Australian Government

Australian Transport Safety Bureau

ATSB TRANSPORT SAFETY REPORT
Occurrence Investigation Report AO-2009-002
Final

Main rotor blade skin debonding
29 December 2008
135 km NE Alice Springs, NT
VH-HZB
Robinson Helicopter Company
R22 Beta

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Main rotor blade skin debonding, 29 December 2008, 135km NE Alice Springs, NT, VH-HZB, Robinson Helicopter Company R22 Beta.

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Abstract

While conducting a survey flight at Ambalindum Station (approximately 135 km north-east of Alice Springs, NT), the pilot of a Robinson R22 Beta helicopter, registered VH-HZB, noticed severe vibration of the main rotor assembly and cyclic controls. The pilot landed the helicopter immediately, and a subsequent inspection revealed that a length of aerofoil skin had peeled back from the leading edge on the underside of one of the main rotor blades.

A review of the current information surrounding Robinson helicopter blade debonds found a number of previous incidents involving a similar failure mechanism. Additionally, the issue of main rotor debond had been addressed by a number of airworthiness directives (ADs) issued by the Civil Aviation Safety Authority (CASA) and the Federal Aviation Authority (FAA), along with a number of safety alerts and service letters issued by the manufacturer.

Debonding of the main rotor blade skin was considered to have been influenced by extensive surface erosion observed around the leading edges of the blade. Additionally, the investigation found no evidence to suggest that the actions contained within the current CASA Airworthiness Directive addressing blade debonding issues (AD/R22/54) had been integrated into the helicopter's maintenance routine. The logbooks and maintenance release documents for the helicopter have since been updated to include reference to AD/R22/54 Amdt 3.

THE AUSTRALIAN TRANSPORT SAFETY BUREAU

The Australian Transport Safety Bureau (ATSB) is an independent Commonwealth Government statutory Agency. The Bureau is governed by a Commission and is entirely separate from transport regulators, policy makers and service providers.

The ATSB is responsible for investigating accidents and other transport safety matters involving civil aviation, marine and rail operations in Australia that fall within Commonwealth jurisdiction, as well as participating in overseas investigations involving Australian registered aircraft and ships. A primary concern is the safety of commercial transport, with particular regard to fare-paying passenger operations.

The ATSB performs its functions in accordance with the provisions of the *Transport Safety Investigation Act 2003* and Regulations and, where applicable, relevant international agreements.

Purpose of safety investigations

The object of a safety investigation is to enhance safety. To reduce safety-related risk, ATSB investigations determine and communicate the safety factors related to the transport safety matter being investigated.

It is a function of the ATSB to apportion blame or determine liability. However, an investigation report must include factual material of sufficient weight to support the analysis and findings. At all times the ATSB endeavours to balance the use of material that could imply adverse comment with the need to properly explain what happened, and why, in a fair and unbiased manner.

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Central to the ATSB's investigation of transport safety matters is the early identification of safety issues in the transport environment. The ATSB prefers to encourage the relevant organisation(s) to proactively initiate safety action rather than release formal recommendations. However, depending on the level of risk associated with a safety issue and the extent of corrective action undertaken by the relevant organisation, a recommendation may be issued either during or at the end of an investigation.

When safety recommendations are issued, they will focus on clearly describing the safety issue of concern, rather than providing instructions or opinions on the method of corrective action. As with equivalent overseas organisations, the ATSB has no power to enforce the implementation of its recommendations. It is a matter for the body to which an ATSB recommendation is directed to assess the costs and benefits of any particular means of addressing a safety issue.

When the ATSB issues a safety recommendation, the person, organisation or agency must provide a written response within 90 days. That response must indicate whether the person, organisation or agency accepts the recommendation, any reasons for not accepting part or all of the recommendation, and details of any proposed safety action to give effect to the recommendation.

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FACTUAL INFORMATION

Occurrence brief

At approximately 1000 Central Standard Time[1] on 29 December 2008, a Robinson Helicopter Company (RHC) model R22 Beta helicopter, registered VH-HZB, was being operated on a survey flight on a property in the Northern Territory. The helicopter was approximately 8 km from the take-off point at Ambalindum Station (approximately 135 km north-east of Alice Springs), when the pilot noted the onset of severe vibration from the main rotor assembly and oscillation of the cyclic controls. The pilot landed the helicopter immediately and a subsequent inspection revealed that a length of aerofoil skin had peeled back from the underside of one of the main rotor blades.

The main rotor blades were subsequently removed from the helicopter and sent to a rebuild specialist. The ends of the blades were removed approximately 550 mm inboard from the tips and forwarded to the Australian Transport Safety Bureau (ATSB) for further examination. Initial inspection revealed extensive erosion of the paint on the leading edge, and debonding of the stainless steel skin along the bond line on the underside of one of the main rotor blades.

Helicopter information and history

The model R22-Beta helicopter is a small, light two-person helicopter, predominantly used for training, personal transport and livestock management. The occurrence helicopter (serial number 0880) was first registered in Australia as VH-HZB in October 1988, having been manufactured that year. Ownership was transferred in July 2006, with the helicopter being subjected to a complete overhaul before being introduced into service for mustering and other related purposes.

At the time of the occurrence, the helicopter had accumulated 5,808.8 hours total time in service (TTIS), and had operated 1.622.8 hours since the overhaul. The last 100-hourly maintenance check was performed on 18 August 2008, and the helicopter had operated for approximately 50.5 hours since that time, with several flights above 8 hours duration.

The logbook entry for the last scheduled maintenance stated ‘R22 SB96 complies’ in reference to an RHC issued service bulletin. The maintenance provider reported that refinishing[2] of the blades was not required at the time of that inspection.

The organisation that took over the maintenance and rework of VH-HZB following the incident, reported that the pilot operating handbook (POH) and approved flight manual onboard VH-HZB at the time of the incident were out of date, and did not include the latest revisions issued in April 2007. Those revisions contained specific

[1] The 24-hour clock is used in this report to describe the local time of day, Central Standard Time (CST), as particular events occurred. Central Standard Time was Coordinated Universal Time (UTC) + 9:30 hours.

[2] Refinishing is reconditioning of the leading edges of the blade, and includes sanding, cleaning and repainting. Refer to Robinson Helicopter Company SL-56 for a comprehensive description.

information regarding the pre-flight inspection for exposed skin-to-spar bond lines on the main rotor blades.

Main rotor blade information

The R22 Beta helicopter employed a semi rigid two-bladed main rotor system, with the blades connected to the main rotor head through a tri-hinge arrangement.

The main rotor blades (part number A016-4) were installed new on VH-HZB in August 2006. The A016-4 main rotor blade type had a mandatory retirement life of 2,200 hours, with the blades on VH-HZB due for retirement at a helicopter TTIS of 6,386.0. At the time of the occurrence, the blades had operated for 1,622.8 hours.

The A016-4 main rotor blade design consisted of two stainless steel outer skins (0.008 in / 0.20 mm thick), adhesively bonded to an expanded honeycomb core, and a 'D' type leading edge stainless steel spar (Figure 1). The skin-to-spar joint consisted of a lap-bond configuration, with the skin adhesively bonded to a recessed surface at the rear of the leading-edge spar, approximately 1 in / 25 mm back from the leading edge. The entire blade, including the skin-to-spar bond line, was coated with a primer, followed by an outer polyurethane enamel paint layer (Figure 2). The paint acts as a protective barrier against environmental influences and moisture ingress, which has been shown to degrade the adhesive, and lead to a reduction in the effectiveness of the joint. The degradation of the adhesive is accelerated in hot and humid environments.

Figure 1: Schematic diagram showing the construction of the current R22 main rotor blade design (P/N A016-4) and the location of debonding

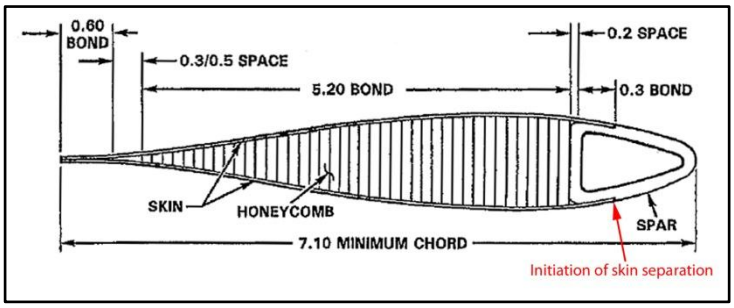


Image source: Edited from RHC Model R22 Maintenance Manual, 25 June 2006, pg 9.22A

Main rotor blade part number A016-4 was introduced in 2004 and replaced earlier designs (Part number A016-1 & A016-2), which had a thicker 0.025 in / 0.635 mm aluminium alloy skin. The new design, A016-4, was similar to part number C016-2 and C016-5 blades fitted to RHC R44 and R44 II model helicopters.

Figure 2: Overview of the Robinson Helicopter main rotor blade features

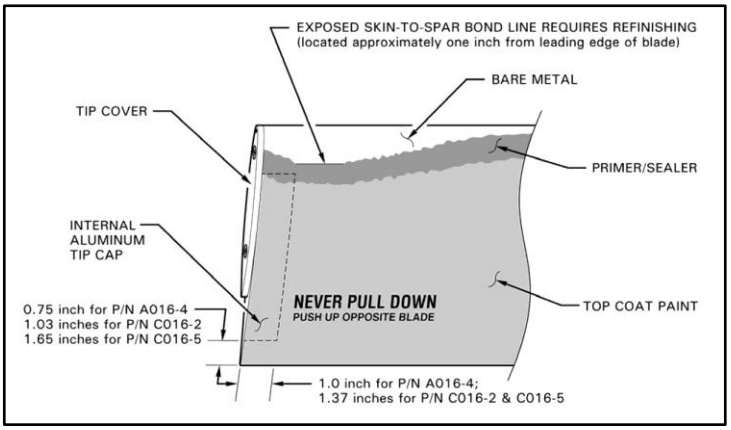


Image source: Robinson Helicopter Company Service Letter SL-56, 29 March 2007

Main rotor blade examination

General

The blades removed from VH-HZB exhibited the following identification markings:

- debonded blade: Part number: A016-4, Serial number: 4225D
- opposite blade: Part number: A016-4, Serial number: 5013D.

Figure 3: General view of the main rotor blade outer sections as received (underside)

The aerofoil skin of rotor blade 4225D (Figure 3) had separated from the blade on the underside, along the skin-to-spar bond line. The blade had debonded for approximately 160 mm along the length of the blade from the tip cap, and 45 mm towards the trailing edge (measured from the skin-to-spar bond line). The separated section of skin had curled backwards towards the trailing edge, and exhibited notable thinning along the forward-most edges. The flap of material formed by the separation along the bond line extended approximately 25-30 mm from the normal aerofoil surface (Figures 4 and 5). Thickness measurements of the skin in the region adjacent to the bond line revealed values of between 0.002 and 0.004 in (0.051 to 0.102 mm); considerably lower than the 0.008 in (0.203 mm) specified in the maintenance manual. Transverse tearing also extended from the forward skin edge into the bulk material.

Figure 4: Main rotor blade 4225D showing the extent of skin separation on the underside of the blade

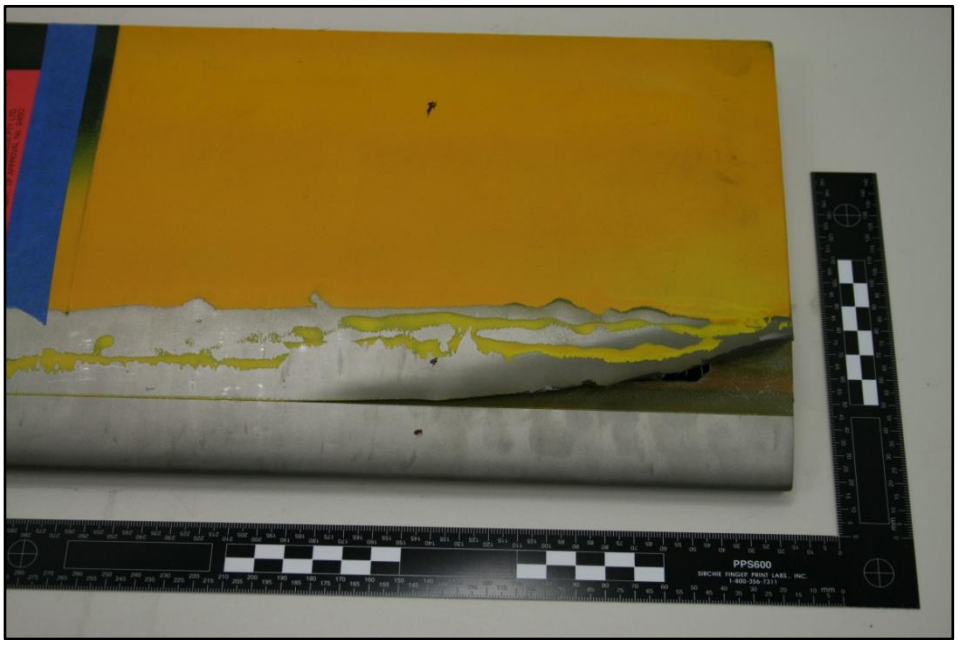
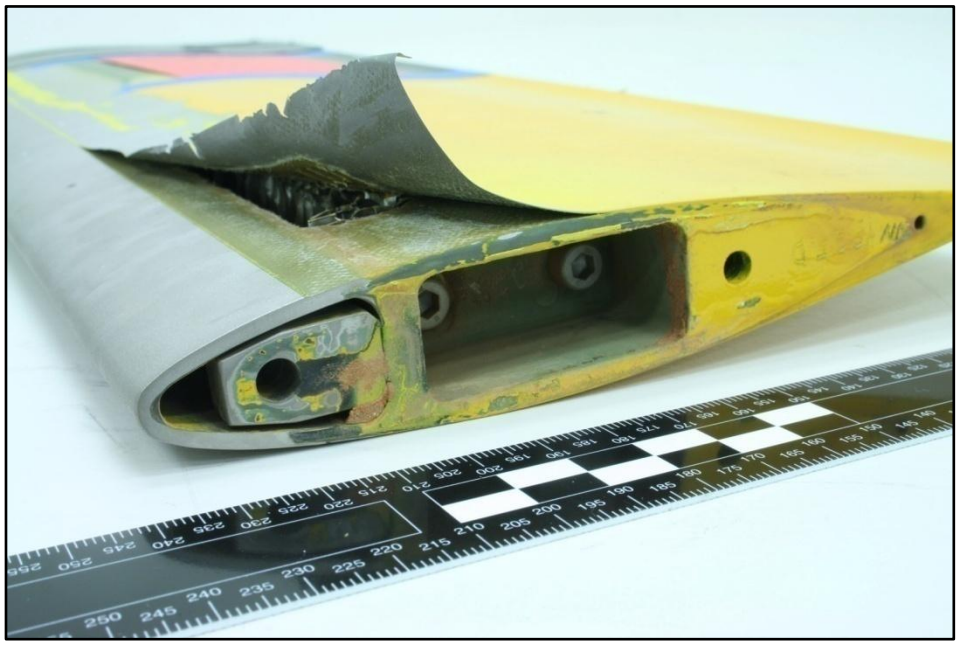


Figure 5: End view of main rotor blade 4225D following removal of the tip cover

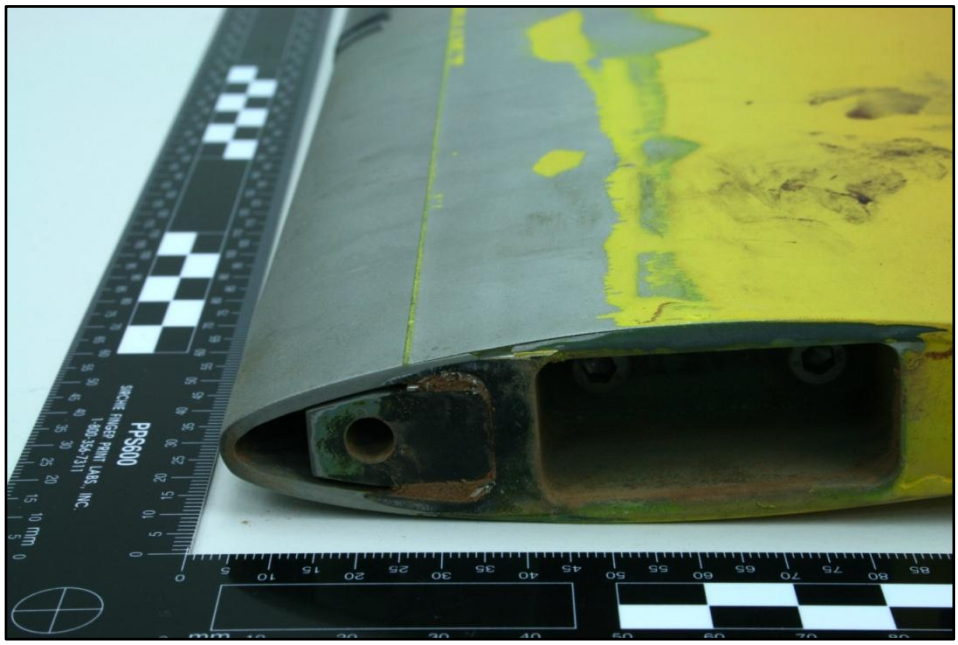


The leading edge on both the upper and lower blade surfaces exhibited prominent erosion of the surface paint and primer. On the underside, the paint line had been eroded to a distance of greater than 35 mm from the bond line towards the trailing edge. The upper surface also exhibited erosion, with no surface paint remaining on the trailing edge side of the skin-to-spar bond line. The surface of the spar and outer surface of the skin was smooth and dull, with a slightly granular appearance, and was consistent with abrasive wear by fine particulate matter, such as dust and sand.

The opposite main rotor blade, serial number 5013D, also showed extensive erosion of the paint and primer on both the upper and lower surfaces. No paint was observed on the underside of the blade to a distance of approximately 25 mm past the bond line; the degree of paint erosion was consistent along the length of the section examined. Additionally, no paint was observed on the spar side of the bond line on the upper surface.

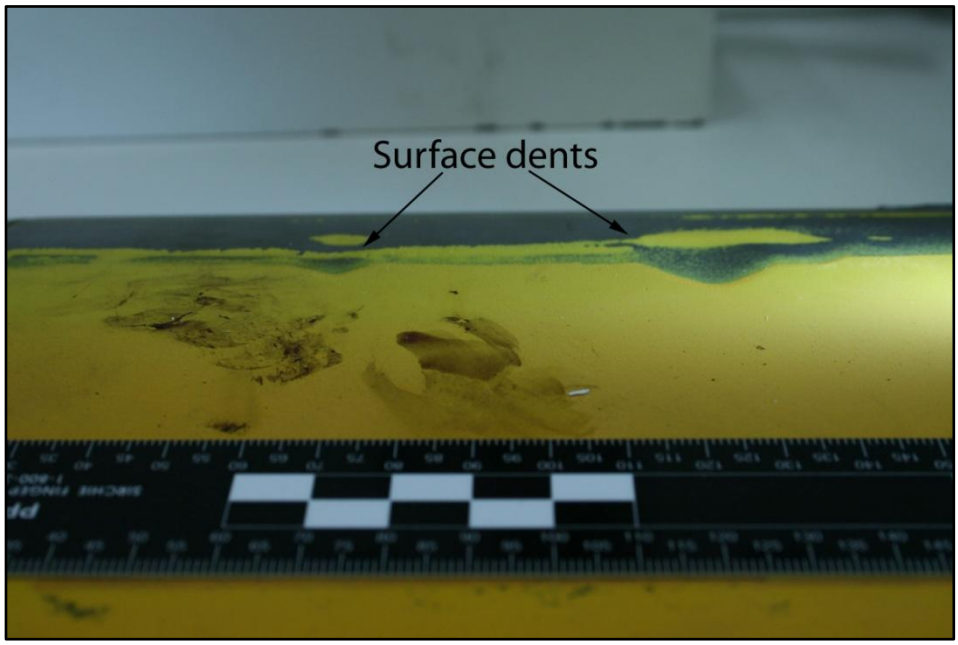
Removal of the tip cover (Figure 6) revealed some thinning of the skin, with a noticeable difference in the height on either side of the skin-to-spar bond line. No evidence of skin separation could be discerned visually and a tap-test, performed in accordance with AD/R22/54 Amdt 3, along the entire length of the submitted section suggested that no debonding had occurred.

Figure 6: Main rotor blade 5013D after removal of tip cover showing erosion of paint and primer, and thinning of the skin



Main rotor blade 5013D exhibited two small dents on the lower surface (Figure 7), which coincided with areas of greater paint erosion. The dents were within the limits specified in the component maintenance manual and a tap test of the surrounding areas revealed no evidence of debonding.

Figure 7: Bond line of blade 4225D in the area adjacent to the separated skin area



Adhesive bond examination

The separated skin-to-spar bond line of blade 4225D and the bond line on the underside of 5013D were examined visually and with the aid of a low-powered stereobinocular microscope. Both blades revealed a gap between the spar recess edge and the overlying skin of approximately 0.5 mm (Figure 8). This was generally consistent with a lap joint configuration; however, it should be noted that in both cases, a slight difference in the height of the skin and spar sections was observed, which suggested some level of erosion of the skin had occurred. The preferential erosion of the surfaces on the trailing edge side of the skin-to-spar bond line was clearly observed when viewed from the end of the blade, with the tip covers removed (refer to Figure 9 & 6)

Figure 8: Bond line of blade 4225D in the area adjacent to the separated skin area

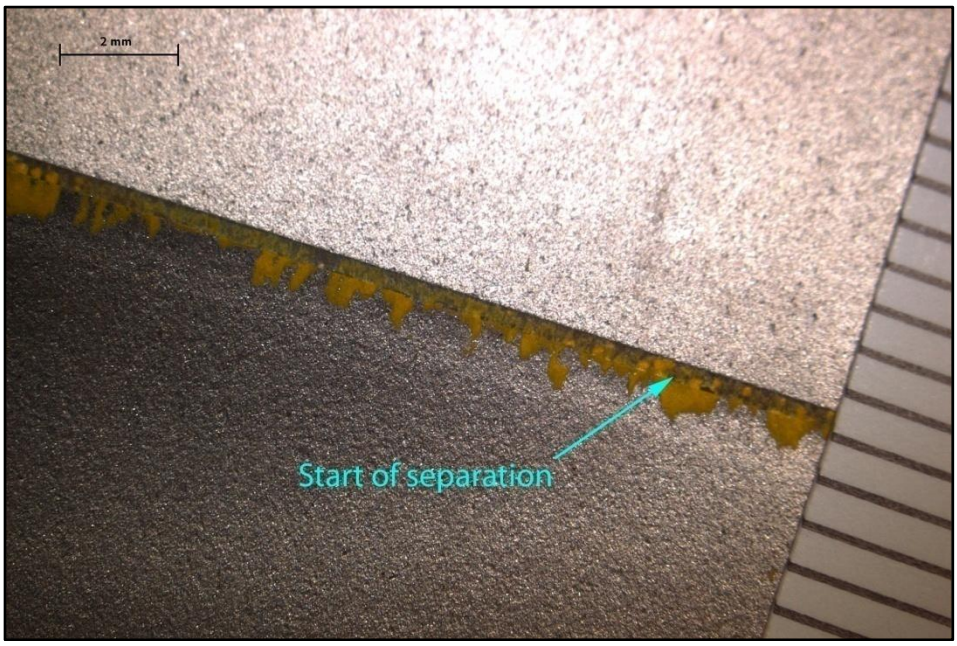
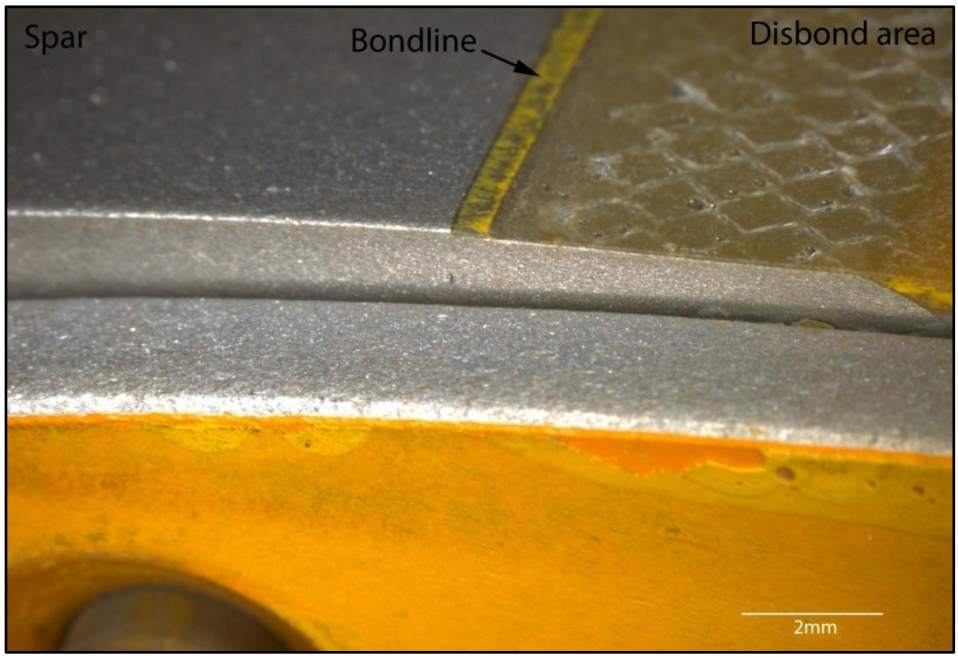


Figure 9: View of the skin-to-spar debond area of blade 4225D taken from tip, showing erosion of the bond line



An inspection of the exposed adhesive on blade 4225D indicated that separation had occurred via a mixed mode failure mechanism, that is, a combination of cohesive[3] and adhesive[4] failure (Figures 10 to 12). The area immediately adjacent to the skin-to-spar bond line was primarily an adhesive failure. The exposed surfaces on both sides of the joint, that is, the mating faces, were smooth and clean. The underside of the separated skin did not exhibit any residue of the adhesive in an area approximately 1 to 1.5 mm wide, along the length of the exposed bond line.

The remaining area of exposed interface exhibited mixed mode failure features, with both smooth areas of adhesive failure, and rough, fibrous areas associated with failure of the adhesive itself, that is, cohesive failure. This mode was also characterised by widespread remnant adhesive remaining on the underside surface of the separated skin. The failure had occurred in close proximity to the interface between the adhesive and the skin, and did not appear to have penetrated the carrier cloth[5].

Evidence of micro-voiding and pores were also observed in the bulk surface of the exposed adhesive. No evidence of decomposition or discolouration of the adhesive was observed.

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[3] Cohesive failure is defined as a failure of an adhesive joint occurring primarily in the adhesive layer, i.e. the adhesive itself fails [ASM Handbook, 2005].

[4] Adhesive failure is defined as the rupture of the adhesive bond such that the separation appears to be at the adhesive-adherend interface [ASM Handbook, 2005].

[5] A carrier cloth is used in adhesively bonded joints to ensure a uniform distribution of the adhesive and that an equal distance is maintained between the two adherends.

Figure 10: Debonded area on blade 4225D showing the surface of the adhesive

Figure 11: Magnified view of the bond line and adhesive surface immediately adjacent to the skin-to-spar bond line

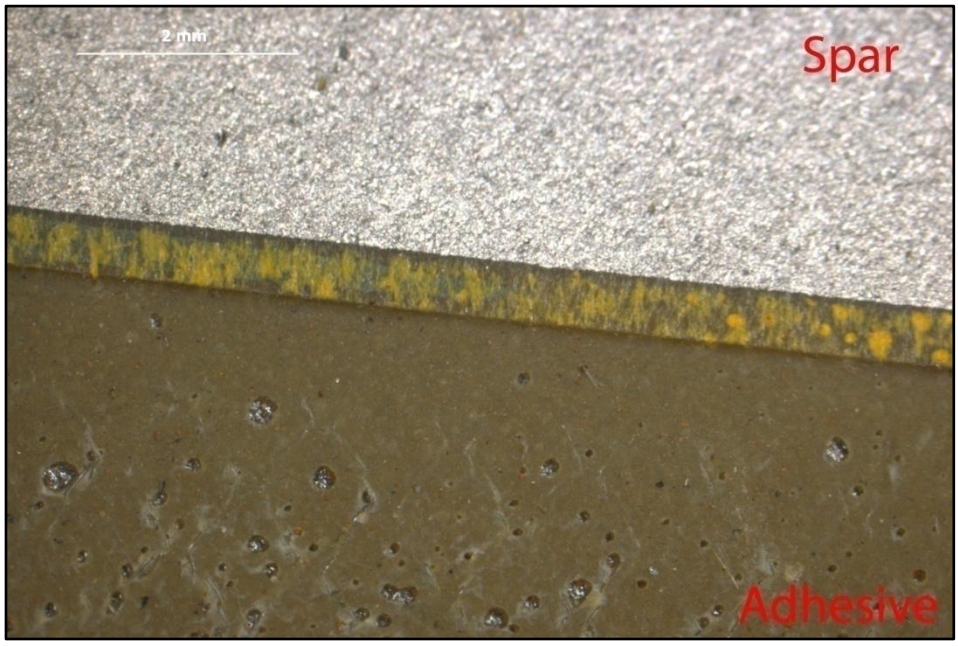
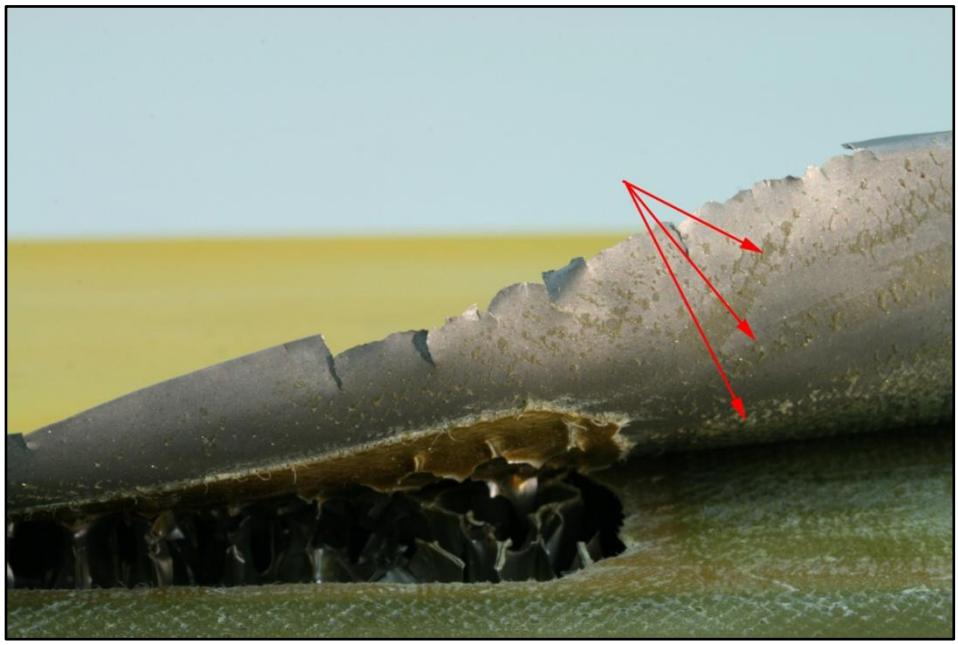
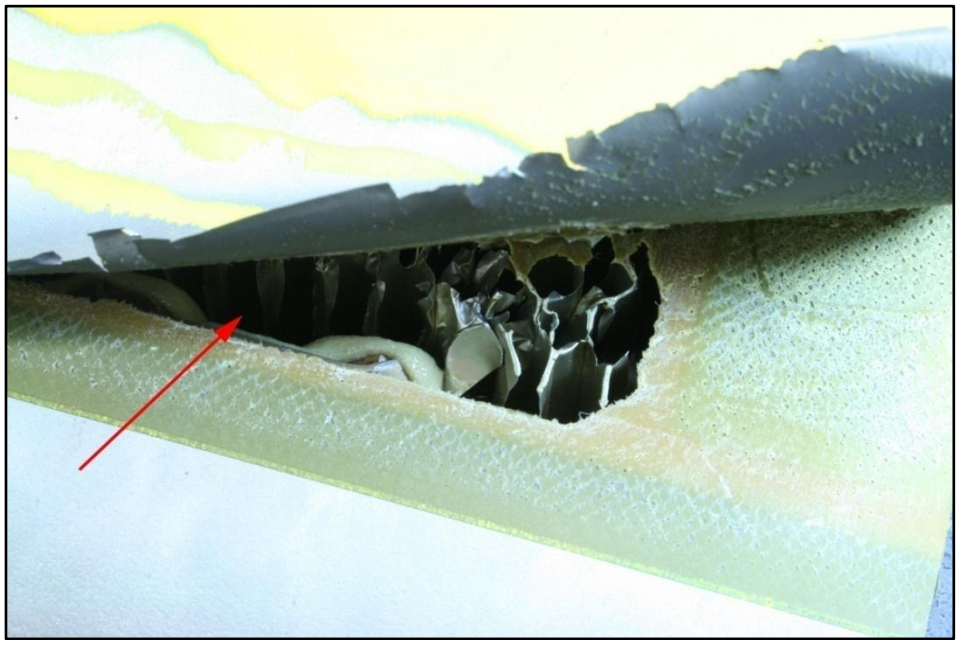


Figure 12: Underside of separated skin on blade 4225D, showing the presence of adhesive on the skin side of the joint (arrowed)



Examination of the core-to-spar bond exposed by the debonded section of skin on blade 4225D, showed evidence of a lack of adhesive in this location (Figure 13). The honeycomb core did not appear to abut with the adhesive on the rear of the spar segment.

Figure 13: Core-to-spar bond of blade 4225D, showing a gap between the aluminium honeycomb structure and the adhesive on the spar



History of R22 main rotor blade debonding

Similar occurrences

A review of the ATSB notification register and the Civil Aviation Safety Authority (CASA) service difficulty report (SDR) database, revealed a total of eight related occurrences involving similar blade types, between January 2006 and July 2009. Of the eight occurrences identified, five involved part number A016-4 blades (R22), while the other three involved part numbers C016-2 and C016-5 blades (R44). The occurrences mentioned above all involved debonding of the skin from the skin-to-spar bond line area towards the tip of the blade.

The ATSB has also published a report into a similar event involving an RHC R22 Beta II helicopter that occurred on 15 March 2007[6]. In addition to the numbers above, the Federal Aviation Administration (FAA) AD 2007-26-12 referred to 11 reports of main rotor blade debond.

Existing safety actions

Following the introduction of the new blade, P/N A016-4 in Feb 2006, the first safety alert[7] regarding the potential for main rotor blade skin debonding was issued by RHC on January 2007, with a revised version in March of that year. The safety alert directed operators to perform a daily pre-flight inspection and refinish blades in accordance with the relevant service letters (SL-56:R22, SL-32:R44) if bare metal was exposed at or beyond the bond line. This was subsequently followed up by an FAA Special Airworthiness Bulletin, SAIB SW-07-16, which was issued following reports of 10 blade debonding incidents involving R22 and R44 helicopters. A CASA Airworthiness Bulletin AWB 62-004, similarly recommended daily pre-flight inspections of the leading edge of the main rotor blades for erosion of the paint near the bond line and was issued in February 2007.

These advisory notices led to airworthiness directives being issued from both the FAA and CASA in early 2008. The FAA issued AD 2007-26-12 in January 2008, and CASA followed with a similar document AD/R22/54 in March 2008. AD/R22/54 is now in its third amendment. A similar Airworthiness Directive, AD/R44/22 was also issued for the R44 helicopter. In addition, a review of a number of main rotor blade debond cases by the National Transportation Safety Board (NTSB) led to the release of a number of safety recommendations to both the FAA and RHC in June 2008.

The CASA Airworthiness Directive, AD/R22/54, had specific instructions for testing of the blade to be performed at the 100-hour inspection or 12 months Time in Service (TIS), along with requirements for a daily pre-flight inspection. The following excerpt was taken directly from AD/R22/54 Amdt 3:

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[6] Aviation Occurrence Investigation 200701625
http://www.atsb.gov.au/publications/investigation_reports/2007/aair/aair200701625.aspx

[7] http://www.robinsonheli.com/srvclib/r22r44sa_blade_debonding_32207.pdf

> This Directive shall be entered on the maintenance release as maintenance required. The Requirement 3(a) visual inspection shall be performed before each flight and may be certified by the Pilot in Command who has been trained to do the inspection by an appropriately qualified person. In this case, a copy of this Directive is to be carried on the aircraft.

It should be noted that 3(a) is a visual check for any exposed (bare metal) blade skin behind the skin-to-spar bond line.

Amendment 3 of the AD/R22/54 also included two alternate methods of compliance (AMOC) with the directive requirements. The first, which was also included in the previous amendment, involved the use of Airwolf Aerospace LLC Rotor Blade Protective Tape. The second was an alternative to the pre-flight check specified in 3(a) provided that the main rotor blades were inspected at every 100 hours or 12 months time in service, and the applicable pilot operating handbook and approved flight manuals were updated to include revisions dated 20 April 2007 and later.

The logbook documents provided to the ATSB did not appear to contain any reference to the current airworthiness directive. AD/R22/54 was not referred to in the logbooks for the last 100-hourly maintenance check, nor was it included on the maintenance release documents for VH-HZB.

ANALYSIS

Blade skin separation

The in-flight vibration experienced by the pilot of VH-HZB was a result of the separation of the external skin at the skin-to-spar bond line on the underside of one of the main rotor blades. The 160 mm long separation, which extended some 25 mm into the aerodynamic plane, would have affected the lift capabilities of the blade, and the asymmetry of the blade surfaces thus created would have contributed to the vibrations felt by the pilot.

During operational service, the paint layers on R22 (and R44) main rotor blades, which serve as a protective coating, can be eroded by environmental factors such as dust, sand and rain. Both main rotor blades removed from VH-HZB showed extensive erosion of the leading edge paint along the entire length of the submitted sections.

Closer examination revealed that the underlying stainless steel blade skin had also been affected by the erosion mechanism. The erosion of the paint beyond the bond line had exposed the joint adhesive to the ambient environment, through the gap between the edge of the recessed area of the spar and the edge of the skin. The exposure of the adhesive could lead to moisture absorption / ingress and a subsequent reduction in the effectiveness of the adhesive.

Although no evidence of discolouration or corrosion was observed, the adhesive failure mechanism features of the exposed surface in the region adjacent to the bond line suggested that the effectiveness of the bond may have been compromised. This possible reduction in bond effectiveness, along with a change in the laminar airflow across the blade due to the non-uniform surface created by the preferential erosion of the blade skin, would have changed the stress state of the blade, and may have increased the propensity for lifting or peeling of the blade skin. Once an area of disbond had developed on the underside of the blade, it would likely continue under the influence of peeling stresses. Additionally, it was considered possible that the lack of bond between the expanded aluminium honeycomb core and the rear edge of the blade spar, may have further contributed to increased stresses on the skin-to-spar joint. However, the scope of the investigation did not extend to the quantification of this effect.

Maintenance

It was reported that the blades were not refinished at the last 100 hour inspection, as the ‘paint line had not eroded beyond the bond line’. It was further noted that the maintenance log entries for the last overhaul contained the statement ‘R22 SB96 complies’ - referring to a Robinson Helicopter Company issued service bulletin. A comparison between SB-96 and the Civil Aviation Safety Authority (CASA) airworthiness directive applicable at the time of the inspection (AD/R22/54 Amdt 2), revealed that although there were slight differences in the inspection requirements, the criteria for refinishing of the blades was the same. That is, the blades are considered un-airworthy and must be refinished before further flight if the paint had eroded beyond the bond line.

The helicopter had operated for 50.5 hours since the last 100-hourly maintenance check, several operations of which were above 8 hours duration. While it was conceivable that erosion of the blades to the extent observed could have occurred since the last 100-hour inspection (under the local operating conditions in central/northern Australia), it was unlikely that the level of erosion sustained had occurred during the last flight of the helicopter (the occurrence flight), which was of 0.3 hours duration.

CASA AD/R22/54, which required a visual examination before each flight and specified limitations for the erosion of the paint line, was not referred to in any of the examined maintenance documentation for the helicopter. While amendment 3 of AD/R22/54 included an additional alternate method of compliance (AMOC), removing the need for signing of a visual examination before every flight, this was on the proviso that the applicable POH and Approved Flight Manual included revisions dated 20 April 2007 and later. The logbooks that were in use at the time of the occurrence did not contain those revisions.

FINDINGS

From the evidence available, the following findings are made with respect to the in-flight debonding of the main rotor blade skin on the R22 Beta helicopter, registration VH-HZB, and should not be read as apportioning blame or liability to any particular organisation or individual.

Contributing safety factors

- While in flight, the skin of one of the main rotor blades of VH-HZB had debonded in the region adjacent to the skin-to-spar bond line towards the tip of the blade. This led to the interruption of laminar flow across the main rotor blade and the vibration felt by the pilot.
- The paint on the leading edge of both main rotor blades had eroded a significant distance past the bond line on the underside of both main rotor blades. The exposure of the bond line has been shown to compromise the effectiveness of the adhesive joint and increase the propensity for debonding of the skin.
- The extent of the erosion observed on both main rotor blades suggested that an adequate pre-flight inspection had not been performed prior to flight on the day of the incident.
- No evidence of the relevant airworthiness directive, AD/R22/54, was found in the logbooks or maintenance release documents for VH-HZB. AD/R22/54 gave specific instructions on the pre-flight inspection requirements for Robinson R22 main rotor blades. It was also reported that the pilot operating handbook (POH) and approved flight manual were not current for the helicopter at the time of the incident. *[Safety issue]*

SAFETY ACTION

The safety issues identified during this investigation are listed in the Findings and Safety Actions sections of this report. The Australian Transport Safety Bureau (ATSB) expects that all safety issues identified by the investigation should be addressed by the relevant organisation(s). In addressing those issues, the ATSB prefers to encourage relevant organisation(s) to proactively initiate safety action, rather than to issue formal safety recommendations or safety advisory notices.

All of the responsible organisations for the safety issues identified during this investigation were given a draft report and invited to provide submissions. As part of that process, each organisation was asked to communicate what safety actions, if any, they had carried out or were planning to carry out in relation to each safety issue relevant to their organisation.

Maintenance organisation

Absence of reference to current Airworthiness Directives and out of date flight manuals

Safety issue

No evidence of the relevant airworthiness directive, AD/R22/54, was found in the logbooks or maintenance release documents for VH-HZB. AD/R22/54 gave specific instructions on the pre-flight inspection requirements for Robinson R22 main rotor blades. It was also reported that the pilot operating handbook (POH) and approved flight manual were not current for the helicopter at the time of the incident.

Action taken by aircraft maintenance provider

The maintenance provider at the time of the incident did not provide the ATSB with details of any specific actions taken with respect to the out-of-date flight documents.

It should be noted that the helicopter has since been sold to another party, and the logbooks and maintenance release documents for the helicopter have been updated to include reference to AD/R22/54 Amdt 3.

APPENDIX A: SOURCES AND SUBMISSIONS

Sources of information

Pilot of VH-HZB

Maintenance provider VH-HZB

Owner VH-HZB

Robinson Helicopter Company

Civil Aviation Safety Authority

Federal Aviation Authority

National Transportation Safety Board

References

ASM Handbook, Volume 21: Composites, ASM International, January 2005.

Submissions

Under Part 4, Division 2 (Investigation Reports), Section 26 of the Transport Safety Investigation Act 2003, the ATSB may provide a draft report, on a confidential basis, to any person whom the ATSB considers appropriate. Section 26 (1) (a) of the Act allows a person receiving a draft report to make submissions to the ATSB about the draft report.

A draft of this report was provided to the helicopter owner (at the time of the occurrence), the pilot, the helicopter maintenance provider (at the time of the occurrence), Robinson Helicopter Company and the Civil Aviation Safety Authority.

Submissions were received from the helicopter owner, the pilot, the helicopter maintenance provider, Robinson Helicopter Company and the Civil Aviation Safety Authority. The submissions were reviewed and where considered appropriate, the text of the report was amended accordingly.

Main rotor blade skin debonding, 29 December 2008
135 km NE Alice Springs, NT
VH-HZB, Robinson Helicopter Company R22 Beta