Australian Government

Australian Transport Safety Bureau

Robinson R44, VH-YKL

43km NW Kununurra, WA

8 November 2003

INVESTIGATION REPORT

BO/200304546

CONTENTS

INTRODUCTION

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

In terms of aviation, the ATSB is responsible for investigating accidents, serious incidents and incidents involving civil aircraft operations in Australia, as well as participating in overseas investigations of accidents and serious incidents involving Australian registered aircraft. The ATSB also conducts investigations and studies of the aviation system to identify underlying factors and trends that have the potential to adversely affect transport safety. A primary concern is the safety of commercial air transport, with particular regard to fare-paying passenger operations.

The ATSB performs its aviation functions in accordance with the provisions of the Transport Safety Investigation Act 2003. The object of an occurrence investigation is to determine the circumstances to prevent other similar events. The results of these determinations form the basis for safety action, including recommendations where necessary. As with equivalent overseas organisations, the ATSB has no power to implement its recommendations.

It is not the object of an investigation to determine blame or liability. However, it should be recognised that an investigation report must include factual material of sufficient weight to support the analysis and conclusions reached. That material will at times contain information reflecting on the performance of individuals and organisations, and how their actions may have contributed to the outcomes of the matter under investigation. 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.

The 24-hour clock is used in this report to describe the local time of day, Western Standard Time (WST), as particular events occurred. Western Standard Time was Coordinated Universal Time (UTC) + 8 hours.

1 FACTUAL INFORMATION

1.1 History of the flight

On 8 Nov 2003, a Robinson Helicopter Company R44 (R44), registered VH-YKL, and a Bell Helicopter Company 206 (B206), registered VH-FHY, were conducting fishing charter flights from Kununurra to the Cape Dommett area of northern WA. The flights were conducted under the visual flight rules (VFR) and were both single-pilot operations. The R44 had four persons on board (POB) and the B206 had five POB. After the passengers had spent the morning fishing, it was decided between them that several would change seating arrangements between the helicopters for the return journey. At about 1015 western standard time, after the passengers assumed their new seating arrangements, the helicopters took off and flew in company at 500 feet above ground level (AGL), for the return flight to Kununurra.

Approximately 17 minutes later, the pilot of the lead helicopter, the B206, received a radio broadcast from the pilot of the R44 stating that "I am going in hard". The pilot of the B206 immediately banked his helicopter around in a tight right turn and, after assuming a reciprocal heading, observed a mushroom cloud of smoke rising from a nearby ridge. The pilot of the B206 broadcast a MAYDAY[1] to air traffic services (ATS) and began to orbit the accident site. The pilot of the B206 was asked by ATS to look for people moving around the wreckage; none could be seen.

With no signs of life visible, and unable to identify a safe place to land, the pilot of the B206 made an operational decision to continue to Kununurra. The first rescue team to arrive at the site confirmed that all four occupants had received fatal injuries.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others	Total
Fatal	1	3	-	4
Serious	-	-	-	-
Minor	-	-	-	-
None	-	-	-	-

1.3 Damage to aircraft

The helicopter was destroyed by impact forces and post-impact fire.

1.4 Other damage

There was no other damage.

[1] MAYDAY – International radio call for urgent assistance.

1.5 Personnel information

Type of licence	Commercial Pilot (Helicopter) Licence
Medical certificate	Class 1
Flying experience (total hours)	190
Flying experience (on type)	15.6
Hours in the preceding 30 days	18.3

The pilot was issued with a student pilot licence on 22 April 2003. He obtained an endorsement to fly Robinson Helicopter Company R22 helicopters on 7 May 2003 and an R44 endorsement on 16 June 2003. He was subsequently issued with a Commercial Pilot Licence (Helicopter) on 4 July 2003. According to his pilot flying logbook he had accrued approximately 15.6 flying hours on the R44 type, including 8.5 hours as pilot in command.

1.6 Aircraft information

Manufacturer	Robinson Helicopter Company
Model	R44 Astro
Serial number	0170
Registration	VH-YKL
Year of manufacture	1995
Certificate of airworthiness	Issued 18 May 1995
Certificate of registration	Issued 15 March 2000
Maintenance release	Valid to 3,118.6 hours or 23 Oct 2004[2]
Total airframe hours	Approximately 3,028.7 hours
Allowable take-off weight	1,090 kg
Allowable centre of gravity limit	Not less than 2,362.2 mm
Centre of gravity at occurrence	2,334 mm

1.6.1 Aircraft certification

The aircraft was manufactured in the US and was certified as a normal category helicopter complying with the requirements of Federal Aviation Regulation 27[3] (FAR 27).

1.6.2 Recent maintenance history

The helicopter had been maintained as a visual flight rules (day) capable, Class B[4] maintenance category helicopter, in accordance with the manufacturer's technical

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2 Whichever occurred first.

3 Airworthiness Standards – Normal Category Rotorcraft

4 A *class A aircraft* means an Australian aircraft, other than a balloon, that satisfies either or both of the following paragraphs:

(a) The aircraft is certificated as a transport category aircraft;

(b) The aircraft is being used, or is to be used, by the holder of an Air Operator's Certificate which authorises the use of that aircraft for the commercial purpose referred to in Civil Aviation Regulations (1988) 206 (1) (c). A *class B aircraft* means an Australian aircraft that is not a class A aircraft.

documentation and Civil Aviation Safety Authority (CASA) continuing airworthiness requirements.

The last recorded scheduled maintenance on the helicopter was a 100-hourly inspection completed on 23 October 2003, 15 days before the occurrence. At that time the helicopter had completed 3018.6 hours total time in service (TTIS). Post-maintenance engine ground runs were carried out with no defects recorded. The helicopter had accrued a further 10.1 hours time in service after the 100 hourly until the time of the occurrence.

The last recorded unscheduled maintenance activity was on 6 November 2003, when a high engine oil operating temperature was reported. An engine oil cooling system component, the oil vernatherm valve[5], was changed and a subsequent test flight proved that the engine temperatures had returned to normal.

1.6.3 Quality of the fuel

Due to the post-impact fire it was not possible to obtain fuel samples from the R44. The tanker trailer used to fuel the R44 was a central fuel source for the operator's piston-engine fleet. A fuel sample from the tanker, the source of the fuel in the R44, was quarantined by the ATSB. Following discussions with the Coroner, and the ATSB investigation establishing that there had been no other fuel related events involving other aircraft that had used the same fuel source, custody of the fuel sample was passed to the Coroner.

1.6.4 Aircraft operating weight

The empty weight of the R44 was recorded as 651.5 kg. The pilot of the B206 reported that all heavy baggage was loaded into the B206 to save weight in the R44. The pilot of the B206 also reported that the passengers of the R44 were only carrying small items such as cameras and fishing reels. An allowance of 2 kg per person was made to cover those items and some items carried by the pilot. Those items were observed in the wreckage trail and main wreckage site.

At the time of the occurrence, the investigation estimated that the R44 had approximately 90 L of fuel on board. The ATSB sought advice from the manufacturer about the fuel distribution and was advised that it would have been 62.4 L in the left (main) tank and 27.6 L in the right (auxiliary) tank. The R44 also carried a standard equipment pack as listed in the operations manual. A water bottle weighing 5 kg and a drum fuel pump, which would normally be carried in the helicopter as standard equipment, were off-loaded by the pilot and were later found in the hangar. The operator reported that the pack, less the water bottle and pump, weighed 10.9 kg. That weight, combined with the weights of the four occupants[6], placed the helicopter all up weight estimation at the scene of the occurrence at 1,117 kg. That figure exceeded the MTOW by 27 kg. The longitudinal centre of gravity was also calculated as having a forward arm of 2,334 mm, which was outside the published forward limit.

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[5] Valve directs engine oil to the oil cooler once the engine has reached a certain operating temperature.

[6] The weights of the occupants were established by description by next of kin and recent medical records.

1.7 Meteorological information

A warm low pressure system was situated over the inland Kimberley with hot and humid conditions prevailing over the north of the region. Isolated afternoon and evening showers and thunderstorms were forecast for the Kununurra area. The Bureau of Meteorology stated that those conditions were a fairly common occurrence during November.

Bureau of Meteorology surface observations and satellite imagery indicated fine weather in the Kununurra area during the morning between 0800 and 1200. Scattered convective cumulous clouds started to develop after 1100, but there was no shower or thunderstorm activity evident.

It was normal for high ambient day time temperatures in this region. This was a factor in planning the trip for early morning in order to have the clients returned home before the heat of the day. The pilot of the B206 did not report any weather conditions during the morning that could have contributed to the occurrence. The passengers in the B206 reported flying through some turbulence just prior to the occurrence.

1.8 Aids to navigation

The R44 was fitted with a global positioning system (GPS) navigation unit that was mounted on the instrument panel glare shield. This unit recorded a positional fix in latitude and longitude, track bearing and a time stamp for each recorded track point. It did not record helicopter altitude.

The recorded GPS flight track data revealed that the helicopter had taken off at 1015:58 from the Cape Dommett area and, after four minutes of manoeuvring, had initially tracked on a heading of 153 degrees true to Kununurra. The recorded ground speed for the R44 ranged from 86 kts at 1019:40 to 102 kts at 1024:05. The heading then changed slowly, beginning at 1029:02 and settled on a heading of 170 degrees true at 1030:40, while the helicopter maintained a groundspeed of about 97 kts.

That heading and groundspeed was maintained until between 1033:02 (last track point with the helicopter on a heading of 170 degrees) and 1033:10 (next GPS recorded track point) at which time the helicopter’s heading started to change and the speed started to decay. The heading continued to change until 14 seconds later at 1033:24 (last GPS track point), when the helicopter had a groundspeed of 48 kts on a heading of 266 degrees true. This track point aligned closely with the initial ground impact point.

1.9 Communications

The pilot of the B206 was in radio contact with the pilot of the R44 by radio, using a frequency allocated by the operator. Immediately after the accident site was identified by the pilot of the B206, he broadcast a MAYDAY to ATS, which was acknowledged. Apart from the initial radio broadcast by the pilot of the R44, no further communications were received from the occurrence helicopter.

1.10 Aerodrome information

Not a factor in this occurrence.

1.11 Flight recorders

The aircraft was not fitted with a flight recorder or a cockpit voice recorder, nor was there any legislated requirement to do so.

1.12 Wreckage and impact information

1.12.1 General

The accident site (Figure 1) was located on the western side of a small hill in remote country 43 km NW of Kununurra. The helicopter initially collided with a tree about 36 ft AGL, just below the crest of a hill with a 12 percent slope, and then impacted with rough boulder-strewn terrain.

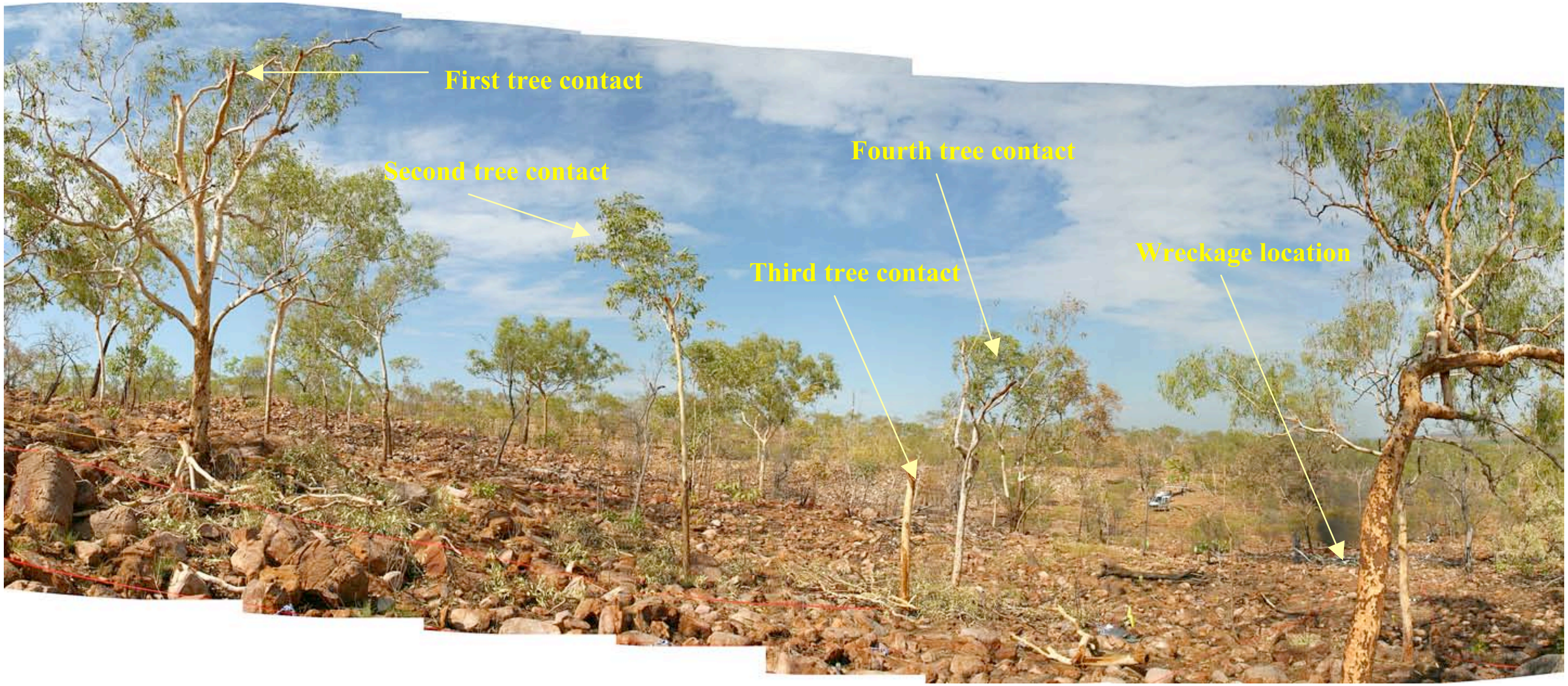
Figure 1: General view of wreckage

Four trees, close to the line of flight (Figure 2) were observed to exhibit varying degrees of damage from contact with the helicopter. Contact with these trees shattered the main rotor blades into numerous fragments that were scattered in the early portion of the debris path. During this contact, one main rotor blade also contacted the tail boom.

Six metres to the right of the fourth tree, ground strike marks attributed to main rotor blade fragments were observed, with other blade debris scattered between the second and fourth tree. The extensive damage to the main rotor blades was consistent with high energy in the rotor system at the time of impact.

The tail boom contacted the base of the third tree and dislodged the tail rotor gearbox from its mount plate. Witness marks on the tree trunk from the tail rotor gearbox and pitch change mechanism (Figure 3) placed the helicopter in an approximate 37 degree nose-up and near wings-level attitude when the gearbox impacted the tree.

Figure 2: Panoramic view of accident site with damaged trees



The fuselage continued on a bearing of 282 degrees, pitched nose down and impacted the down slope of the hill 25 m from the initial tree contact. The helicopter then came to rest on a reciprocal heading, on its left side, 38 m from the initial tree contact. A post-impact fire ensued, which consumed most of the wreckage.

1.12.2 Flight controls

Steel flight control hardware was located amongst the ash and appropriate flight control system locking devices were identified by the investigation team. Because of the loss of aluminium components such as control tubing due to the fire, it was not possible to verify the integrity of the flight control runs throughout their entire length. However, all steel components associated with the collective and cyclic flight controls were found in their expected locations. Cyclic trim and engine governor electrical components were also destroyed and their remnants identified in the debris. The flight control pushrods for cyclic and collective input at the swashplate were found connected and appropriately locked.

The main rotor pitch change link rod ends were also found appropriately locked. One pitch change link had failed through overload during the impact sequence. The blade droop stops, up-coning stops and tusks were examined and found to exhibit contact marks. The tail rotor pedals, lateral torque shafts and mounting hardware were thrown clear of the main wreckage as a complete assembly during the break up sequence.

Figure 3: Tail rotor gearbox assembly tree imprint

Although damaged by a main rotor blade strike, the tail rotor push-pull tube was found within the tail boom. It had failed through overload at the input connection to the pitch change mechanism when the tail rotor gearbox was separated from the tail boom by impact forces with the third tree. The clutch driveshaft was examined and found intact and still connected to the main gearbox.

The tail rotor drive shaft was found with a torsional twist in the shaft section immediately aft of the upper pulley sheave. That torque twist was indicative of sudden stoppage of the tail drive section while the drive train forward of that continued to rotate. The damage was consistent with the tree contact described earlier (Figure 3).

All major components of the helicopter were accounted for at the crash site.

1.12.3 Cockpit switching and instrumentation

Post-impact fire damage to cockpit switches, controls and instruments precluded further examination.

1.12.4 Powerplant

All powerplant ancillary components such as wiring harnesses, magnetos and carburettor were destroyed by the impact and post-impact fire, which precluded their examination. The remnant powerplant was removed from the accident site for later examination. Technical examination of the powerplant revealed no defect that could have contributed to the occurrence.

1.13 Medical information

The pilot’s aviation medical certificate was valid and had no restrictive endorsements.

There was no evidence to suggest that the pilot suffered any sudden illness or incapacity that may have affected his ability to control the helicopter. There was also no evidence that physiological or psychological factors had adversely affected his performance.

1.14 Fire

There was no evidence of an in-flight fire. During the impact sequence the aircraft’s fuel tanks were ruptured and a post-impact fire ensued, which consumed the wreckage.

1.15 Survival aspects

Three-point lap/sash type seat and shoulder harnesses were fitted to all four seating positions in the helicopter. On-site examination revealed that all seat belts were fastened at the time of impact. The accident was not considered survivable.

1.16 Tests and research

1.16.1 Tests

The main rotor blade segments were all located and accounted for on site. The on-site investigation team identified some damage to the second main rotor blade (blade 2) that appeared consistent with aerodynamic peeling of the skin from the blade. That apparent anomaly required closer technical examination. The retrieved parts were taken for further off-site examination (refer to technical analysis report at Appendix A) by the ATSB.

The examination revealed that, although somewhat burned, the skin of this blade showed evidence of having folded forward along most of the separated length, producing a characteristic crease immediately behind where the back edge of the leading edge spar would normally be located. Such a feature was consistent with the damage being produced during physical break-up of the blade during the accident. The creasing would not be expected if the skin had lifted due to de-bonding and aerodynamic effects.

1.16.2 Research

A number of accidents had been documented overseas in which low gravitational forces were implicated. In 1996, as a result of those accidents, the United States of America (US) National Transportation Safety Board (NTSB) released special investigation report *NTSB/SIR-96/03 - Robinson Helicopter Company - loss of main rotor control accidents*. This research stated in part that:

> Large, abrupt control inputs could lead directly to mast bumping or induce blade stall, which in turn could lead to mast bumping. Turbulence may produce blade stall or lead pilots to make large control inputs. Some low-G manoeuvres initially resulted from deliberate control inputs, but at times these may be followed by larger inputs during recovery from the low-G situation that may lead to loss of main rotor control.

In addition, the helicopter manufacturer’s R44 Pilot Operating Handbook stated that:

> LOW-G[7] PUSHOVERS - EXTREMELY DANGEROUS[8]
>
> Pushing the cyclic forward following a pull-up or rapid climb, or even from level flight, produces a low-G (weightless) flight condition. If the helicopter is still pitching forward when the pilot applies aft cyclic to reload the rotor, the rotor disc may tilt aft relative to the fuselage before it is reloaded. The main rotor torque reaction will then combine with tail rotor thrust to produce a powerful right rolling moment on the fuselage. With no lift from the rotor, there is no lateral control to stop the rapid right roll and mast bumping can occur. Severe in-flight mast bumping usually results in rotor blade contact with the fuselage and/or main rotor shaft separation.
>
> The rotor must be reloaded before lateral cyclic can stop the right roll. To reload the rotor, apply an immediate gentle aft cyclic, but avoid any large aft cyclic inputs. (The low-G which occurs during a rapid autorotation entry is not a problem because lowering collective reduces both rotor lift and rotor torque at the same time.)
>
> Never attempt to demonstrate or experiment with low-G manoeuvres, regardless of your skill or experience level. Even highly experienced test pilots have been killed investigating the low-G flight condition. Always use great care to avoid any manoeuvre which could result in a low-G condition. Low-G mast bumping accidents are almost always fatal.

The helicopter’s main rotor was examined for mechanical evidence of possible low-G event induced contact between the mechanical stops that limit main rotor droop, teeter

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7 G – The force acting on a body or thing by the earth’s gravitation.

8 Robinson Helicopters R44 Pilot Operating Handbook Safety Notice SN-11.

and up-coning. The spindle tusks were also examined. The blade spindle up-coning stops exhibited evidence of minor surface scraping contact with the hub. There was no evidence of abnormal rotor conditions on any of the remaining surfaces.

1.17 Organisational information

1.17.1 Aircraft operator

The operator utilised a large fleet of both piston and turbine helicopters to conduct mustering, tourism and various other activities in remote areas of Australia.

The operator held a valid Air Operator's Certificate (AOC) issued by CASA that authorised charter and aerial work activities in accordance with certain schedules attached to the AOC. Those schedules identified each helicopter type that met the company requirements for each activity listed. The R44 was listed in Schedule 2 titled Charter Operations, as an acceptable helicopter type for charter operations.

Civil Aviation Regulation (CAR) 215 required an operator to provide an operations manual for the use and guidance of their personnel. The manual provided the minimum experience requirements for flight crew, when operating single engine VFR helicopters not above 2,750kg maximum take off weight (MTOW), in the charter category. Those requirements stated that pilots must hold a:

- Commercial Pilot (Helicopter) Licence
- type or class endorsement
- minimum of 5 hours as pilot in command or acting as pilot in command under supervision on the helicopter type.

1.17.2 Checking and training

The operator did not have a requirement under CAR 217 for a Training and Checking organisation, however, it was approved to operate a helicopter flying school. That approval was entered on the AOC. The school's Chief Flying Instructor (CFI) was appointed in March 2003. He had industry wide experience that included Chief Pilot, Chief Flying Instructor (CFI) and Flying Operations Inspector. He stated that he had conducted all flight training for the occurrence pilot. He was also a CASA Approved Training Officer.

The CFI who conducted all of the occurrence pilot's training stated that he had found him to be a cautious student with a professional attitude, who was good at assimilating the training and flew both the R22 and R44 types particularly well. He described the occurrence pilot as 'having a common sense approach to his flying and was not a risk taker'. The CFI related that, during autorotation training at the school, the occurrence pilot had successfully demonstrated practice autorotation descents to the flare, with a power-on recovery.

He also stated that the occurrence pilot had been rigorously trained by the CFI to include the nature of his emergency, if he had identified it, in any radio transmission he made. These would include "engine failure", "drive belt failure" or "tail rotor failure" for any of these serious emergencies. The student was required to annunciate the nature of each identified emergency to the instructor, which allowed him to confirm the student's correct assessment of the situation. The occurrence pilot did not make any such reference in his only radio transmission on the occurrence flight.

1.17.3 Passenger list and flight note

The operator's operations manual stated that:

> For all passenger carrying flights, other than standard tourist flights, a passenger list on a Pax/Cargo List & Flight Note[9] shall be compiled and left at the place of departure in the custody of a Company representative or other responsible person.

The manual provided information regarding the use of standard weight calculations that used a chart for all passenger carrying activities with a maximum seating capacity (including crew) of between seven and fourteen. Load calculations for all of the operator's helicopters with less than seven seats, which included the occurrence helicopter, were to be made using actual weights for all passengers and baggage.

The manual also stated that:

> If a passenger embarks or disembarks at an intermediate stopping place, a new List must be completed, and a copy left at that place, except where that particular change had been notated on the List left at the initial aerodrome of departure.

A flight note was left at Kununurra that included details for both the R44 and the B206. That flight note did not detail passenger names or weights, and did not contain a change of passenger details covering the passenger exchange prior to takeoff for the return flight. Those actions were not in accordance with the published requirements of the operator's operations manual.

1.18 Additional information

1.18.1 Digital imagery

Digital imagery retrieved from the front seat passenger's camera allowed the investigation team to compare the time stamp of the stored images with the GPS track point timings and topographical maps of the area and then to overlay the track onto the map aligned with known features. Some of the helicopter's operating information was also obtained from those images. The images depicted some instrument readings both during the start and warm up, and in flight. The image of the helicopter's instruments taken while in flight at time 1023:22[10] showed that their respective parameters were within the normal operating range for the helicopter as listed in the R44 operating handbook. There were no other images depicting cockpit instrumentation captured in the camera during the next ten minutes of flight. The heading and speed changes recorded on the GPS just before the accident occurred, were three minutes and fifty-two seconds after the last image was stored in the camera memory.

1.18.2 Autorotation and flight handling techniques

In an engine-off situation, helicopters are designed to enter a glide, known as autorotative flight. During an autorotation, airflow through the main rotor, drives and maintains rotor RPM. Depending on the weight of the helicopter, appropriate manipulation of the flight controls by the pilot is required to keep the RPM within a range specified by the helicopter manufacturer to achieve a successful outcome. The

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9 Pax/Cargo List & Flight Note was an approved company document that combined the functions of passenger (Pax) manifest, cargo manifest and flight note.

10 Time corrected to align with GPS derived times discussed in section 1.8.

stored energy in the rotor is utilised by the pilot when terminating the descent close to the ground to slow the helicopter's speed and rate of decent to nearly zero, and land safely at a chosen point.

The helicopter manufacturer published information about autorotative descent configurations[11] in the pilot's operating handbook as follows:

> MAXIMUM GLIDE DISTANCE:
>
> 1. Airspeed approximately 90 knots indicated air speed (KIAS)
> 2. Rotor RPM approximately 90%
> 3. Best glide ratio is about 4.7:1 or one nautical mile per 1300 feet above ground level (AGL)
>
> MINIMUM RATE OF DESCENT:
>
> 1. Airspeed approximately 55 KIAS
> 2. Rotor RPM approximately 90%
> 3. Minimum rate of descent is about 1350 feet per minute.

The published figures for minimum rate of descent showed that an autorotative descent from cruise height in this occurrence would have taken approximately 22 seconds. In an autorotative descent using best glide distance configuration, the figures showed the expected travel distance for the R44 would have been approximately 712 m for that elapsed time.

The recorded GPS track points showed approximately 22 seconds of flight after the R44 departed from track. The GPS recorded a position change of approximately 757 m for that period. The GPS record also showed that the helicopter did not slow to less than 48 kts of forward airspeed prior to the last recorded GPS track point.

1.19 New investigation techniques

Not relevant to this investigation.

[11] Robinson Helicopters R44 Operating Handbook Section 3.3.

2 ANALYSIS

The pilot had undergone training by an approved organisation on the helicopter type and was well regarded by his CFI. During the course of that training, he had also conducted a number of practice autorotations, and had successfully executed power-on recoveries to the flare. The pilot in command also met the operator's minimum flying experience requirements listed in the operations manual to conduct the occurrence charter flight.

The absence of passenger information on the flight note indicated that an accurate calculation of MTOW was probably not conducted, and the pilot was probably not aware of the helicopter's actual take-off weight and centre-of-gravity position.

The occurrence pilot had been trained by the CFI to habitually include the nature of any emergency in his radio transmission if it had been identified. These identifiable failures would prompt calls of 'engine failure', 'drive belt failure' or 'tail rotor drive failure' as part of the emergency radio transmission. The occurrence pilot did not identify the nature of the emergency in his brief radio transmission.

Due to the destruction of the engine the investigation was unable to determine the amount of power being produced by the engine immediately prior to impact.

The investigation team examined a number of reasons for the helicopter diverging from the planned flight path track.

While prevailing weather conditions were unlikely to have contributed to the occurrence, the effect of an upset due to turbulence leading to large control inputs by the pilot and a possible low-G manoeuvre could not be ruled out. The physical evidence that would point to this type of event would be damage to the blade flapping restraint components. In extreme examples of this phenomenon, the main rotor mast may exhibit damage from contact by the main rotor head as it reached a teetering and or flapping limit. Also separation of the main rotor mast and severing of the tail boom structure are not uncommon in such situations and would have been evidence of a possible low-G occurrence.

The main rotor mast of the R44 was examined and no evidence that might be attributed to low-G manoeuvre, to the extent that mast bumping had occurred, was observed. The blade droop stops, up-coning stops and tusks were also examined and found to exhibit contact marks consistent with the normal range of rotor blade movement. The marks consisted of minor surface scraping. The investigation was unable to determine when the marks occurred.

The damage to the tail boom, evident at the accident site, was considered to be as a result of a main rotor blade contacting it after the first main rotor blade tree strike during the break up sequence.

Given the similarity of distance covered, and the flight time after the divergence from track when compared with the published figures, it was also possible that the R44 was established in autorotational flight, and that the pilot initiated a right turn to a selected forced landing site.

The metallurgical evidence indicated high energy in the rotor system. This could indicate that the pilot may have been terminating the flight in a forced landing autorotative manoeuvre, or may have been in the midst of a recovery manoeuvre such as that required for a low-G event recovery.

If the pilot had been executing an autorotation, the high gross weight of the helicopter would have assisted him in maintaining optimum rotor RPM, if the autorotation procedures recommended by the helicopter manufacturer had been followed. However, the pilot would have had to use an amount of aft cyclic input to the flight controls to counteract the effects of the forward centre of gravity. If he had been attempting an autorotative landing, the forward centre of gravity may have compounded the already aft cyclic position and adversely affected his ability to flare the helicopter to the extent required to arrest the descent and reduce forward groundspeed. This may have resulted in a heavier than intended landing and a higher than intended groundspeed and may have been the reason for the pilot's broadcast that he was going in hard. It was unlikely that the pilot had previously conducted an autorotation at MTOW and/or with a forward centre of gravity in the occurrence helicopter type.

The helicopter was most likely under the control of the pilot until the moment it contacted the trees at approximately 36 feet AGL with a groundspeed of about 48 knots. From that point, the helicopter departed from controlled flight due to the damage to the main rotor system caused by impact with the trees. Given that the short radio transmission by the pilot of the R44 did not allude to a specific problem, and in the absence of witness reports of the occurrence, and the lack of physical evidence due to post-impact fire, the reason(s) for the descent from cruise altitude, and the subsequent impact with terrain could not be established.

3 CONCLUSIONS

3.1 Findings

1. The R44 departed cruise flight in a descending right turn approximately 17 minutes after take off from the Cape Dommett area.

2. The R44 first contacted trees at a height of 36 ft AGL.

3. The R44 was approximately 27 kg over the MTOW for the helicopter type at impact.

4. The R44 centre of gravity was outside the forward limit for the helicopter type at impact.

5. The accident was not survivable.

4 SAFETY ACTION

LOCAL SAFETY ACTION

As a result of the accident, the operator has highlighted to its pilots the requirements contained in the operations manual, and reiterated the importance of calculating the centre of gravity position prior to flight.

Appendix A: Technical Analysis Report BE/200300032

TECHNICAL ANALYSIS REPORT

Report No. 11/04

Task No. BE/200300032

Updated July 2006

Examination of Main Rotor Blade Damage

Robinson Helicopter Co. R44, VH-YKL

8 November 2003

1. FACTUAL INFORMATION

1.1 Examination brief

As part of the Australian Transport Safety Bureau's investigation into the fatal helicopter accident involving Robinson Helicopter Company model R44, registered VH-YKL, the ATSB Technical Analysis Unit was requested to evaluate the damage exhibited by the main rotor blades following the event. The examination brief was to determine as far as practically possible, the likely levels of main rotor drive power during the accident, and also to evaluate the nature of the damage sustained for any indications of pre-existing deterioration, damage or faults that may have presented helicopter controllability problems to the pilot.

1.2 Samples received

A preliminary examination of the main rotor assembly was carried out at the accident site, 43 km north-west of Kununurra, Western Australia. All major sections of the rotor blades and mounting assemblies were accounted for at that time and a brief structural evaluation was conducted.

The main rotor blades fitted to the helicopter were identified as follows.

- Part No. C106-2 Rev. U, Serial No. 4186-A
- Part No. C106-2 Rev. U, Serial No. 4202-A

All blade wreckage items were recovered from the accident site and forwarded to the ATSB's Canberra laboratories for more detailed examination.

1.3 Blade information

The main rotor blades installed on the helicopter were constructed using a continuous leading edge steel 'D-spar' which connected to the aluminium alloy root fitting via a step-wise transverse bolting arrangement. The main aerofoil section of the blades comprised an expanded metallic honeycomb, encapsulated and bonded to a stainless steel sheet skin. The forward edges of the skin were adhesively bonded to the surfaces of the D-spar over a width of approximately 14 millimetres. A shallow step in the surfaces of the D-spar allowed for the thickness of the skin and bonded joint.

The blades fitted to the helicopter had been installed as a new set at an aircraft total-time in service of 2,142.6 hours. At the time of the accident, the blades had accumulated approximately 886 hours of operation, with no serviceability problems or repair work recorded in the maintenance documentation.

1.4 Visual examination

Both main rotor blade units from the helicopter had sustained severe breakage and fragmentation as a result of multiple impacts. The leading edge D-spars had fractured in multiple locations and sustained gross bending deformation about the fracture locations. Small ground fires, ignited during the accident, had damaged some localised areas of blade skin and core honeycomb, and the root fitting and hub of blade S/N 4186-A had also sustained moderate fire damage.

1.4.1 Blade S/N 4186-A aerofoil section

As recovered, the leading edge spar of main rotor blade serial number 4186-A had fractured into five sections, with the bulk of the damage occurring within the outermost 1,500 mm of the blade length (Annexes 3.1 & 3.2). The honeycomb cored aerofoil section behind the spar had fragmented into numerous pieces, ranging in length from 350 mm to nearly 1,000 mm, with a notable transition to smaller fragments along the blade length toward the tip. Separation of the blade skin from the leading edge spar had again occurred in most areas by ductile tearing along the inner edge of the adhesive joint. Some adhesive failure of the joint was noted, where the aerofoil skin had curled and peeled away axially along the blade length.

The fractures of the leading edge spar were typical of overload initiated ductile failures, with most fracture points towards the tip end of the spar occurring between the segments of leading edge weighting material. Multiple hard object impact signatures were evident along the spar length.

1.4.2 Blade S/N 4186-A root fitting and hub

The leading edge spar had separated from the root fitting at the outer end of the bolted connection and the skin had torn around the base of the doubler sheets on the upper and lower aerofoil surfaces. The spar separation was typical of ductile fracture under localised bending overloads, and a close inspection of the fracture found no evidence of pre-existing cracking or other potentially contributory defects.

The hub components had been exposed to a ground fire after the accident and had sustained moderate surface charring and discolouration as a result. Despite that damage, the assembly was examinable (figure 1) and showed no evidence of abnormal rotor conditions. The spindle tusk showed no evidence of impact or abnormal loading and the hub teeter stop and up-coning stop contact surfaces showed no unusual markings or damage, other than a band of disrupted paint on the blade spindle that indicated contact with the up-coning stop at some time prior to or during the accident. The pitch-change linkage was not connected to the pitch horn when the blade hub was examined, having been disconnected at the accident site in preparation for transport to the ATSB's laboratories. The bore of the interconnecting pitch link bolt hole showed distortion and scoring damage consistent with exposure to heavy forces through the pitch link and bolt.

Figure 1: Hub assembly of blade S/N 4186-A showing general sound condition and absence of gross mechanical damage. Contact against the up-coning stops was evident (arrowed).

1.4.3 Blade S/N 4202-A aerofoil section

As recovered, the main rotor blade serial number 4202-A had fractured transversely into five main sections, with the leading edge spar in four sections (Annexes 3.3 and 3.4). The leading edge spar had separated from the aerofoil sections for the full length of the blade, with the separation occurring almost entirely by ductile tearing of the surface skin along the rear edge of the spar. A 470 mm length of upper aerofoil skin, extending from the tip of the blade, had separated from the leading edge spar by failure of the adhesive joint. Although fire damaged, the separated skin showed backward folding and curling away from the joint in a manner that suggested aerodynamic effects (figure 2). That area of skin separation, being atypical of the rest of the blade skin damage, was the subject of a more detailed examination as documented in section 1.5 of this report.

Figure 2: Area at the tip of blade S/N 4202-A that exhibited backward peeling separation of the skin from the leading edge spar.

All fractures of the leading edge spar showed features typical of ductile tearing under gross bending overloads. Many of the spar sections also showed evidence of hard object impacts adjacent to the points of fracture. In general, the spar and aerofoil sections of blade S/N 4202-A showed lengthwise upward bending characteristics, particularly where the spar section had sustained localised buckling. Two areas of red paint transfer were noted on the upper surfaces of the leading edge spar – a small area at approximately 2,775 mm from the hub base and a larger region encompassing approximately 250 – 300 mm, starting at 3,300 mm from the hub base.

1.4.4 Blade S/N 4202-A root fitting and hub

The root fitting and hub of this blade had separated from the main aerofoil length by the fracture of the leading edge spar at the outermost end of the root fitting. The blade skin behind the fracture had torn around the end of the skin doubler sheets that overlayed the root fitting.

General examination of the hub (after on-site removal from the rotor head) showed little external mechanical damage to the spindle, with the spindle tusk and teeter stop showing no evidence of abnormally heavy contact (figure 3). The upper spindle surfaces showed evidence of contact against the up-coning stop at some stage prior to or during the accident sequence. Tearing and abrasion of the hub sealing boot was typical of accident-induced damage. The pitch change linkage had fractured through the base of the rod-eye at the horn end of the assembly – the fracture showing bending overload features.

Figure 3: Hub assembly of blade S/N 4202-A – contact against the up-coning stop shown at arrows.

1.5 Skin separation

As revealed during the general examination, blade S/N 4202-A showed a 470 mm long area of upper aerofoil skin that had separated from the leading edge spar and rolled backward, suggesting aerodynamic influences. The skin separation had occurred by failure of the adhesive joint between skin and spar, exposing the adhesive material which remained predominantly on the spar surface. To characterise the mechanism of joint failure, a section of the spar containing an area of comparatively undamaged adhesive (figure 4) was removed and compared against a similar area where the adhered skin had been mechanically peeled away in the laboratory (figure 5). Comparison involved optical and electron microscopy of the adhesive base and the skin under-surface (bonded surface).

The observations made during examination of the separated skin joints indicated that both were very similar in physical appearance. Both showed a predominantly adhesive failure at the skin interface, with isolated areas of cohesive failure of the bonding agent around small voids that were dispersed throughout the joint. In no area was there any evidence of pre-existing bond failure or indications that the bonding agent was breaking down or failing.

Figure 4: This image is a low magnification SEM view of the surface of the adhesive along the leading edge spar to skin joint found separated after the accident. The image shows a mixture of adhesive failure (area A) and cohesive failure (area B).

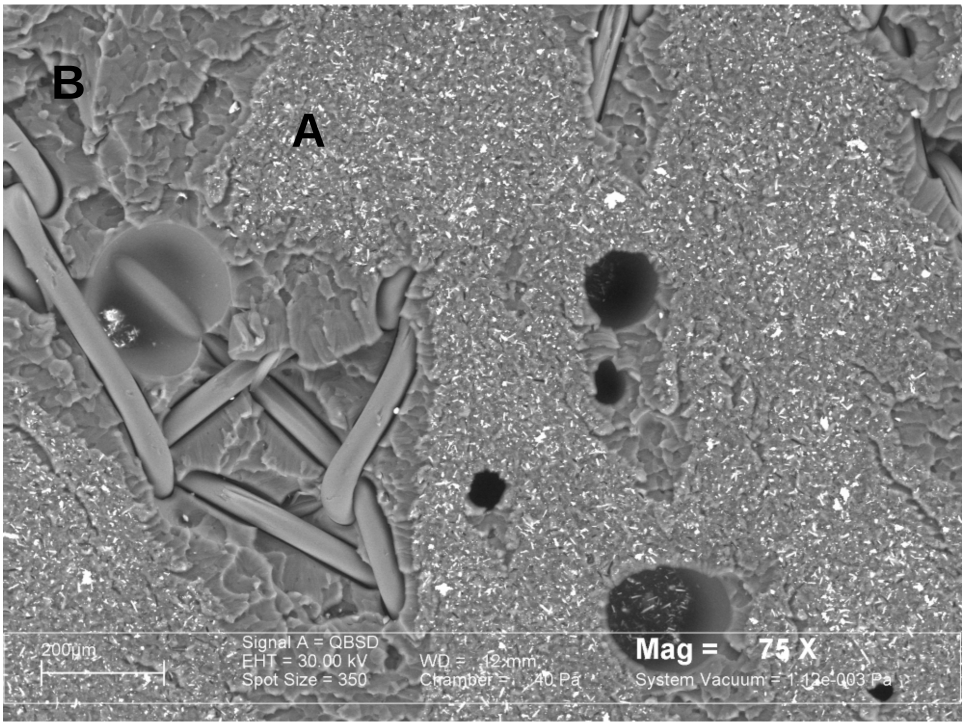
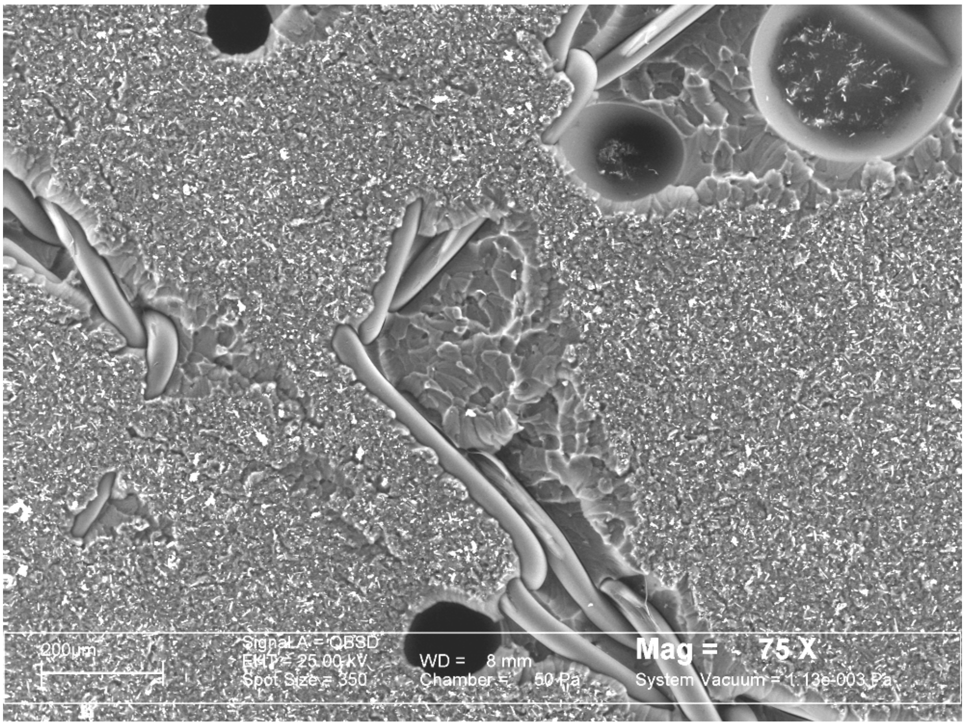


Figure 5: This image is a SEM view of the surface of the adhesive along the leading edge spar to skin joint that was separated mechanically in the laboratory. Note the general similarities to figure 4 above.



2. ANALYSIS

2.1 Blade damage

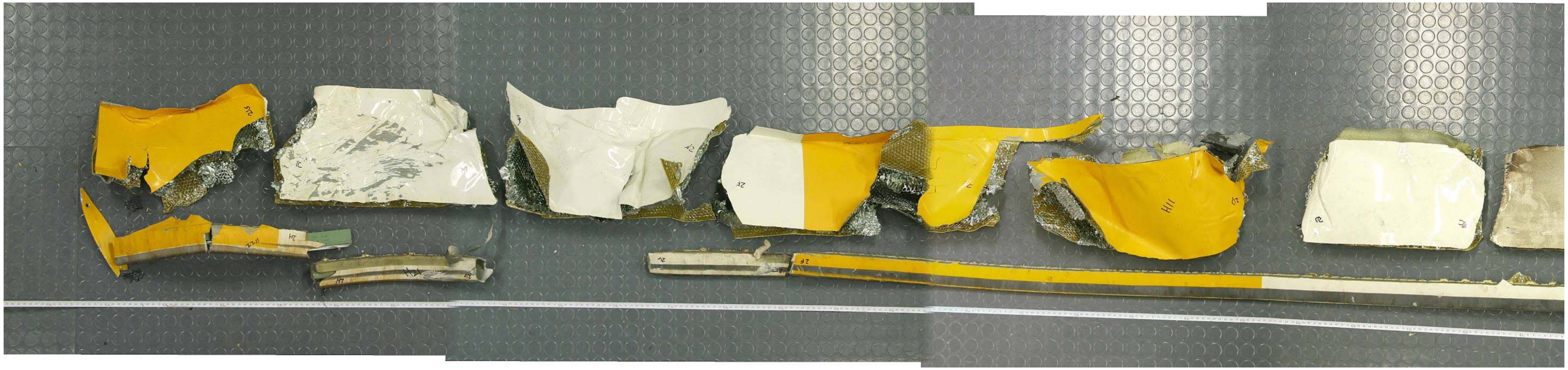
Both main rotor blades from the helicopter had sustained extensive mechanical damage as a result of impact with terrain during the accident. All physical fractures and fragmentation of the blade structure were entirely consistent with overload forces sustained during the event. The examination did not find any evidence of pre-existing faults or defects within the structure of the main rotor blades, nor did it find any significant evidence of abnormal main rotor behaviour or loss of main rotor control at any time prior to, or leading up to the accident.

The lifting of the skin from the upper edge of the leading edge spar at the tip of blade S/N 4202-A was shown by examination to have characteristics consistent with a peeling or rolling type separation under forces sustained during the ground impacts. There was no evidence to indicate that the separation had occurred in-flight.

The extent of physical fragmentation of the rotor blades, particularly the leading edge spars, suggests that the main rotor system was operating at speed with high rotational inertia when it encountered the terrain during the accident.

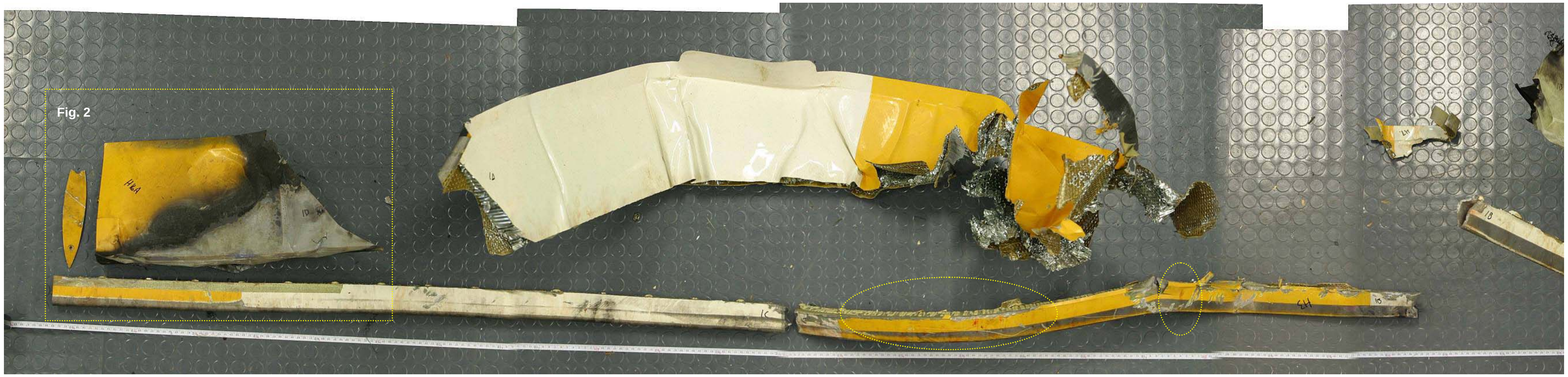
3. Annexes

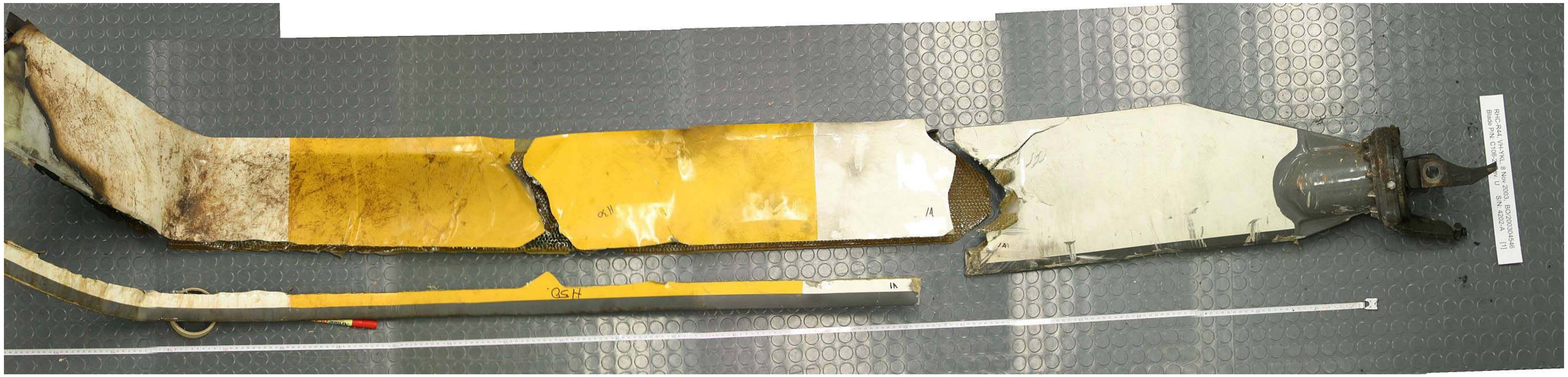
3.1 Blade S/N 4186-A – upper surface montage image



3.2 Blade S/N 4186-A – lower surface montage image

3.3 Blade S/N 4202-A - upper surface – montage image (paint transfer marks circled)





3.4 Blade S/N 4202-A - lower surface – montage image