Australian Government
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ATSB TRANSPORT SAFETY INVESTIGATION REPORT

Aviation Occurrence Investigation – 200701625

Final

Main rotor blade skin separation
15 March 2007
Mareeba Aerodrome, Qld
VH-HPI
Robinson Helicopter Company R22 Beta II

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Postal address:	PO Box 967, Civic Square ACT 2608
Office location:	15 Mort Street, Canberra City, Australian Capital Territory
Telephone:	1800 621 372; from overseas + 61 2 6274 6440
	Accident and incident notification: 1800 011 034 (24 hours)
Facsimile:	02 6247 3117; from overseas + 61 2 6247 3117
E-mail:	atsbinfo@atsb.gov.au
Internet:	www.atsb.gov.au

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Figure 1 courtesy of Cairns Helicopter School.

Figure 2 from Robinson maintenance manual, model R22, page 9.22A

Figure 16 courtesy of Robinson Helicopter Company, Engineering Dept.

Abstract

While undertaking a demonstration autorotational descent during an instructional flight test in a Robinson R22 Beta II helicopter, the student pilot and flight instructor noted an unusual mechanical noise, followed by the onset of severe vibrations from the main rotor system. After immediately landing the helicopter, it was found that the skin from the underside of one main rotor blade had disbonded from the leading edge spar over a length of approximately 450 mm from the blade tip.

The skin separation was found to be associated with abrasion and loss of the rotor blade leading edge paint across the bond line between the skin and leading edge spar. Erosion along the bond line had produced an undercutting effect and a feathering of the skin edge. Associated with random voids and pores in the adhesive that filled the gap between skin and spar recess edges, it was probable that the erosion had produced localised stresses within the adhesive joint, promoting the lifting of the feathered edges and the subsequent peeling separation of the skin.

As a result of a number of similar failures in both R22 and R44 main rotor blades, the helicopter manufacturer published a series of safety alerts, service letters and service bulletins, recommending the regular inspection of the blades for evidence of skin disbonding and the refinishing of blades showing abrasion of the leading edge paint to, or beyond, the skin bond line. Airworthiness directives from the US Federal Aviation Administration and the Civil Aviation Safety Authority subsequently mandated the initial and repeat inspection of R22 and R44 main rotor blades for this issue. Those airworthiness directives became effective in January 2008.

THE AUSTRALIAN TRANSPORT SAFETY BUREAU

The Australian Transport Safety Bureau (ATSB) is an operationally independent multi-modal bureau within the Australian Government Department of Infrastructure, Transport, Regional Development and Local Government. ATSB investigations are independent of regulatory, operator or other external organisations.

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 not the object of an investigation to determine blame or 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.

Developing safety action

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.

The ATSB has decided that 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 implement its recommendations. It is a matter for the body to which an ATSB recommendation is directed (for example the relevant regulator in consultation with industry) to assess the costs and benefits of any particular means of addressing a safety issue.

About ATSB investigation reports: How investigation reports are organised and definitions of terms used in ATSB reports, such as safety factor, contributing safety factor and safety issue, are provided on the ATSB web site www.atsb.gov.au.

FACTUAL INFORMATION

Occurrence brief

At approximately 1500 Eastern Standard Time[1] on 15 March 2007, a student helicopter pilot and accompanying flight instructor were conducting an instructional flight test in a Robinson Helicopter Company (RHC) model R22 Beta II helicopter, registered VH-HPI. While passing 300 ft during an unpowered autorotational descent, the student and instructor noted an unusual mechanical noise, followed by an increase in vibration from the main rotor assembly. The student immediately re-applied power and landed the helicopter safely, after which it was noted that the main rotor speed (RPM) could no longer be raised above 80% with the available engine power. After shutting down and exiting the helicopter, it was found that a length of aerofoil skin had separated and peeled back from the underside of one of the main rotor blades (Figure 1).

Figure 1: Separation of the main rotor blade lower skin, VH-HPI

Helicopter information and history

The model R22-Beta II was a two-person light utility helicopter, predominantly used for training, mustering and personal transport. The helicopter (serial number 3408) was first registered as VH-HPI in January 2003, and was transferred to its present owner in February 2006. The helicopter had reportedly been used mainly

1 The 24-hour clock is used in this report to describe the local time of day, Eastern Standard Time (EST), as particular events occurred. Eastern Standard Time was Coordinated Universal Time (UTC) + 10 hours.

for mustering and other related purposes since that time. At the time of the occurrence, the helicopter had accumulated 2,246 hours total time in service (TTIS) and had around 36 hours to run before its next scheduled 100-hourly maintenance check.

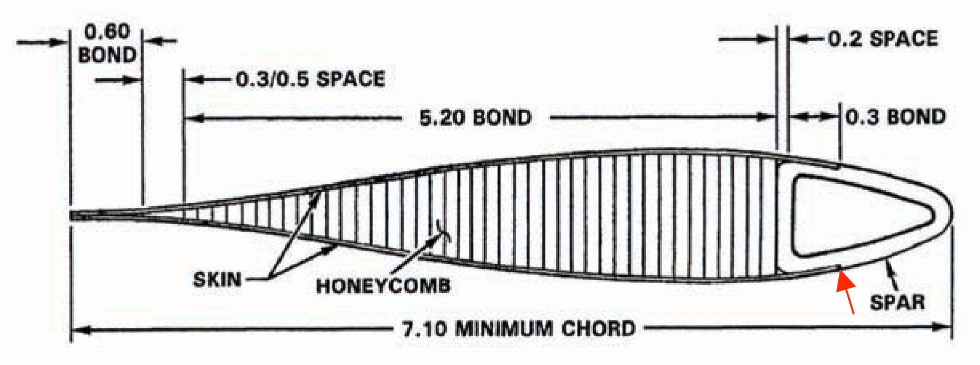
Main rotor blade information and history

The R22 Beta II helicopter employed a two-blade, rigid-in-plane[2] rotor design, with the blades connected to the main rotor head through individual flapping[3] hinges.

The main rotor blades (part number A016-4) were installed new on VH-HPI in November 2005, at a helicopter TTIS of 1,647.3 hours. At the time of the occurrence, the blades had operated for 596.7 hours. The A016-4 main rotor blade type had a mandatory retirement life of 2,200 hours or 12 years in service.

The A016-4 main rotor blade design consisted of a single piece leading-edge hollow D-spar, with the aerofoil section comprised of an expanded aluminium honeycomb core overlayed on the upper and lower surfaces with an adhesively-bonded stainless steel skin (Figure 2). The aerofoil section skin was lap-bonded to a recessed surface at the rear of the leading-edge spar, with any small gaps between the skin edge and recess corner being filled with adhesive that presumably extruded from the joint during manufacture. The entire length of the upper and lower skin-spar joints was coated with primer and polyurethane enamel paint, with the leading edges also having a supplementary black polyurethane enamel paint coating, extending over and beyond the external skin-spar bond lines.

Figure 2: Typical construction of the part number A016-4 R22 main rotor blade aerofoil section - under surface 'bond line' shown at red arrow



The part number A016-4 main rotor blade was a comparatively new design[4], introduced in 2004 and superseding the earlier part number A016-1 and A016-2 blades. The earlier A016-1 and -2 blades had an 0.025 inch thick aluminium alloy

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2 The rigid-in-plane rotor design allows the blades to move independently of each other in the vertical (flapping) plane, but not the horizontal plane of rotation.

3 Flapping is the vertical movement of the blade as a result of aerodynamic forces.

4 Refer to Robinson Helicopter Company service letter SL-54, service bulletin SB-94 and Civil Aviation Safety Authority (CASA) airworthiness directive AD/R22/53.

upper and lower aerofoil skin, whereas the A016-4 part incorporated a higher strength and thinner stainless steel sheet skin (0.008 inch thick), similar to the part number C016-2 and C016-5 blades fitted to R44 and R44 II model helicopters.

Blade examination

The blades were identified as follows:

Disbonded blade: Part number: A016-4, serial number: 3584E Rev. AL

Opposite blade: Part number: A016-4, serial number: 3519E Rev. AL

The lower (underside) aerofoil skin of rotor blade 3584E (Figure 3) had separated for approximately 450 mm inboard from the blade tip, and for around 65 mm chordally towards the trailing edge (measured at the blade tip). The skin had visibly disbonded along the spar bond line and curled backward, forming a triangular flap of material that projected approximately 60 to 70 mm beneath the normal aerofoil surface (Figure 4). A tap-test[5] of the remaining bond line revealed no evidence of the disbond extending further inboard towards the blade hub; nor was there any evidence of disbond along the spar upper skin bond line.

Figure 3: Extent of lower skin separation on blade 3584E

Figure 4: Extent of lifted skin projection from the aerofoil profile (blade upside-down)

5 A test of the skin-spar bond line, where a light metallic object, such as a coin, is lightly tapped along the joint and the acoustic response noted. Disbonded areas typically respond with a dull 'hollow' sound.

The leading edge and lower blade aerofoil skin in the area of separation was characterised by the complete abrasive removal of the surface paint and primer along and behind the bond line (Figure 5). Bare skin metal had been exposed for 35 mm back from the bond line at the blade tip, reducing to 5 mm back from the bond line at the inboard end of the lifted skin. The appearance of the abraded area was typical of the surface wear that occurs along the outer leading edges of rotor blades operated in rain or dusty environments.

Rotor blade 3519E showed a similar degree of leading edge paint abrasion, extending to approximately 800 mm from the blade tip and 35 mm beyond the bond line (Figure 6). There was no evidence of skin separation and a tap-test conducted for the length of the abraded area showed no indication of disbonding.

Figure 5: View from the trailing edge of blade 3584E, showing the extent of surface erosion across the bond line

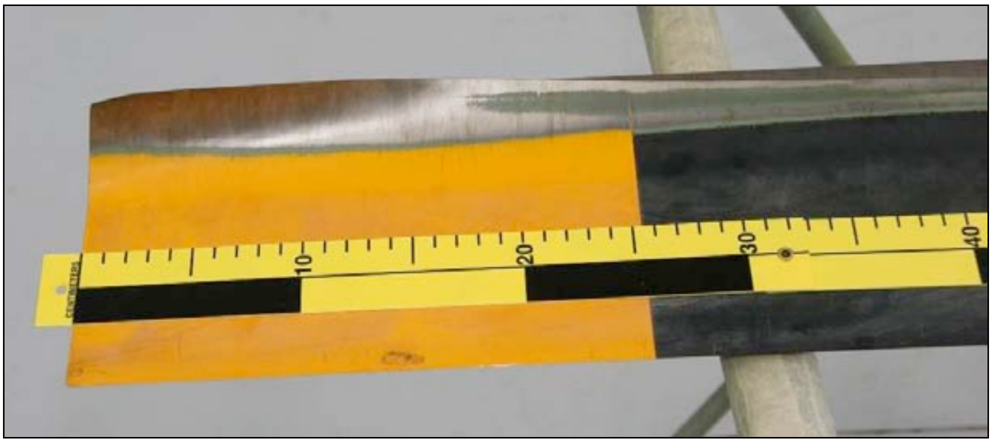
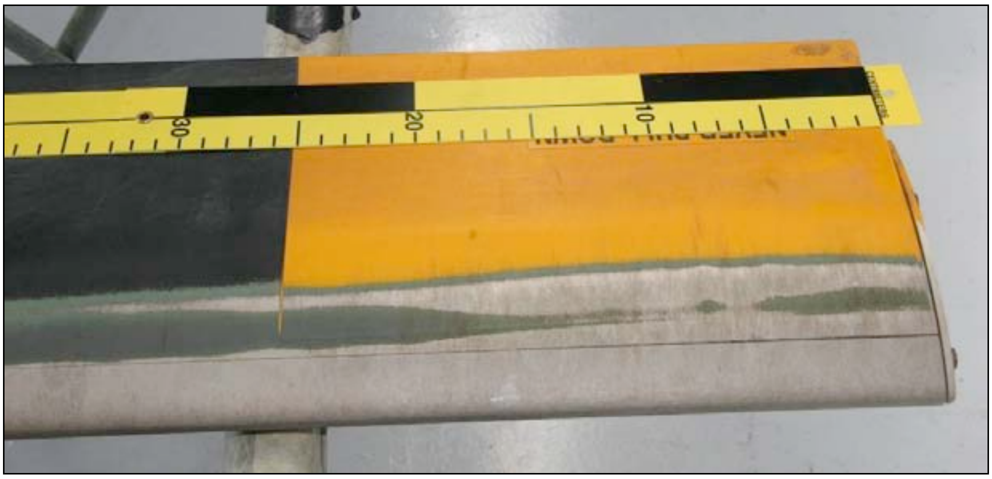


Figure 6: Erosion on the opposite blade (3519E) lower surface



Bond line examination

The separated bond between the skin and leading edge spar of blade 3584E was examined under low-power magnification. A line of local erosion and channelling of the adhesive was evident along the forward edge of the bond line; typically 1 to 1.5 mm in width (Figure 7). The corresponding edge of the lifted skin showed a similar 'feathered' appearance, with localised metal erosion leaving a thin and irregular edge (Figure 8). Examination of the bond line adjacent to the point of skin separation showed a variation in the width of the adhesive-filled gap between the skin edge and the spar recess corner. Voids and gaps in the line of adhesive were noted (Figure 9), with some evidence of localised erosion around those areas. The lifted skin at the blade tip was characterised by the abrasive rounding of the corner, and evidence of surface corrosion and environmental ingress suggested by the discolouration of the lifted adhesive in that area (Figure 10). Beyond the area of corrosion, the separated skin surface presented a mixture of cohesive[6] and adhesive[7] failure in the bonded region (Figure 11). The corresponding spar bond surface showed a uniform colouration, with no suggestion of pre-existing bond failure or skin separation.

Figure 7: Erosion and channelling of the adhesive along the external bond line of blade 3584E

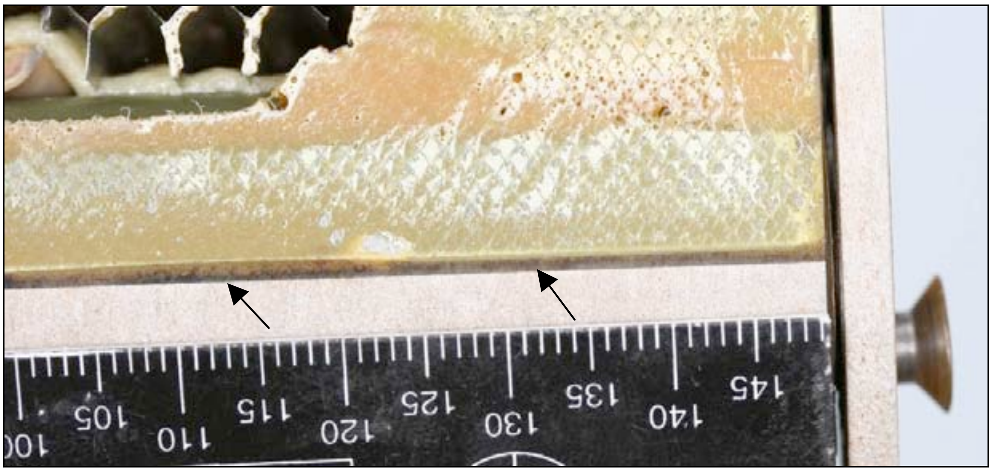
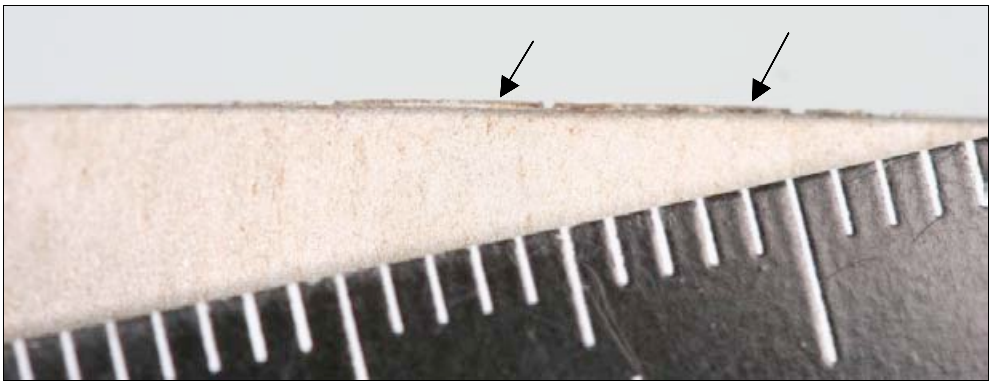


Figure 8: Erosion and feathering of the forward skin edge along the bond line of blade 3584E



6 Cohesive failure is defined as separation through the adhesive compound, typically leaving material adhering to both separated surfaces.

7 Adhesive failure is defined as separation of the bond at one or more of the parent material surfaces, leaving little or no material adhering to one of the separated surfaces.

Figure 9: Voids and pores along the bond line, inboard of the lifted section

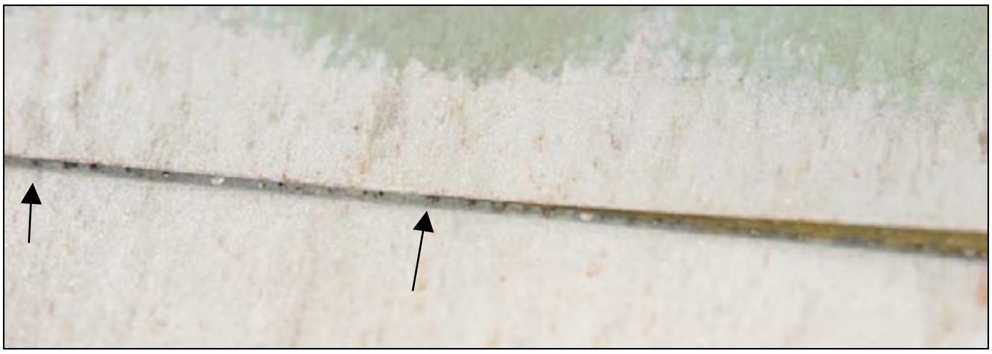


Figure 10: Eroded skin corner and evidence of disbond along the tip edge due to corrosion/ingress of moisture or contaminants (arrow)

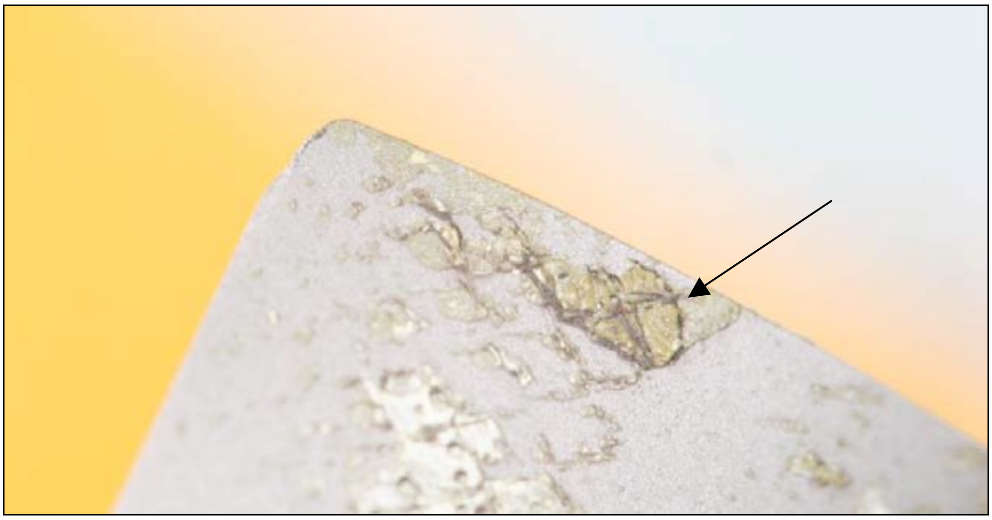


Figure 11: Disbonded skin surface, showing patchy adhesive and cohesive failure modes

The external bond line towards the tip of blade 3519E, although not separated, showed the local erosion and undercut of the adhesive line and forward skin edge. Again, the width of the gap between skin and spar edges varied (Figure 12), and was at a maximum of approximately 1.5 mm at the tip end (Figure 13). Numerous discontinuities were noted in the abraded length of the adhesive line (Figure 14), with evidence of increased skin erosion and edge undercutting associated with the larger voids (Figures 15, 16).

Figure 12: Comparison of bond line gap at the tip (upper image) and around 40 cm inboard of the tip (lower image), blade 3519E

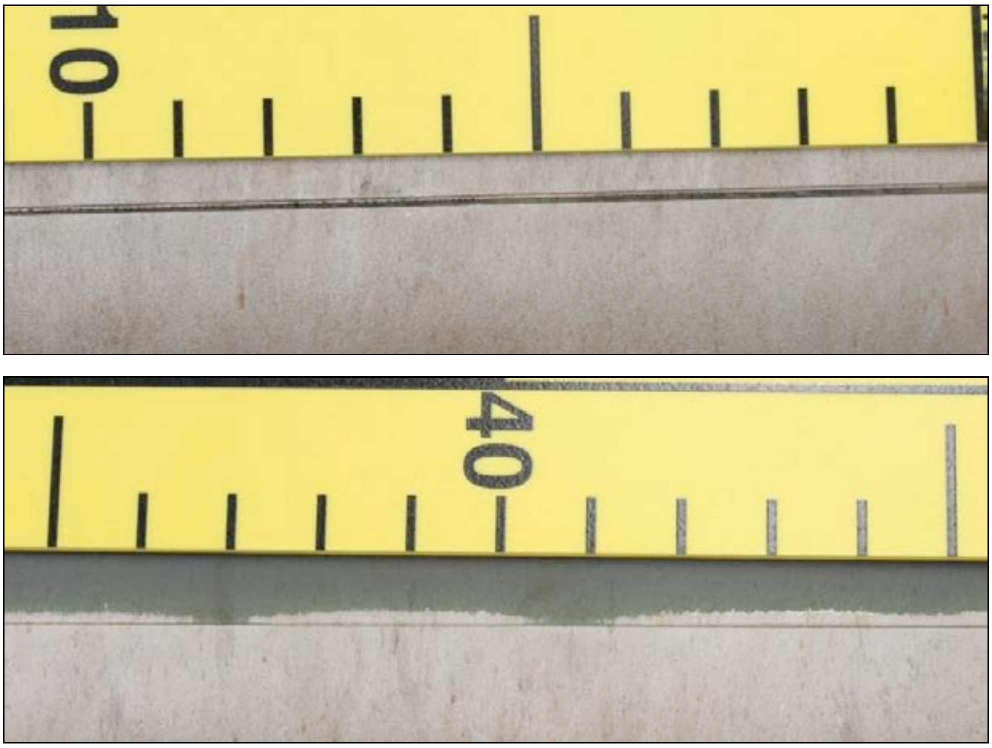


Figure 13: Closer view of the bond line at the blade tip. Note the small voids in the adhesive and the eroded skin edge

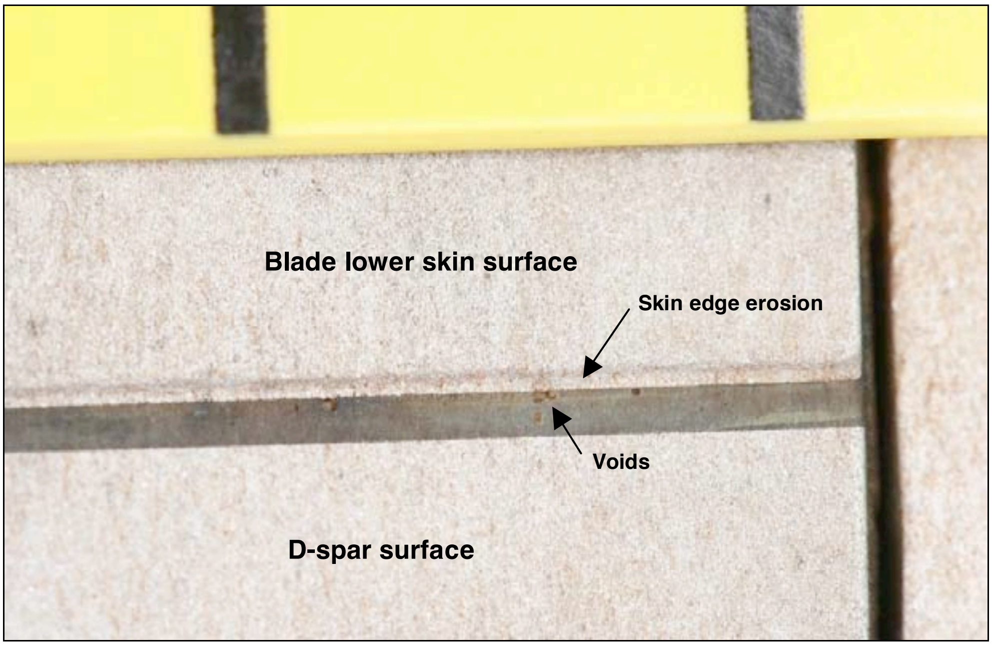


Figure 14: Distribution of voids and discontinuities and the erosion of the skin edge along the bond line of blade 3519E

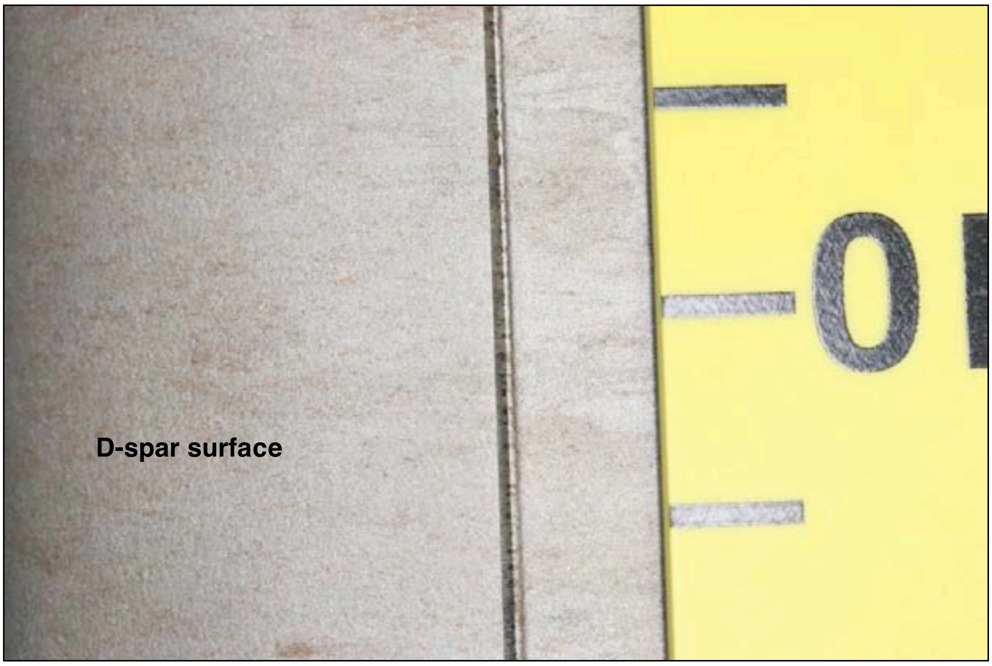


Figure 15: Closer view of voids and eroded areas along the bond line, blade 3519E. Larger void arrowed

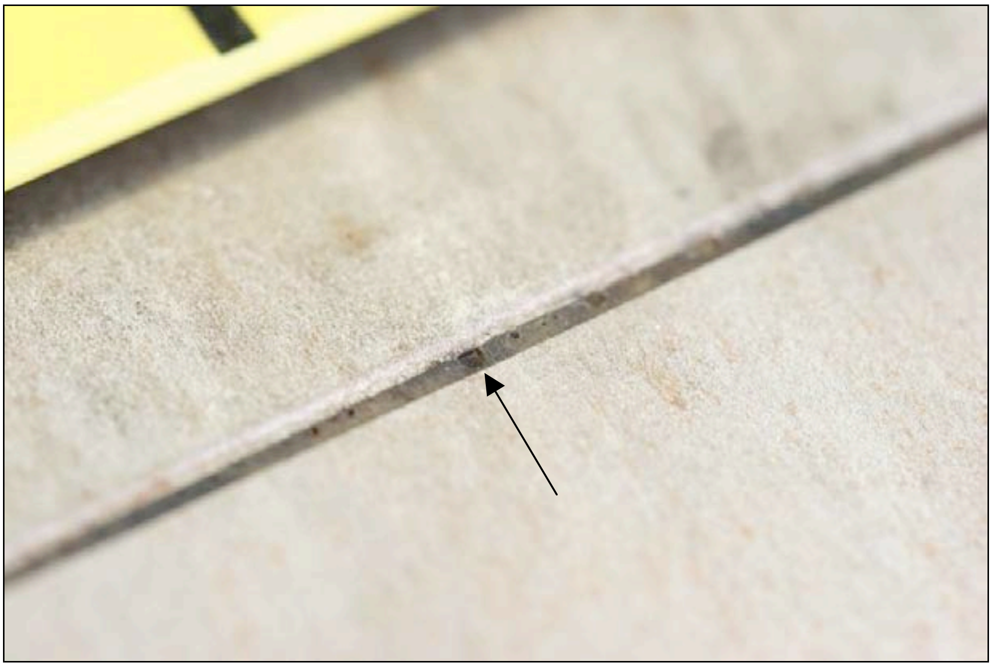
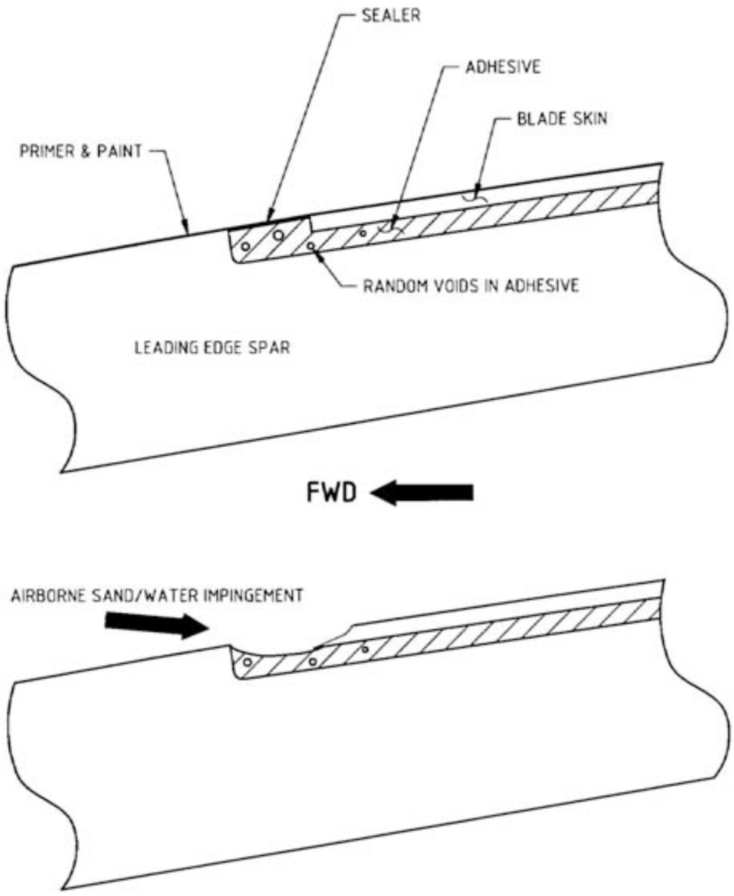


Figure 16: Illustration of as-manufactured (top) and erosively damaged spar-skin bond line (bottom), as observed



Previous occurrences

Five previous instances of main rotor blade skin disbonding in Robinson R22 and R44 model helicopters were identified from the Civil Aviation Safety Authority (CASA) service difficulty report (SDR) database. Occurring between September 2006 and February 2007, the occurrences all involved the disbonding of skin from the leading edge bond line; either at or close to the blade tip. All involved part number A016-4 (R22), C016-2 or C016-5 (R44) blades with stainless steel surface skins.

Existing safety action

The issue of localised main rotor blade skin disbonding in Australian registered RHC helicopters was first encountered in 2003, when two instances of skin separation were discovered on blades from R44 model helicopters. In response, CASA airworthiness directive AD/R44/18 was published, and became effective in February 2003, requiring daily inspections of the upper and lower skin-spar seams for evidence of disbonding. Amendment 1 to AD/R44/18 was published in May 2006, relaxing the interval between re-inspections, after it was established that the incidence rate of disbond events was comparatively low. Model R22 helicopters were not affected by this directive.

On 4 January 2007, the helicopter manufacturer published a Safety Alert, notifying owners and operators of R22 and R44 helicopters of the possibility of main rotor blade skin disbonding, and recommending the careful inspection of the skin-to-spar joint area for evidence of separation. That action was followed on 9 February 2007, by the US Federal Aviation Administration (FAA) publishing a Special Airworthiness Information Bulletin on the issue (SW-07-16), after it had received 10 reports of skin disbond events in part number A016-4 (R22) and C016-2 (R44) main rotor blades. CASA airworthiness bulletin AWB 62-004 followed on 19 February 2007, reiterating the content of SW-07-16.

At the time of the VH-HPI blade disbond event, there were no related service bulletins or airworthiness directives applicable to the R22 helicopter main rotor blades.

ANALYSIS

The controllability difficulties experienced by the pilot of VH-HPI were brought about by the partial separation of a 450 mm length of surface skin along the leading edge of one main rotor blade. Separating from the underside of the blade, the skin had folded backward under aerodynamic effects and would have severely compromised the generation of lift from the affected portion of the blade, resulting in the vibratory effects noted by the pilot.

The design of the R22 and R44 helicopter main rotor blades incorporated an adhesively-bonded joint between the leading edge spar and the aerofoil skin surfaces. That joint is normally protected from environmental influences by a polyurethane enamel paint coating. However, during operational service, the coating can be progressively eroded away by airborne particulate matter (dust, sand) or precipitation. Both main rotor blades from VH-HPI showed erosion of the underside leading edge paint beyond the joint line, extending for around 800 mm of the outermost blade length. Erosion of the adhesive and leading edge of the skin sheeting was also evident, undercutting the surface to produce a channelling effect along the bond line. The erosion was most prominent towards the blade tips, where it appeared the gap between the spar recess edge and the abutting skin sheet was greatest.

The erosion of the joint line in the localised manner observed would be expected to interrupt the high-speed laminar airflow across the blade surface during flight. Isolated regions of stagnant or turbulent airflow may thus develop, producing stresses which could act to promote lifting or peeling of the eroded leading edge of the blade skin. The presence of voids and discontinuities in the adhesive filled region between spar corner and skin edge could further exacerbate that behaviour. Once an area of disbond develops at the edge, it would be likely to grow under the influence of peeling stresses as the skin is progressively lifted upward around the disbonded region. Typically, adhesive joints are designed to withstand tensile and/or shear stresses. However, resistance to peeling stresses may be poor, particularly for the higher strength and more rigid adhesive compounds.

Environmental ingress and the development of corrosion beneath the blade skin, particularly at the tip edges was also identified as a possible factor contributing to the commencement of skin disbond. The presence of voids in the adhesive along the bond line could also promote the ingress of moisture or contaminants. Stresses developed at the bond interface due to the growth or corrosion products, and the degradation of the adhesive material under environmental exposure were both potentially influential in the disbond failure affecting VH-HPI.

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FINDINGS

From the evidence available, the following findings are made with respect to the in-flight separation of a section of aerofoil skin from one main rotor blade of R22 Beta II helicopter, VH-HPI, and should not be read as apportioning blame or liability to any particular organisation or individual.

Contributing safety factors

- The adhesive bond line between the leading edge spar and aerofoil skin of part number A016-4, C016-2 and C016-5 main rotor blades, as fitted to R22 and R44 model helicopters, is susceptible to erosion and subsequent in-flight failure, if the bond line becomes exposed due to abrasion of the protective paint coatings. *[Safety Issue]*
- The protective leading edge paint applied to R22 and R44 helicopter main rotor blades is subject to accelerated abrasive erosion and loss when the helicopters are flown in dusty environments or in rain. *[Safety Issue]*
- While the manufacturer, the FAA and CASA had all published related airworthiness advisory material, the problem of main rotor blade skin disbonding was an emerging airworthiness issue at the time of the occurrence, and as such, there was no mandatory requirement for maintenance providers or operators of R22 helicopters, to periodically inspect the main rotor blades for excessive surface erosion that exposes the adhesive bond line *[Safety Issue]*

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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.

Depending on the level of risk of the safety issue, the extent of corrective action taken by the relevant organisation, or the desirability of directing a broad safety message to the aviation industry, the ATSB may issue safety recommendations or safety advisory notices as part of the final report.

Robinson Helicopter Company

Susceptibility to main rotor blade skin disbonding if the bond line becomes exposed due to abrasion of the leading edge paint coatings.

Safety issues

- The adhesive bond line between the leading edge spar and aerofoil skin of part number A016-4, C016-2 and C016-5 main rotor blades, as fitted to R22 and R44 model helicopters, is susceptible to erosion and subsequent in-flight failure, if the bond line becomes exposed due to abrasion of the protective paint coatings.
- The protective leading edge paint applied to R22 and R44 helicopter main rotor blades is subject to accelerated abrasive erosion and loss when the helicopters are flown in dusty environments or in rain.

Action taken by Robinson Helicopter Company (RHC)

Shortly after the VH-HPI occurrence, RHC issued service letters SL-56 and SL-32 for the R22 and R44 helicopters respectively, providing instructions for the refinishing/restoration of the leading edge paint coating, and guidance as to when that is recommended. RHC also revised the safety alert addressing the skin disbond issue (first published on 4 January 2007), including references to SL-56 and SL-32. The service letters and safety alerts were subsequently revised on 22 March 2007 and again on 29 March 2007, to tighten the recommendations for refinishing and to include a recommendation to inspect for corrosion under the blade tip caps.

On 29 March 2007, service bulletins SB-96 (R22) and SB-61 (R44) were issued by RHC, requiring the periodic inspection of main rotor blades for erosion and skin disbonding. A further letter to owners/operators was released on 25 May 2007, providing additional information regarding main rotor blade skin disbonding and indicating that RHC had tightened blade production tolerances to minimise the width of the bond line and reduce susceptibility to erosion damage.

Federal Aviation Administration (FAA)
Civil Aviation Safety Authority (CASA)

No regulatory requirement for the periodic inspection for main rotor blade paint/skin erosion, tip cap corrosion or skin disbonding.

Safety Issue

While the manufacturer, the FAA and CASA had all published related airworthiness advisory material, the problem of main rotor blade skin disbonding was an emerging airworthiness issue at the time of the occurrence, and as such, there was no mandatory requirement for maintenance providers or operators of R22 helicopters, to periodically inspect the main rotor blades for excessive surface erosion that exposes the adhesive bond line.

Action taken by the Federal Aviation Administration

FAA airworthiness directive AD 2007-26-12 became effective on 18 January 2008 and required the inspection of any exposed (bare metal) blade skin aft of the skin-to-spar bond line on the lower surface of each blade. A tap test of the bonded areas was also required, as was an examination for corrosion, separation or voids at the skin-to-spar bond line beneath the blade tip caps, and the repainting of any exposed areas of the main rotor blades. After the initial inspection/s, the directive required that the outermost 24 inches (600 mm) of the main rotor blades be checked for any exposed skin-spar bonded area before each subsequent flight.

Action taken by the Civil Aviation Safety Authority

On 2 April 2007, CASA released issue 2 of its earlier Airworthiness Bulletin (AWB 62-004) discussing the issue of bond line erosion and referencing the RHC safety alerts. Subsequently, airworthiness directives AD/R22/54 and AD/R44/22 were introduced and became effective on 18 January 2008, reiterating the requirements of FAA AD 2007-26-12.

Airwolf Aerospace LLC

Accelerated erosion/abrasion of the protective main rotor blade leading edge paint coatings when operated in rain or in dusty environments.

Safety issue

The protective leading edge paint applied to R22 and R44 helicopter main rotor blades is subject to accelerated abrasive erosion and loss when the helicopters are flown in dusty environments or in rain.

Action taken by Airwolf Aerospace LLC

On 25 October 2007, Airwolf Aerospace LLC, USA, was issued FAA supplementary type certificate (STC) approval for the installation of protective rotor blade tape to the leading edges of main rotor blades from model R22 and R44 helicopters (STC SR02491CH). Promotional literature from the company states that the STC "comprises a permanent, one time application of rotor blade protective tape to the outer section of the main rotor blades", and that the "solution obviates the need for ongoing blade inspections and re-spay applications". It was noted however, that the solution may not provide protection against corrosion beneath the internal aluminium tip cap, and as such, the application of the rotor tape may not provide a terminating action for the re-inspection requirements of FAA AD 2007-26-12, CASA AD/R22/54 or AD/R44/22.