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National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation

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In reply refer to: A-96-14

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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. 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.

[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.

As a result of the several R22 accidents involving excessive teetering and blade contact with the tailboom, RHC conducted in 1982 a series of flight tests to ensure that adequate teetering clearances existed during all normal flight regimes and that the rotor decay rates were not excessive. The flight tests consisted of throttle chops and flight control inputs. Parameters of pitch, roll, and teeter angle were recorded as were other parameters such as main rotor rpm, airspeed, altitudes, and acceleration. Pitch and roll rate responses to cyclic input were calculated.

The tests determined that the margin of tailboom clearance was satisfactory during all maneuvers and that adverse flight characteristics were not obtained during any of the maneuvers, even those outside the normal flight envelope. Following power changes, a reduction of the collective stick resulted in a positive rpm response, and the helicopter remained controllable with normal inputs. The RHC concluded that the R22 rotor system would not stall, exceed its teeter clearance, or contact the tailboom when the aircraft is flown within its approved limitations.

The tests showed that, during cruise, the cyclic is forward and to the right of neutral while the rotor plane is tilted aft and to the left, about 5°. Changes to the cyclic generally produce like changes in the tilt of the rotor plane. For example, if the cyclic is moved aft and left from the cruise position, the tilt of the rotor plane can be expected to increase in the aft and left direction.

During July 1995, the Federal Aviation Administration (FAA) participated in flight tests of the R44 at the RHC facilities in Torrance, California. The R44 was fully instrumented to record information from the main rotor system, helicopter performance information, and flight control positions. The flight tests were accomplished to confirm that the R44 can be operated safely. According to the FAA, the results indicated that the R44 could safely perform any nominal flight activity without main rotor divergence tendencies. The flight tests comprised engine power reductions, push-overs, and normal flight training maneuvers.

A Safety Board staff review of the flight test results showed that some of the flight test maneuvers were performed with large control inputs and at substantial input rates. A standard used by one helicopter manufacturer is to input 10 percent of the total control input available in 0.1 second. The R44 was subjected to a 10 percent cyclic push in 0.17 second continuing to 25 percent in 0.4 second.

The FAA reported that all flights were flown consistent with flight test procedures and that at no time was the safety of the flight questionable. Unfortunately, because tests were not (and could not safely be) conducted to determine the helicopters' response to large, abrupt cyclic inputs while in steady state flight with the cyclic already forward and to the right (normal high speed forward flight), the results of the flight tests did not provide the data needed to determine the mechanism for the blade diverging into the body of the helicopter.

The FAA awarded a grant to the Georgia Tech School of Aerospace Engineering to develop a computer-based mathematical simulation of the R22 to allow the study of the aircraft and rotor system dynamics. The development of a simulation model had been recommended by the Safety Board and the FAA's R22 technical panel. The objective of this effort was to use the simulation to study the effects of flight control inputs, rotor rpm stall, low-G maneuvers, and

turbulence on the operation of the helicopter and the three-hinge rotor system.

Georgia Tech researchers stated to the Safety Board that the research was concluded in December 1995 when the available funds were expended and before the mathematical model was thoroughly validated by comparison to flight test data. Modeling of such a complex system required more resources than had been allotted for the project. According to the researchers, more research, including future testing that produces excessive flapping or rotor divergences, is needed to fully validate the mathematical modeling of the R22 in the areas of flapping and divergent tendencies.

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 NASA, in conjunction with the FAA, 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.

Therefore, the National Transportation Safety Board recommends that the National Aeronautics and Space Administration:

> In conjunction with the Federal Aviation Administration, continue the development of the simulator model of lightweight helicopters, using flight tests and whirl tower tests 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, disseminate the information and data gathered to the appropriate agencies and industry. (Class II, Priority Action) (A-96-14)

Also as a result of its investigation, the Safety Board issued Safety Recommendations A-96-9 through -13 to the Federal Aviation Administration.

Chairman HALL, Vice Chairman FRANCIS, and Members HAMMERSCHMIDT, GOGLIA, and BLACK concurred in this recommendation.

By: Jim Hall
Chairman