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National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation

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In reply refer to: A-96-9 through -13

Honorable David R. Hinson
Administrator
Federal Aviation Administration
Washington, D C. 20591

The National Transportation Safety Board's special investigation[1] of accidents involving loss of main rotor control by the Robinson Helicopter Company (RHC) R22 was prompted, in part, by an accident that occurred during an instructional flight near Richmond, California, on June 29, 1992. The flight instructor had 2,000 hours in the R22, and the student had 4 hours. The findings in that accident—that the helicopter was being operated at normal main rotor revolutions per minute (rpm) within the approved flight envelope and with no indication of weather being a factor—coupled with the Safety Board's difficulty in determining the causes of many similar loss of main rotor control accidents in the past, led the Safety Board to investigate these accidents as a group in an attempt to find common factors and to develop appropriate recommendations to prevent occurrence of similar accidents in the future.

Since 1981, the Safety Board has investigated or researched 31 R22 and three R44 accidents (domestic and foreign) involving an in-flight loss of main rotor control and contact of the main rotor blades with the tailboom or fuselage of the helicopter.[2]

The Board examined various potential scenarios that could lead to an in-flight rotor/fuselage contact, including the following: an unstable main rotor design; too rapid rotor rpm decay; mechanical failures; high blade angles (rotor stall); mast bumping; over-sensitive flight controls; or sensitivity to multiple or large control inputs. During this investigation, the Safety Board found no direct evidence of an unstable blade or rotor system design. The extensive operational history, the wreckage evidence, flight tests, and computer simulations indicate that a dynamically unstable main rotor system is unlikely.

The Safety Board originally determined that the probable causes of most of the past R22

[1]For more detailed information, read Special Investigation Report--"Robinson Helicopter Company R22 Loss of Main Rotor Control Accidents" (NTSB/SIR-96/03).

[2]The R44 is a four-place version of the R22. The Safety Board's special investigation initially focused on R22 accidents in which the main rotor blade diverged from its normal path and struck the helicopter. When similar R44 accidents occurred, the special investigation was expanded to include those accidents.

accidents were the result of pilots allowing the main rotor rpm to decay or low-G maneuvering. The absence of preexisting material defects in the rotor system, the FAA's assurance that all relevant certification standards had been met, and the belief that the certification standards were adequate led the Safety Board to that determination. However, the Safety Board's investigation of the R22 accident at Richmond, California, presented evidence of an in-flight loss of main rotor control with normal rpm until the breakup began. In the other accidents, the rotor system rpm at the moment of loss of control is unknown. Further, the majority of the evidence in most of the accidents is not consistent with pilot maneuvers that would result in a low-G condition before the loss of control.

Indications of mast bumping were present in all of the loss of main rotor control accidents discussed in the Board's special investigation report, although the mast bumping generally did not result in significant damage at the point of contact with the mast. The Safety Board does not believe that mast bumping was the precipitating causal event in the R22 and R44 loss of main rotor control accidents.

A number of situations could have led to the mast bumping in the R22 and R44 accidents. Unstable blade or rotor system design has been considered, as were rotor blade stall; low-G maneuvers; large, abrupt control inputs; and turbulence. Large, abrupt control inputs can lead directly to mast bumping or induce blade stall, which, in turn, can lead to mast bumping. Turbulence may produce blade stall or lead pilots to make large control inputs. Some low-G maneuvers initially result from deliberate control inputs, but at times these may be followed by larger control inputs during recovery from the low-G situation that may lead to a loss of main rotor control.

Given that the R22 helicopter is very responsive to control inputs, the Board became concerned that many of the loss of control accidents involved large control inputs leading to the loss of main rotor control and subsequent in-flight airframe contact by the main rotor. The Safety Board notes that large, abrupt control inputs when the R22 is in a steady-state condition with an already existing teeter could cause the teeter limit (12°) to be exceeded, followed by a mast strike and subsequent loss of main rotor control.[3] Although a mathematical model of the R22 by the Georgia Institute of Technology was not developed sufficiently to demonstrate this conclusively, the results of the studies suggest that large, abrupt cyclic movements can lead to blade stall and/or mast bumping.

The Board notes that this is not new information; an earlier study on teetering rotor systems by Bell Helicopter also highlighted that large flapping amplitudes could be expected with large, abrupt control inputs.[4] The report stated that blade flapping can increase rapidly from

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[3]The Safety Board is aware of only two incidents in which an R22 experienced a mast strike and recovered.

[4]*Rotor Blade Flapping Criteria Investigation*. December 1976. Prepared for the Eustis Directorate, U.S. Army Air Mobility Research and Development Laboratory by Bell Helicopter Textron, Ft. Worth, Texas.

acceptable to excessive angles in only one or two revolutions.

Further, because R22s are used extensively for training, the Safety Board attempted to determine if limited pilot experience and the training environment might have been common factors in some of the loss of main rotor control accidents. Although many accidents involved low-time pilots, the Board cannot be certain in many of the dual-instructional accidents whether the student or the flight instructor was manipulating the flight controls immediately preceding the loss of control. In many of these accidents, student pilots were probably operating the flight controls, but instructor pilots may have been demonstrating maneuvers. Although flight instructors should be able to prevent a student pilot from improperly manipulating the controls by guarding the controls, the Board is concerned that flight instructors may not always or properly guard the cyclic flight control during long periods of instructional flight because of the somewhat awkward position of the cyclic-T handle for the nonflying pilot. Based on the Richmond, California, accident, the Bell Helicopter study, and the Georgia Tech study, the Board concludes that the low inertia main rotor blade can diverge from normal rotation to strike the body of the helicopter in just a few revolutions of the blade. This would take less than 0.5 seconds when the blade is operating at a normal rate of 530 rpm. Thus, unless the instructor is actually holding the cyclic handle and preventing a large, abrupt input, there is insufficient time for the instructor to react once a student makes such an input.

The Safety Board recognizes that all of the loss of control accidents may not have resulted from a single scenario. Some may have involved low rotor rpm leading to blade stall, and some may have involved turbulence. The responsiveness of the helicopter to flight control input combined with possible lack of pilot skills, knowledge, proficiency, or alertness could also offer possible explanations for some of the subject accidents. Further, because of the responsiveness of the R22 to cyclic input and the rapidness with which the rotor blade could diverge and strike the fuselage, it is possible that diversion of attention to tasks such as retrieving charts or tuning radios could result in a control input and subsequent change in aircraft attitude that requires corrective action to which even an experienced pilot may inadvertently respond with a large, abrupt movement of the cyclic control.

Although the Board could not identify a particular cause that led to the in-flight rotor blade contact with the fuselage of the R22s, during the investigation, the FAA did implement numerous operational changes, such as Special Federal Aviation Regulation (SFAR) 73, Flight Standardization Board (FSB) specifications, and airworthiness directives (ADs) applicable to the operation of the R22 and R44, primarily to ensure that pilots and flight instructors were more knowledgeable of specific R22 operational hazards and were better trained, and that flights in adverse weather conditions by low-experienced pilots were limited. There have been no in-flight rotor/fuselage contacts of the R22 in the United States in the past year since the changes were implemented. Although the Safety Board cannot conclude that the operational changes will eliminate all in-flight rotor strikes, the absence of such accidents since these actions were implemented suggests that they have been effective. The absence of such accidents also supports the proposition that most of the accidents were caused by large, abrupt control inputs and the corrective actions taken should help prevent such accidents. Because the R22 appears to be more responsive to control inputs than other helicopters normally used in training or routinely used by

low-time pilots, the Board concludes that there is a need to continue the special operating rules for flight instructors and student, low-experience, and non-proficient pilots to ensure the safe operation of the helicopter. Therefore, the Safety Board believes that the FAA should ensure that SFAR 73, the FSB specifications, and the ADs applicable to the operation of the R22 and R44 are made permanent.

The Board is also concerned that in the future, other highly responsive helicopters are likely to be designed and built that may have characteristics similar to the R22. Consequently, the Safety Board believes that as a part of the certification process for highly responsive helicopters, the FAA should establish operational requirements, student pilot training requirements, and instructor pilot requirements, such as those imposed on the R22 and R44, to ensure that pilots at all levels of qualification and skills can adequately operate the helicopter. The Safety Board concludes that although the response rate of the R22 to cyclic input is not unsafe so long as the special operating rules remain in place, there is a need for the FAA to consider the responsiveness of helicopters (especially lightweight, high performance helicopters such as the R22) as part of the certification process to determine if special operating rules or guidance are necessary. Thus, the Safety Board believes that the FAA should require helicopter manufacturers to provide data on the response of helicopters to large, abrupt cyclic inputs as a part of the certification process and require operational limitations or other measures for those helicopters that are more responsive, such as the R22.

The Safety Board is aware of the complexity, difficulty, and potential hazards associated with flight tests and full-scale wind tunnel testing. However, further research into lightweight helicopter behavior would benefit the helicopter industry and create a national resource tool that would aid certification of future helicopter models, especially those that are lightweight and responsive. Therefore, the Safety Board believes that the FAA, in conjunction with NASA, should continue the development of the simulator model of lightweight helicopters, using flight tests and whirl tower tests as needed to validate the model, to create a national resource tool for the study of flight control systems and main rotor blade dynamics.

The R22 has been the subject of three FAA special certification reviews (SCRs).[5] Following several R22 fatal accidents that occurred in 1981 and 1982, an SCR of the R22 by the FAA, with the participation of RHC personnel, was completed on October 24, 1982. On January 25, 1988, the manager of the FAA's Southwest Region, Aircraft Certification Division, requested another SCR of the R22. (In 1987, there were three accidents involving the R22 involving in-flight loss of control.) On January 18, 1994, following additional accidents and Safety Board recommendations, the FAA Los Angeles Aircraft Certification Office issued another SCR of the R22. The review found, as in the two previous certification reviews, that the R22 met all 14 CFR Part 27 certification requirements. However, the FAA's reports of all three SCRs made internal recommendations for FAA action, the results of which the Safety Board was unable to obtain.

[5]The SCRs provided to the Safety Board followed the format specified in FAA Orders 8110.4 (p. 21 and p. 167, dated 1/31/77) and Rotorcraft Directorate Standard Procedures (dated 10/1/92).

Records made available to the Safety Board suggest that resolution of internal recommendations made during the SCRs has not been documented and may not have been accomplished. The Safety Board believes that the FAA should review the process and procedures by which the FAA's aircraft certification offices and management resolve or bring to closure safety recommendations that are presented in internal documents, including SCRs, assuring that each recommendation is properly reviewed and that the disposition of the recommendations is properly documented.

Therefore, the National Transportation Safety Board recommends that the Federal Aviation Administration:

Ensure that Special Federal Aviation Regulation 73, the Flight Standardization Board specifications, and the airworthiness directives applicable to the operation of the R22 and R44 are made permanent. (Class II, Priority Action) (A-96-9)

Establish, for future certification of highly responsive helicopters, operational requirements, student pilot training requirements, and instructor pilot requirements, such as those imposed for the R22 and R44, necessary to ensure that pilots of all levels of qualification and skills can adequately operate the helicopter. (Class II, Priority Action) (A-96-10)

Require helicopter manufacturers to provide data on the response of helicopters to flight control inputs to be used as part of the certification process, and require operational limitations or other measures for those helicopters that are highly responsive. (Class II, Priority Action) (A-96-11)

In conjunction with the National Aeronautics and Space Administration, continue the development of the simulator model of lightweight helicopters, using flight tests and whirl tower tests as needed to validate the model, to create a national resource tool for the study of flight control systems and main rotor blade dynamics. If any unusual main rotor blade system characteristics are found, ensure that the information and data gathered are disseminated to the appropriate agencies and industry. (Class II, Priority Action) (A-96-12)

Review the process and procedures by which the Federal Aviation Administration's aircraft certification offices and management resolve and bring to closure safety recommendations that are presented in internal documents, including special certification reviews, and take appropriate action, if necessary, to ensure that each recommendation is properly reviewed and that the disposition of the recommendations is properly documented. (Class II, Priority Action) (A-96-13)

Also as a result of its investigation, the Safety Board issued Safety Recommendation A-96-14 to the National Aeronautics and Space Administration.

Chairman HALL, Vice Chairman FRANCIS, and Members HAMMERSCHMIDT, GOGLIA, and BLACK concurred in these recommendations.

By: Jim Hall
Chairman