Transport Accident Investigation Commission

*Watchlist*

# Robinson helicopters: mast bumping accidents in NZ

## What is the problem?

The Transport Accident Investigation Commission is concerned about the number of accidents in New Zealand in which Robinson helicopters have experienced 'mast bumping'. These accidents have raised concerns about the risks of flying these helicopters in the mountainous terrain and weather conditions that are common in New Zealand.

Mast bumping is contact between an inner part of a main rotor blade or a rotor hub and the main rotor drive shaft (or 'mast'). Serious mast bumping in flight usually results in the helicopter breaking up in flight, which is fatal for those on board.

Part of the problem is that the available evidence has not allowed the circumstances and contributing factors of all of these 'mast bumping' accidents to be fully determined. However, a significant proportion have been found to have occurred in 'low-G'* flight conditions. Helicopters with semi-rigid two-bladed main rotor systems, as used on Robinson helicopters, are particularly susceptible to mast bumping in 'low-G' conditions. Low-G can be caused by large or abrupt flight control inputs or by turbulence. The risk of mast bumping in turbulence increases with high power settings and operating at high speed and light weight.

## What is the solution?

Operators must select a type of aircraft suited to the risk profile of the intended use. Similarly, all pilots must understand the helicopter's operating limitations, avoid circumstances which could see these inadvertently exceeded, and receive proper training in the causes, dangers, and prevention of mast bumping, including in low-G conditions. It is particularly important for Robinson pilots to be aware of the risks of flying a lightly loaded helicopter at high speed in turbulence. Prohibitions against in-flight low-G demonstrations must be

* *A low-G condition occurs when an object is subjected to a net vertical force less than the force of gravity. When the vertical force is zero, the object is described as being 'weightless'.*

observed, and low-G recovery training must be conducted only on the ground.

The regulatory environment must:

- support high quality training and improved pilot awareness of mast bumping risks, including in low-G conditions
- require the manufacturer to clearly state the limitations of the helicopters
- encourage use of the helicopter as appropriate to the operating conditions.

We encourage further research into the factors that can lead to mast bumping and the dynamic loading characteristics of the rotor hub and drive shaft assembly.

The widespread use of cockpit video recorders and/or other means of data capture would provide useful data to investigations.

The Commission acknowledges that since this item was placed on the Watchlist, good progress has been made in implementing some of these measures.

# Background

Robinson helicopters are relatively inexpensive to purchase and cost effective to operate. They are therefore popular, comprising one quarter of New Zealand's helicopter fleet. About 230 are registered in New Zealand, mostly R22 and R44 models, with a small number of turbine-powered, 5-seat R66 models. These are used for flight training, agricultural, tourism, and commercial operations. All Robinson helicopter pilot operating handbooks state that pilots should avoid flying in high winds or turbulence, and subjecting the helicopter to low-G conditions.

Since 1991 the Commission or the Civil Aviation Authority (CAA) have investigated 15 mast bumping accidents or incidents involving Robinson helicopters. Six of these accidents occurred between 2012 and 2015 and the most recent in 2018 (see the table on the last page). Nineteen people have died in the 15 accidents, including ten in known low-G mast bumping accidents. The low-G related rate in New Zealand is considerably higher than in other parts of the world[*]. The Commission's inquiries have resulted in several safety recommendations.

Mast bumping is contact between an inner part of a main rotor blade or a rotor hub and the main rotor drive shaft. Helicopters with the semi-rigid two-bladed rotor systems, like that used on Robinson helicopters, are susceptible to mast bumping during low-G flight conditions. Serious mast bumping that occurs in flight usually results in the helicopter breaking up during flight, which is fatal for those on board. For this reason, it is often difficult to determine exactly what happened to cause the mast bump.

Low-G conditions can arise in turbulence. Significant areas of New Zealand terrain are mountainous, and they are often exposed to strong wind. Therefore, New Zealand pilots are more likely to encounter turbulence than pilots in some other parts of the world where

[*] For instance, the low-G mast bumping accident rate in New Zealand compared with the United States is about nine times higher. This is based on fleet size of about 300 compared to 2700, and the same number of low-G mast bumping accidents in each market since the year 2000 (data provided by Robinson Helicopters in August 2016). Variations in types of use or average hours flown may explain some of this difference.

Robinson helicopters are used. Pilots must be aware of how hazardous it can be to operate Robinson helicopters in moderate or greater turbulence.

Instructors and pilots must clearly understand the hazards of operating semi-rigid two-bladed helicopters in low-G conditions, and how inadvertent or improper flight control inputs can cause mast bumping. Low-G recovery training must be conducted as ground training only.

The Commission also identified that the rate of Robinson helicopter in-flight break-up accidents in New Zealand had not been significantly reduced by New Zealand's adoption of the Federal Aviation Administration (FAA) measures intended to help prevent such accidents. We also found the format of the Robinson helicopter flight manuals and their terminology did not draw enough attention to safety critical instructions and conditions that could result in serious injury or death.

We recommended that the CAA:

- conduct a review of Robinson safety awareness training in New Zealand and facilitate the development and adoption of best practice across the sector, including a level of consistency in the way instructors deliver the safety awareness training.[1]
- review FAA SFAR 73 [Special Federal Aviation Regulation 73, which mandated special safety awareness training for all R22 and R44 pilots and set a threshold for minimum pilot experience] in the context of the New Zealand aviation system and adopt relevant improvements that would be likely to enhance the operational safety of Robinson helicopters in New Zealand.[1]
- include the knowledge and training requirements of Special Federal Aviation Regulation No. 73, or an equivalent requirement, as a prerequisite for the issue of a Robinson R66 type rating.[2]
- promptly publicise the recent changes to the Robinson R66 (and R44) Pilot's Operating Handbooks that caution against flight in high winds and turbulence, and which advise pilots to reduce power and speed if turbulence is expected or encountered.[2]

In response, the CAA reviewed Robinson safety awareness training in New Zealand. It has since put in place civil aviation rules that it has used to direct specific training for pilots of the R22 and R44 helicopters. The CAA decided not to include the R66 in the safety awareness training, saying that the FAA had rejected the inclusion of the R66 in SFAR 73, and that it would monitor advice from Robinson Helicopters and the FAA*. The recommendations on training have been implemented.

In November 2020, we released our report into the fatal crash of an R44 in Wanaka in 2018.[2] We noted that investigations into loss-of-control or mast bumping accidents involving Robinson helicopters continue to be hampered by a lack of data. Allied with this is a lack of understanding of how the main rotor performs in adverse conditions. This lack of factual information has limited the effectiveness of safety investigations.

* The CAA and the FAA signed a Bilateral Aviation Safety Agreement (BASA) in 2002, which included enhanced cooperation and efficiency, and reciprocal acceptance of airworthiness approvals.

One of the recommendations from an earlier inquiry[3] was that the FAA reinstate research into the dynamic behaviour of the Robinson's rotor system under conditions of low-G.

The FAA and Robinson had conducted post-certification flight testing in 1982 (for the R22), 1995 (for the R44), and 2014 (for the R66), which included limited low-G manoeuvres. Due to the dangers of low-G, it is not possible to investigate more severe conditions with test pilot flying. However, computational sciences and aerospace engineering have advanced to such a degree that a fuller understanding of the dynamic behaviour of the Robinson and other semi-rigid two-bladed rotor systems should now be possible. In May 2017, the FAA wrote to the Commission stating that modelling rotor behaviour was very limited in its application because of the many variables involved, and validating the results of such modelling would subject flight crews to unnecessary flight hazards. However, in February 2017, Robinson Helicopter Company partnered with the University of Maryland to perform computational analysis and testing to gain an understanding of rotor and flight dynamics that drive mast bumping. This work was not completed and Robinsons has informed the Commission of research work with other partners.[4] The Commission commends this initiative and looks forward to its conclusions.

Following an R44 accident,[5] the Commission further recommended that the CAA and Secretary of Transport promote, through the International Civil Aviation Organization, the need for cockpit video recorders and/or other means of data capture in certain classes of helicopter. Such systems are essential for helping to determine why accidents happen. The US' National Transportation Safety Board has made similar recommendations to the US regulator, the Federal Aviation Administration (FAA). The FAA has not mandated recorders, resulting in the NTSB calling on helicopter manufacturers to install these systems.[6]

The CAA has accepted the Commission's recommendation; in December 2020 it approved a product that records video, audio, and flight data for voluntary use in helicopter cockpits. The Ministry of Transport advises that it is investigating policy work in this area. The Robinson Helicopter Company has informed the Commission that in 2020 it began installing digital engine monitoring units (EMUs) on all new R22 and R44 helicopters, as with the R66 (the EMU records and alerts mechanics and pilots to predominantly engine-related exceedances and provides flight data during accident investigations); and from 2021 a custom cockpit camera will be standard on new R66 models and optional for all new R22s and R44s. Changes to new models do not effect the existing fleet; nevertheless, the Commission acknowledges the substantial progress in this area.

The Commission's recommendations are seeking concerted actions by regulatory authorities, the manufacturer, operators, instructors and pilots to promote the safe operation of Robinson helicopters in the New Zealand environment; and to better understand the helicopter's operating characteristics and the factors that can lead to mast bumping. The Commission acknowledges the high degree of attention that all parties are giving to these safety matters. We are encouraged by the manufacturer's response to our recommendations, and its demonstrated commitment to safety. In addition, the Commission is aware that some New Zealand operators have changed the way they use the Robinson helicopters in their fleets in recognition of the suitability of the aircraft for the environment in which the operators are flying. The CAA has advised that the current Robinson helicopter accident rate is about one third of what it was between 2013 and 2017.

The Commission encourages the sector to continue its efforts to avoid such accidents happening again, and sees good progress towards implementation of the actions we were seeking when we first placed this item on the Watchlist.

# References


[1] Transport Accident Investigation Commission *Report AO-2011-003: In-flight break-up ZK-HMU, Robinson R22, near Mount Aspiring, 27 April 2011*
http://www.taic.org.nz/inquiry/ao-2011-003
Safety recommendations 003/14 (first bullet in background section) and 004/14 (second bullet point)

[2] Transport Accident Investigation Commission *Report AO-2018-006: Robinson R44 Helicopter, ZK-HTB, collision with lake, Wanaka, 21 July 2018*
http://www.taic.org.nz/inquiry/ao-2018-006

[3] Transport Accident Investigation Commission *Report AO-2013-003: Robinson R66, ZK-IHU, Mast bump and In-flight break-up, Kaweka Range, 9 March 2013*
http://www.taic.org.nz/inquiry/ao-2013-003
Safety recommendations 002/16 (third bullet point in background section), 004/16, 005/16 (fourth bullet point), and 011/16

[4] Correspondence from Robinson Helicopter Company to Transport Accident Investigation Commission, 26 April 2018 and January 2021.

[5] Transport Accident Investigation Commission *Report AO-2015-002: Mast bump and in-flight break-up, Robinson R44, ZK-IPY Lochy River, near Queenstown, 19 February 2015*
http://www.taic.org.nz/inquiry/ao-2015-002
Safety recommendations 014/16 and 015/16

[6] NTSB news release:
NTSB Asks Helicopter Manufacturers to Install Recording Systems FAA Refuses to Require

## *Mast bumping accidents in New Zealand, September 2020*

| Investigation reference | Report title | Fatalities |
|---|---|---|
| *TAIC 91-001 | Robinson R22 Beta ZK-HDC, main rotor separation after mast bumping in turbulence, near Hukerenui, North Auckland, 4 January 1991 | 1 |
| CAA 96/3239 | Robinson R22 Beta ZK-HDD, Matawai, Gisborne, 5 December 1996 | 2 |
| CAA 02/71 | Robinson R22 Beta ZK-HEZ, Balfour Range, near Fox Glacier, 14 January 2002 | 2 |
| CAA 03/127 | Robinson R22 Beta ZK-HUL, Masterton, 17 January 2003 | 1 |
| *CAA 04/39 | Robinson R22 Beta ZK-HXT, 10 km north-east of Taupo, 10 January 2004 | 2 |
| *TAIC 08-007 | Robinson R22 Alpha ZK-HXR, loss of control, Lake Wanaka, 1 November 2008 | 1 |
| CAA 10/3987 | Robinson R22 Beta ZK-HIP, loss of rotor RPM, Bluff Harbour, 14 October 2010 | 2 |
| TAIC 11-003 | Robinson R22 Beta ZK-HMU, inflight break-up, near Mt Aspiring, 27 April 2011 | 2 |
| *CAA 12/4957 | Robinson R22 Beta ZK-HCG, loss of main rotor control, Cardrona Valley, Wanaka, 8 November 2012 | 1 |
| *TAIC 13-003 | Robinson R66 ZK-IHU, inflight break-up, Kaweka Range, 9 March 2013 | 1 |
| *TAIC 13-005 | Robinson R22 Beta ZK-HIE, inflight loss of control, near New Plymouth, 30 March 2013 | 0 |
| *TAIC 14-006 | Robinson R44 Helicopter ZK-HBQ, in-flight break-up, Kahurangi National Park, 7 October 2014 | 1 |
| *TAIC 15-002 | Robinson R44 ZK-IPY, Mast bump and in-flight break-up, Lochy River, near Queenstown, 19 February 2015 | 2 |
| *CAA 15/1229 | Robinson R22 Beta ZK-HMW, mast bump, Clevedon, 19 March 2015 | 0 |
| TAIC 18-006 | Robinson R44 Helicopter, ZK-HTB, collision with lake, Wanaka, 21 July 2018 | 1 |

* Known low-G accidents

For more information see Appendix 1 to Transport Accident Investigation Commission *Report 15-002: Mast bump and in-flight break-up, Robinson R44, ZK-IPY Lochy River, near Queenstown, 19 February 2015*
*http://www.taic.org.nz/inquiry/ao-2015-002*

# Version history

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Updated: August 2017
*Updated content*: acknowledgement of aviation sector interest; closure of inquiry 14-006.
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*Updated content*: update of actions taken by Robinson Helicopter Company, reference to CAA leading a project to assess the use of helicopter flight data recorders, reference to Ministry of Transport policy work, reference to CAA direction of training for pilots of R22 and R44 helicopters.
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*Te Kōmihana Tirotiro Aituā Waka*
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