] Aeroshell Grease 64 (MIL-G-21164D approved)has replaced the Aeroshell 33MS grease. The 64 is the same grease as the Aeroshell 33 (MIL-PRF-23827C) which is still being manufactured but molybdenum disulfide has. been added in to it. Molybdenum disulfide is a solid lubricant which enhances extreme pressure properties. The color of Aeroshell 64 is dark grey and Aeroshell 33 is green.

Based on the NTSB report and the SIAF investigations, it can be concluded that the nut thread in the nut assembly of the screw (close-up in Figure 3) had been stripped, and the threads were significantly worn before being cut off. Otherwise the actuator, including the pinion and its bearings, appeared to be in serviceable condition apart from normal wear.

Figure 4. The actuator screw assembly housing was cut open. Lubricating grease and bronze particles had deposited right at the root of the screw. Layers of different colour could be discerned in the grease. A small amount of red grease was found lowest at the bottom. (Photo: Safety Investigation Authority, Finland)

Figure 5. After the grease had been washed away, the bronze threads cut off from the nut assembly were found right at the root of the screw assembly. The nut thread fracture surface was about 0.4 mm wide, which corresponds to the fracture surface that can be seen in Figure 3. (Photo: Safety Investigation Authority, Finland)

1.9.1 History of the landing gear actuator

According to the documentation, the actuator (P/N 50-820208-5, S/N 416639) is a component overhauled by an authorised maintenance organisation. The overhaul was carried out by Airspace Turbine Rotables, Inc.[6] in the United States on 24 June 2013, and after inspection, the certificate of airworthiness was signed on 5 August 2013. After this the component was dispatched through International Airspare Inc. to Scanwings Ltd., Finland.

Based on the certificate of release to service, the component was overhauled and certified in accordance with the manufacturer's instructions (CMM rev B6, 2011 and SCMM rev 1, 2008). The overhaul included disassembly, NDT test[7], and finally an end play check. The end play was then 0.003 in – 0.004 in (0.08 mm – 0.10 mm).

Scanwings Ltd subjected the component to a usual acceptance check, in which the maintenance documents and the qualification status of the person who carried out the work were reviewed. When there is no reasonable cause to suspect whether the maintenance documents correspond with the actual component, there is no requirement to measure the end play for verification. The component was installed on the aircraft on 6 September 2013.

An additional end play check was made on 22 October 2014, so that the component maintenance interval could be matched with the maintenance cycle of the main landing gear to streamline the work. At that time the end play was 0.015 in (0.38 mm) and within acceptable limits (see Table 1).

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[6] FAA Repair Station Nr. NV2R045L; EASA Cert Nr. EASA.145.4033.
[7] Non-Destructive Testing

Date	Actuator landing cycles	Actuator time since overhaul (TSO)	Event	Aircraft cycles	End play[8] [in]
24 Jun 2013	0	0	Overhaul (Aerospace Turbine Rotable, Inc)		Maximum allowed end play after repair 0.010 in (0.254 mm)
5 Aug 2013			Inspection and certificate of airworthiness (Aerospace Turbine Rotable, Inc)		0.003 in (0.076 mm)
6 Sep 2013			Dispatch from supplier (Airspare, Inc). Acceptance check and installation on the aircraft (Scanwings Ltd.)	11 186	0.003 in (0.076 mm)
22 Oct 2014	473		End play check (Scanwings Ltd.)	11 659	0.015 in (0.381 mm)
26 Aug 2015	906		Threads fail during flight	12 092	
	1 000 or	30 months	Interval for lubrication and end play check.		Criteria for end play less than 0.016 in: OK 0.016 in - 0.018 in: check every 200 landings 0.018 in or more: to be replaced
	8 000 or	6 years	Time between overhauls		

Table 1. History of the actuator (P/N 50-820208-5, S/N 416639) since overhaul.

1.9.2 Maintenance requirements

Before year 2010, the manufacturer's (Hawker Beechcraft) maintenance instructions did not include lubrication of the screw assembly between overhauls. However, in 2010 an accident similar to that described in this report occurred in the United States[9], in which the threads of the nose landing gear screw assembly failed during the first fifth of the time between overhauls. Based on the NTSB investigation and the manufacturer's analysis, failure of the screw assembly due to insufficient lubrication during use was established as the root cause. After this, Hawker Beechcraft amended the King Air maintenance requirements to include lubrication of the screw and nut assembly with an interval of 1000 landings or 30 months, whichever is reached earlier.

In addition to the lubrication requirement, end play checks are already required at the same interval (1000 landings / 30 months). In accordance with the maintenance instructions, if the end play is less than 0.016 in, the component can be mounted back on the aircraft and operations continued as usual. If the play is 0.016–0.018 in, the component can still be used, but subjected to an end play check with an interval of 200 landings. When the end play has increased to 0.018 in or more, the component is not serviceable and must be overhauled or replaced with a new.

The actuator time between overhauls is 8000 landings or 6 years, whichever is reached earlier.

Hawker Beechcraft maintenance instructions require that lubricating grease of specification MIL-G-21164 (or MIL-PRF-10924) must be used for lubrication. The Aeroshell 64[10] grease

[8] Total end play means the axial play between the screw and nut assembly.

[9] NTSB: ID CEN10LA302, Beech C90, Fort Worth, Texas, 3.6.2010

[10] Aeroshell Grease 64 (MIL-G-21164D approved)has replaced the Aeroshell 33MS grease. The 64 is the same grease as the Aeroshell 33 (MIL-PRF-23827C) which is still being manufactured but molybdenum disulfide has. been added in to it. Molybdenum disulfide is a solid lubricant which enhances extreme pressure properties. The color of Aeroshell 64 is dark grey and Aeroshell 33 is green.

(MIL-PRF-23827C) used in the accident aircraft is suitable for use in items subject to that specification. According to the maintenance instructions[11], half of the nut assembly volume must be filled with lubricating grease.

For the actuator installed in the aircraft OH-BEX, the time between overhauls had not been reached. Therefore no lubrication during use had yet been performed after overhaul.

1.9.3 Other information on operations

Besides commercial flights, the accident aircraft is used for pilot training on type rating courses. The course flight instruction syllabus includes training for landing gear emergency extension procedures. Every student practices gear extension once during the training.

1.10 Organisational and management information

Scanwings Ltd. is a Finnish business aviation company established in 1977. The company operates three Beechcraft King Air C90 turbopropeller aeroplanes and one Cessna C525A jet aircraft on business, calibration, ambulance and cargo flights. It also provides operation and maintenance services.

The company has a quality and safety management system approved by the aviation authority.

[11] Component Maintenance Manual 32-20-00; Hawker Beechcraft Corporation, King Air Series.

2 ANALYSIS

2.1 Accident analysis

When the pilots realised that the nose landing gear did not retract normally after take-off, they acted in accordance with the aircraft instructions. Having selected gear down again, they noticed that the main landing gears were locked as usual, but the green indicator light for the nose landing gear was not lit and the ”Gear in transit” light remained on.

As instructed on the checklist, the pilots selected gear up again. The green indicator lights for the main landing gear extinguished but the ”Gear in transit” light was still on. Based on this the pilots assumed that the main landing gear was operating normally, while the nose landing gear was left in an intermediate position.

After this the pilots selected gear down and took further action as instructed in the aircraft documentation. They noted that the emergency action checklist for landing with the nose gear up did not require engine fuel supply to be cut. However, closing the fuel cocks is mentioned in a separate action list for emergency landing. The pilots decided to add closing the fuel cocks to their own list of actions.

In the prevailing weather conditions, the landing succeeded well and the aircraft damage was kept to a minimum. The pilots acted reasonably and followed the instructions. They also closed the fuel cocks to reduce the risk of fire. The airport rescue services were left with the duty to make sure that the aircraft would not catch fire, and there was no need for other rescue action.

2.2 Landing gear malfunction

The nose landing gear malfunction was caused by failure of the gear actuator, as the worn-out threads of the nut part in the screw assembly were cut off when the gear was retracted. The actuator time between overhauls is basically 8000 landings or 6 years (whichever is earlier), but it was now damaged after only about 900 landings since last overhaul.

Besides the time between overhauls, the component had a requirement for end play check and for lubrication at an interval of 1000 landings or 30 months, whichever is reached earlier. The required intervals for check and lubrication were thus not reached before the threads failed.

2.3 Factors possibly contributing to the wear and failure of the threads

Based on an analysis carried out at the material laboratory, the screw assembly appeared to contain a normal amount of lubricating grease. This was revealed when the nut part of the screw assembly was sawed lengthwise in two. In accordance with the maintenance instructions[12], the tube-formed nut assembly (Figure 2, no. 9) must be filled halfway with lubricating grease.

The NTSB analyses of two grease samples from the nut assembly did not show any abrasive substances, such as sand or metal particles, but only a small amount of soot. No aluminium

[12] Component Maintenance Manual 32-20-00 and Aircraft Maintenance Manual 32-30-07; Hawker Beechcraft Corporation, King Air Series.

bronze particles, which would have indicated thread wear during use, were reported in the grease samples either.

In further investigations made by SIAF, thick lubricating grease with metal particles in it was found at the root of the screw assembly after the housing was removed.

A spectrum analysis revealed that the grease used corresponded with the Aeroshell 64 quality. The spectrum showed no essential signs of aging of the grease, and the additives can therefore be assumed to have maintained their normal performance.

Even if there was the instructed amount of lubricating grease inside the nut assembly, lubrication may not have been evenly spread in the screw assembly threads, or sufficiently effective at the screw root over time. The actuator is in a position where the greased nut assembly is lowest in the vertical direction and the screw root is highest.

Based on the interviews, the nose landing gear actuator had been correctly installed in accordance with the instruction. This is supported by the fact that the analysis showed no marks that might have been caused by an incorrect mounting angle, for example. Moreover, the landing gear is tested after maintenance by operating it through full travel.

No hard landings that would have required an inspection were reported in the interviews or in the aircraft maintenance history. The maximum landing gear operating speeds (VLO/VLE) were not reported to have been exceeded either.

The aircraft is used for type rating training that includes landing gear extension using the alternative procedure. As the component life limit, however, is calculated in aircraft landings, it does not precisely correspond with the actual number of gear extensions. Landing gear extension is also tested during maintenance. In all, the impact of these factors still remains marginal with regard to the maintenance interval. The Operations Manual[13] instructs that pumping the handle must be stopped when the green indicator lights for all landing gears have illuminated.

2.4 Monitoring of thread wear

According to the inspection protocol of Aerospace Turbine Rotable Inc., the end play after overhaul was 0.003–0.004 in (0.076–0.101 mm), in which condition the component was certified and dispatched to Finland for installation on the aircraft. The maximum end play allowed after overhaul[14] is 0.010 in (0.254 mm).

After a scheduled end play check in line maintenance[15], the actuator can be returned to service if the total end play in the screw assembly is less than 0.016 in (0.406 mm). If the end play is 0.016 in–0.018 in, the actuator can still be used but the screw assembly condition must be monitored with a shortened interval by measuring the end play after every 200 landings. When the end play is 0.018 in (0.457 mm) or more, the component may no longer be used but must be overhauled or replaced with new.

In a supplementary end play check made by the operator (Table 1), the play was measured as 0.015 in (0.381). Even though the value was still within acceptable limits, the wear had progressed unusually fast during the 473 landings. The limit for additional monitoring was exceeded by only 0.001 in (0.025 mm). From the progress of the wear at that time, it could have

[13] Operational Manual Part B: 3.11.5.2 Landing gear manual extension.
[14] Manufacturer Component Maintenance Manual 32-31-03 (P/N 50-820208) ; Hawker Beechcraft Corporation
[15] Aircraft Maintenance Manual 32-30-07-601; Hawker Beechcraft Corporation, King Air Series.

been concluded that the screw assembly would not stay within acceptable limits for the 527 landings remaining before next scheduled inspection.

When the thread finally was cut off, the thickness of the root end was only 0.016 in (0.4 mm), which is less than one third of the original thread thickness (Figure 6).

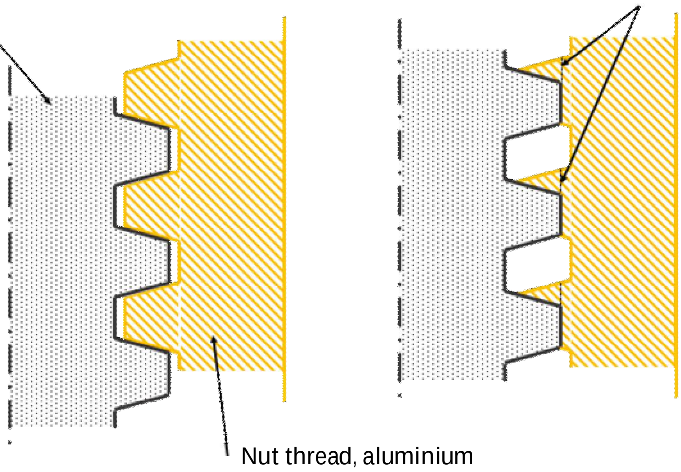

Figure 6. Trapezoid thread used in the screw assembly. Thread in normal condition on the left. The picture on the right shows a situation where the screw thread of steel has abraded the softer bronze thread to a thickness of only about 0.4 mm at the root, when the remaining thread no longer sustained the transmitted force but was cut off. (Graphics: Safety Investigation Authority, Finland)

This kind of screw assembly typically wears during use despite lubrication[16], for which reason an end play check is included in the maintenance programme. The effectiveness of lubrication, amount of friction between screw surfaces, and therefore the wear of the threads is affected by several factors that may be difficult to control. Wear can be indirectly assessed through measuring the end play. On the other hand, previous safety investigations[17] have also revealed inaccuracies in end play measurements and the reliability of their results.

Excessive wear can be detected with more frequent end play checks. Considering that the check is rather simple, quickly performed, and does not require significant resources, shortening the inspection interval can be regarded as a reasonable means to prevent similar accidents. However, the inaccuracies involved in end play measurements must be known to ensure that reliable results are obtained.

There is no alternative procedure available for locking the gear in an extended position for landing in case the screw assembly is damaged. Due to this operating principle, the actuator screw assembly is the critical weakest link in the system.

[16] Source: Koneenosien suunnittelu, M. Airila, WSOY, 1995
[17] NTSB AAR-02/01, Loss of Control and Impact with Pacific Ocean Alaska Airlines Flight 261, January 31, 2000

2.5 Safety management analysis

The operator has a quality and safety management system approved by the national civil aviation authority (Trafi[18]). The system includes procedures for risk management and occurrence reporting. Based on the interviews, the staff is accustomed to reporting any occurrences or non-compliances, and the company culture is open and supportive to reporting.

After the incident, the operator duly initiated its own risk management actions. As a precautionary measure, the landing gear actuator condition and total end play were checked in all aircraft of the same type that the company operates. The actuators were found to be in a normal condition.

3 CONCLUSIONS

3.1 Findings

1. The aircraft was airworthy in accordance with applicable airworthiness requirements when departing for the flight.
2. The pilots were appropriately trained, and their licences and qualifications were valid.
3. When the pilots selected gear up after take-off, they heard an abnormal crushing sound from the nose landing gear. The indicator light showed that the gear had not retracted normally.
4. The pilots took action as instructed on the emergency checklist, but the indicator light showing that the nose landing gear was down and locked was not lit.
5. The pilots decided to return to the departure aerodrome. During landing, the aircraft nose skidded on the ground for about 500 metres. The nose, landing gear doors and propellers were damaged.
6. In addition to the actions instructed on the emergency checklist, the pilots closed the engine fuel cocks. Closing the fuel cocks is not mentioned in the checklist for landing with nose gear up, but only in a separate instruction for emergency landing.
7. Technical investigations revealed that the nut threads of the nose landing gear actuator screw assembly had been cut off. The threads were significantly worn, even to less than one third of the original thickness.
8. In the additional end play check the threads had been worn from an end play value of 0.003 inches to 0.015 inches during only 473 landings. The wear rate of the threads had been exceptionally high, which indicates uneven lubrication.
9. In accordance with the maintenance requirements, an end play check and lubrication must be performed at an interval of 1000 landings or 30 months. In this case, about 900 landings had been recorded for the actuator when it was damaged.
10. The amount of lubrication grease inside the screw assembly appeared to be normal. The grease spectrum and the color corresponded with the quality (Aeroshell 64) suitable for this purpose. There were no signs of aging or degradation of additives, and the lubrication properties of the grease can be considered normal.
11. The landing gear system had been operating normally on the previous flights.

[18] Finnish Transport Safety Agency; the national civil aviation authority of Finland.

12. The investigation revealed no signs of earlier damage or overloading (hard landing or exceedance of gear operating speeds) that could have significantly affected the condition of the threads.
13. The alternative procedure for gear extension is only designed for situations where power is lost or the electric motor fails. Therefore the manual handle for emergency extension cannot be used to lock the gear down for landing in case the screw assembly threads are cut off.
14. The actuator and particularly the screw assembly nut threads form the critical weakest link for landing gear operation, as there is no fail-safe mechanism to substitute them.

3.2 Probable causes

The nose landing gear actuator sustained damage and became inoperative when the nut threads of the screw assembly were stripped as the gear was retracted. The failure was caused by extensive wear of the bronze threads, and finally they could no longer sustain the force transmitted. Typical wear of the screw assembly was accelerated by the fact that the method of lubrication used does not guarantee that the thread surfaces are evenly lubricated over time. In addition, inaccuracies involved in end play measurements have an effect on how wear is detected. For this reason end play checks must be performed with particular care, and the inspection interval of 1000 landings is too long.

A contributing factor to the accident was that there is no alternative procedure available in case of failure of the landing gear actuator screw assembly.

4 SAFETY RECOMMENDATIONS

4.1 Safety actions already implemented

After the incident and on its own initiative, the company decided to check the actuators of its other similar aircraft as a precautionary measure. The devices were in normal condition.

4.2 Safety recommendations

4.2.1 Shortening the end play check interval for the nose landing gear actuator screw assembly

Due to the landing gear operating principle, the screw assembly forms a critical weakest link in the system. Sufficient lubrication and wear rate are affected by several factors, in relation to which the end play check interval is too long. Moreover, end play measurement requires particular care.

The Safety Investigation Authority, Finland recommends that

The Federal Aviation Administration (FAA) require the aircraft manufacturer, Beechcraft Corporation, to review the maintenance requirement so that the end play check interval will be significantly shortened and that the thread wear rate is also observed. [2016-S19]

Helsinki, 3.10.2016

Ismo Aaltonen Hannu Halonen Tuomas Tuisku

REFERENCE MATERIAL

The following reference documents or their copies are archived at the Safety Investigation Authority, Finland.

1. Decision of investigation
2. NTSB Materials Laboratory Report 16-020
3. NTSB Materials Laboratory Report 16-020B; 29 April 2016
4. Maintenance documentation for the landing gear actuator
5. Certificates and other official documents required for aircraft operation
6. Operations Manual, Part B, and aircraft type-specific material
7. Photographs from the accident site and investigations
8. Recordings and summaries of interviews
9. E-mail correspondence

SUMMARY OF THE COMMENTS RECEIVED ON THE DRAFT INVESTIGATION REPORT

Comments on the draft investigation report were requested from the Finnish Transport Safety Agency (Trafi), the National Transportation Safety Board (NTSB) of the United States, the Federal Aviation Administration (FAA) of the United States, the European Aviation Safety Agency (EASA), Finavia Corporation, the operator Scanwings Ltd. and the aircraft manufacturer Textron Aviation.

Finnish Transport Safety Agency (Trafi)

The Finnish Transport Safety Agency (Trafi) presented no official comments on the report. However, Trafi attached some comments and corrections on certain details of the investigation report. The comments mainly concerned aircraft type certification and the quality of lubricating grease used in the actuator. The investigation team reviewed these issues and clarified them in the investigation report. The comments also related to the history of the landing gear actuator, maintenance requirements and thread wear monitoring.

National Transportation Safety Board (NTSB), United States

No comments.

Federal Aviation Administration (FAA), United States

No comments received.

European Aviation Safety Agency (EASA)

No comments.

Finavia Corporation

No comments.

Scanwings Ltd

The aircraft operator Scanwings Ltd. underlined in its comments that the airline had performed an additional end play check in accordance with the maintenance instruction. The investigation report was clarified at this point. The company also wished that the root cause for excessive wear in the screw assembly nut thread be more accurately described. The company will add to its instructions an end play check and recording of end play value for an overhauled actuator to be installed, and shorten the end play check interval as recommended in the investigation report.

Textron Aviation

No comments.