Transportation Safety Board of Canada

Bureau de la sécurité des transports du Canada

AVIATION INVESTIGATION REPORT

A02P0126

MAIN ROTOR BLADE FAILURE

HELIFOR INDUSTRIES LTD.
MD HELICOPTERS INC. 369D (HELICOPTER) C-GHFA
KAMLOOPS, BRITISH COLUMBIA
19 JUNE 2002

Canada

The Transportation Safety Board of Canada (TSB) investigated this occurrence for the purpose of advancing transportation safety. It is not the function of the Board to assign fault or determine civil or criminal liability.

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Summary

The MD Helicopter Inc. 369D, serial number 290459D, registration C-GHFA, was operating from the operator's Horizon Camp near Adams Lake, 56 nautical miles northeast of Kamloops, British Columbia, in heli-logging support functions. The pilot reported that at higher torque settings there was some resistence in the collective; the resistence subsequently went away. The main rotor blade track appeared to be out of alignment and the aircraft had a strong vibration. The pilot completed the crew and material moves then landed. Company maintenance personnel inspected the helicopter and found a crack in the lower skin of one of the five main rotor blades.

Ce rapport est également disponible en français.

Other Factual Information

The operator reported that in the days leading up to the occurrence, the blades had been flying out of track[1] for quite some time. Company personnel had to re-track them almost every shift, but the blades did not fly well together. Also during a flight, one of the riggers had noted that the skids were shaking excessively. The whole aircraft had a significant vertical vibration.

The blades had been removed on the 18 June 2002 at 8350 flight hours when a 100-hour inspection was performed on the helicopter. A torque event[2] inspection was performed 19.7 hours and 197 torque events before the 100-hour inspection. The blades were inspected twice on the morning of the occurrence: by the company aircraft maintenance engineer (AME) and during the pilot's pre-flight. The AME inspected the helicopter controls and main rotor blades at 8353.6 total airframe hours (TAFH) and found the red blade cracked on the underside from the trailing edge to the spar. The failed main rotor blade P/N: 500P2100-101, S/N: A340 had accumulated 2981.1 total time since new (TTSN).

The MD Helicopter 369D is equipped with a five-blade, fully articulated main rotor, and the main rotor blades are colour-coded to facilitate balance and tracking functions. The 369D Rotorcraft Flight Manual (RFM) states that for a sudden onset of vibration, set the helicopter down immediately and do not fly again until the source of the vibration has been determined. The MD Helicopter Inc. Maintenance Manual HMI-2, Chapter 62-00-00, contains a warning at Paragraph 2 - Main Rotor System Troubleshooting, which states in part, "…sudden onset of excessive and/or unusual main rotor vibration should be investigated immediately as to the cause, prior to continued flight. Under no circumstance should main rotor tracking be attempted to correct the problem until a thorough inspection of the main rotor blades, hub assembly and strap pack assembly has been performed". The five main rotor blades installed on the helicopter were a mix of MD Helicopter Inc. and Helicopter Technology Corporation (HTC) blades with various times in service. It is generally recognized in the industry that tracking and balancing certain combinations of blades can be difficult.

HTC holds Supplemental Type Certificate (STC) number SR09074RC, and in 1999 began to manufacture all main rotor blades for MD Helicopters under a Parts Manufacturing Approval (PMA). An STC is a certificate issued when an applicant has received FAA approval to modify an aircraft from its original design. The STC, which incorporates by reference the related type certificate, approves not only the modification but how that modification affects the original design. The P/N: 500P2100-101 main rotor blades are essentially built the same as the blades originally built by MD Helicopters Inc. and the blades built by the preceding helicopter Type Certificate holder, McDonnell Douglas Helicopter Systems (MDHS).

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[1] The blade alignment in flight along the blade tip path plane.

[2] A torque event is a condition of operation that can produce high fatigue damage on certain components and is recorded manually for each transition from forward flight to a hover and any external lift operation. Each lift of an external load is to be recorded as two torque events. (CSP-HMI-2 Section 04-00-00). For this definition of torque event, "forward flight" is considered to be flight at any airspeed after attaining transitional lift.

The blades were normally tied down when the helicopter was parked. About a week before the occurrence, the night before being flown to Adams Lake, the helicopter was parked at Campbell River with one rotor blade secured with a sock tie-down cord. The winds reached a high of eight knots that night. The MD Helicopter Maintenance Manual Chapter 10-10-00, "Parking and Mooring practices and instructions" caution to take up slack but not to apply bending loads on blades when securing them with sock tie-down cords and to install blade socks on all blades. Bending loads are hazardous to the structural integrity of the blades. Normally, the blades become rigid in plane with centrifugal force exerted in rotation; when parked, the helicopter blades may be subjected to wind gusts that cause bending loads. Whenever severe storm conditions or wind velocities higher than 40 knots are forecast, the helicopter should be hangared or evacuated to a safer area, or the blades must be removed as they can be subjected to severe bending loads.

MDHS issued Service Letter SL369D-111, dated 11 January 1999, to establish a new approach to calculating retirement lives of various helicopter components. Components such as the main-rotor blades were to be assigned retirement lives based on information gathered from flight tests, fatigue tests, and field experience. Some operators reported exceeding the estimated amount of high-stress manoeuvres in the flight spectrum during daily operations, causing MDHS to re-evaluate the method of establishing limited lives which, until this time, only considered time in service (TIS).

It was proposed that torque events be considered in the flight spectrum equation. Subsequently, on 15 May 2001, MDHI issued Service Bulletin SB369D-201, annotated as mandatory compliance. On 24 July 2001, MDHI issued SB369D-201R1. These bulletins contain criteria to assist operators in understanding the level of usage, the impact of that usage on the main rotor blade life, and the corresponding inspections required to find cracks that might occur. Under Canadian Aviation Regulations, service letters and bulletins themselves are not mandatory unless mandated by the foreign civil aviation authority, or referenced by an airworthiness directive (AD).

MDHI publishes airworthiness limitations that establish life limits for helicopter components. In accordance with the MDHI Maintenance Manual, Chapter 4, revision 29, the life limit for the subject blade, part number 500P2100-101, is 3530 hours. The blades have an initial scheduled inspection interval of 100 hours and, in accordance with SB369D-201R1, after a blade has accumulated 750 flight hours and 13 720 torque events, operators are required to perform a main-rotor blade torque-event inspection every 35 flight hours or at 200 torque events whichever occurs first. No finite torque event number is established for the main rotor blades.

The TSB previously investigated a main rotor blade failure (A01P0061) that was attributed to a manufacturing defect at the first lightening hole of the "C" channel at about station (STN) 36.5 inches. During this previous investigation, MDHI studied 28 blades to determine the mode of failure. An examination of the "C" channel was part of the study protocol. Of the 28 blades, 4 showed cracking at the first lightening hole in the "C" channel. Of the four blades that showed cracking, three came from one aircraft involved in operations with a very high number of torque events per hour. The fourth was used in a manner that reportedly exceeded the normal rotorcraft flight manual limits. The "C" channel cracks observed in this study did not appear to be from any manufacturing defect. Blades exposed to a high number of torque events were more likely to display cracks. The study showed that the cracked "C" channel found in the blade was rare but not unique. It also showed that if a crack were present, its progression would be discovered very early with the implementation of Service Bulletin SB369D-201R1. Lightening

holes are normally designed in a structural member to afford weight savings but may also affect its torsional, flexure or bending properties, and fatigue life. The weight saving for this main rotor blade is reportedly insignificant.

Following the occurrence, the TSB Engineering branch was provided with 16 main rotor blades to determine the frequency of occurrence of cracks at the "C" channel lightening holes.[3] Four of the main rotor blades, sectioned and examined, were found to have cracks at the first lightening holes, about STN 36.5. None of the blades with cracks in the "C" channel lightening holes had propagated to the outer skin (Appendix A - TSB LP069/2002). Given the small thickness of the "C" channel (0.28 mm), any surface imperfection in the bore / lightening hole, would represent a large stress concentration factor. In at least two and possibly three cracks the initiation sites coincided with surface irregularities. The cracks were well developed meaning that they formed and propagated while the blades were well below the time limit of 3530 hours. This points to a weakness in the blade and the insidious nature of the cracking (undetectable by conventional inspections). The structural integrity of the blade was compromised. There are no prescribed inspections for identifying lightening hole cracks, or any documented standards to accept material flaws in this part of the main rotor blades, like a crack in the "C" channel.

A search of the Transport Canada and the Federal Aviation Administration (FAA) Service Difficulty Reporting (SDR) databases produced seven reports of main rotor blade cracking on the 369 series model helicopters, four of which were specifically identified and located about STN 36.5. The main rotor blades for the MDHI 600N model helicopter have a similar construction and are also subject to cracking at this location as revealed in two reports of the SDR databases.

As part of the FAA requirement for certification of the main rotor blades, MDHI produced a stress analysis for Model 369F helicopter[4] based on a computer model to evaluate stresses at certain locations of the main rotor blade. Analysis of the stresses applied at blade STN 36.5 were not determined. MDHI developed the inspection interval based on their analysis of crack growth.

The incident main rotor blade S/N A340 was preliminarily examined at the TSB regional facility, and metallurgical testing was performed under TSB supervision by R. J. Waldron & Company (1987) Ltd. who produced Technical Analysis Summary Report Number 02-230.

Transport Canada also provided the TSB with an example of a failed blade. It had about 2400 hours in service and an estimated 17 000 TE. The lower skin was cracked and TSB engineering services confirmed that the crack located near blade STN 36.5 originated from the "C" channel lightening hole.

The visible crack on the exterior surface of the blade measured 4.5 inches long and ran in a chord-wise direction from the approximate aft edge of the spar to the trailing edge of the lower skin at STN 36.5. Once the blade was sectioned it was found that, in addition to the lower skin crack, the "V" channel at the trailing edge of the blade had a longitudinal crack that

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[3] TSB Engineering Branch Report No. LP 069/2002.

[4] Hughes Helicopters, Inc. Report No. 369-S-8010.

measured 2.7 inches long. This crack was roughly centred about the lower skin crack and the "C" channel crack, below the first lightening hole. No cracking of the spar or upper skin were detected in the area of the lower skin crack. (Figure 1)

The "C" channel crack fracture faces were found to exhibit beach markings and patches of deteriorated striations that are indicative of a fatigue mode of progressive cracking. The fatigue cracking was found to initiate from the inside diameter of the first lightening hole in the "C" channel of the blade. It progressed downward through the lower section of the channel and into the channel to skin adhesive. A line type fatigue initiation was observed on the inside surface of the lower skin below the "C" channel. The fatigue then progressed through the lower skin to its outside surface and spread both forward and rearward in a chord-wise direction from that point.

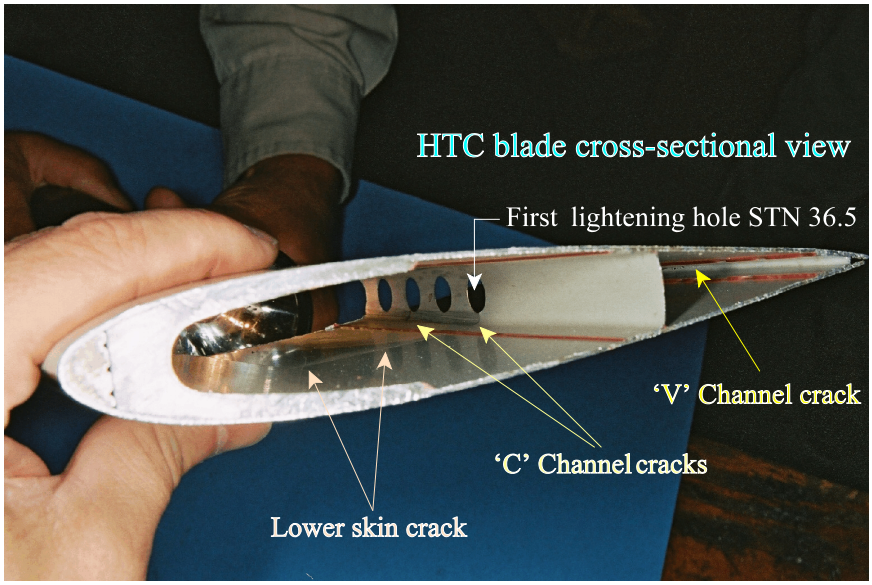

Figure 1. Main rotor blade cracking

The fatigue initiation was found to be associated with relatively large pits on the "C" channel (Figure 2) lightening hole surface. The pitting on the "C" channel was present when primer was applied to the part. Rods of strontium that are incorporated into the primer were found adhered to the surfaces of the pits. A secondary crack extended out of the lower side of the third "C" channel lightening hole. The cracking at the third "C" channel lightening hole appeared to be

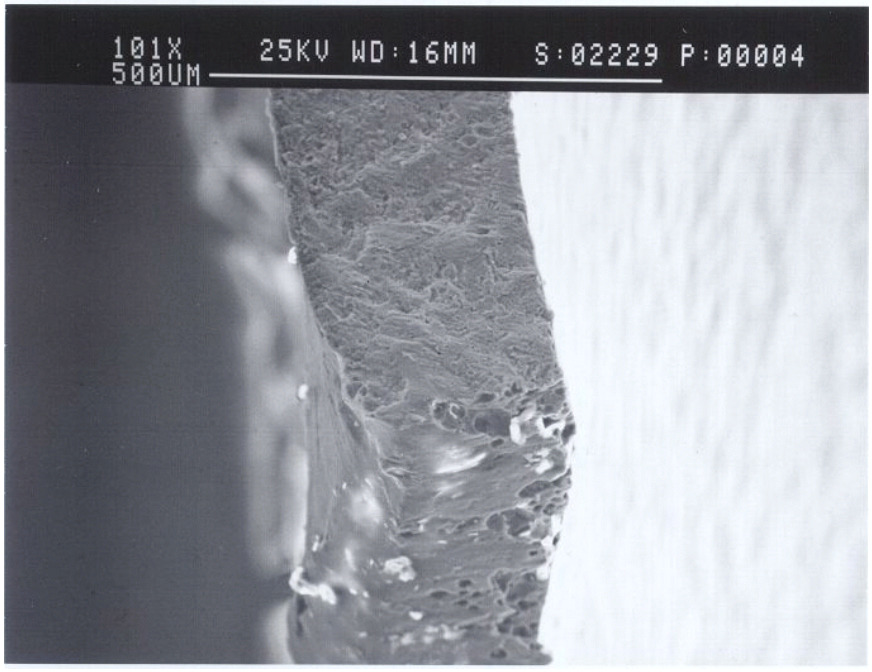

Figure 2. SEM image revealing pitting (101 X magnification)

associated with pitting on the inside diameter surface of the hole. The blade skin and "C" channel were both found by material analysis to be typical of Alclad aluminum alloy AA 2024. No significant contaminants were detected on the crack fracture surfaces.

The quality assurance process detailed by HTC for the method of inspection of the "C" channel consists of running a protected/covered finger along its length to check for surface flaws or imperfections, such as burrs or nicks.

MD Helicopters Inc. has incorporated a finite number of torque events for the 600N model helicopter which is based on retirement index number (RIN) accounting. The 369 Series helicopter model is not subject to the same requirement.

Analysis

The pitting on the "C" channel was present when primer was applied to the part. These imperfections or pits caused a stress riser and were the origin of a crack in the "C" channel lightening hole that propagated to the blade's lower skin. The structural integrity of the main rotor blade was compromised.

The out-of-track condition of the main rotor blade was exacerbated by the crack that propagated to the lower skin. A torque event inspection of the blade, carried out by company maintenance shortly before the incident, failed to detect any damage or crack on the underside, suggesting that crack propagation may develop rapidly and/or be difficult to detect with the prescribed visual inspection method on that exterior surface of the blade, which is usually painted black. The occurrence blade had accumulated 2981.1 hours TTSN and 24 950 torque events. The previous investigation, TSB Occurrence A01P0061, revealed that a failed blade was removed after accumulating a TTSN of 2266.3 hours. It was estimated that, that blade had about 32 523 torque events. No finite torque event number is established for the main rotor blades. The blades essentially reach "on-condition" status because the manufacturer relies on the inspections to reveal cracks and retire the component. Several main rotor blades were found to have developed cracks at or near STN 36.5. The FAA-approved stress analysis for the Model 369F Helicopter did not evaluate the stresses applied at this location. MDHI developed the inspection interval based on their evaluation of crack growth analysis. There are no prescribed inspections for identifying lightening hole cracks, or any documented standards to accept material flaws in this part of the main rotor blades, so the crack in the "C" channel rendered the rotor blade not airworthy[5]. The blades may not reach their expected life of 3530 hours TIS.

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[5] "Airworthy" - in respect of an aeronautical product, means in a fit and safe state for flight and in conformity with its "type design"; - means *(a)* the drawings and specifications, and a listing of those drawings and specifications that are necessary to define the design features of an aeronautical product in compliance with the standards applicable to the aeronautical product, *(b)* the information on dimensions, materials and manufacturing processes that is necessary to define the structural strength of an aeronautical product, *©)* the approved Sections of the approved flight manual, where required by the applicable standards of airworthiness, *(d)* the airworthiness limitations Section of the instructions for continued airworthiness specified in the applicable chapters of the *Airworthiness Manual*; and *(e)* any other data necessary to allow, by comparison, the determination of the airworthiness and, where applicable, the environmental characteristics of later aeronautical products of the same type or model.

In operations where the helicopter is subjected to a high number of torque events, accounting of torque events may be more difficult and imprecise because the helicopter does not automatically register and record the number of times that it transitions from a hover to forward flight, and/or the number of lifts; it relies on the pilot's recollection of the operations. Service bulletin SB369D-201 issued on 15 May 2001 was annotated as mandatory compliance by MDHI. Under Canadian Aviation Regulations, service letters and bulletins themselves are not mandatory unless mandated by the foreign civil aviation authority or referenced by an airworthiness directive (AD). Hence, MDHI rotor blades are subjected to a "fatigue factor" that may not be accurately tracked by operators.

The manufacturer's method of inspection for the "C" channel consists of running a finger over the lightening holes to check for surface flaws or imperfections, such as burrs or nicks; this may be inadequate because a finger swipe along the length of this channel may not reveal slight imperfections which are best detected with magnification. HTC incorporated an ultrasonic inspection as part of its manufacturing process to detect bonding voids. This inspection may not detect slight sub-surface anomalies or imperfections that are critical to the structural integrity of the main rotor blade and its fatigue life.

About a week before the occurrence, the operator secured only one main rotor blade in light wind conditions. Tying down only one blade may exacerbate the bending forces, because the four unsecured blades flutter in the wind and exert leveraged bending forces as they rise and fall. The structural integrity of the main rotor blades may have been compromised.

TSB Engineering Branch report LP 069/2002, MD Helicopters Inc. study, and SDR databases suggest that the main rotor blades are susceptible to cracking at the first lightening hole, blade STN 36.5. Lightening holes in the "C" channel may afford an insignificant weight saving. TSB investigation A01P0061 found that a manufacturing defect at the first lightening hole compromised the structural integrity of the main rotor blade.

The following TSB Engineering Branch report was completed:

> LP 069/2002 – Main Rotor Blades, MD 369 Helicopters (various), C-CHFA, 18 June 2002

Findings as to Causes and Contributing Factors

1. The main rotor blade cracked as a result of metal fatigue, which originated from relatively large pits or imperfections on the "C" channel lightening hole surface. These pits caused a stress riser and were the origin of a crack that propagated to the blade's lower skin.

2. The pitting on the "C" channel was present when primer was applied to the part. The structural integrity of the main rotor blade was compromised by pits before it was surface treated.

Findings as to Risk

1. The out-of-track condition of the main rotor blade was exacerbated by the crack in the blade, which propagated to the lower skin. Maintenance interventions to correct for the out-of-track condition were not successful because a crack propagation may develop rapidly and/or be difficult to detect with the prescribed visual inspection. method.

2. Service Bulletin SB 369D-201R1 requires that operators track and record in the applicable technical logbook, the number of torque events experienced by the helicopter. Compliance with Service Letters and Bulletins is not mandatory under present Canadian Aviation Regulations.

3. Main rotor blades are subjected to a "fatigue factor" that may not be accurately tracked by operators because accounting of torque events relies on the pilot's recollection of the operations.

4. The lightening holes on the "C" channel of the main rotor blades may afford an insignificant weight saving and may have slight imperfections that go unnoticed during the quality assurance inspection process; imperfections in the "C" channel may lead to cracking under certain operations and ultimately compromise the structural integrity of the blades.

5. There are no documented standards to accept material flaws in this part of the main rotor blades, so the crack in the "C" channel rendered the rotor blade technically not airworthy.

6. The quality assurance finger swipe inspection method for surface flaws or imperfections at the lightening holes of the "C" channel is inadequate, because these imperfections are best detected with magnification.

7. About a week before the occurrence the operator secured only one main rotor blade in light wind conditions. Tying down only one blade may exacerbate the bending forces, because the four unsecured blades flutter in the wind and exert leveraged bending forces as they rise and fall.

Safety Action

TSB Investigation report A01P0061, released 23 May 2002, reported that the US Federal Aviation Authority was working on a notice of proposed rule making to expedite an airworthiness directive (AD) to effect mandatory compliance with MD Helicopter Inc. (MDHI) Service Bulletin SB369D-201R1. No airworthiness directive has been issued. The FAA is considering an amendment to the field inspection method that will require that the blades be inspected with 10X magnification.

During investigation A01P0061, Transport Canada noted that compliance with publications recommending the incorporation of modifications, the performance of inspections, or times between overhaul are optional. However, aircraft owners have a duty to be aware of the contents of these publications and to evaluate the need for compliance in light of their own

circumstances. Commercial operators should have a formalized process for conducting this evaluation as part of the evaluation program required by Canadian Aviation Regulation 706.15 & 726.15. Notice of Proposed Amendments (NPAs) 2000-249 and 2000-250, *were approved by* the Canadian Aviation Regulatory Advisory Council (CARAC). These NPAs are to amend the CARs, making operators' responsibilities in this matter clear.

Transport Canada had stated that they would continue to monitor investigation A01P0061 and consider taking unilateral action through an airworthiness directive should the Federal Aviation Authority not mandate MDHI Mandatory Service Bulletin SB369D-201R1.

Helifor Industries Ltd. have instituted a policy to require daily main rotor blade torque event inspections on all their 369 series helicopters.

Helifor has changed its policy on parking and mooring of the MD 500's. They have establishing a minimum separation from the heavy lift helicopters to minimize severe rotor downwash and have changed their tie down equipment. They also performed eddy current inspections on 60 main rotor blades with disparate times in service and found 14 blades with cracked "C" channel lightening holes. None of these had propagated to the outer skins. Helifor has removed from service any blades that were determined to have cracks.

Helifor has performed an eddy current inspection of its blades in service in accordance with Helicopter Technology Company inspection procedure HTCQ-010. This inspection will detect cracks in the C channel before they propagate to the skin. Although there is no evidence to establish the propagation rate and that blades have reached retirement with cracks in the C channel, Helifor has removed from service any blades that were determined to have cracks. This inspection has been incorporated into our Transport Canada approved Schedule. As well, the requirement for a daily inspection of the blades as per MDHS Service Bulletin SB369D-201R1 is in place.

As a product improvement, Helicopter Technology Company removed the lightening holes in the "C" channel from new production blades HTC P/N 500P21100-103 and blades sold by MDHI as part number 369D21120-503. HTC publishes Mandatory Service Bulletin 2100-3R2 on their web site:**http://www.helicoptertech.com/techpub.html**. HTC advised the TSB that all blades that come in for repair are Eddy Current inspected.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board authorized the release of this report on 10 March 2004.

Visit the Transportation Safety Board of Canada web site - www.tsb.gc.ca - for information about the TSB and its products and services. There you will also find links to other safety organizations and related sites.

Appendix A - Excerpt from LP069/2002

Blades from helicopters involved in high torque events. Highlighted blades are those that exhibited cracks.

Part Number 369D21100	
Serial Number	**Service Hours**
E582-515	238
E709-515	238
E587-515	238
E578-515	238
E583-515	238
K071-523	3340
3838-513M	3503
2709-513M	3522
2727-513M	3522
0736-513M	3531
B9660-513	3530
2811-513M	3522
H450-517	3119
2816-513M	3522
0258-513M	3503
3315-513M	3483