Log 2304

National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation

Date: August 20, 1991

In reply refer to: A-91-77

Honorable James B. Busey
Administrator
Federal Aviation Administration
Washington, D.C. 20591

On March 3, 1991, at 0944 mountain standard time, United Airlines Flight 585, a Boeing 737-291 airplane, crashed during an approach to the Colorado Springs, Colorado, airport. The crew of 5 and the 20 passengers were killed. The airplane was destroyed by the impact and a postcrash fire. The weather was clear with unlimited visibility. There were windshear reports during the day. At the time of the accident the surface winds were reported to be out of the northwest at 20 knots gusting to 28. The Safety Board has not determined the cause(s) of the accident, and an investigation of airframe, operational, and weather factors is continuing.

Although its relevance to the accident has not been established, the Safety Board is concerned about a flight control anomaly discovered during its investigation. During the postaccident examination of the rudder control components, it was noted that the input lever for the auxiliary (standby) actuator was seized to the point that it could not be moved by hand. According to the manufacturer, the maximum force to move the input lever relative to the actuator housing should not exceed 0.5 pounds. The 6.72-inch input lever is attached to the actuator input shaft (P/N 1087-23). The shaft is supported by a bearing (P/N 1087-22) that is threaded into the body (housing) of the standby rudder actuator. Because of the tight tolerance between the parts, the shaft and the bearing are a matched pair and together are referred to as P/N 1087-21 shaft assembly.

During assembly, the bearing should be installed into the actuator housing to a torque value specified by the actuator manufacturer and then a safety wire should be installed. During disassembly, a torque far in excess of that specified for assembly was needed to remove the P/N 1087-22 bearing from the actuator housing. The torque required during disassembly is the compound effect of rotating the bearing inside diameter surface around the actuator input shaft and the bearing outside diameter threads within the actuator housing. The Safety Board believes that most of the torque needed to remove the bearing was the result of binding between the bearing and housing threads caused by excessive heating of the hydraulic fluid during the postcrash fire.

The actuator input shaft is 0.613 inches in diameter and has a reduced diameter groove for the insertion of a teflon seal. Inward into the actuator from this seal, the shaft assembly is lubricated by hydraulic fluid. Outward of the seal, there is no lubrication between the shaft and the inside diameter surface of the bearing. After disassembly, the bearing and shaft displayed evidence of galling damage (metal transfer) on the unlubricated area of the parts. The metal transfer was from the softer 416 stainless steel bearing onto the harder 440C stainless steel shaft. The bearing wall had shallow cavity areas corresponding in size and shape to the areas of the shaft containing deposited metal. The size of the galled area on each part was estimated to be about 0.1 square inch.

When hydraulic power is applied to the main rudder power control unit (PCU), the standby rudder actuator input lever and shaft are normally free to rotate with the rudder control system torsion tube in response to rudder pedal input. Rotation of the torsion tube provides an input into the main rudder PCU, resulting in rudder deflections. If the standby rudder actuator shaft and lever become bound, the standby actuator lever will apply a force, through the push rod, to the torsion tube. The force at the torsion tube will cause input to the main rudder PCU, resulting in rudder deflection (deflection that is not commanded by inputs from the rudder pedals or yaw damper).

As part of the postaccident investigation, the Boeing Company performed tests of shaft assemblies with reduced clearance between the shafts and bearings to rapidly induce galling between the parts. The size of the galled area of each test specimen and the force needed at the end of a 6.72-inch lever arm to rotate the shaft in the bearing were measured. Safety Board personnel determined that the size of the galled area on the parts from the accident airplane corresponds to a force of 70 to 80 pounds at the end of the lever arm when using the force-versus-area data produced from tests. Data from Boeing indicate that galling forces of 70 to 80 pounds at the standby rudder input lever can result in uncommanded rudder deflections from 2 to 5.5 degrees. However, tests have also shown that with a sufficiently galled area, galling can increase the force required to move the lever to at least 125 pounds. A force of about 130 pounds can result in full rudder deflection (26 degrees).

Hydraulic fluid residue was cleaned from the bearing and housing threads on the parts from the accident airplane to facilitate reassembly of the bearing into the housing. After this reassembly, the galled portions of the bearing and shaft could be aligned when the bearing was fully seated and the lever was in the neutral position. However, comparison of the reassembled bearing in the housing to an x-ray radiograph made prior to disassembly showed that the bearing, as found after the accident, was backed off (unscrewed) about 30 degrees of rotation from its fully seated position on the housing boss. Soot accumulation on the underside of the bearing flange and on the housing boss surface confirmed that these surfaces were not mated together during the fire. Calculations and test data show that a 70- to 80-pound force at the end of the lever can untorque the bearing from the housing boss, if the shaft and bearing are galled and bound together.

Boeing indicated that the movement of the lever relative to the actuator housing boss is restricted to about 4 1/2 degrees by mechanical stops in the system. Therefore, the 30-degree displacement of the bearing relative to its torqued position within the actuator housing is not yet understood and its relation to preimpact loss of control of the accident airplane is unknown.

Maintenance records for the accident airplane indicate the occurrence of rudder control system anomalies on two other occasions prior to the accident. In addition, the Safety Board is aware of three other incidents involving galling of the rudder auxiliary actuator components in Boeing 737-100/-200 and -300 airplanes. These incidents are documented in Boeing's "In Service Activities" Report 86-05, dated May 8, 1986. In two of the three incidents, operators reported unsatisfactory yaw damper performance and rudder pedal feedback in flight along with erratic rudder pedal steering with the yaw damper engaged. Both airplanes had accumulated less than 50 flight hours. In the third incident, similar discrepancies were noted on an undelivered airplane. In all three incidents, the cause of this condition was traced to galling and binding of the actuator input shaft for the standby rudder actuator; the force needed to move the input lever was reported to be as great as 57 pounds.

During its analysis of the 1986 incidents, Boeing determined that the clearance between the bearing and shaft was less than the specified 0.0004 inch to 0.0005 inch, and that galling was a result of excessive tightening of the bearing during actuator assembly. In the rudder auxiliary actuator of the accident airplane, the clearance between the actuator input shaft and bearing away from the galled areas ranged from 0.0001 inch to 0.0004 inch.

As a result of the 1986 incidents of galling between the input shaft and bearing, a design change was made that increased the clearance between the two parts in the galled area by reducing the diameter of the unlubricated portion of the P/N 1087-23 shaft by 0.003 inches (revision G, adopted 9/3/86). Measurement of the diameter of the unlubricated parts of the accident airplane's rudder auxiliary actuator shaft showed that it had not been reduced to increase the clearance in this area. Boeing has indicated that despite the design change, there were no programs initiated to increase the clearance on parts already installed in airplanes, nor were inspections initiated to determine if other rudder auxiliary units contained inadequate clearances or excessive binding. The Safety Board understands that these same components are also used in the rudder controls of Boeing 727 model airplanes.

The Safety Board has not determined what effect, if any, the galling damage had on the controllability of the accident airplane. Nonetheless, the Safety Board is concerned that excessive binding between the input shaft and bearing for the standby rudder actuator could cause an uncommanded rudder input to these airplanes, which may lead to control difficulties.

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

Issue an Airworthiness Directive requiring a check on all Boeing 737 and 727 model airplanes with the P/N 1087-23 input shaft in the rudder auxiliary actuator unit for the force needed to rotate the input shaft lever relative to the P/N 1087-22 bearing of the auxiliary actuator unit. During this check, the bearing should be inspected to determine if it rotates relative to the housing. All shaft assemblies in which rotation of the bearing occurs, or in which excessive force is needed to move the input lever, should be removed from service on an expedited basis and the assemblies should be replaced with a P/N 1087-21 shaft assembly that has a reduced diameter on the unlubricated portion of the shaft in accordance with revision G of the P/N 1087-23 engineering drawing. All assemblies meeting the force requirement should be rechecked at appropriate intervals until replaced with a P/N 1087-21 shaft assembly containing a P/N 1087-23 shaft that has a reduced diameter on the unlubricated portion of the shaft. (Class II, Priority Action)(A-91-77)

Chairman KOLSTAD, Vice Chairman COUGHLIN, and Members LAUBER, HART, and HAMMERSCHMIDT concurred in this recommendation.

By: James L. Kolstad
Chairman