Inquiry AO-2013-005: In-flight loss of control, Robinson R22,
ZK-HIE, near New Plymouth, 30 March 2013

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Final Report

Aviation inquiry AO-2013-005
In-flight loss of control
Robinson R22, ZK-HIE

near New Plymouth
30 March 2013

Approved for circulation: May 2015

Transport Accident Investigation Commission

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Nature of the final report

This final report has not been prepared for the purpose of supporting any criminal, civil or regulatory action against any person or agency. The Transport Accident Investigation Commission Act 1990 makes this final report inadmissible as evidence in any proceedings with the exception of a Coroner's inquest.

Ownership of report

Citations and referencing

Information derived from interviews during the Commission's inquiry into the occurrence is not cited in this final report. Documents that would normally be accessible to industry participants only and not discoverable under the Official Information Act 1980 have been referenced as footnotes only. Other documents referred to during the Commission's inquiry that are publicly available are cited.

Photographs, diagrams, pictures

Unless otherwise specified, photographs, diagrams and pictures included in this final report are provided by, and owned by, the Commission.

Robinson R22, ZK-HIE
(Photograph provided by Ice Aviation)

Source: mapsof.net

Location of the accident

Contents

Abbreviations ii
Glossary ii
Data summary iii
1. Executive summary 1
2. Conduct of the inquiry 2
3. Factual information 3
3.1. Narrative 3
3.2. Damage to aircraft 5
3.3. Personnel information 7
3.4. Aircraft information 7
3.5. Special training for Robinson helicopter pilots 9
3.6. Helicopter instructors' forum 10
3.7. Previous inquiry 11
4. Analysis 13
4.1. Introduction 13
4.2. The cause of the un-commanded roll 13
4.3. Conducting the special training 15
4.4. Flight manual (clarity of critical information) 16
5. Findings 18
6. Safety actions 19
General 19
7. Recommendations 20
General 20
Recommendations 20
8. Key lesson 21
9. Citations 22
Appendix 1: Participants in forum held 9 May 2013 23
Appendix 2: Earlier safety reviews and actions concerning the R22 24
Appendix 3: Robinson Safety Notice SN-11 26

Figures

Figure 1 Blade spindle, showing evidence of mast contact 5
Figure 2 Crushed and split teeter stop 6
Figure 3 R22 main rotor head components (Image used with permission of Burkhard Domke) 7
Figure 4 Typical R22 dual flight controls 8
Figure 5 Forces acting on a helicopter fuselage 9

Abbreviations

CAA	Civil Aviation Authority of New Zealand
Commission	Transport Accident Investigation Commission
FAA	Federal Aviation Administration (United States)
G	the acceleration (9.8 metres per second per second) due to the force of gravity
NTSB	National Transportation Safety Board (United States)
RPM	revolutions per minute
SFAR	Special Federal Aviation Regulation (United States)
UTC	co-ordinated universal time

Glossary

attitude	the orientation of an aircraft, usually with respect to Earth as the frame of reference. Examples: inverted, rolled to the left, diving
collective lever	one of two main rotor controls. This control changes the main rotor blade pitch angles collectively, which causes the helicopter to climb or descend
cyclic stick	one of two main rotor controls. The cyclic stick causes the rotor blade pitch angles to change at the same point during their rotation cycle, which causes the rotor disc to tilt in the same direction that the pilot has put the stick. The helicopter then moves in that direction. This can be sideways, forwards or backwards (aft) or any direction
flap forward	a normal response of the main rotor disc to an airspeed or power decrease, which causes the rotor disc to pitch down
flapping	the vertical movement of the rotor blade about an axis at right angles to the blade span
low-G	or reduced G; an acceleration less than that due to the force of gravity. The force on an object equals the product of the mass of the object and the acceleration being experienced. For a given mass, the force is often expressed as a multiple of, or compared with, the value of G
mast bump	a mast bump (on the R22) occurs when the inboard end of a main rotor blade spindle strikes the main rotor drive shaft (sometimes called the mast)
moment	the turning or lever effect of a force acting about a point
rotor disc	the area swept by the rotor blades each revolution
teeter	the see-saw movement of a two-bladed,centrally mounted rotor hub

Data summary

Aircraft particulars

Aircraft registration:	ZK-HIE
Type and serial number:	Robinson Helicopter Company R22 Beta II, 3724
Number and type of engines:	one Textron Lycoming O-360-J2A, reciprocating
Year of manufacture:	2004
Operator:	Ice Aviation Limited
Type of flight:	pilot training
Persons on board:	two
Pilot's licence:	airline transport pilot licence (helicopter)
Pilot's age:	50
Pilot's flying experience:	7141 hours total, including 462 hours on type
Date and time	30 March 2013, 1300[1]
Location	near New Plymouth latitude: 39° 02´ south longitude: 174° 12´ east
Injuries	nil
Damage	moderate

[1] Times in this report are in New Zealand Daylight Time (UTC+13 hours) and expressed in the 24-hour format.

1. Executive summary

1.1. This accident occurred during a dual training flight to revise handling procedures prior to the student pilot being tested for the initial issue of a private pilot licence. One of the exercises to be revised was the recommended recovery procedure in the event of an un-commanded right roll, as might occur when subjected to an acceleration (or force) less than that due to gravity (G). The instructor had no intention of deliberately causing a low-G condition.

1.2. The instructor first demonstrated an unrelated helicopter flight characteristic, main rotor flap-forward that is a normal reponse to a speed reduction, during the climb. He had just completed that demonstration and was about to commence the roll-recovery exercise when the helicopter suddenly rolled to the right and pitched down. In spite of being confronted with an un-commanded right roll, the instructor did not follow the recovery procedure he had been about to discuss. However, he did regain control of the helicopter and was able to land safely. The occurrence caused a mast bump and damage that required the replacement of many of the main rotor system components.

1.3. A mast bump event in a Robinson Helicopter Company (Robinson) helicopter usually has a fatal outcome. The Transport Accident Investigation Commission (Commission) has inquired into other mast-bump and loss-of-main-rotor-control accidents in Robinson helicopters and was concerned that the incidence of such accidents had not decreased. Therefore, this safe recovery was an opportunity to understand the circumstances and determine the causes of the temporary loss of control. The intended exercise was part of mandated safety awareness training, but when the helicopter did commence an un-commanded right roll, the instructor did not follow the procedure recommended in that training. Therefore the inquiry also considered the content and delivery of the mandated training.

1.4. The Commission made the following findings:

- no environmental condition or helicopter defect caused the un-commanded roll
- it was probable that the un-commanded roll was caused by an inadvertent reduction in G during the transition from the flap-forward demonstration to the next exercise, while the engine power was at a relatively high setting
- the section of the United States Special Federal Aviation Regulation No. 73, which requires Robinson helicopter pilots to have dual flight instruction in the effects of low-G manoeuvring, appears to contradict the R22 helicopter flight manual, which prohibits the demonstration of low-G conditions
- the importance of some critical safety information in Robinson flight manuals was likely to have been diminished by Robinson's use of "Caution", rather than "Warning", for operating conditions and practices that involve a risk of personal injury or loss of life.

1.5. The Commission is making the following recommendations to the Administrator, Federal Aviation Administration (FAA) of the United States, which certificates Robinson helicopters:

- that he amend section 2(b) of Special Federal Aviation Regulation No. 73 – Robinson R-22/R-44 Special Training and Experience Requirements to make it clear that dual instruction in the "effects of low G maneuvers" is limited to discussion only, and to reiterate that deliberate in-flight reduced G conditions are prohibited;
- that he require Robinson Helicopter Company to amend its flight manuals to include the use of "Warning" for those operating conditions and practices that involve a risk of personal injury or loss of life

1.6. The key lesson learnt from the inquiry into this occurrence was:

> Pilots, particularly flight instructors, must be alert to conditions that could result in an inadvertent breach of a flight manual prohibition of low G.

2. Conduct of the inquiry

2.1. The accident happened on 30 March 2013. The pilot instructor (the instructor) involved in this occurrence informed the Commission of the circumstances on 3 April 2013, prior to notifying the Civil Aviation Authority (CAA). The Commission opened an inquiry the next day. The damage to ZK-HIE meant that the occurrence met one of the criteria for an accident (section 2 of the Civil Aviation Act 1990).[2]

2.2. The instructor owned the helicopter. He and his contracted maintenance engineer inspected the helicopter soon after the occurrence. The main rotor was removed in preparation for commencing repairs. This was the condition of the helicopter when the Commission's investigators inspected it at New Plymouth aerodrome on 8 April 2013.

2.3. The student pilot (the student) was interviewed at New Plymouth on 8 April 2013. The instructor was overseas on business at the time. He was interviewed by telephone on 24 April 2013. Other correspondence with the instructor complemented the interviews.

2.4. On 9 May 2013 Commission investigators hosted a forum to further their understanding of issues relating to the performance and handling of Robinson helicopters, and the mandated special training and experience requirements for Robinson pilots and how that training was delivered. The forum participants included five experienced New Zealand helicopter instructors, three CAA officials and five Commission staff.[3] Robinson was not asked to participate. The instructor provided details of the accident to the forum.

2.5. On 6 August 2014 the National Transportation Safety Board (NTSB) of the United States, the country that manufactured the helicopter, appointed an accredited representative in accordance with Annex 13 to the Convention on International Civil Aviation.

2.6. On 29 October 2014 the Commission approved the draft report for circulation to interested persons for their comment.

2.7. Submissions were received from the instructor, Robinson, the CAA, and four of the other helicopter instructors who attended the forum held on 9 May 2013. The submissions were considered by the Commission and the report revised where appropriate.

2.8. On 25 February 2015, after considering the revised report, the Commission requested a section to be added dealing with the clarity of critical safety information in Robinson flight manuals. On 26 February 2015, the Commission approved the new draft report for circulation to interested persons for their comment.

2.9. Further submissions were received from the CAA and the NTSB only. The NTSB's submission did not indicate that it was made on behalf of the FAA Administrator or Robinson.

2.10. On 28 May 2015 the Commission approved this report for publication.

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[2] An occurrence in which the aircraft sustains damage or structural failure that adversely affects the structural strength, performance or flight characteristics of the aircraft and would normally require a major repair or replacement of the affected component.

[3] See Appendix 1 for details of participants.

3. Factual information

3.1. Narrative

3.1.1. On the morning of 30 March 2013 the student had two local training flights, one solo and one dual, from New Plymouth aerodrome in a Robinson R22 helicopter, registered ZK-HIE (the helicopter). This was the second successive day of consolidation training before the student would sit a flight test the following week for the issue of a private pilot licence.

3.1.2. At about 1300 the student and the instructor departed on another dual training flight, one purpose of which was to review the recovery action for an un-commanded right roll, which might occur when the helicopter was subjected to a force less than that of gravity (low-G).[4] The instructor had previously covered this exercise with the student after about 18 flight hours of training.

3.1.3. The low-G condition could only be discussed, because the R22 flight manual included the following prohibitions (CAA, 1996, p.2-6):

> **FLIGHT AND MANEUVER LIMITATIONS**
>
> Aerobatic flight prohibited.
>
> Low-G cyclic pushovers prohibited.
>
> **CAUTION**
>
> A pushover (forward cyclic maneuver) performed from level flight or following a pull-up causes a low-G (near weightless) condition which can result in a catastrophic loss of lateral control. To eliminate a low_G condition, immediately apply gentle aft cyclic. Should a right roll commence during a low-G condition, apply gentle aft cyclic to reload rotor before applying lateral cyclic to stop the roll.
>
> NOTE
>
> Low G hazards training shall NOT under any circumstances be demonstrated or practised in the air.

3.1.4. The hazard of low-G flight in the helicopter was an element of the mandatory special training and experience for Robinson R22 pilots (the special training). The special training was initially mandated by the FAA and largely adopted by other countries, including New Zealand.[5] Pilots needed to know how to recover from an un-commanded right roll under conditions of low G because the recommended action was counter-intuitive. If the recovery actions were performed incorrectly or abruptly, a mast bump could occur.[6]

3.1.5. The previous day the instructor and student had reviewed a video that was part of the special training, and the intended recovery actions were briefed immediately before this flight. The instructor said he emphasised that he would induce a slow roll to the right, without any reduction in G, then hand control to the student for him to perform the recovery. The student recalled that the instructor said he would demonstrate "a low-G push-over without actually going low G".

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[4] An object experiences low G when the net downward force is less than the force of gravity ("one G"). Occupants of an aircraft experiencing low G will tend to rise in their seats and feel the strain of their seat belts. If the net downward force is zero, the occupant or object is sometimes said to be weightless.

[5] The special training is described in section 3.5 and Appendix 2.

[6] A mast bump occurs when the inboard end of a main rotor blade spindle strikes the main rotor drive shaft.

3.1.6. The student had control of the helicopter for the lift-off and the initial climb. The pilots said the flight conditions were smooth, with a light wind and no cloud in the vicinity, although an hour earlier there had been local rain showers and scattered cloud below 2000 feet.

3.1.7. At about 1000 feet above the aerodrome, while still climbing at about 60 knots airspeed, the instructor took control to first review the effect of main rotor flap-forward following a speed reduction during the climb.[7] The instructor said that the purpose of the review was to illustrate that flap forward under some circumstances, if not checked, could become excessive and potentially lead to a reduction in G and an un-commanded roll.

3.1.8. The student was not required to "follow through" on the controls during this or the following exercise. The instructor initially applied and held a small amount of aft cyclic to raise the nose, which reduced the airspeed. The main rotor disc responded by flapping forward.[8] This exercise was completed at about 1500 feet altitude.

3.1.9. The instructor said he reduced the engine power to "approximately 22" inches of manifold pressure, which was close to a cruise power setting, for the next exercise. He said that the helicopter had stopped pitching and was close to level flight and in balance before he was about to induce a right roll. Without warning, and before the instructor had initiated the exercise, the helicopter rolled rapidly to the right and pitched down steeply. However, the student said he thought that the helicopter pitched down first, and was then rolled by what seemed to him to be "another force". The student said he felt a slight reduction in G, perhaps about half of the reduction normally experienced when entering autorotation from level flight, but the instructor did not feel that.

3.1.10. The instructor estimated that the initial roll rate was 120 degrees per second. He said that because an extreme angle of bank was reached quickly, he did not apply the recommended recovery action that he had been about to review. That action was to apply aft cyclic gradually to ensure the rotor disc was subjected to positive G before rolling level using left cyclic. He said he had previously considered what he would do if the helicopter unexpectedly entered an extreme attitude[9], and had decided the safest action would be to try to keep the rotor disc at right angles to the mast. Accordingly, in this case, he applied right cyclic to "follow" the roll.

3.1.11. The pilots described the helicopter rolling over and pitching downwards until it was pointing almost vertically down, although neither pilot was certain of the exact flight path. The instructor saw that the airspeed was high and rapidly increasing. The student thought the helicopter was "twitching" during this stage. He (but not the instructor) recalled hearing the warning horn for low main rotor revolutions per minute (RPM) and then seeing the RPM at about 90%.[10] The student immediately reached for his collective lever and pushed it down a little before stopping because he was not the pilot in control.[11] The instructor did not recall whether he moved the collective lever himself during the manoeuvre.

3.1.12. The instructor was very aware of the potential for a mast bump if he countered the abrupt roll with left cyclic, and also that the main rotor could strike the tail boom if he applied too much aft cyclic, or applied it too abruptly. He was also concerned that the high airspeed might lead to retreating blade stall.[12] He said he attempted to keep the rotor disc at right angles to the

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[7] Flap-forward is a normal response of the main rotor disc to an airspeed or power decrease, which and causes the rotor disc tohelicopter to pitch down.

[8] The rotor disc is the area swept by the rotor blades each revolution.

[9] The orientation of the helicopter with respect to Earth.

[10] The alarm sounds when the main rotor RPM decreases below 97%.

[11] Lowering the collective lever was the appropriate response to a low-rotor-RPM warning.

[12] The retreating blade is the blade moving in the opposite direction to the direction of flight. To avoid dissymmetry of lift caused by the resultant airflow being slower over the retreating blade than it is over the advancing blade, the retreating blade flaps downwards, which increases its angle of attack and hence the lift. Higher forward speeds (and their associated greater power demands) require further increases in the retreating blade angle of attack, until a speed is reached at which part of the retreating blade reaches its stall angle. The speed at which retreating blade stall becomes a problem is one of a number of factors that determine a helicopter's maximum speed.

mast throughout the manoeuvre. The helicopter descended 800 or 900 feet before he was able to regain control and pull out of the dive to straight and level flight.

3.1.13. The training flight was terminated, with no technical abnormalities noted during the return to the aerodrome. Neither pilot was injured.

3.1.14. The instructor believed that they recovered from the unusual attitude because he was familiar with extreme flight attitudes from aerobatic training in aeroplanes, and because he was acutely aware of the need to "fly" the main rotor disc so that it didn't contact the fuselage.

3.2. Damage to aircraft

3.2.1. The maintenance engineer had made an initial inspection of the rotor head and removed the main rotor blades before the Commission's investigators arrived, but that did not affect the investigation. The rotor head showed clear evidence of a mast bump. The main rotor blade spindles had contact marks and the teeter stops were crushed and split (see Figures 1 and 2).

3.2.2. The manufacturer advised the engineer of the special inspections to be made after a mast bump. The main rotor blades did not require replacement, but the following major parts were replaced (see Figure 3):

- main rotor hub
- main rotor gearbox and rotor drive shaft
- droop stops and teeter stops
- main rotor blade spindles
- main rotor teeter and coning (or "flapping") bolts
- main rotor blade pitch links.

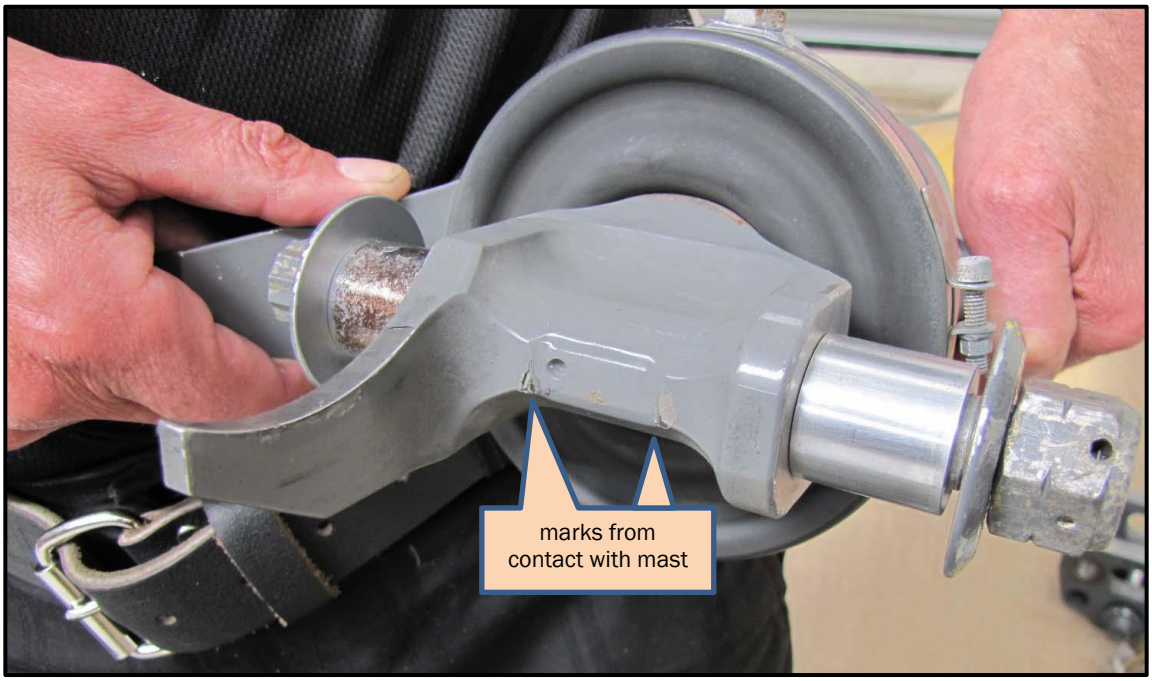

Figure 1
Blade spindle, showing evidence of mast contact

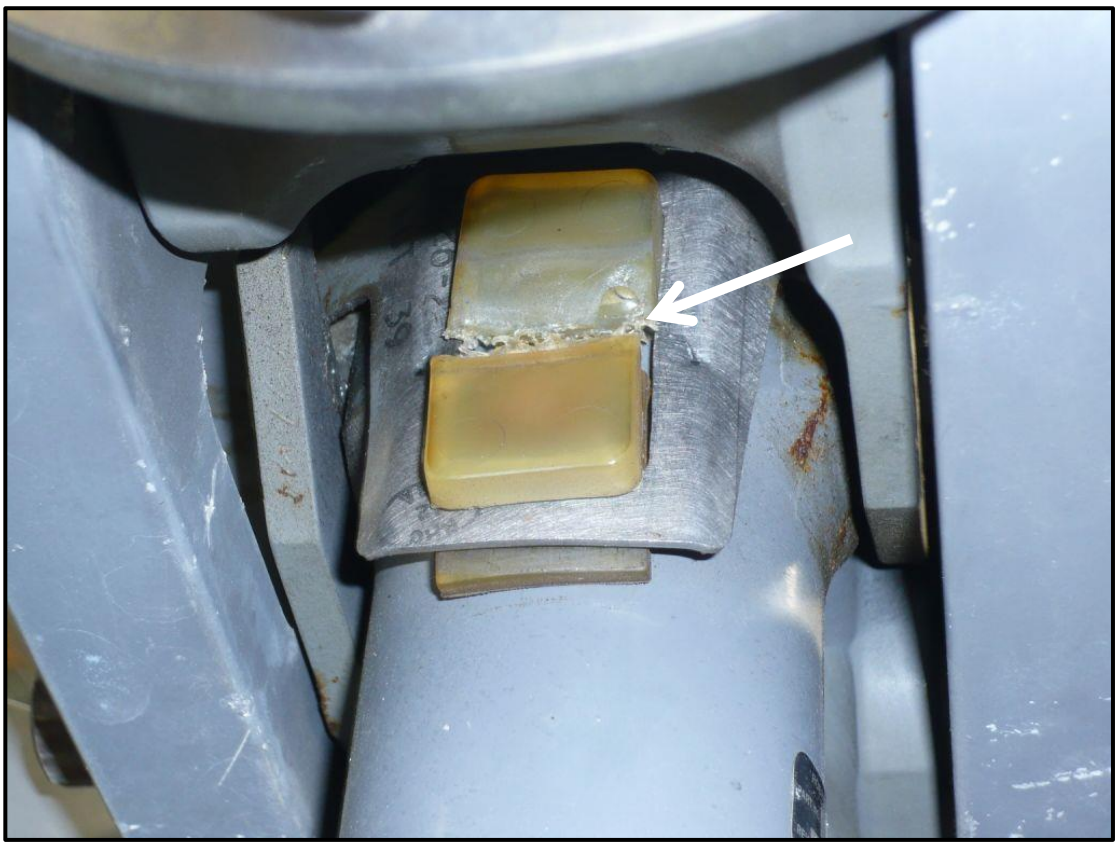

Figure 2
Crushed and split teeter stop

3.3. Personnel information

3.3.1. The instructor was a military-trained, career helicopter pilot with more than 7100 flight hours. He held an A-category instructor rating and a general aviation helicopter flight examiner rating. He had instructed for approximately 1900 hours, mostly in two-bladed, teetering rotor helicopters.

3.3.2. The instructor had obtained his R22 type rating in 2003 and had since accrued 462 hours on the type. His initial R22 training had included the mandatory special training and that had been refreshed during subsequent biennial flight reviews. In November 2011 he had attended a pilot safety course conducted by Robinson in the United States.

3.3.3. The instructor said that he had experienced an un-commanded right roll during a low-G condition in an R22 on four other occasions, but each of them had involved a gentle onset and a slow roll rate. Two occasions had been when other instructors were demonstrating the condition and the required recovery action. The other two times had occurred inadvertently while he was training. He said that in each case the roll had been gentle and easily corrected with a small amount of aft cyclic.

3.3.4. The student had begun his helicopter training with the instructor in June 2011. He had completed the initial requirements of the special training on 1 April 2012, shortly before his first solo flight. On 30 March 2013 the student had accrued approximately 62 flight hours, all of them in the same helicopter.

3.4. Aircraft information

3.4.1. The two-seat R22 light helicopter was manufactured by Robinson in the United States and was first certificated by the FAA in 1979. The two blades of the underslung, teetering main rotor can flap independently, a design feature that was unique to Robinson helicopters (see Figure 3).

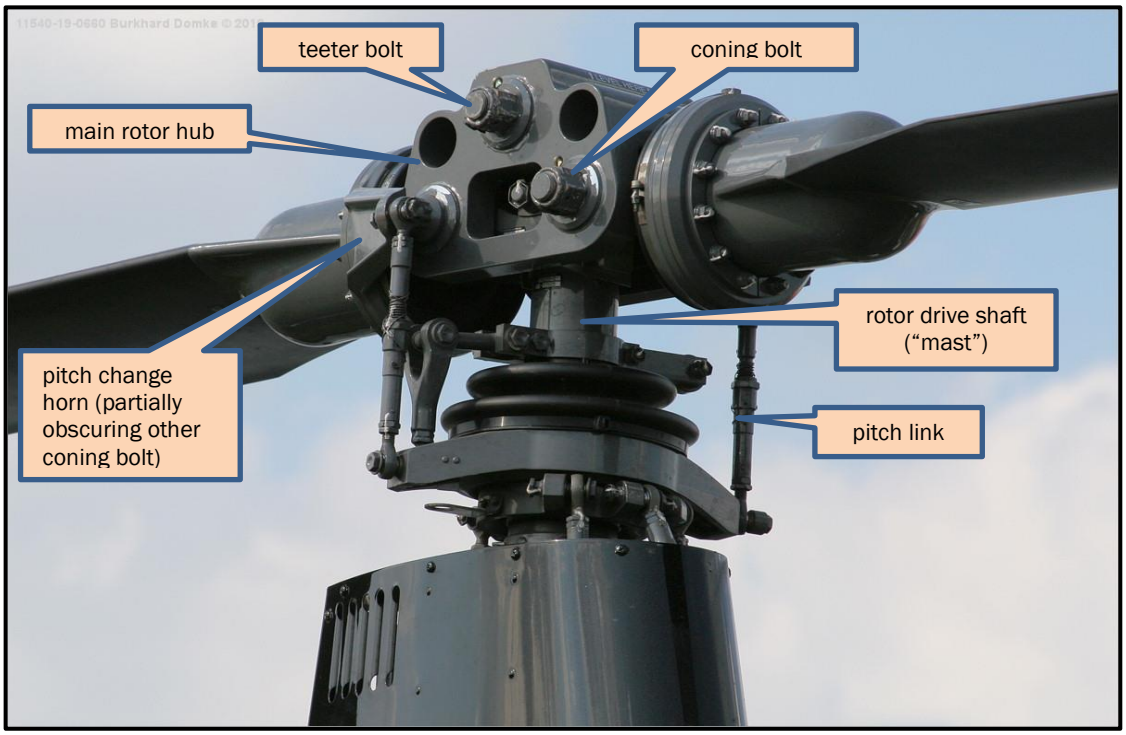

Figure 3
R22 main rotor head components
(Image used with permission of Burkhard Domke)

3.4.2. The helicopter is popular for basic helicopter pilot training, for which purpose it is equipped with dual flight controls. These include a collective lever and tail rotor pedals for each pilot, and a centrally mounted cyclic stick (see Figure 4). The main rotor disc tilts in the same

direction that the cyclic pitch control is moved. If the cyclic is moved forward, the rotor disc tilts forward; if the cyclic is moved aft, the disc tilts aft, and so on.

3.4.3. Student helicopter pilots learn the "effects of controls" in their first training lesson. The natural response to counter an un-commanded roll – for example, in gusty wind conditions – is to apply the cyclic stick in the opposite direction to the roll. However, if an un-commanded right roll occurs during a low-G condition, the flight manual's recommended action is to apply gentle aft cyclic to "load" the main rotor before applying left cyclic. That response is counter-intuitive, particularly for a low-time helicopter pilot. If left cyclic is first applied to correct an un-commanded right roll during a low-G condition, a mast bump can occur, especially if the cyclic stick movement is large or abrupt. A strong mast bump can sever the mast with an obvious fatal consequence. Therefore Robinson pilots had to understand correctly the recommended recovery technique (see section 3.5).

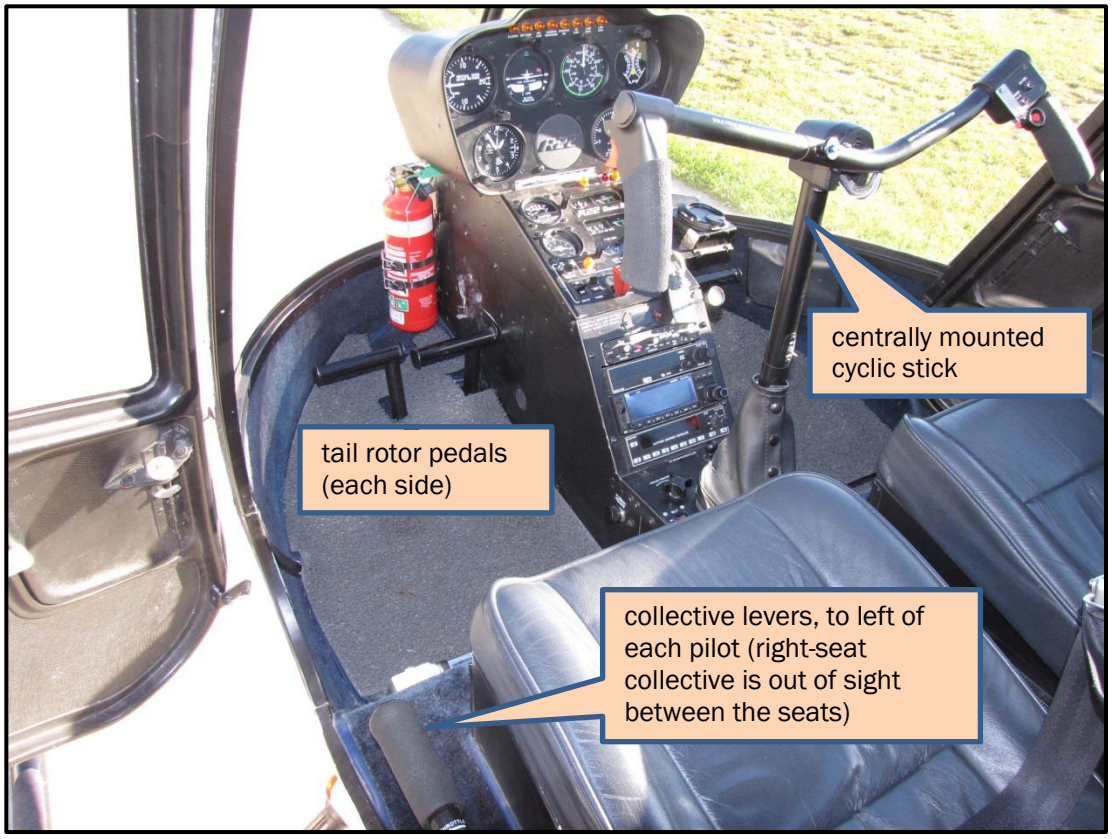

Figure 4
Typical R22 dual flight controls

3.4.4. The tail rotor thrust counters the normal tendency of the fuselage to turn in the opposite direction to the main rotor. When more power is put into the main rotor, for example, to climb or to go faster, the fuselage torque increases and the tail rotor must also produce more thrust in order to keep the helicopter on the same heading (see Figure 5).

3.4.5. If the tail rotor thrust acts above the helicopter's centre of gravity, it can have a secondary effect of creating a rolling moment.[13] This is normally countered through design or by applying opposite cyclic. The higher that the tail rotor thrust line acts above the centre of gravity, and the greater the tail rotor thrust, the greater the rolling moment.

3.4.6. In a condition of low G, the main rotor disc still responds to cyclic control inputs. Therefore an attempt to counter a right roll with left cyclic will tilt the rotor disc to the left, but the

[13] A moment is the turning or lever effect of a force acting about a point. In this case the tail rotor thrust creates a moment about the helicopter's centre of gravity.

underslung fuselage may not follow (depending on the G loading at the time). In such a case, if the left movement of the disc combined with the right roll of the fuselage reaches the limits of the rotor hub geometry, a mast bump can occur.

3.4.7. The helicopter involved in the accident was manufactured in 2004 and had accrued 3735 flight hours at the time of the accident. A review of the log books showed that it had been maintained in accordance with the approved maintenance programme. There was no deferred defect rectification.

3.4.8. Both pilots weighed less than 80 kilograms and the fuel on board was less than three-quarters of the full capacity. The helicopter's weight and balance were estimated to have been within the flight manual limits.

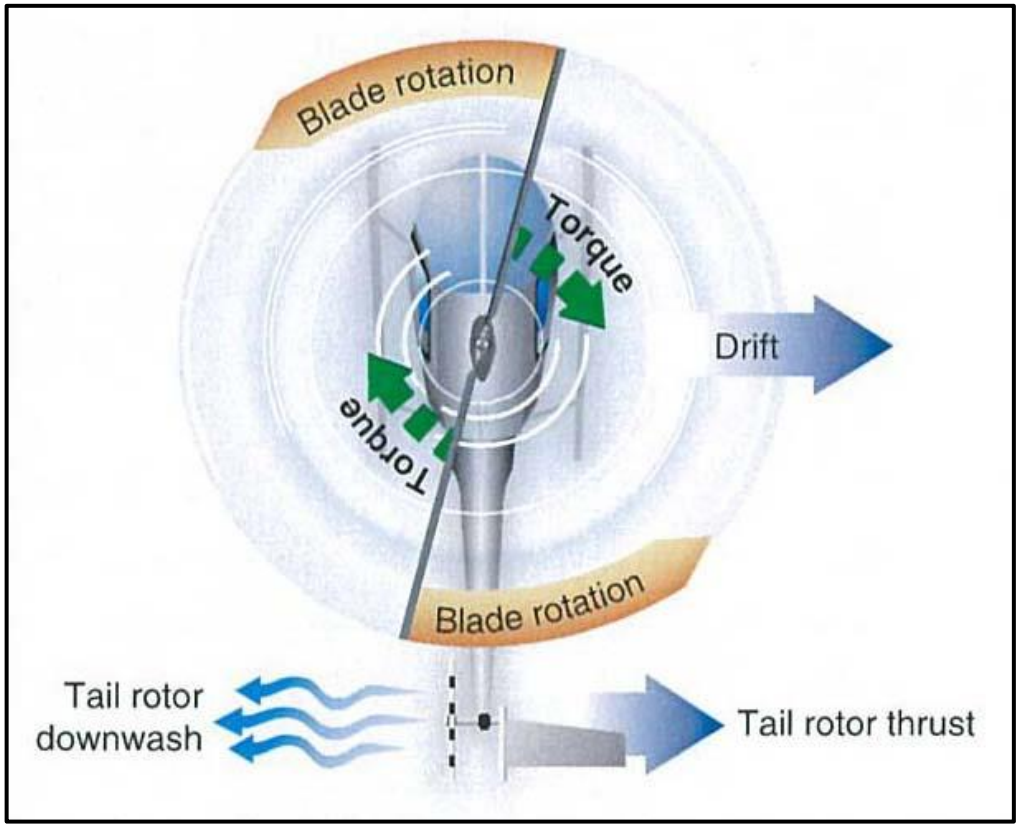

Figure 5
Forces acting on a helicopter fuselage
(Image from FAA Helicopter Flying Handbook, 2012)

3.5. Special training for Robinson helicopter pilots

3.5.1. During the 1980s and early 1990s there was concern in the United States about the number of R22 accidents that appeared to have involved a loss of main rotor control followed by in-flight break-up of the helicopters. During this period the FAA conducted three special certification reviews of the helicopter and the NTSB conducted a special investigation of the problem.[14]

3.5.2. In 1995 the FAA took action in an attempt to reduce the incidence of mast bump accidents. An airworthiness directive limited the operation of the R22 in wind or turbulence above specified levels, and provided a recommended procedure should turbulence or low G be encountered. That airworthiness directive, amended to apply particularly to pilots with little

[14] NTSB SIR-96/03, Robinson Helicopter Company R22 loss of main rotor control accidents, 2 April 1996.

experience, remains in force as at the date of this report.[15] The CAA adopted, with some changes, the FAA airworthiness directive and later amendments.

3.5.3. In 1995 the FAA also issued Special Federal Aviation Regulation No. 73 (SFAR 73) – "Robinson R-22/R-44 Special Training and Experience Requirements" to address the pilot training and proficiency issues that had been identified during the above reviews.[16] SFAR 73 introduced minimum experience requirements for pilots of the R22 (and the larger Robinson R44) and more stringent biennial flight review requirements for pilots of both types. SFAR 73 also required specified awareness training and aeronautical experience (the special training) to improve the knowledge and handling skills of pilots of Robinson helicopters. SFAR 73 was made permanent on 29 June 2009. The CAA adopted most of the SFAR 73 requirements by adding them to the Limitations section of the New Zealand R22 flight manual.

3.5.4. Prior to the initial issue of SFAR 73, there had been no mandated requirement for pilots to have knowledge of mast bumping and low-G hazards before they were issued with helicopter licences. SFAR 73 introduced the requirement for "awareness training" in these and other hazards, and for "aeronautical experience", that is, in-flight dual instruction, on the "effects of low-G manoeuvres and proper recovery procedures". The exercise about to be conducted when this accident happened was intended to meet that special training requirement.

3.5.5. However, also in 1995 and shortly after SFAR 73 was issued, the FAA issued an emergency airworthiness directive that prohibited deliberate low-G manoeuvres.[17] That action was prompted by an FAA analysis of Robinson flight test data that indicated a low-G cyclic push-over could result in mast bumping on the R22. A similar directive was made for the R44. Both directives remain in force as at the date of this report. However, in spite of SFAR 73 having been reviewed twice since 1995, the aeronautical experience section of SFAR 73 has not been amended to reflect the prohibition.

3.5.6. The usual practice when training an R22 pilot was for the instructor to introduce the special training topics at appropriate levels for the stages of the student's training. For example, a student had to be competent in controlling the rotor RPM well before their first solo flight; and had to understand how to avoid and recover from low-G conditions prior to the first solo navigation exercise. The total time spent on the special training during initial training could be two or three hours, depending on the pilot's prior helicopter experience. Qualified pilots were required to review the key aspects of the special training at each biennial flight review.

3.6. Helicopter instructors' forum

3.6.1. On 9 May 2013 Commission investigators hosted a forum of expert New Zealand helicopter instructors and CAA staff for the purpose of gaining an understanding of the handling behaviour of Robinson helicopters and how the special training was conducted in practice.[18] At the time the Commission had three open inquiries into Robinson helicopter accidents, including that which is the subject of this report.

3.6.2. It was agreed at the forum that the full benefits of the special training and the lessons learned from investigations into fatal accidents had not been well disseminated in New Zealand, even to the most experienced helicopter instructors. As a consequence, the intended knowledge transfer had not always occurred and it was very likely that there were helicopter instructors who did not fully understand the requirements of, and rationale for, the training.

3.6.3. A criticism made at the forum was that the instruction on the recovery from an un-commanded right roll was unconvincing, given that demonstrations of low-G conditions are prohibited. Anecdotes were heard at the forum, and subsequently, of in-flight demonstrations of low G in spite of the prohibition.

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[15] United States airworthiness directive 95-26-04, dated 26 January 1996.
[16] See Appendix 2 for further information on the development of the special regulations.
[17] United States airworthiness directive 95-11-09, dated 14 July 1995.
[18] See Appendix 1 for details of participants.

3.6.4. The senior instructors at the forum expressed concern about the number of less-experienced instructors whom they had examined for instructor categorisation upgrades who had not fully understood the low-G problem and what they were trying to teach. The forum instructors agreed that the CAA ought to have adopted the FAA requirement specifically to endorse instructors who would conduct the special training, in part to standardise the quality of the special training.

3.6.5. The expert instructors also discussed the effectiveness and intuitiveness of the procedure that Robinson recommended for recovery from an un-commanded right roll, and alternative recovery procedures. The CAA later published an article written by one of the participants, which described the problem of un-commanded right roll in low-G conditions and commented on alternative recovery procedures.[19]

3.6.6. The forum was also concerned about the differences between New Zealand and the United States regarding pilot currency requirements for Robinson helicopters. The FAA, in SFAR 73, required pilots of Robinson helicopters to have current biennial flight reviews in the models (R22 or R44) flown. If this had been adopted by the CAA, a pilot who was rated on both models would have had to have a separate flight review in each type. However, the CAA permitted a flight review to be conducted on any helicopter type for which the pilot was rated. Some flight examiners in New Zealand had chosen to meet the spirit of the SFAR 73 requirement by conducting, for pilots who were rated on Robinsons and one or more other types, alternate flight reviews in Robinsons. The forum agreed that the New Zealand requirement possibly reduced the effectiveness of the special training and potentially put at risk pilots who flew R22s infrequently.

3.6.7. The forum participants generally supported the following views:

- there was no standard in New Zealand for how the special training was delivered
- the special training should be delivered in New Zealand by endorsed instructors who work within a certificated flight training organisation
- Robinson R22 (and R44) helicopters should not be flown by pilots who do not have current biennial flight reviews completed in one of those types.

3.7. Previous inquiry

3.7.1. In a previous inquiry[20] the Commission noted that the incidence of R22 accidents in New Zealand had not decreased to the same extent as in the United States, particularly following the CAA's approval in 1998 of flight manual operating and training provisions that were less stringent than those in SFAR 73. Since 1998 there had been an average of one R22 in-flight break-up accident every 18 months in New Zealand.

3.7.2. The Commission made the following findings in its report on the previous inquiry:

- the New Zealand regulatory system has not provided sufficient mandatory requirements and guidance for instructors, pilots and operators of the Robinson type R22 and R44 helicopters to minimise the known risk of exceeding the helicopters' capabilities
- the rate of R22 in-flight break-up accidents in New Zealand has not been reduced by the New Zealand version of the FAA hazard mitigation measures intended to prevent such accidents.

3.7.3. On 26 February 2014 the Commission recommended that the Director of Civil Aviation:

a. 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 (003/14)

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[19] Spencer-Bower, S. 'Low-g Effects – A New Perspective'. Vector, Nov/Dec 2013. Civil Aviation Authority, Wellington.
[20] Report 11-003, In-flight break-up, Robinson R22, ZK-HMU, near Mt. Aspiring, 27 April 2011.

b. review FAA SFAR 73 in the context of the New Zealand aviation system and adopt relevant improvements that would likely enhance the operational safety of Robinson aircraft in New Zealand (004/14).

3.7.4. On 5 March 2014 the Director replied, in part:

> 003/14 – the recommendations will be implemented in the form of a review by the Personal Licencing and Flight Training Unit, along with the Helicopter and Agricultural Operations Unit of the CAA. The review is envisaged to take approximately 12 to 15 months to complete.
>
> 004/14 – the recommendation will be implemented in the form of a review by the Helicopter and Agricultural Operations Unit. The review is envisaged to take approximately 12 to 15 months to complete.

4. Analysis

4.1. Introduction

4.1.1. This accident occurred during an instructional flight that was to review the recognition of and recovery from an un-commanded right roll, with an assumed condition of low G. The instructor understood the theory of the effect and had safely carried out the intended exercise many times, including with the student earlier in his training and another student the day before the accident flight. The very thing that was meant to be avoided happened instead.

4.1.2. The instructor recognised that the extreme attitudes reached by the helicopter during the event presented a great risk of a substantial mast bump or of the main rotor contacting the fuselage, either of which could have been catastrophic. The damage to the rotor head showed that a mast bump did occur.

4.1.3. There have been few occasions when an R22 has landed safely after a significant mast bump. However, in this case the pilot was able to regain control of the helicopter by gentle control inputs. The fortunate outcome provided an opportunity to identify with greater confidence the possible contributing factors.

4.1.4. There were a number of reasons for the inquiry also considering the content and conduct of the special training:

- the number of Robinson helicopter accidents in New Zealand had not decreased as expected following the introduction of the special training for pilots
- all of the pilots involved in the recorded accidents had received the special training
- the intended exercise was a required part of the special training
- the exercise involved an experienced helicopter instructor
- although the recovery was successful, the instructor had not followed the recommended procedure for an un-commanded roll that he had been about to review with the student.

4.2. The cause of the un-commanded roll

4.2.1. The weather on 30 March 2013 was benign. There was no turbulence that could have caused an inadvertent low-G condition. There were no technical defects with the helicopter.

4.2.2. The instructor said that at the completion of the flap-forward demonstration the helicopter was almost in level flight when it rolled before he made any control movement to start the next exercise. However, if the helicopter had been still pitching down due to the flap-forward effect or the instructor had hastened the level-off (by moving the cyclic stick forward) in preparation for the roll-recovery practice, the G could have reduced slightly. The student, but not the instructor, recalled the G reducing noticeably before the roll.

4.2.3. The instructor said the engine power was approximately 22 inches of manifold pressure, or a little less than the normal cruise setting. Therefore the pitch of the main rotor blades would have been in the normal range and the main rotor RPM was very likely at 100% with the instructor in control. The student did not hear the low-RPM warning horn until after the roll had begun.

4.2.4. Most of the expert instructors at the forum held in May 2013 had been shown the exercise and had demonstrated it themselves prior to the flight manual amendment that prohibited demonstrations of the effects of low G. The expert instructors suggested that the power setting they had used for the exercise had probably not exceeded 18 to 20 inches of manifold pressure, in order to minimise the tail rotor thrust that was the cause of the rolling moment. Some of them were of the view that the higher power used by the instructor in this case would have been a factor in the high rate of roll, if there had been a coincident reduction in G. The instructor accepted their view that the relatively high power could have been a contributing

factor. However, there is no published guidance on a suitable exercise or recommended power setting, because the hazard should now be a discussion topic only.

4.2.5. It was not possible to verify the precise conditions and control inputs immediately before the sudden roll. The instructor was in current flying and instructional practice, and he met the CAA requirements for him to conduct the special training. He understood the usual cause of an un-commanded right roll, and had attended the manufacturer's safety course 16 months earlier. It was very unlikely that he would have made an abrupt movement of the flight controls.

4.2.6. The circumstances of this accident suggest that it was probable that a reduced G condition was induced inadvertently during the transition from the flap-forward demonstration to the roll-recovery exercise. A reduced G condition would have been very unlikely had the instructor completed the flap-forward review and positively achieved stable, straight and level flight before starting the next exercise.

4.2.7. The forum instructors considered that the onset of a low-G roll in the R22 was usually benign and control was easily recovered, if the roll occurred at a low airspeed with a low engine power setting. That was also this instructor's experience. However, he and the student emphasised that in this case the onset of the roll was sudden and the rate of roll was high. The instructor, with the R22 accident history in mind, suggested that the alarming rate at which the helicopter had departed from controlled flight indicated that another factor, such as main rotor divergence, could have been involved. However, unless either pilot had made a sudden control input, the sudden roll was more likely to have been caused by an unintended reduction in G combined with a relatively high power setting while the tail rotor was above the vertical centre of gravity.

4.2.8. Both pilots said that an extreme angle of bank occurred before any recovery was attempted. The recommended procedure was designed as the response to a more benign onset of right roll. It has not been possible to determine whether the recommended procedure would have been successful in recovering the helicopter after it had reached an extreme angle of bank.

4.2.9. The instructor said he did not perceive reduced G at the time, so he assessed the situation to have been different from the condition he had been about to review. As a result, and because an extreme angle of bank was reached so quickly, he reacted with his previously considered response to an unusual attitude. He judged it to be of critical importance to "fly" the main rotor so that it would not strike the fuselage. That rationale was indirectly supported later by a very experienced instructor when commenting on the low-G article in the CAA magazine (see paragraph 3.6.5): "The overriding goal for a pilot in a negative G event, especially when accompanied by un-commanded roll, must always be to keep the disc parallel to fuselage floor". The writer added, "this is not to say that the recommended recovery procedure should not be applied" (CAA, 2014, p.22).

4.2.10. Although the instructor did not perceive a low-G condition, his reaction to the sudden roll was reasonable under the circumstances and not an intentional disregard for a recommended procedure.

Findings

1. No environmental condition or helicopter defect caused the un-commanded roll.
2. It was probable that the un-commanded roll was caused by an inadvertent reduction in G during the transition from the flap-forward demonstration to the next exercise, while the engine power was at a relatively high setting.

4.3. Conducting the special training

4.3.1. The phenomenon of un-commanded right roll and the potential hazard of mast bumping are not confined to Robinson helicopters, but they are more likely to be encountered with helicopters, like the Robinson designs, that have two-bladed underslung main rotors. Knowledge of these hazards is now included in the helicopter pilot training syllabi in New Zealand and the United States, but the special training applies only to pilots of the R22 (and, in the United States, to pilots of the R44).

4.3.2. The NTSB credited the special training required by SFAR 73 with having reduced the incidence of loss-of-main-rotor-control accidents in the United States (NTSB, p.27). Such accidents still occur there, but less often. Although the FAA requires instructors who conduct the special training to be specifically endorsed, the CAA does not have that requirement.

4.3.3. The expert instructors at the forum supported the specific endorsement of instructors because of their sense that the standard and effectiveness of the training had become "diluted" over successive generations of helicopter pilots. The experts offered, in support of that view, their observation that too many candidates for instructor rating upgrades did not understand fully all of the special training theory and requirements. However, the experts' discussion on the effectiveness of recovery methods, while offering valuable insights into the problem of low-G effects, showed that there were diverse opinions regarding the special training requirements..

4.3.4. The R22 flight manual has prohibited demonstrations of low G since 1995, but SFAR 73 still shows a requirement for **dual flight instruction** in "the effects of low-G maneuvers and proper recovery procedures". New Zealand adopted SFAR 73 by inserting most of the same text into the R22 flight manual. Instructors could potentially interpret the wording of SFAR 73 as sanctioning the demonstration of low-G situations when conducting dual flight instruction. There is evidence that in-flight demonstrations have continued to take place in New Zealand, and not always without incident. Of particular concern are reports of demonstrations that amount to experimentation. Anecdotal evidence suggests that some of the pilots asked for further instruction in the recovery procedure from a low-G roll to restore their confidence after what has seemed to be a spate of accidents involving R22 helicopters.

4.3.5. The Commission is recommending that the Administrator of the FAA resolve what could potentially be contradicting requirements of SFAR 73 and the R22 flight manual.

4.3.6. The discussion at the expert instructors' forum suggested that there could be industry support for the following changes to the delivery of the special training in New Zealand:

- standardised content and techniques
- delivery by endorsed instructors working within a certificated flight training organisation
- a specific requirement for Robinson helicopter pilots to have current biennial flight reviews in a Robinson helicopter.

4.3.7. These conclusions complement the recommendations made by the Commission to the Director of Civil Aviation after inquiry 11-003 (TAIC, 2014). SFAR 73 prescribed a comprehensive training response to reduce the incidence of R22 accidents, but the CAA adopted the requirements with some variations. The lack of standardisation in instructor technique and lesson content, identified in report 11-003, likely led to variations in pilot understanding of the special training goals, and could have been an unrecognised systemic factor in earlier R22 accidents in New Zealand.

4.3.8. Although the recommendations in inquiry 11-003 were made by the Commission after the date of this accident, the circumstances of this accident underline the urgency for the CAA to take effective action. On 28 August 2014 the CAA advised that progress was being made in response to those recommendations. Accordingly, no finding or recommendation has been made in this inquiry regarding the content or conduct of the special training.

Finding

3. The section of the United States Special Federal Aviation Regulation No. 73, which requires Robinson helicopter pilots to have dual flight instruction in the effects of low-G manoeuvring, appears to contradict the R22 helicopter flight manual, which prohibits the demonstration of low-G conditions.

4.4. Flight manual (clarity of critical information)

Safety issue – The Robinson helicopter flight manuals do not conform to the aviation industry practice for the use of "Warnings" to emphasise flight conditions and operating practices that can cause death or serious injury.

4.4.1. The purpose of the helicopter flight manual "is to provide an authoritative source of information considered … necessary for or likely to promote safe operation of the helicopter" (FAA, 1999, p. G33). It is an operating guide for pilots and contains the material required by national regulations to be made available to pilots, as well as supplemental information provided by the manufacturer. Required information includes the helicopter limitations, the emergency procedures, the normal procedures and data necessary for a pilot to determine the helicopter performance under various conditions of, (for example) weight, altitude and air temperature. The supplemental information includes systems descriptions and the means to calculate the weight and balance of the helicopter. Pilots are required to have a thorough knowledge of the flight manual, which must be carried on board.

4.4.2. The R22 flight manual contains the information required by the regulations. Robinson Helicopters includes an additional section in the manual that contains "Safety Tips and Notices". The safety tips provide generic advice for the safe operation of helicopters like the R22. Many of the safety notices, which have been issued by Robinson "as a result of various accidents and incidents", also have generic application, but some of them specifically address hazards that are more likely to affect Robinson helicopters; for example, low rotor RPM and low-G pushovers (see Appendix 3). The key messages in some of these notices have been repeated in the "Limitations" section of the flight manual. The avoidance of a low-G condition is one such example.

4.4.3. The Commisison has previously commented that Robinson helicopter flight manuals did not always contain the text and emphasis expected for certain safety critical conditions.[21] For example, in 1995 the FAA restricted the R22 airspeed in turbulent conditions to 70% of the maximum permitted speed.22 In 1998 Robinson issued a safety notice on the subject of flight in high winds and turbulence, which noted the potential for a mast bump under such conditions. The flight manual has been revised several times since 1995, but none of the FAA-approved sections of the manual refers to the airspeed restriction, or even mentions "turbulence".[23] As flight in turbulent conditions has been cited as a possible cause for a number of R22 in-flight break-up accidents, it would have been appropriate to have recognised the importance of the airspeed restrictions by including them in the Limitations section of the flight manual.

4.4.4. The instructor in this accident had no intention of demonstrating a low-G condition. He was familiar with the flight manual "caution" (paragraph 3.1.3) and understood the hazard. However, anecdotal evidence suggested that, in spite of safety awareness training that all pilots of Robinson helicopters must complete, not all pilots fully appreciate that a low-G condition in a Robinson helicopter can be fatal. One reason for this could be that the consequences (personal injury or death) of entering a low-G condition are not being clearly articulated in the Robinson helicopter flight manuals, because the manuals are not following the aviation industry norm for the use of "warnings".

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[21] Inquiry 11-003, in-flight break-up, ZK-HMU, Robinson R22, near Mount Aspiring, 27 April 2011.
[22] Airworthiness Directive 95-26-04.
[23] As at February 2015.

4.4.5. FAA Advisory Circular 27-1B describes the acceptable means of compliance for meeting the certification requirements of Federal Aviation Regulation 27, Certification of Normal Category Rotorcraft.[24] In regard to Regulation 27.1585, which deals with the section on operating procedures in a flight manual, the advisory circular states, in part:

> Notes, cautions, and warnings may be used to emphasize specific instructions or information in general accord with the following.
>
> (i) "Note" should be used with respect to matters not directly related to safety but which are particularly important …
>
> (ii) "Caution" should be used with respect to safety matters of a secondary order not immediately imminent …
>
> (iii) "Warning" should be used with respect to safety matters of a primary order or immediately imminent.

4.4.6. The aviation industry has generally interpreted the above words to mean the following:[25]

> Note: an operating procedure, technique or maintenance condition which is considered essential to emphasise
>
> Caution: an operating procedure, technique or maintenance practice which may result in damage to equipment if not carefully followed
>
> Warning: an operating procedure, technique or maintenance practice which may result in personal injury or loss of life if not carefully followed.

4.4.7. Robinson, however, does not use Warnings in its flight manuals, even though they contain references to conditions or practices that could lead to "a catastrophic loss of control", which clearly suggests the likelihood of loss of life. Instead, Robinson uses the following definition:

> *CAUTION* Equipment damge, injury, or death can result if procedure or instruction is not followed.

4.4.8. Robinson's choice for distinguishing between Warning and Caution is not in accord with the advisory circular and with aviation industry.

4.4.9. Many investigations into loss-of-control accidents that involved Robinson helicopters have been concluded without a definite cause being established. In spite of the special training that has been required since 1995 for pilots of Robinson helicopters, many experienced pilots have lost control and their lives. It is possible that some of those accidents occurred because the pilots involved had not appreciated the significance of critical safety information in the flight manuals. Robinson's avoidance of the term Warning was likely to have diminished the perceived importance of some critical safety information.

4.4.10. Therefore, the Commission is recommending that the FAA require Robinson to amend its flight manuals to include the use of "Warning" for those operating conditions and practices that involve a risk of personal injury or loss of life.

Finding:

4. The importance of some critical safety information in Robinson flight manuals was likely to have been diminished by Robinson's use of "Caution", rather than "Warning", for operating conditions and practices that involve a risk of personal injury or loss of life.

[24] FAA Advisory Circular 27-1B, Certification of Normal Category Rotorcraft, 30 September 1999.
[25] Example taken from the flight manual for the Pacific Aerospace Limited 750 XL aeroplane.

5. Findings

5.1. No environmental condition or helicopter defect caused the un-commanded roll.

5.2. It was probable that the un-commanded roll was caused by an inadvertent reduction in G during the transition from the flap-forward demonstration to the next exercise, while the engine power was at a relatively high setting.

5.3. The section of the United States Special Federal Aviation Regulation No. 73, which requires Robinson helicopter pilots to have dual flight instruction in the effects of low-G manoeuvring, appears to contradict the R22 helicopter flight manual, which prohibits the demonstration of low-G conditions.

5.4. The importance of some critical safety information in Robinson flight manuals was likely to have been diminished by Robinson's use of "Caution", rather than "Warning", for operating conditions and practices that involve a risk of personal injury or loss of life.

6. Safety actions

General

6.1. The Commission classifies safety actions by two types:

(a) safety actions taken by the regulator or an operator to address safety issues identified by the Commission during an inquiry that would otherwise result in the Commission issuing a recommendation

(b) safety actions taken by the regulator or an operator to address other safety issues that would not normally result in the Commission issuing a recommendation.

Safety actions addressing safety issues identified during an inquiry

6.2. The recommendations made to the Director of Civil Aviation by the Commission in its inquiry 11-003, regarding the special training required by the United States SFAR 73, were issued after the date of this accident. The circumstances of this accident underlined the urgency for the CAA to take effective action.

6.3. On 23 April 2015, in response to those recommendations, the CAA published a consultation document, "Robinson helicopter fleet", that identified issues with the way that Robinson safety awareness training was conducted in New Zealand. The CAA proposed the following actions to address the identified issues:

a. require all Robinson safety awareness training to be done under the authority of either a Part 119 or Part 141 certificate

b. require the training given to be acceptable to the Director [of the CAA]

c. require those persons delivering Robinson safety awareness training to have been approved to do so by a flight examiner

d. require Robinson safety awareness training as part of the type rating requirements for the R44 and R66

e. require Robinson safety awareness training to be completed by all pilots who hold R44 and R66 type ratings and who wish to exercise the privileges of those type ratings

f. increase the minimum flight experience for first solo flight in an R22 from 10 hours to 20 hours

g. amend the R22 flight manual to remove references to low "G" flight demonstration and enhanced autorotations.

Safety actions addressing other safety issues

6.4. Nil.

7. Recommendations

General

7.1. The Commission may issue, or give notice of, recommendations to any person or organisation that it considers the most appropriate to address the identified safety issues, depending on whether these safety issues are applicable to a single operator only or to the wider transport sector. In this case, two recommendations have been issued to the Administrator of the FAA, with notice of the recommendations given to the Director of the CAA.

7.2. In the interests of transport safety it is important that these recommendations are implemented without delay to help prevent similar accidents or incidents occurring in the future.

Recommendations

7.3. On 23 April 2015 the Commission recommended to the Administrator, Federal Aviation Administration, that he:

7.3.1. Amend section 2(b) of Special Federal Aviation Regulation No. 73 – Robinson R-22/R-44 Special Training and Experience Requirements to make it clear that dual instruction in the "effects of low-G maneuvers" is limited to discussion only, and to reiterate that deliberate in-flight reduced G conditions are prohibited. (003/15)

7.3.2. Require Robinson Helicopter Company to amend its flight manuals to include the use of "Warning" for those operating conditions and practices that involve a risk of personal injury or loss of life. (007/15)

7.4. No response was available from the Administrator at the time this report was published.

8. Key lesson

8.1. Pilots, particularly flight instructors, must be alert to conditions that could result in an inadvertent breach of a flight manual prohibition of low G.

9. Citations

CAA. (1996), Air 2140, Rotorcraft flight manual, Robinson R22; Civil Aviation Authority, Wellington.

CAA. (2014). Low-g response. Vector, Mar/Apr 2014. Civil Aviation Authority, Wellington.

FAA. (1995). Robinson R-22 Flight Standarization Board Report; FAA Aircraft Evaluation Group, Fort Worth, Texas.FAA. (1996, January 26). *Federal Aviation Administration\Airworthiness Directives.* Retrieved March 8, 2013, from Current Airworthiness Directives by product Type: http://rgl.faa.gov/Regulatory_and_Guidance_Library/rgAD.nsf/0/91BE0874983FB92686256A4D0061449D?OpenDocument

FAA. (1999). *AC27-1B, Certification of Normal Cateogory Rotorcraft.* Washington, D.C.: Federal Aviation Administration.

FAA FSB. (1995). *FAA R22 Flight Standardization Board Report, Aircraft Evaluation Group,.* Fort Worth, Texas: Fedral Aviation Administration.

NTSB. (1996). *Special Investigation Report NTSB/SIR-96/03.* Washington, D.C. 20594: National Transportation Safety Board.

NTSB. (1996). Robinson Helicopter Company R22 loss of main rotor control accidents. SIR-96/03. Washington, DC.

Spencer-Bower, S. (2013). Low-g Effects – A New Perspective. Vector, Nov/Dec 2013. Civil Aviation Authority, Wellington.

TAIC. (2014). Inquiry 11-003, In-flight break-up, Robinson R22, ZK-HMU, near Mt. Aspiring, 27 April 2011. Transport Accident Investigation Commission, Wellington.

Appendix 1: Participants in forum held 9 May 2013

Name	Position	Experience and expertise
Larry Bennett	Former Chief Executive and Chief Pilot, North Shore Helicopters	Airline Transport Pilot Licence (helicopter) (ATPL(H) Category A instructor General Aviation flight examiner 15,500 flight hours
Paul Breuilly	CAA, Team Leader, Safety Investigation Unit	
Tim Burfoot	TAIC, Chief Investigator of Accidents	
David Gill	CAA, Team Leader Airworthiness	Bachelor of Engineering (Mechanical)
Ian McClelland	TAIC, Investigator of Accidents	
Andy McKay	CAA, Aviation Examiner	Category A and D instructor General Aviation flight examiner
Rama Rewi	TAIC, General Counsel	
Neil Scott	Chief Pilot, Garden City Helicopters	ATPL(H), Commercial Pilot Licence (CPL) (aeroplane) Category A, D and E instructor for both helicopters and aeroplanes General Aviation flight examiner for both helicopters and aeroplanes 24,800 flight hours
Dave Sowman	Head of Training – Utility HNZ New Zealand	CPL(H) and CPL(A) Category A, D and E instructor General Aviation flight examiner 7600+ rotary wing flight hours
Simon Spencer-Bower	Chief Executive and Chief Flying Instructor Wanaka Helicopters	CPL(H) and CPL(A) Category A helicopter instructor Category D aeroplane instructor General Aviation flight examiner 21,000 flight hours, 18,600 on helicopters, 15,000 on Robinsons
Barry Stephenson	TAIC, Investigator of Accidents	
Ian Wakeling	Chief Executive and Chief Pilot Aviation Development Ltd	CPL(H) and CPL(A) Category B instructor General Aviation flight examiner Former Vice President and production test pilot, Fairchild-Hiller Helicopters 16,000 flight hours
Peter Williams	TAIC, Deputy Chief Investigator of Accidents	

Appendix 2: Earlier safety reviews and actions concerning the R22

The R22 was certificated by the FAA in 1979. The type accrued an unusually high incidence of in-flight break-up accidents, which led the FAA to conduct special certification reviews of the helicopter in 1982, 1988 and 1994. In essence, these reviews concluded that the R22 was safe if the flight manual limitations were observed.[26]

A further review by an FAA Flight Standardization Board in 1995, convened to consider training requirements for R22 pilots, reported (FAA, 1995, p. 6):

> The Robinson R-22 has characteristics which makes [sic] awareness of certain aerodynamic factors mandatory. The awareness of low "G" operations, rotor blade stall potential, energy management, and low rotor RPM recovery techniques are [sic] critical.

The 1995 Flight Standardization Board report set out stringent training and currency requirements for R22 (and R44) pilots and instructors, and suggested areas of research into pertinent areas of helicopter design and operation. Two outcomes of this work were the issuing of airworthiness directives concerning Robinson helicopter operations, and SFAR 73, which deals with training and the special training. Those pertaining to the R22, as amended, remain current today.

In 1992 the NTSB was prompted by a perplexing fatal accident (the "Richmond, California" accident) to open a special investigation into R22 loss-of-main-rotor-control accidents (NTSB, 1996). During the course of its investigation the NTSB issued 11 safety recommendations dealing with helicopter equipment and operations. Those recommendations were closed by the time the investigation ended in 1996.

The final report on the NTSB's special investigation included another six recommendations, including one that the special training requirement be made permanent. The FAA accepted that recommendation. The NTSB continued to have concerns about the following issues:

- control of rotor RPM – there is a very short time (less than one second) available for a pilot to take corrective action if the main rotor RPM reduces below the normal range
- mast bumping – if the main rotor blade spindles contact the mast, one or both of the main rotor blades could contact the fuselage or separate from the mast
- main rotor divergence and loss of control – the precise cause of the R22 main rotor diverging from its normal plane of rotation and striking the fuselage is unknown. The NTSB and the FAA accepted that flight tests to examine this problem were too high risk. A mathematical model developed to simulate main rotor dynamic conditions was terminated (due to a lack of funding) before the extremes of the dynamic conditions were validated
- low-G conditions –under low G the R22 can roll unexpectedly to the right and the intuitive response can cause a mast bump. The recommended recovery action is counter-intuitive. The flight manual Limitations section cautions pilots that a low-G condition may not be demonstrated or practised.

The CAA accepted the FAA rotorcraft type certificate when the first R22 was imported in 1985. As the type certificate includes the FAA-approved flight manual, the CAA was obliged to accept amendments to the flight manual. The initial issue of SFAR 73 amended the Limitations section of the flight manual, but the CAA's amendment of the New Zealand version of the flight manual did not adopt fully the same text.

The FAA considered the knowledge issues to be so critical that, when SFAR 73 was first issued, R22 and R44 pilots were required to complete the training before their next flights. The CAA allowed a more gradual introduction. Pilots, such as the instructor's own instructor, who already had R22 type ratings met the initial training requirements at a subsequent instructor seminar or through training conducted by visiting Robinson instructors.

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[26] This appendix provides a very brief summary of the reports, reviews and studies mentioned. Refer to the source documents for full information.

A significant difference between the United States and New Zealand regarding SFAR 73 and the special training is that the FAA specifically endorsed R22 instructors to conduct the special training, whereas the CAA required only that instructors who conducted the training had themselves completed it beforehand. The CAA requirement was essentially meaningless, because the flight instructors, being rated on the helicopter, would have already completed the special training.[27] With no other requirement for external standardisation of the standard or content of the special training, its effectiveness was bound to be "diluted" over generations of pilots.

Other differences between the FAA and CAA requirements were that the CAA did not require pilots to have current biennial flight reviews in the specific types flown, and did not make the special training permanent for R44 pilots.

[27] This might not have been the case when the special training was introduced, but it would have quickly become so.

Appendix 3: Robinson Safety Notice SN-11

ROBINSON
HELICOPTER COMPANY

Safety Notice SN-11

Issued: Oct 82 Rev: Nov 00

LOW-G PUSHOVERS - EXTREMELY DANGEROUS

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 main rotor shaft separation and/or rotor blade contact with the fuselage.

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 maneuvers, 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 maneuver which could result in a low-G condition. Low-G mast bumping accidents are almost always fatal.

NEVER PERFORM A LOW-G PUSHOVER!!

Recent Aviation Occurrence Reports published by the Transport Accident Investigation Commission (most recent at top of list)

AO-2013-007	Boeing 737-838, ZK-ZQG, stabiliser trim mechanism damage, 7 June 2013
AO-2013-009	RNZAF Boeing 757, NZ7571, landing below published minima,Pegasus Field, Antarctica, 7 October 2013
AO-2013-002	Robinson R44, ZK-HAD, engine power loss and ditching, Lake Rotorua, 24 February 2013
11-007	Descent below instrument approach minima, Christchurch International Airport, 29 October 2011
11-006	Britten-Norman BN.2A Mk.III-2, ZK-LGF, runway excursion, Pauanui Beach Aerodrome, 22 October 2011
11-003	In-flight break-up ZK-HMU, Robinson R22, near Mount Aspiring, 27 April 2011
12-001	Hot-air balloon collision with power lines, and in-flight fire, near Carterton, 7 January 2012
11-004	Piper PA31-350 Navajo Chieftain, ZK-MYS, landing without nose landing gear extended, Nelson Aerodrome, 11 May 2011
11-005	Engine compressor surges, 18 September 2011
11-001	Bell Helicopter Textron 206L-3, ZK-ISF, Ditching after engine power decrease, Bream Bay, Northland, 20 January 2011
11-002	Bombardier DHC-8-311, ZK-NEQ, Landing without nose landing gear extended Woodbourne (Blenheim) Aerodrome, 9 February 2011
10-010	Bombardier DHC-8-311, ZK-NEB, landing without nose landing gear extended, Woodbourne (Blenheim) Aerodrome, 30 September 2010
12-001	Interim Factual: Cameron Balloons A210 registration ZK-XXF, collision with power line and in-flight fire, 7 January 2012
10-009	Walter Fletcher FU24, ZK-EUF, loss of control on take-off and impact with terrain, Fox Glacier aerodrome, South Westland, 4 September 2010
10-007	Boeing 737-800, ZK-PBF and Boeing 737-800, VH-VXU airspace incident, near Queenstown Aerodrome, 20 June 2010

Price $15.00

ISSN 1179-9080 (Print)
ISSN 1179-9099 (Online)