An Avro 146's nose landing gear failure can be traced to fatigue cracks in its main fitting, investigators say.

Gear Collapse

BY LINDA WERFELMAN

Accident investigators blame the rough finish on a landing gear part and the incomplete performance of a corrective airworthiness directive for a fatigue failure that caused the collapse of the nose landing gear on an Avro 146-RJ100 after touchdown at London City Airport.

Three passengers were treated for minor injuries after the Feb. 13, 2009, accident, which damaged the landing gear and the lower forward fuselage, according to the final report by the U.K. Air Accidents Investigation Branch (AAIB).

The scheduled flight from Amsterdam and the instrument landing system approach in London had been uneventful, the report said.

But then, "after touching down on the main wheels, the commander, who was the pilot flying, lowered the nosewheel onto the runway," the report said. "As she did so, the aircraft continued to pitch down until the fuselage contacted the surface. She then applied the

wheel brakes fully as smoke started to emanate from behind the instrument panel. This was followed by the illumination of the 'ELEC SMOKE' warning."

The crew stopped the airplane on the runway, declared an emergency and, after the engines had stopped, ordered passengers to evacuate.

The pilots donned oxygen masks to operate the engine fire handles, completed their "evacuation drills" and evacuated the airplane through the direct vision windows, the report said.

Investigation

Investigators found scoring on the runway and a trail of hydraulic fluid, both of which indicated that the nose landing gear had broken soon after touchdown. The airplane stopped on the runway centerline about 500 m (1,641 ft) beyond the touchdown point. The landing gear had "folded rearward and penetrated the forward equipment bay," the report said, adding that the landing gear's collapse caused the lower fuselage to scrape the runway, resulting in damage to the nose landing gear doors, the fuselage skin and structure immediately behind the landing gear bay, and the forward face of the lower section of the nose landing gear.

The Avro 146's lower fuselage was damaged after the landing gear's collapse. Above, the accident airplane, photographed on another day, at London City Airport.

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Initial examination of the broken landing gear showed that it had fractured above its pivot, near the top of the leg.

"Visual examination of the fracture surface indicated several relatively small areas of crack progression due to a fatigue mechanism, together with a large area characteristic of a failure in overload," the report said.

Certification Tests

A review of records showed that during the manufacturer's certification testing of the nose landing gear main fitting, a test fitting completed 360,532 flight cycles without failure.

"However, a subsequent [nondestructive test] inspection identified a fatigue crack in the upper section of the internal bore that had propagated partially through the radial wall," the report said. "The surface finish (roughness) of the inner bore was confirmed as being within the limit specified at production of 3.2 microns."

In a second fatigue test, a fitting failed at 43,678 cycles without fracture, but a fatigue crack was then found in the upper internal bore; the crack had spread through the radial wall section, the report said. The surface roughness of the internal bore was measured at 6.95 microns — more than the production limit.

"Examination of the two test specimens revealed that the high value of surface roughness present in the second specimen had resulted in a significant reduction in the number of flight cycles required to initiate a fatigue crack in the material," the report said.

As a result of the tests, in June 2000, Messier-Dowty, the manufacturer of the landing gear, issued service bulletin (SB) 146-32-149, which called for an ultrasonic inspection of the main fitting bore every 2,500 flight cycles after the fitting exceeded 8,000 flight cycles. Compliance subsequently was incorporated into the U.K. Civil Aviation Authority (CAA) airworthiness directive (AD) 002-06-2000.

A second service bulletin, SB 146-32-150, called for a maximum surface roughness value of no more than 1.6 microns for the main fitting internal bore, as well as shot-peening to

Accident investigators found fatigue cracks on the fracture surface of the landing gear's main fitting.

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"restore the fatigue life of the main fitting." New main fittings were manufactured according to these specifications, and the specifications were "recommended to be [retroactively] embodied at next overhaul for in-service main fittings," the report said.

"Incorporation of this SB terminated the repetitive inspections introduced by SB 146-32-149 and CAA AD 002-06-2000," the report said, noting that the failed main fitting had been modified in accordance with SB 146-32-150.

Maintenance records showed that the nose landing gear main fitting on the accident airplane had accumulated 18,299 flight cycles, and that it had been overhauled at a Messier-Dowty facility in Sterling, Virginia, U.S., in January 2006 — 3,302 cycles before its failure. Both SBs had been in effect at the time; therefore, additional repetitive inspections of the main fitting were no longer required.

Post-Accident Examination

After the accident, the nose landing gear was removed from the airplane for analysis by the AAIB and Messier-Dowty.

The examination found no abnormalities in material or microstructure of the main fitting. Nevertheless, the report said that on the fracture surface, there were three fatigue cracks that "had become conjoined to form a single crack extending 23.2 mm [0.9 in] around the circumference of the upper section of the internal bore, with a maximum depth of 2.21 mm [0.09 in]." The fatigue crack was located in the same area where fatigue cracks were found in the two fatigue tests.

The fatigue cracks originated in "the trough of a fine circumferential machining groove" that was in the bore when the fitting was manufactured, and propagated for about 2,800 cycles before the accident, the report said. Smaller cracks were found in the same groove and in other nearby grooves.

"Examination of the inner bore confirmed that the shot-peening process had been carried out, in accordance with the requirements of SB 146-32-150, but that the surface roughness close to the origin of the fatigue cracks was 9.5 to 10.1 microns, in excess of the finish specified in the service bulletin," the report said.

Further examination showed that the landing gear actuator and torque link had failed as a result of the main fitting's failure.

Accident investigators concluded that the fracture of the main fitting caused the nose landing gear to collapse and to penetrate the lower fuselage, damaging the equipment bay and causing disconnection of the battery. When the landing gear penetrated the fuselage, hydraulic fluid was released, causing smoke and fumes to enter the airplane. Because the battery was disconnected, the remote cockpit door release mechanism could not be operated after the engines were shut down, forcing the pilots to evacuate through the cockpit direct vision windows.

Safety Actions

In August 2009, Messier-Dowty issued SB 146-32-174, describing a new ultrasonic inspection technique for the nose landing gear main fittings and prescribing a shorter re-inspection interval. The new service bulletin superseded SB 146-32-149. BAE Systems, which holds the Avro 146 type certificate, subsequently issued alert service bulletin A32-180 (Revision 1), which introduced SB 146-32-174 and canceled the requirements of SB 164-32-149, and the European Aviation Safety Agency published AD 2009-0197-E, which mandated compliance with the two new Messier-Dowty and BAE bulletins.

Messier-Dowty also issued SB 146-32-173 to require borescope inspections of nose landing gear main fittings that had been overhauled by its Sterling, Virginia, facility.

This article is based on U.K. Air Accidents Investigation Branch accident report no. EW/C2009.02/03, published in February 2010.