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Australian Transport Safety Bureau

ATSB TRANSPORT SAFETY INVESTIGATION REPORT

Aviation Research and Analysis report - B2004/0292

Final

Robinson R22 helicopter aerial mustering usage investigation

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CONTENTS

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Abstract

The Robinson R22 helicopter is the most common model of rotary-wing aircraft on the Australian register and has been a popular choice for private operations, flying training and various types of aerial work activity. The R22 has a relatively good safety record compared with other light piston-engine helicopters in Australia based on activity levels.

The R22 is also the favoured type for aerial stock mustering operations – an uniquely Australian application that supports the local beef cattle industry. Despite its popularity in this type of work, little was known about the helicopter's suitability for the task. Like other helicopters on the Australian register, the R22 received its initial airworthiness certification in its country of manufacture (United States). The spectrum of manoeuvres conducted in aerial stock mustering did not form part of the flight profile used when the helicopter type received its certification.

In 2004 the ATSB commissioned AeroStructures, an Australian engineering company, to undertake a study of forces acting on an R22 engaged in aerial mustering operations.

Their study offers some useful data on R22 flight profiles in aerial mustering operations, and compares these with the flight profiles used by Robinson Helicopter Company when the helicopter was initially certified.

The AeroStructures testing showed that mustering operations can involve large and sudden power changes that apply very high loads on the helicopter's drive system, and these may exceed the limits set during the certification process. Their report highlights the importance of handling technique, and especially good engine management.

THE AUSTRALIAN TRANSPORT SAFETY BUREAU

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

The ATSB is responsible for investigating accidents and other transport safety matters involving civil aviation, marine and rail operations in Australia that fall within Commonwealth jurisdiction, as well as participating in overseas investigations involving Australian registered aircraft and ships. A primary concern is the safety of commercial transport, with particular regard to fare-paying passenger operations.

The ATSB performs its functions in accordance with the provisions of the Transport Safety Investigation Act 2003 and Regulations and, where applicable, relevant international agreements.

Purpose of safety investigations

The object of a safety investigation is to enhance safety. To reduce safety-related risk, ATSB investigations determine and communicate the safety factors related to the transport safety matter being investigated.

It is not the object of an investigation to determine blame or liability. However, an investigation report must include factual material of sufficient weight to support the analysis and findings. At all times the ATSB endeavours to balance the use of material that could imply adverse comment with the need to properly explain what happened, and why, in a fair and unbiased manner.

Developing safety action

Central to the ATSB's investigation of transport safety matters is the early identification of safety issues in the transport environment. The ATSB prefers to encourage the relevant organisation(s) to proactively initiate safety action rather than release formal recommendations. However, depending on the level of risk associated with a safety issue and the extent of corrective action undertaken by the relevant organisation, a recommendation may be issued either during or at the end of an investigation.

The ATSB has decided that when safety recommendations are issued, they will focus on clearly describing the safety issue of concern, rather than providing instructions or opinions on the method of corrective action. As with equivalent overseas organisations, the ATSB has no power to implement its recommendations. It is a matter for the body to which an ATSB recommendation is directed (for example the relevant regulator in consultation with industry) to assess the costs and benefits of any particular means of addressing a safety issue.

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

ABBREVIATIONS

ATSB	Australian Transport Safety Bureau
BTRE	Bureau of Transport and Regional Economics
CASA	Civil Aviation Safety Authority
KCAS	Knots calibrated airspeed
MAP	Manifold pressure
RHC	Robinson Helicopter Company
TRDS	Tail rotor drive shaft

1 INTRODUCTION

1.1 Background to the report

The number of helicopters registered in Australia has grown steadily over the last decade. By the end of 2006, there were 1,322 helicopters on the Australian civil aircraft register, an increase of nearly 200 per cent since 1996, when there were just 684 helicopters registered. Of the helicopters registered in Australia, the most common type is powered by a single piston engine. These account for 818 aircraft, or 62 per cent of all civil-registered helicopters. Of the 818 piston engine helicopters, the vast majority are certified aircraft, with 62 operating under the amateur-built category.

Aerial stock mustering is one of the many uses of helicopters in Australia. Despite its popularity in some parts of the country, there has been little in the way of a systematic effort to analyse the safety of this type of operation. Accordingly, in late 2004 the Australian Transport Safety Bureau (ATSB) commissioned AeroStructures, an Australian engineering company, to conduct a study of stress affecting the Robinson R22 helicopter conducting aerial stock mustering operations.

The study was initiated to understand the forces acting on R22 aircraft in mustering operations, and to determine how these forces might differ from those considered as part of the helicopter's initial certification process. The R22 was originally certified in the United States in accordance with Federal Aviation Regulation Part 27, and was subsequently certified on this basis for use in Australia in the normal category[1] operations.

1.2 Aerial stock mustering operations

Aerial stock mustering is the use of aircraft to locate, direct and concentrate livestock while the aircraft is flying below 500 feet above ground level and for related training operations (Civil Aviation Safety Authority (CASA) Civil Aviation Order 29.10). Pilots conduct aerial stock mustering to complement traditional mustering techniques using horses and motorcycles.

Mustering with the assistance of aircraft appears to be a uniquely Australian activity, used mainly in remote areas in the north and west of the country. It can be a cost-effective alternative to solely ground-based mustering on larger properties. Aerial stock mustering is mostly conducted in northern Australia during the dry season, between April and October. Activity data from the Bureau of Transport and Regional Economics (BTRE) includes information about aerial mustering operations. In 2004, 88.5 per cent of all general aviation (fixed-wing and rotary-wing aircraft) aerial mustering was conducted in three northern states/territories (Table 1).

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1 Normal category applies to aircraft that are intended for non-acrobatic operations, which have a seating capacity of nine or less (excluding the pilots seat), and a maximum take-off weight of 5,700 kg or less, or 2,750 kg of less for helicopters (CASA Advisory Circular 21.1(1)).

Table 1: General aviation aerial work mustering activity data, 2004

Location	Hours flown	Per cent of total aerial mustering activity
Queensland	45,500	44.05%
Northern Territory	24,100	23.33%
West Australia	21,800	21.10%

Aerial stock mustering involves operating in an inherently hazardous environment – aircraft are manoeuvred at very low level, close to obstacles. When helicopters are used, dust from rotor blade downwash can reduce visibility. Outside air temperature in these parts of Australia is also generally high, and this can degrade aircraft performance.

Aerial mustering is undertaken as either a private category operation over the land occupied by the aircraft owner, or as a commercial aerial work operation, using one of the specialist companies that operate a fleet of aeroplanes or light utility helicopters on a fee-for-service basis. According to CASA's website, 104 holders of air operator certificates are endorsed for aerial stock mustering. Of those, 86 are authorised to operate helicopters in this role.

Pilots wishing to conduct stock mustering are subject to the requirements of Civil Aviation Order 29.10. This Order includes the syllabus of training for an aerial stock mustering endorsement. The aeronautical experience required for an aerial stock mustering endorsement is set out below, though certain exemptions are granted for pilots who hold an agricultural rating.

Civil Aviation Order 29.10

7 Aeronautical experience

7.1 An applicant for approval to conduct aerial stock mustering in an aeroplane, a helicopter or registered gyroplane shall have gained the total number of hours in aeronautical experience applicable to the grant of a commercial pilot licence. The aeronautical experience shall include:

(a) 100 hours as a pilot in command of an aircraft which shall include at least fifty hours in command of the kind of aircraft for which the approval is sought; and
(b) 5 hours low flying in the appropriate kind of aircraft in accordance with the syllabus at Appendix I; and
(c) 10 hours training in aerial stock mustering operations in the appropriate kind of aircraft in the preceding 90 days in accordance with the syllabus at Appendix I; and
(d) 5 hours experience in the type of aircraft to be used for mustering.

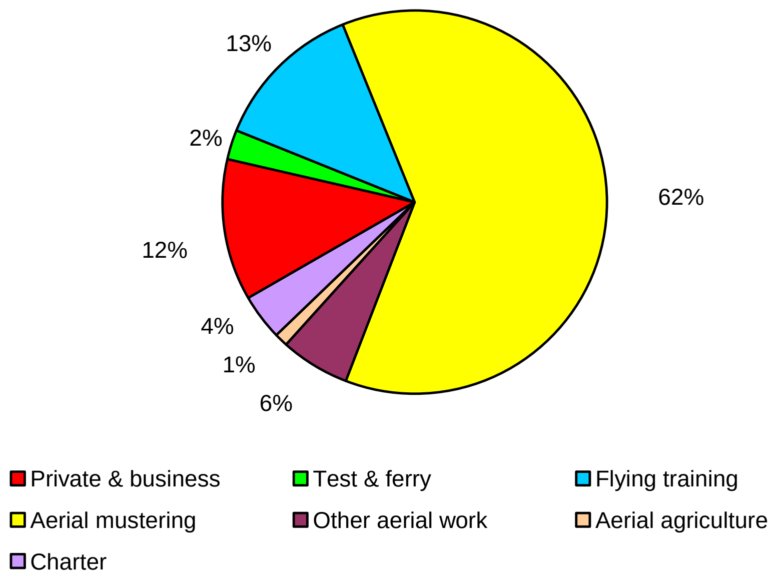
7.2 The 10 hours operations training specified at paragraph 7.1 shall consist of a minimum of 6 hours dual training and the remainder may, at the discretion of the approved pilot, be in command under supervision training or solo operations under his or her direct supervision.

While fixed-wing aircraft are sometimes used for mustering, helicopters are far more commonly used because their handling and flight characteristics (lower speeds and the ability to hover) are better suited to the task. A number of different types of small piston-engine helicopter are used for mustering, including the Bell 47, Robinson R22 and Hughes model 269. All of these aircraft are manufactured overseas and certified in accordance with regulations in the state of manufacture. The Civil Aviation Safety Authority, in a Regulation Impact Statement released in 2003[2], noted that aerial mustering is not generally approved by overseas airworthiness authorities during the certification process.

1.3 Robinson R22 activity in Australia

The most common make of piston-engine helicopter in Australia is the Robinson R22, manufactured by Robinson Helicopter Company (RHC) in the United States. In 2004, when the AeroStructures study was commissioned, there were 371 Robinson R22 helicopters registered in Australia, equivalent to approximately half of all the single-engine piston helicopters operating in Australia. In the same year, Robinson R22 helicopters flew 120,399 hours, of which 62 per cent were recorded against aerial mustering operations (Figure 1). The activity of the R22 in aerial mustering may be even higher, as aerial mustering might also be conducted as a private operation, but the proportion of private/business hours involving mustering is not captured by the BTRE annual survey of general aviation activity.

Figure 1: Robinson R22 activity, 2004



By comparison, only 6.2 per cent of flying activity for all other types of helicopter combined was recorded against aerial stock mustering (11,930 hours from a total of 191,355 hours). As the R22 fleet makes up a large proportion of the total helicopter fleet, they account for the greatest proportion of the helicopter aerial stock mustering operation, equal to 86 per cent in 2004.

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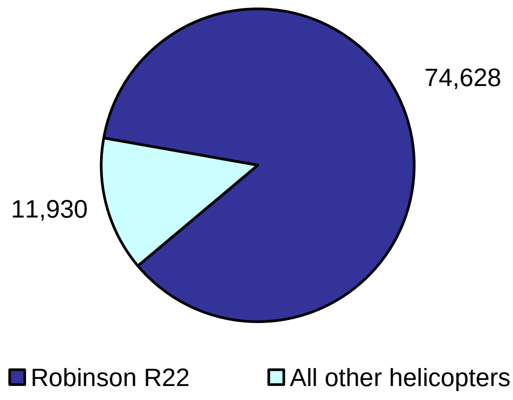
2 Regulation Impact Statement, CASA #0320, AD/R22/31 - Main Rotor Blades, 21 August 2003.

Figure 2: Robinson R22 aerial mustering activity (hours) as a proportion of all helicopter mustering, 2004



1.4 Robinson R22 accidents in Australia

In June 2004, the ATSB published the report *Light Utility Helicopter Safety in Australia* (ATSB, 2004), which examined accident rates among four models of light utility helicopter between 1983 and 2003. Of the 776 accidents during this period, 274 (or just over one third) involved various models of the R22. However, the accident rate, calculated for the period 1990 to 2002, was the lowest of the four most common light utility helicopters at 18 accidents per 100,000 hours, and the fatal accident rate was considerably lower than most other types at 1.5 per 100,000 hours.

The study also examined accidents by type of flying and found that of the 274 accidents involving an R22, 141 were engaged in aerial work operations. Of those, 102 (70.2 percent) were conducting aerial stock mustering. This consisted mostly of aerial stock mustering operations in the R22. However, when exposure (flying hours) was taken into account, the picture for aerial work operations improved. The accident rate for aerial work operations was 14 per 100,000 hours, which was considerably better than the accident rate for private flying (76 accidents per 100,000 hours) or aerial agriculture operations (55 accidents per 100,000 hours).

An analysis of the types of accidents involving light utility helicopters between 1996 and 2003 was also conducted. For the period examined, there were 120 accidents involving R22 helicopters, which identified two main types of accident. The vast majority (103 occurrences, or 85.8 per cent) involved a collision with terrain, trees, man-made features or other obstacles. The remaining 17 accidents (14.2 per cent) were the result of the loss of normal flying capability. Most of those (11 occurrences) were the result of an engine malfunction, with a further four (3.3 per cent of all occurrences) the result of rotor malfunction.

2 THE AEROSTRUCTURES STUDY

In December 2004 the ATSB contracted AeroStructures to analyse the flight characteristics of an R22 helicopter during aerial mustering operations. This was performed by fitting a MaxLife usage monitoring system to an R22 helicopter owned by Heliwork WA Pty Ltd, based in Kununurra. Data was collected from the helicopter over a 26 week period commencing on 30 April 2005.

The MaxLife system records 16 parameters including main rotor speed, engine manifold pressure, aircraft indicated airspeed, and yaw, pitch and roll rates, and angles that describe the flight profile. A full description is provided in the attached AeroStructures report.

A total of 299 files containing data from the MaxLife system were recorded, providing information on 350 hours of R22 operations. AeroStructures reported that these 350 hours accounted for around 55 per cent of the total hours operated by this helicopter over the 26 weeks of the study. AeroStructures could not determine the reason for the difference between the total number of hours the aircraft operated and the number of hours recorded by the MaxLife system, but concluded that the 350 hours of MaxLife data provided a suitable basis for further analysis.

A preliminary analysis of the flight data by AeroStructures indicated that aerial mustering operations involved a much higher proportion of low speed flight compared with the flight profile used for initial certification, and several manoeuvres found in mustering operations were not part of the original certification process. After consultation between AeroStructures, the ATSB and RHC, it was agreed to conduct a further study of the effects of aerial stock mustering operations using an R22 fitted with a strain gauge at RHC.

The RHC machine was fitted with a MaxLife system so that data acquired from the strain gauges could be correlated with the usage data previously collected by AeroStructures in Kununurra. A range of manoeuvres, representative of aerial mustering operations, were flown by the instrumented R22, along with a series of reference manoeuvres normally conducted in RHC flight trials.

2.1 Findings

2.1.1 Aerial mustering operations

The 350 hours of data acquired during aerial stock mustering operations provided a flight profile for this type of operation that can be compared with the flight profile used to certify the R22 helicopter. As expected, the analysis of this data showed that aerial mustering operations involve considerable periods of low speed flight and abrupt manoeuvring with rapid power changes:

- The MaxLife data indicated 10.7 per cent of hours involved the rotor turning on the ground, compared with 1.5 per cent ground running assumed during certification;

- Airspeed below 50 KCAS[3] accounted for 45.9 per cent of aerial mustering flights, but only 16.1 per cent of the certification process;
- Airspeed above 90 KCAS accounted for only 4.8 per cent of mustering operations, but 20.8 per cent of flight time in the RHC specification; and
- Aerial stock mustering also involves more pitch-up/push-over events (+ 15 degrees pitch) than for certification, but these manoeuvres were performed at lower speeds.

2.1.2 Robinson Helicopter Company flight tests

Important additional data was obtained fitting the MaxLife system to the strain gauge-equipped R22 at the RHC factory. The helicopter was flown on two simulated aerial mustering flights and included the following manoeuvres:

- a ‘quick stop’ to reduce forward speed while maintaining altitude;
- high-power take-offs using high engine manifold pressure and rotor speeds throughout the manoeuvre;
- flight involving rapid changes in forward speed and high roll angles; and
- hammerhead turns at various entry speeds, using a variety of control inputs.

Following analysis, only five measurands[4] showed higher peak stresses for the aerial mustering flights than for the certification flights. These were:

a. tail rotor drive shaft (TRDS) torque, with a maximum manoeuvre mean torque 1.04 times higher and a maximum cyclic range of torque 2.38 times higher than for the certification flights;

b. tailcone forward vertical bending, with a maximum manoeuvre mean bending 1.14 times higher than for the certification flights;

c. aft push-pull tube force, with a maximum manoeuvre force 1.12 times higher than for the certification flights;

d. main rotor station 16 bending, with a maximum manoeuvre mean bending 1.07 times higher than for the certification flights; and

e. main rotor station 32 bending, with a maximum cyclic range of torque 1.03 times higher than for the certification flights.

The other measurands were either close to the certification values or had a cyclic component significantly below the certification values. The report found that the abrupt manoeuvring associated with aerial mustering produced relatively small stresses, whereas the peak stresses found during certification occurred during high speed flight, which is uncommon in mustering operations.

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3 KCAS is the abbreviation for knots calibrated airspeed, which is the indicated airspeed corrected for instrument errors.

4 Measurand: a particular quantity subject to measurement ((Hurll, 2005).

AeroStructures also noted that, ‘of the measurands with higher values in the aerial mustering trial flights, the tail rotor drive shaft (TRDS) torque appeared of most concern. In particular the peak cyclic value appeared as a high-speed high-amplitude damped oscillation at about 5 Hz during a rapid and large power reduction as part of a ‘quick stop’ manoeuvre. This manoeuvre, and others like it with rapid, large power level changes, are not uncommon in aerial mustering usage’ (paragraph 8.3.5 AeroStructures report).

Data from the MaxLife files recorded during aerial stock mustering operations identified 1,105 power chops of between 10 and 21 in.Hg (inches of mercury) in less than 2 seconds. A total of 480 of these events occurred when the aircraft recorded a forward speed of at least 20 KCAS.

AeroStructures consulted RHC about the effects of the TRDS torque cycle oscillations. Robinson Helicopter Company engineers concluded that the cycles observed during mustering were causing more damage to the TRDS than had been allowed for during the certification process, but that the additional damage was not sufficiently severe.

RHC replied, in part,

> At present, the tail rotor drive shaft is not a life-limited component and its endurance limit is nearly as high as the loads imposed by your largest cycles. Therefore, only the first few of your 11 cycles for only the more severe MAP changes are damaging. Our present calculated service life (including all safety factors) is approximately 44,000 hours. Adding the mustering data reduces this life to approximately 34,000 hours. Calculated service lives of more than 25,000 hours are considered unlimited. Therefore, although the manoeuvre in question imposes some additional fatigue damage, it does not affect part life.

AeroStructures recommended the ATSB seek assurance from RHC that no components in the rotor drive train are adversely affected or life limited under the high amplitude torsional loading measured during aerial mustering operations. Robinson helicopters responded to the ATSB and reiterated its earlier advice, set out above.

3 CONCLUSION

The R22 in Australia has a relatively good safety record compared with other light piston-engine helicopters in Australia, and that record has improved since the early 1990s. The various models have been popular for training, private operations and for some aerial work applications.

The R22 has also found favour among operators of aerial stock mustering businesses. However, when the R22 was initially certified, mustering operations were not considered part of the normal spectrum of flight manoeuvres. This study has provided some insights into the R22's flight profile and assessed the stresses placed on the helicopter and tail rotor drive shaft during aerial mustering operations.

The AeroStructures report highlights the importance of good handling technique, and especially good engine management. Large and sudden power changes apply very high loads on the aircraft's drive system, and exceed limits set during the certification process.

Although there have been several accidents involving helicopters in aerial stock mustering operations, most appear to be the result of operational handling particularly at low levels, although a few have also been the result of a mechanical failure. Of those accidents that have resulted from mechanical failure, it appears that all were the result of problems with maintenance procedures.

Light utility helicopters are likely to remain engaged in aerial mustering operations. The R22 has been the most popular model for these types of operations, but owners and operators need to fully appreciate the stresses placed on aircraft during mustering operations, and the characteristics of aerial mustering operations, which may be quite different the type of flying for which the type originally received certification.

4 REFERENCES

ATSB. (2004). *Light utility helicopter safety in Australia* (BE04/73). Canberra: Australian Transport Safety Bureau.

Hurll, J. (2005). *Software and measurement.* Paper presented at the DC&LF Club meeting.

5 APPENDIX

See attached report by AeroStructures ‘Robinson R22 Helicopter Aerial Mustering Usage Investigation’.

Robinson R22 helicopter aerial mustering usage investigation