## ACCIDENT

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|---|---|---|
| **Aircraft Type and Registration:** | Robinson R22 Beta, G-OODX | |
| **No & Type of Engines:** | 1 Lycoming O-320-B2C piston engine | |
| **Year of Manufacture:** | 1987 (Serial no: 720) | |
| **Date & Time (UTC):** | 1 August 2018 at 1248 hrs | |
| **Location:** | Near Naunton Beauchamp, Worcestershire | |
| **Type of Flight:** | Private | |
| **Persons on Board:** | Crew - 1 | Passengers - 1 |
| **Injuries:** | Crew - None | Passengers - 1 (Minor) |
| **Nature of Damage:** | Extensive | |
| **Commander's Licence:** | Private Pilot's Licence | |
| **Commander's Age:** | 46 years | |
| **Commander's Flying Experience:** | 220 hours (of which 100 were on type)<br>Last 90 days - 18 hours<br>Last 28 days - 4 hours | |
| **Information Source:** | AAIB Field Investigation | |

### Synopsis

During a flight from Culworth in Northamptonshire to Worcester, drive was lost to the main rotor. The pilot established the helicopter in autorotation but as he flared for landing the tail struck the ground and the helicopter rotated forward before coming to rest. The pilot and passenger were able to exit the helicopter with minor injuries.

The investigation found that both drive belts between the engine and drive shaft had failed but the cause of that failure was not determined.

### History of the flight

On the day of the accident the pilot hired the helicopter from Denham Aerodrome and flew to a private site near Bedford. He then flew from Bedford to a private site near Culworth in Northamptonshire. The pilot then planned to fly from Culworth to a private site near Worcester, taking off at 1218 hrs. He reported that the first two flights were uneventful. He recalled seeing the clutch light illuminate for approximately one second on two occasions after leaving Bedford and again on two occasions on the accident flight.

The pilot reported that whilst cruising at 800 ft and 80 kt he heard a sudden bang, the helicopter "aggressively" yawed to the left, he heard the low rpm horn and saw the clutch light illuminate. He initially established the helicopter in autorotation at 60 kt but then reduced the speed to 30 kt to reduce the range and reach a suitable field. During the descent, the pilot pulled the clutch circuit breaker because the clutch light had been illuminated for some time.

He recalled that the low rpm horn was sounding throughout the descent. As the helicopter approached the ground, the pilot flared but this did not sufficiently arrest the descent rate and the tail of the helicopter struck the ground followed by the skids.

**Figure 1**

G-OODX after the accident (provided by the operator)

The pilot recalled the helicopter rotated forward one or two times before coming to a halt. The pilot and passenger were able to exit the helicopter without serious injury.

**Helicopter examination**

The AAIB did not attend the accident site. After initial assessment, the AAIB authorised the helicopter operating company to photograph the scene (Figure 1 and 2) and transport the wreckage back to their premises.

They reported that the drive belts were missing when the aircraft was examined initially. An extensive search was carried out using both a camera equipped drone and a search dog but neither belt was located. The aircraft was subsequently examined, at the operator's premises, by the AAIB.

Examination confirmed that the aircraft was extensively damaged. The damage precluded any assessment of the pre-impact alignment of the driving and driven pulley pairs.

Small fragments of a drive belt were recovered from the wreckage and retained for laboratory examination.

Some months later, a walker found a broken belt lying in a nearby field. This was passed to the operator, which identified it as being of the type used in the R22 helicopter type. It was also returned to the AAIB and subjected to laboratory examination.

**Figure 2**
G-OODX after the accident (provided by the operator)

**Pilot's pre-flight checks**

The pilot recalled completing a pre-flight check on the helicopter before the first flight of the day and did not detect any defects. He checked the drive belts and both appeared normal.

**Weather**

The pilot stated that, at the time of the accident, the weather was CAVOK, temperature 20°C, and the surface wind was from approximately 200° at 8 kt.

An aftercast produced by the Met Office confirmed the weather would have been benign, with light south or south-westerly winds, visibility of 10 km or more and no significant cloud below 5,000 ft.

## Pilot information

The pilot held a Helicopter Private Pilot's Licence (PPL(H)) with R22 and R44 ratings. His R22 rating was valid until 31 March 2019. He had last flown the R22 in May 2018 whilst completing his night rating.

The pilot also held a fixed wing pilot's licence. The pilot reported he had flown approximately 75 hours fixed wing and 19 hours rotary in 2018.

## Recorded information

The pilot was using a navigation app. Copies of the data recorded by the app were provided to the AAIB. The ground track from the accident flight is shown in Figure 3 and 4.


**Figure 3**

Track recorded by navigation app, showing flight from Culworth

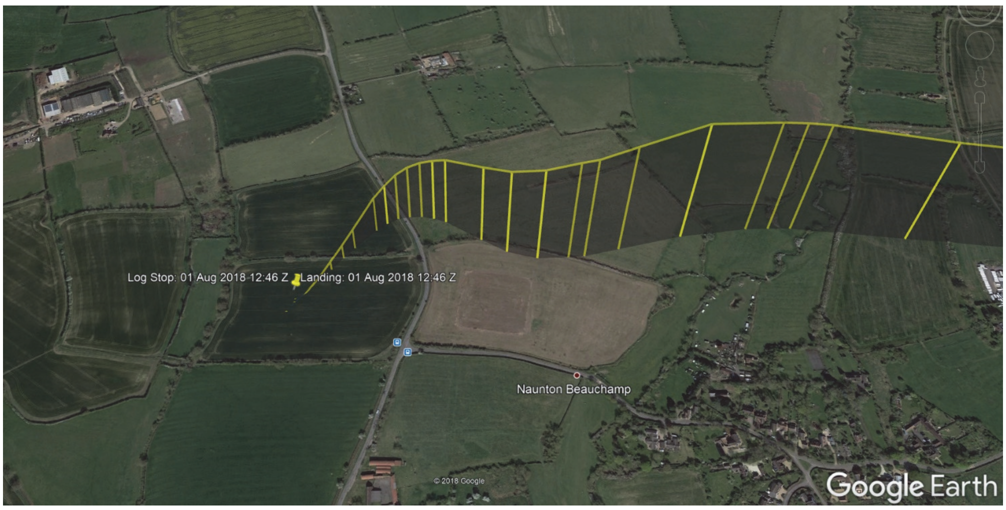


**Figure 4**

Track recorded by navigation app, showing autorotation

Figure 5 shows the helicopter's groundspeed, altitude, vertical speed and track recorded by the app. As the autorotation was flown into wind the groundspeed shown is approximately 10 kt less than the indicated airspeed seen by the pilot. Figure 5 shows the groundspeed initially stable at 50 kt. Once the descent was established the groundspeed reduced to approximately 30 kt then increased back to 60 kt. At approximately 60 ft above the ground the groundspeed was 60 kt. The groundspeed and rate of descent then reduced as the pilot flared the helicopter.

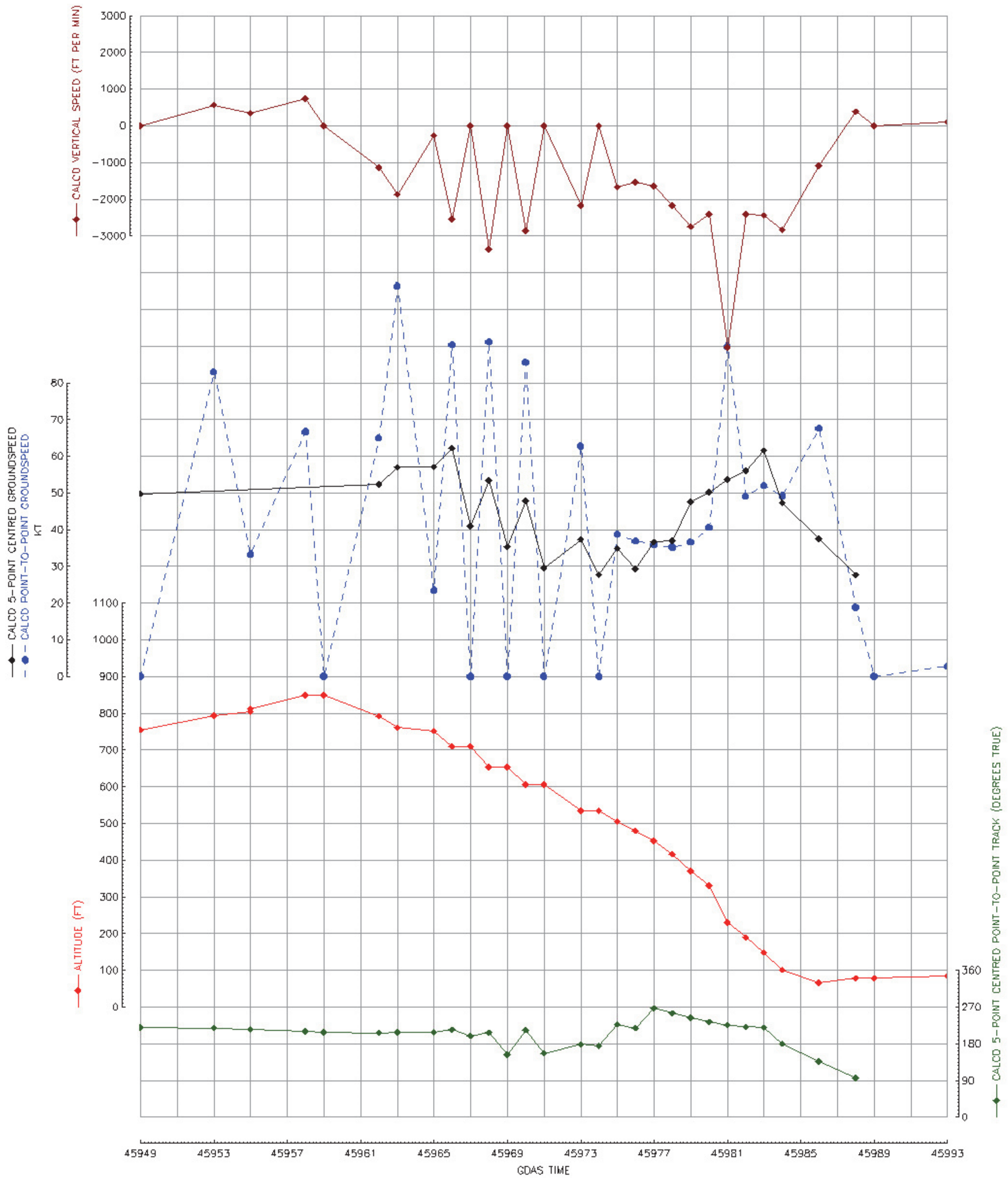


**Figure 5**

Helicopter Vertical Speed, Groundspeed, Altitude and Track during the autorotation, derived from navigation app

**Helicopter information**

The R22 utilises a double belt arrangement to transmit drive from the engine to the rotor system (Figure 6). The driven pulleys (or sheaves) are mounted on the tail rotor drive shaft. The shaft can be moved vertically by the functioning of an electrically operated actuator. This allows the tension in the belts to be altered and enables the system to act as a clutch. The engine is started with the belts slack and operation of the actuator gradually tensions them. As this occurs, the rotors begin to turn. The actuator continues to move the shaft/pulley arrangement until the belts are tight and slippage ceases.

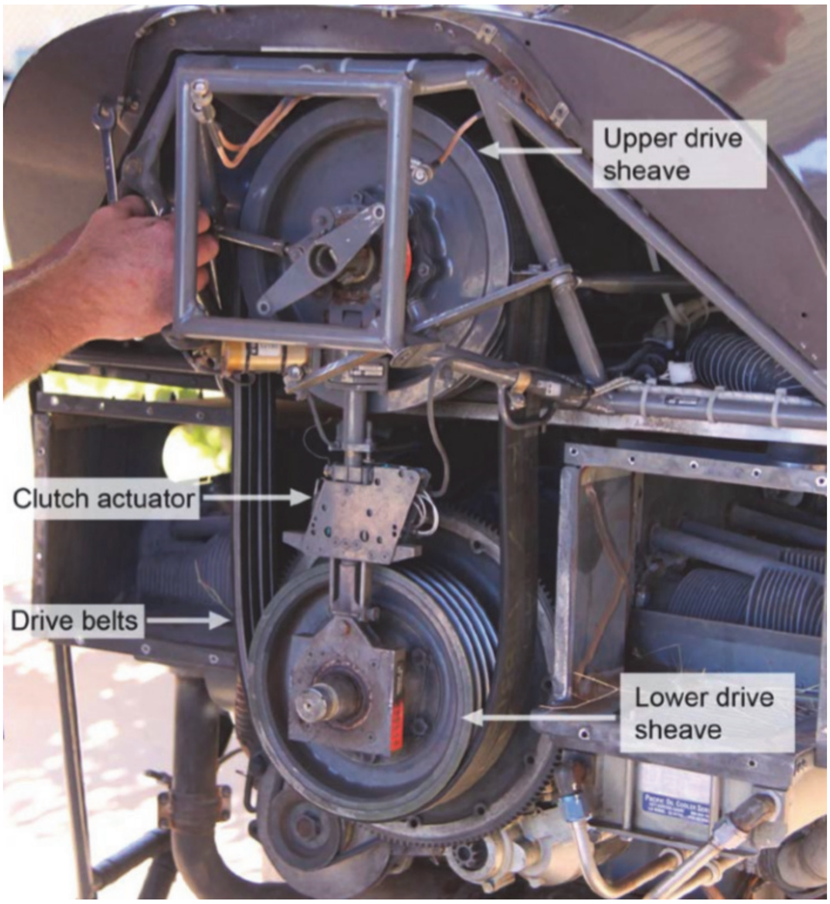


**Figure 6**

R22 Drive system (from Australian Transport Safety Bureau report AI-2009-038[1])

During normal flight, the belt tension is monitored and the actuator automatically re-tensions the belts if any slackness is detected. A ‘clutch’ light in the cockpit illuminates when the actuator is operating. The R22 pilot’s operating handbook contains the following note:

**Footnote**

1 ATSB report ‘Reliability of the Robinson R22 helicopter belt drive system’ - http://www.atsb.gov.au/media/4120236/ai-2009-038_final.pdf [accessed 4 April 2019]

The R22 pilot's operating handbook contains the following note:

> *'Clutch light may come on momentarily during run-up or during flight to retension belts as they warm-up and stretch slightly. This is normal. If, however, the light flickers or comes on in flight and does not go out within 10 seconds pull CLUTCH circuit breaker and land as soon as practical.'*

The two belts are identical and each is of a type having inclined side running surfaces and a central v-groove. Each pulley has four running surfaces engaging with the corresponding running surfaces of the belt.

**Laboratory examination**

The belt found in a field sometime after the accident was examined and found to be complete but fractured (Figure 7). Although some slight wear was identified within the v-groove, there was no evidence that the belt was running other than correctly on both the engine drive pulley and the driven pully on the tail rotor drive shaft. No damage or witness marks were visible on the running surfaces of the belt. There was similarly no evidence that the strength of the belt was significantly reduced. Evidence suggested that the failure was one of simple tensile overload.

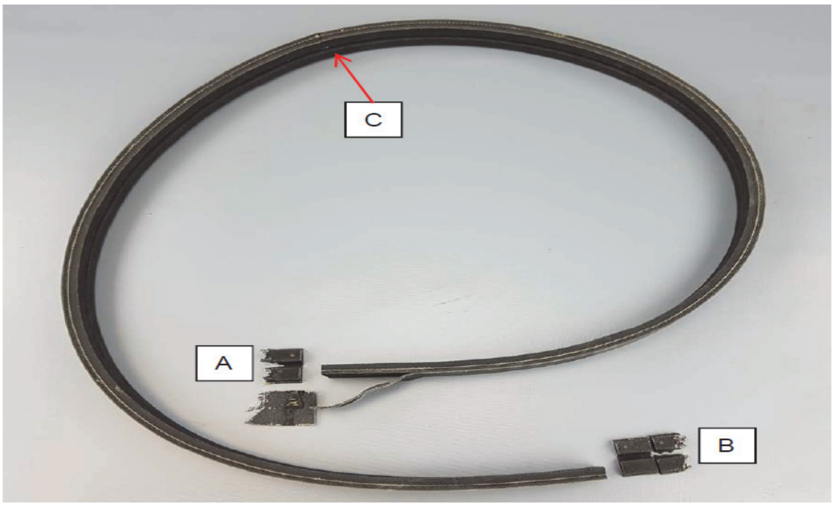


**Figure 7**

Damaged belt with fractured ends detached for analysis

The fragments of the other belt found with the helicopter wreckage, represented small lengths and in each case were ground away such that all the material defining the side running surfaces and the v-groove was no longer present; only the external tie band and some tensile reinforcing chords, with associated rubber matrix material, remained (Figure 8). This was consistent with the belt having been operated whilst no longer aligned in the pulleys.

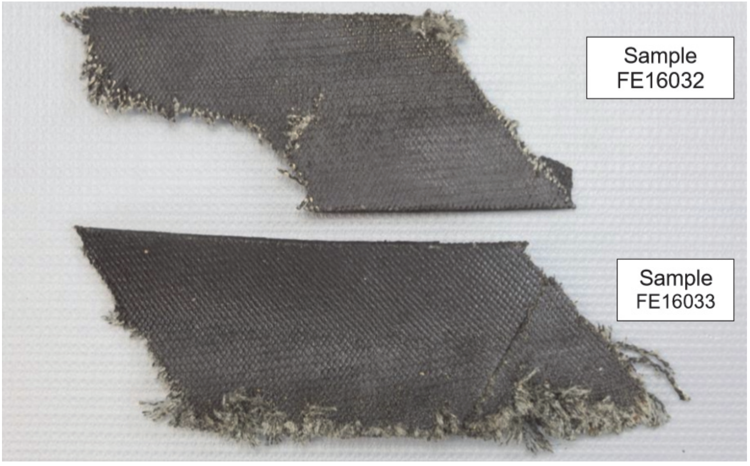


**Figure 8**

Belt fragments

## Other information

*Autorotation*

If a helicopter's engine fails in flight or if drive is lost to the main rotor the pilot can safely land the helicopter by descending in autorotation. During autorotation the up-flowing air generated by descending is sufficient to maintain rotor rpm. The procedure for the R22 is given in the pilot operating handbook (Figure 9).

**POWER FAILURE ABOVE 500 FEET AGL**

1. Lower collective immediately to maintain rotor RPM.
2. Establish a steady glide at approximately 65 KIAS. (For maximum glide distance, see page 3-3.)
3. Adjust collective to keep RPM between 97 and 110% or apply full down collective if light weight prevents attaining above 97%.
4. Select landing spot and, if altitude permits, maneuver so landing will be into wind.
5. A restart may be attempted at pilot's discretion if sufficient time is available (See "Air Restart Procedure", page 3-3).
6. If unable to restart, turn unnecessary switches and fuel valve off.
7. At about 40 feet AGL, begin cyclic flare to reduce rate of descent and forward speed.
8. At about 8 feet AGL, apply forward cyclic to level ship and raise collective just before touchdown to cushion landing. Touch down in level attitude with nose straight ahead.

**Figure 9**

Robinson R22 procedure for power failure above 500 ft

It is important to maintain the rotor rpm between 97 and 110% to ensure there is sufficient energy in the rotor to arrest the rate of descent for landing. If the rotor rpm drops below 97% a low rpm light illuminates and a horn sounds. The handbook contains the caution:

> *'The R22 has a light, low-inertia rotor system. Most of the energy required for an autorotation is stored in the forward momentum of the aircraft, not in the rotor. Therefore, a well-timed cyclic flare is required and rotor RPM must be kept in the green until just before ground contact.'*

The procedure recommends descending at approximately 65 kt. Pilots can shorten the glide distance by reducing airspeed below this value, but the airspeed should be increased again before 40 ft to give sufficient airspeed to arrest the rate of descent before landing.

*Similar events*

During 2012, the Australian Transport Safety Bureau became aware of several accidents and serious incidents involving Robinson R22 helicopters in which failure of either one or both rotor drive v-belts had occurred. The report of a subsequent study[2] identified eight belt related occurrences in Australia between 2004 and 2011 of which two were fatal and one involved serious injury.

A survey of information available from the UK, USA, Canada and New Zealand, published in the same report, identified 21 similar occurrences outside Australia between 1991 and 2012, of which one was fatal. During this period the modification states of belts and pulleys changed and evolved so the reports do not necessarily relate to the same belt/pulley configuration.

## Analysis

*Drive belt failure*

A tensile failure was found on the drive belt found lying in a field. No evidence of degradation of belt strength was found during its laboratory analysis. There was no damage or witness marks on the running surfaces of the belt to indicate that it had "de-railed" or suffered foreign object contamination whilst running. The failure was thus consistent with that of a belt of the correct strength being overloaded in tension.

The fragments of the other belt found amongst the wreckage had become eroded with removal of most of the belt cross-section indicating that it had run for a period with the belt not correctly seated on one or both pulleys. The belt was in several fragments and most of its length was not recovered.

It is possible that the fragmented belt had operated incorrectly, for an unknown reason, and had largely been eroded away before breaking. The automatic tensioner had caused the actuator to increase the tension in the second belt so that the correct total tension force

**Footnote**

[2] ATSB report 'Reliability of the Robinson R22 helicopter belt drive system' - http://www.atsb.gov.au/media/4120236/ai-2009-038_final.pdf [accessed 4 April 2019]

was exerted, but that force was balanced by tension in only one belt. This would cause approximately twice the normal stress in the remaining belt, or more if sudden failure of the first belt and operation of the tensioner caused the total load to overshoot the desired tension. This high load in the remaining belt would probably have led to its failure in tensile overload, as evidenced on the belt located in the field.

The Australian report suggested several possible causes for incorrect operation of the drive belts, although no single specific cause could be identified. Similarly, the cause of the incorrect operation that led to the initial belt failure in G-OODX was not determined.

*Autorotation*

The pilot recognised the loss of drive to the rotor and established the helicopter in autorotation. During the descent he reduced airspeed to shorten the glide range to land in a suitable field. Rotor rpm during the descent is not known but the pilot reported that the low rpm horn was on throughout the descent. At approximately 60 ft the recorded data showed the helicopter was back at the correct airspeed to flare for landing. The pilot reported that he flared the helicopter, but the tail struck the ground. It is not known if the pilot misjudged the flare or if the rotor rpm was insufficient to arrest the rate of descent sufficiently before landing.

## Conclusion

The drive belts connecting the engine to the drive shaft failed causing a loss of drive to the rotor system. The cause of the initial belt failure could not be determined.

The pilot recognised the failure, entered autorotation and landed in a field. Both occupants were able to exit the helicopter with only minor injuries but the helicopter was extensively damaged.

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