SUMMARY OF FINDINGS

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NTSB Accident Number: CEN13LA462 – N327FL, Embraer EMB-505 at Eden Prairie, Minnesota

Wreckage Exam

Federal Aviation Administration (FAA) Inspectors quickly responded to the accident scene and reported that the impact damage to both wings and the fuselage was substantial.

A postaccident examination of the engines and the airframe revealed no evidence of mechanical malfunctions or failures that would have precluded normal operation.

The brake control unit (BCU) was examined at the manufacturer's facility. Detailed results are shown below. The BCU passed a full functional test and it was returned to service.

Examination of the Brake Control System

The BCU was removed from the airplane, quarantined, and sent in a sealed box to Meggitt Aircraft Braking at Coventry, England. On October 3, 2013, a Senior Inspector of the Air Accidents Investigation Branch of the United Kingdom traveled to Meggitt's facilities, and provided direct oversight for an examination of the BCU.

The sealed box was opened and the BCU, serial number 230000159, was visually examined. There was no evidence of damage.

Unit History

Records showed the BCU, serial number (s/n) 230000159, part number (p/n) DAP00100-07, had been manufactured on August 15, 2011, as -06 Mod 0 standard, and was upgraded to -07 standard in November, 2011.

Essential System Description

The normal braking system for the EMB-505 is "brake by wire". The brake pedals operate a left and right brake transducer, each of which contains two linear variable differential transformers (LVDT). Each LVDT consists of a secondary and primary coil. According to AMM II task 32-41-02-820-801-A, the pedals should be adjusted to 86 percent to 89 percent (87 percent is the nominal value) when displaced to the maximum pedal mechanical stop.

Download of Fault Codes

The fault codes were downloaded via Meggitt's BCU Test Equipment (F2895), with the significant fault CODES as follows:

Code Fault Time from power up

51 Pedal Fail R1 2 hours 51 minutes 40.036 seconds

52 Pedal Fail R2 2 hours 51 minutes 39.952 seconds

34 External Pedal Fail R1 2 hours 52 minutes 5.268 seconds

35 External Pedal Fail R2 2 hours 52 minutes 5.268 seconds

Production Acceptance Test

A full functional test of the BCU was carried out on the manufacturers test rig, including execution of part B batch files. The BCU passed the test.

Review of FDR Data

A review of Flight Data Recorder (FDR) data showed touchdown and brake pedals applied at 13.47:29. Brake pressure showed that approximately 4 seconds after the brakes are applied there was anti-skid activity which occurred until loss of brake pressure. At approximately 17 seconds, data showed the right pedal displacement went to 94.49 percent of travel and then went to zero displacement. At the same time the main brake pressure dropped from 670 psi to 50 psi, and the warning BRKFAIL was generated. Three seconds later the CAS BRKFAIL warning was generated and brake pressure dropped. The aircraft stopped decelerating for approximately 3 seconds before decelerating at a slightly slower rate.

The FDR Emergency / Parking brake lever discrete showed the brake to be on at the start of the flight and moved to the release position for taxing. The Emergency / Parking brake lever remained off for the remainder of the flight.

Discussion

The fault codes Pedal Fail R1 and R2 means that the BCU had detected a failure of the secondary coil in the LVDT for both coils in the right hand pedal transducer. The software in the BCU waits until the wheels have stopped rotating for 5 seconds before running a diagnostic routine. It was this routine that generated External Failure R1 and R2. The combination of these fault codes indicates that there has been a simultaneous fault in the secondary coils, or in the interface circuitry in both LVDTs in the right pedal transducer. It was possible that the fault code could also have been caused by over-travel of the right pedal which contains the LVDTs.

The system is designed such that if a failure occurs in both LVDTs, in either pedal transducer, then the system will declare a brake failure and close the main brake system shut-off valve. The brakes can then be controlled by the emergency brake system via the emergency / park brake handle; there is no anti-skid with this emergency system.

The FDR data indicated that the brakes initially operated normally with the anti-skid operating; During landing, the pedal displacement gradually increased over 17 seconds until the brake failure occurred. The displacement of the right pedal suggests that this failure probably occurred as a result of the pedal moving beyond the mechanical stop; or possible but less likely, a failure of both LVDTs.

Following the brake failure the aircraft stopped decelerating for approximately 3 seconds. The emergency checklist procedures show that the pilot would then be expected to apply the emergency / park brake in order to operate the emergency braking system. FDR data showed that during the accident landing the BCU discrete for the park brake remained at off.

Embraer reported that the most probable scenario which could explain the loss of normal braking during the landing was the BRK FAIL message which was triggered at 0847:46 when the right brake pedal position recorded values approaching the upper limit of the pedal travel and then fell abruptly. Embraer also noted that based on this information, the BRK FAIL message was probably triggered due to an overtravel of the right brake pedal. In the then current BCU-7, the BRK FAIL message is triggered when the pedal displacement reaches 95 percent deflection (when 100 percent corresponds to 38.1 mm of LVDT excursion). To mitigate the risk of new events, Embraer has incorporated changes to the BCU, which among other objectives aims to increase robustness to allow higher full pedal strokes.

Postaccident Changes to the BCU

On September 9, 2014, Embraer issued Service Bulletin (SB) 505-32-0015, which decreases the possibility of occurrence of the loss of main brakes if a brake pedal overtravels during an emergency situation. The overtravel monitoring remains active on the airplane in case of an actual transducer failure.

The changes implemented by the SB on BCU p/n DAP00100-09 include the following:

The "ANTISKID FAIL" message will appear on CAS when one of the pedals moves above 95.8 percent. The CAS message "ANTISKID FAIL" will be triggered on ground when the aircraft is stationary for 5 seconds, in order to indicate that the brake pedal adjustment is required before next flight – no loss of anti-skid function.

The "BRK FAIL" message will appear on CAS when one pedal achieves 100 percent and the other pedal is below 60 percent (resulting in loss of main brake).

The "BRK FAIL" message will NOT appear on CAS when one pedal is at 100 percent and the other pedal is above 60 percent (no brake loss).

Additional Information:

FAA AC 120-108 states “A stabilized approach is a key feature to a safe approach and landing (and is) characterized by maintaining a stable approach speed, descent rate, vertical flight path, and configuration to the landing touchdown point ... at a rate of descent no greater than 1,000 feet per minute (fpm)”

FAA Safety Alert for Operators - SAFO 15009 Date: 8/11/15
Subject: Turbojet Braking Performance on Wet Runways

“Several recent runway landing incidents/accidents have raised concerns with wet runway stopping performance assumptions. Analysis of the stopping data from these incidents/accidents indicates the braking coefficient of friction in each case was significantly lower than expected for a wet runway as defined by the Federal Aviation Administration (FAA) in Federal Air Regulation (FAR) 25.109 and Advisory Circular (AC) 25-7C methods. These incidents/accidents occurred on both grooved and un-grooved or non-Porous Friction Course overlay (PFC) runways. The data indicates that applying a 15 percent safety margin to wet runway time-of-arrival advisory data as, recommended by SAFO 06012, may be inadequate in certain wet runway conditions.”

FAA Advisory Circular AC No: 91-79A - Date: 9/17/14
Subject: Mitigating the Risks of a Runway Overrun Upon Landing

Paragraph 6, c, (1): “A 10 percent increase in final approach speed results in a 20 percent increase in landing distance.”
…

Paragraph 6, j.: “Landing distances in the manufacturer-supplied AFM provide performance in a flight test environment that is not necessarily representative of normal flight operations. For those operators conducting operations in accordance with specific FAA performance regulations, the operating regulations require the AFM landing distances to be factored to ensure compliance with the pre-departure landing distance regulations. These factors should account for pilot technique, wind and runway conditions, and other items stated above. Pilots and operators should also account for runway conditions at the time of arrival (TOA) to ensure the safety of the landing. *Though the intended audience of SAFO 06012 is turbojet airplanes, it is highly recommended that pilots of non-turbojet airplanes also follow the recommendations in SAFO 06012*.”

(1) The SAFO urgently recommends that operators develop a procedure for flightcrews to assess landing performance based on conditions actually existing at the TOA, as distinct from conditions presumed at time of dispatch. Those conditions include weather, runway conditions, the airplane’s landing weight, landing configuration, approach speed, and the flightcrew deploys deceleration devices in a timely manner.

(2) Once the actual landing distance is determined, an additional safety margin of at least

15 percent should be added to that distance. Except under emergency conditions, flightcrews should not attempt to land on runways that do not meet the assessment criteria and safety margins as specified in SAFO 06012.

(3) A safety margin of 15 percent should be added, and the resulting distance should be within the runway length available. *The FAA considers a 15 percent margin to be the* <u>*minimum*</u> *acceptable safety margin.*

…

Appendix 1; Paragraph 2: Definitions:

j. Unfactored or Certified Landing Distance. The landing distance determined during certification as required by 14 CFR part 23, § 23.75 and 14 CFR part 25, § 25.125. The unfactored landing distance is not adjusted for any safety margin additives. The unfactored certified landing distance may be different from the actual landing distance because not all factors affecting landing distance are required to be accounted for by certification regulations. For example, the unfactored certified landing distances are based on a dry, level (zero slope) runway at standard day temperatures, and do not normally take into account the use of autobrakes, autoland systems, HGS, or thrust reversers. This is considered the baseline landing distance from which all subsequent user calculations emanate.

k. Factored Landing Distance. For applicable operations, the dispatch landing distance allows the airplane to land and stop within 60 percent of the available runway when the runway is dry. The factored landing distance is the certified landing distance multiplied by 1.67, which can then be compared directly to the available landing distance. When the runway is wet, the certified distance is multiplied by 1.97 to account for the 15 percent additional runway requirement.

FAA Safety Alert for Operators SAFO 10005 - Date: 3/1/10
Subject: Go-Around Callout and Immediate Response

"It is critical to flight safety that both the pilot flying and the pilot monitoring should be able to call for a go-around if either pilot believes an unsafe condition exists. Also, although CRM principles prescribe that some cockpit decisions can be made by crew consensus, others, including the go-around callout, require immediate action, without question, because of the immediacy of the situation."

Flight Options – Flight Operations Manual
Page 4-19 – Date June 1, 2012
Subject: Go around

"Any time a "Go Around" is called, the PF will immediately execute the briefed maneuver. Any crewmember can call a "Go Around." "

Flight Options – Flight Operations Manual
Page 4-98 – Date June 1, 2012
Subject: Stabilized Approach Criteria

"All flights must be stabilized at 500' above MDA/DH when IMC or 500' above airport elevation when in VMC conditions. A go-around must be initiated if the aircraft does not meet the stabilized approach criteria … An approach is stabilized when it meets the following criteria: 1. All briefings have been conducted. … 3. IAS airspeed is no more than VREF + 20 KTS and no less than VREF.

…
An approach that becomes unstabilized requires an immediate go-around.

Flight Options – Part 135 / 91K Aircrew Training Manual
Page A6-11 – Date April 15, 2013
Subject: Visual Approach and Landing

The pictorial shows that on base leg for a visual approach and landing the landing gear should be down, the before landing checklist should have been completed, the flaps should be at Flaps 3, the bank should not exceed 30 degreed, and the airspeed should be 120 knots. The pictorial also shows that when the airplane is crossing the runway threshold the airspeed should be at Vref.

Flight Options – Phenom 300 Aircraft Specific Standard Operating Procedures (SOP)
Page 9 – Date July 13, 2012
Subject: Visual Traffic Patterns

The SOP shows that when the airplane is at 500 feet above the airport surface on a visual approach the pilot monitoring (PM) should call out "500 FT, Stabilized" and the pilot flying (PF) should then respond with "Stabilized". If the PM calls out "500 FT, Go Around", the PF should then respond with "Go Around"

(end)