National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation

Date: May 28, 2004

In reply to refer to: A-04-44 through -45

Honorable Marion C. Blakey
Administrator
Federal Aviation Administration
Washington, D.C. 20591

Background

On May 12, 1997, about 1529 eastern daylight time, an Airbus A300-600, N90070, operated by American Airlines as flight 903, experienced an in-flight upset at an altitude of 16,000 feet near West Palm Beach, Florida. During the upset, the stall warning system activated, the airplane rolled to extreme bank angles left and right, and the rudder was moved rapidly back and forth to its in-flight limits. During the event, the airplane was stalled several times and rapidly descended more than 3,000 feet. One crewmember sustained serious injuries, and the airplane received minor damage. Flight 903 was being conducted under the provisions of 14 *Code of Federal Regulations* Part 121 as a domestic, scheduled passenger service flight from Boston, Massachusetts, to Miami, Florida.

Approximately 5 years after the flight 903 accident, the National Transportation Safety Board and Airbus reexamined the flight 903 flight data recorder (FDR) data[1] and determined that the vertical stabilizer experienced loads outside of the certificated design envelope.[2] That determination led to the grounding of the incident airplane for further inspections and the replacement of the vertical stabilizer as a result of de-lamination damage discovered during those inspections. Further review of the FDR data for flight 903 revealed that the rudder exceeded the designed travel limits during the upset. As further discussed below, the investigation determined

[1] The Safety Board's renewed interest in the data from flight 903 resulted from preliminary findings in its investigation of the November 12, 2001, accident involving American Airlines flight 587. The cause of that accident is still under investigation, but information to date indicates that the vertical stabilizer was subjected to large aerodynamic structural loading during the accident sequence. The flight 587 accident sequence did not involve a rapid increase in airspeed. The safety issues discussed in this letter were not a factor in the flight 587 accident.

[2] The Safety Board and Airbus each independently calculated the sideslip and rudder angles for flight 903 from FDR data. Then, using Airbus data to calculate the resulting loads on the rudder and vertical stabilizer at these angles, the Safety Board determined that the loads on the vertical stabilizer exceeded those for which the airplane was certificated.

that two factors contributed to this exceedance: a rapid increase in airspeed during the upset and apparent high force applied to the rudder pedal when the pedal was at the in-flight limit.[3]

Effect of Rapid Airspeed Change

Airplane control surfaces produce a stronger effect as airspeed increases. Therefore, manufacturers of transport-category airplanes commonly design flight control systems so as to limit or reduce the maximum possible displacement of control surfaces as airspeed increases, or even lock out some control surfaces at higher airspeeds. The A300-600 has a rudder travel limiter (RTL) system to reduce the amount of available rudder displacement as airspeed increases. Specifically, the A300-600 has the following RTL schedule in terms of computed airspeed: a maximum of 30° of rudder at 165 knots and below; 14.5° at 220 knots; 9.3° at 240 knots; 7° at 270 knots; 5° at 310 knots; 4° at 350 knots; and 3.5° at 395 knots and above.[4] However, the flight 903 investigation determined that the A300-600 RTL can only maintain this schedule in response to airspeed changes that occur at a moderate rate, such as those typically experienced during normal commercial operations. It cannot maintain this schedule in response to more rapid airspeed changes, such as those experienced during the flight 903 upset.

For example, the investigation determined that, in the airspeed range of 165 to 220 knots, the A300-600 RTL can maintain the designed rudder travel limitations for airspeed changes up to approximately 2.4 knots per second.[5] However, during the flight 903 incident, on one occasion the airplane experienced a much more rapid airspeed increase, going from 190 knots to 220 knots in 3 seconds, which equates to an increase of up to 10 knots per second, and exceeds by as much as 4 times the rate at which the RTL system could respond. The airspeed then continued to generally increase over the following 20 seconds, at 2.6 knots per second. Because the airspeed kept increasing, the RTL position lag (introduced by the previous 3-second rapid increase), although decreasing, was still present through most of the upset.

Because of the rapid initial airspeed change and continued airspeed increase, the rudder was allowed to travel in excess of its RTL design limit for approximately 20 seconds. During that time, on four occasions the rudder moved beyond its RTL design travel limit in response to pilot input. Two of those times, the rudder exceeded the design limit by approximately 8° and the other two times it exceeded the limit by approximately 5°. Rudder travel beyond the designed RTL limits could lead to high loads on the vertical stabilizer. The potential for this is especially high during in-flight upsets because rapid airspeed changes accompanied by rudder inputs are more likely to occur during upsets than during normal flight.

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[3] The rudder pedal position was not recorded on the FDR. However, rudder pedal forces were derived from an analysis of the rudder surface movements.

[4] This RTL schedule applies to A300-600s on which the vertical stabilizer is made of composite material, as it was on the flight 903 airplane. A300-600s with vertical stabilizers made of aluminum have a slightly different RTL schedule.

[5] The RTL can move at approximately 0.68° of rudder per second. In the region of the RTL schedule between 165 knots and 220 knots, the RTL schedule is changing at 0.2818 ° of rudder per knot. So, in this airspeed range, the maximum rate of change of airspeed the RTL system can support is 0.68/.2818 = 2.4 knots per second. In the higher airspeed ranges, the rates of change are as follows: 3.9 knots per second at 220 to 250 knots; 5.9 knots per second at 250 to 270 knots; and 13.6 knots per second at 270 to 310 knots.

Effect of Rudder Pedal Force

A review of the flight 903 FDR data for rudder position showed that, even after accounting for the slow response rate of the RTL, the rudder still appeared to exceed the estimated position at which it should have been limited by the RTL. This exceedance was as high as 4° near the end of the upset. The A300-600 RTL is designed and constructed so that it limits the rudder by reducing the allowable displacement of the rudder pedals. Testing of the RTL determined that if a pilot applies a sufficiently large pedal force when the pedal is at its travel limit, this will further slow or stop the movement and, consequently, the effectiveness of the RTL. As demonstrated by this event, such slowing or stopping of the RTL by application of large pedal forces could result in the rudder position substantially exceeding the designed travel limit. The Safety Board is concerned that such an increase in available rudder beyond the designed RTL restrictions could permit excessive rudder movements and possibly result in high loads on the vertical stabilizer.

Therefore, the Safety Board believes that the FAA should require Airbus to develop a design modification for the A300-600 RTL system so that it can respond effectively to rapid airspeed changes such as those that might be experienced during upsets and not be adversely affected by pedal forces, and issue an airworthiness directive to require the installation of that modification. The Safety Board also believes that the FAA should evaluate other transport-category airplanes with rudder limiting systems to determine whether any of those systems are unable to effectively respond to rapid airspeed changes such as those that might be experienced during upsets, or whether any of those systems are adversely affected by pedal forces and, if so, require corrective modifications to those systems.

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

> Require Airbus to develop a design modification for the A300-600 rudder travel limiter system so that it can respond effectively to rapid airspeed changes such as those that might be experienced during upsets and not be adversely affected by pedal forces, and issue an airworthiness directive to require the installation of that modification. (A-04-44)
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> Evaluate other transport-category airplanes with rudder limiting systems to determine whether any of those systems are unable to effectively respond to rapid airspeed changes such as those that might be experienced during upsets, or whether any of those systems are adversely affected by pedal forces and, if so, require corrective modifications to those systems. (A-04-45)

Chairman ENGLEMAN CONNERS, Vice Chairman ROSENKER, and Members GOGLIA, CARMODY, and HEALING concurred in these recommendations.

Original Signed

By: Ellen Engleman Conners
Chairman