National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation

Date: August 20, 2001

In reply refer to: A-01-30 through -34

Honorable Jane F. Garvey
Administrator
Federal Aviation Administration
Washington, D.C. 20591

On May 23, 2001, about 1504 central daylight time, the right main landing gear (MLG) of an American Airlines Fokker F.28 Mark 100 (F.100) airplane fractured upon initial touchdown at Dallas-Fort Worth International Airport, Dallas-Fort Worth, Texas (DFW). The pilots were able to maintain control of the airplane with rudder control and brought the airplane to a stop on the runway. None of the occupants was injured and the airplane sustained substantial damage. The flight was operating as a regularly scheduled passenger flight from Charlotte, North Carolina. Although the National Transportation Safety Board's investigation of this accident is ongoing, preliminary findings have revealed a safety issue regarding certain MLGs on F.100s that warrants the Federal Aviation Administration's (FAA) immediate action.

The F.100's right MLG is a two-wheel landing gear that has three support points—the forward attach, the aft attach, and the side stay strut attach (see figure 1). The accident airplane's right MLG was part of the original equipment installed on the airplane and had accumulated 15,380 cycles in 21,589 hours over a period of 8 years and 11 months of service. Postaccident examination of the airplane revealed that the right MLG cylinder had fractured into five pieces. The MLG cylinder was manufactured by Messier-Dowty Limited[1] from a forged block of an aluminum alloy.[2] Further examination at the Safety Board's materials laboratory revealed that one of the fractures stemmed from a preexisting crack that measured 2.5 mm in depth and 12 mm in length.[3] The crack was located on the forward face of the MLG above a dowel pin bushing and forward of the up-stop damper abutment (see figure 2). Metallographic examination of a section that was made through the crack origin area revealed that the microstructure contained features typical of a forging fold.[4]

[1] Messier-Dowty Limited is the United Kingdom subsidiary of Messier-Dowty International, which is headquartered in France.

[2] Specifically, Messier-Dowty used United Kingdom designation High-Duty Alloys (HDA) 77-aluminum alloy, which is the designated equivalent to U.S. specifications for 7014-aluminum alloy.

[3] More than 65 striations typical of fatigue cracking were found at the perimeter of the preexisting crack on the fracture surface.

[4] A forging fold is a defect that can be caused by hot metal that flows back onto itself while it is flowing into the die cavity.

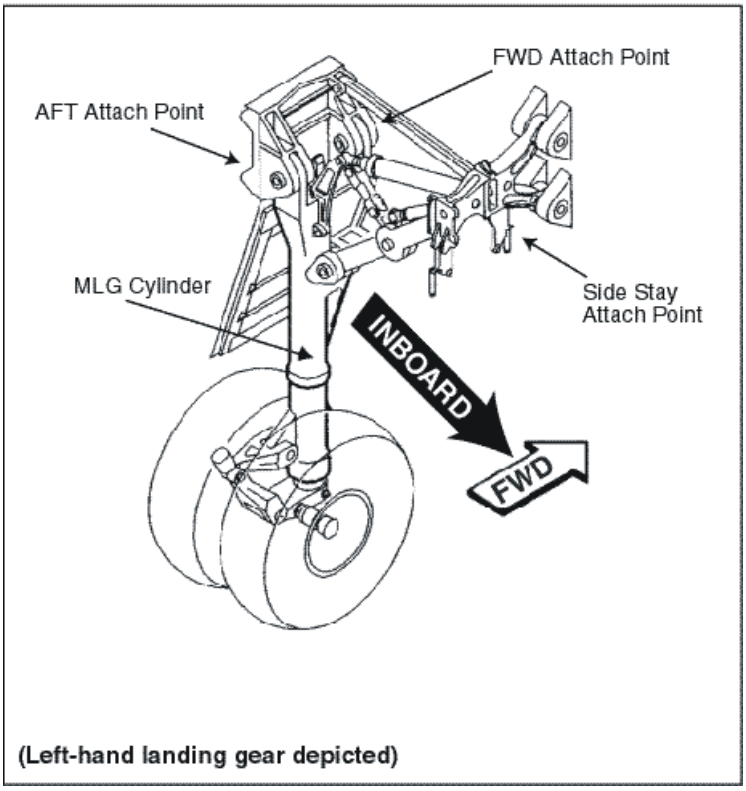
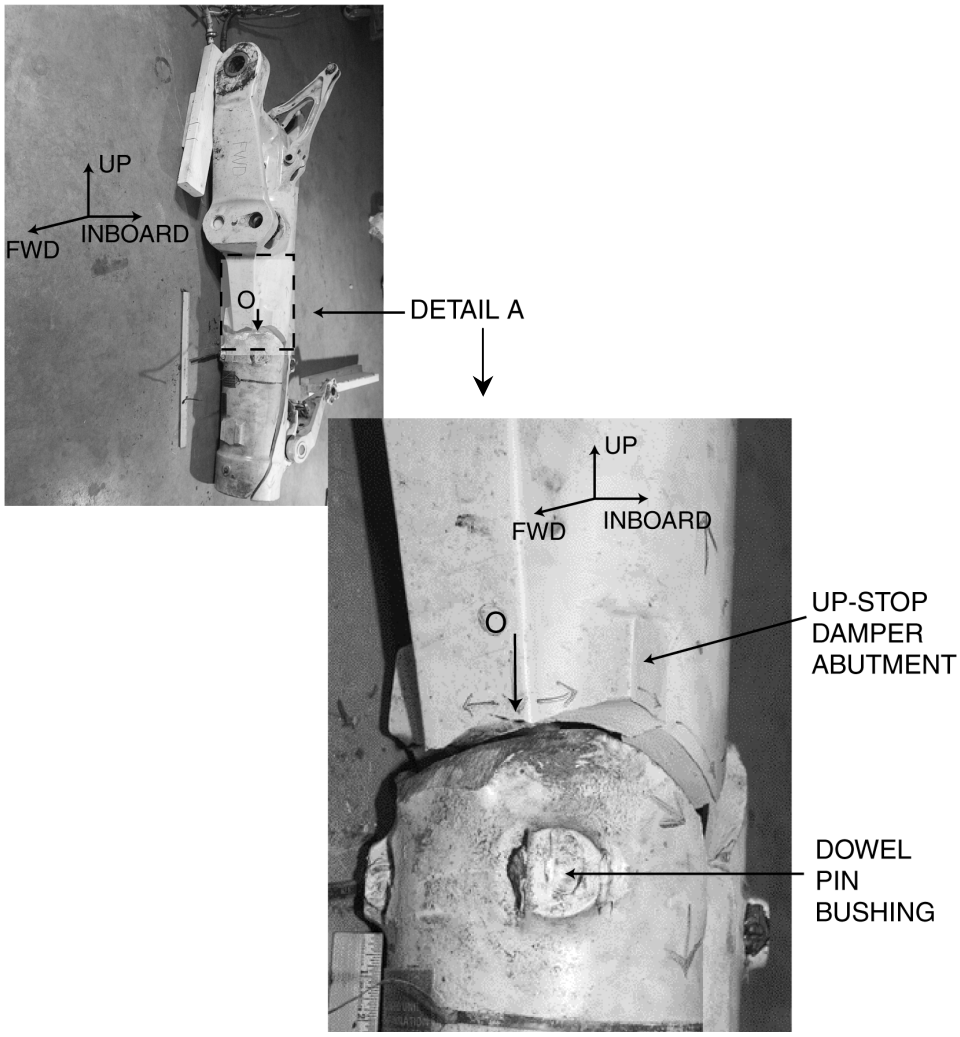


Figure 1. F.100 MLG assembly

Following the accident, U.S. operators of the F.100 began inspecting all similar MLGs in the area where the crack was found on the accident MLG using the eddy current inspection technique.[5] One MLG identified as having flaws similar to those found on the accident MLG was examined at the Safety Board's materials laboratory and was found to contain a preexisting crack that measured 0.5 mm in depth and 1.3 mm in length. As with the accident MLG, the crack was located on the forward face of the MLG above a dowel pin bushing and forward of the up-stop damper abutment and also originated from a forging fold defect. Further examination also revealed fatigue cracking that initiated from the forging fold defect. Following the accident, Fokker Services[6] also began conducting eddy current inspections of F.100 MLGs; however those inspections covered a broader area of the MLG than those conducted by U.S. operators. As a result of these combined inspections, six additional MLGs were subsequently identified with flaws or cracks similar in type to those found on the accident MLG. Several of those cracks were outside the area covered by the inspections conducted by U.S. operators. If these flaws and/or cracks had remained undetected, they could have continued to propagate to their critical crack length and resulted in MLG failures.

[5] Eddy current is a nondestructive inspection technique that measures fluctuations in an alternating magnetic field around a part. A transducer carrying an alternating current generates the magnetic field. The inspection is used to locate surface and near-surface defects.

[6] Fokker Services was formerly known as Fokker Aircraft Company and was acquired by the Stork Group in 1996. Fokker Services is headquartered in the Netherlands.



Note: Arrows indicate direction of fracture propagation and arrow "O" indicates fracture origin.

Figure 2. Photographs of the accident MLG and the crack origin area

In June 2001, Fokker Services and Messier-Dowty issued Service Bulletins (SB) F100-32-128 Revision 1 and F100-32-100 Revision 1, respectively, instructing operators of the F.100 to perform a one-time fleetwide eddy current inspection of the forward face of certain MLGs[7] and to repair or replace them as necessary. Because this inspection area goes beyond that already inspected by U.S. operators and because of the potentially catastrophic consequences of an MLG failure, the Safety Board is concerned that the eddy current inspections called for in the SBs are not mandatory. Therefore, the Safety Board believes that the FAA should require all operators of Fokker F.100 series airplanes equipped with the MLGs that are identified in Messier-Dowty SB F100-32-100 Revision 1 to immediately conduct an eddy current inspection of the MLG cylinders for forging folds and fatigue cracks as described in the most recent revision of Fokker Services SBF100-32-128 and to remove from service all landing gear in which such forging folds or cracks are found until the gear are returned to an airworthy condition.

[7] SB F100-32-100 Revision 1 identified part/type numbers 201072011 through 201072016, which includes main fitting subassemblies 201072283, 201072284, and 201251258 (main fittings 201072383, 201072384, and 201072389).

The Safety Board is also concerned that the SBs only recommend a one-time inspection of the subject MLGs and that no requirement exists for recurrent inspection. Forging fold defects and any associated cracks may not be detected by the one-time inspection called for in the SBs. As the Safety Board noted in its report on the accident involving Delta Air Lines flight 1288 at Pensacola, Florida,[8] experience has shown that detectable flaws or cracks may escape detection even when the part has undergone in-service nondestructive testing. Probability-of-detection data confirm that even when inspection procedures are properly performed, some detectable cracks will be missed.[9] Further, forging fold defects at which cracks have not begun to initiate may not be revealed by an eddy current inspection. However, a crack may initiate and begin to propagate from such a forging fold at any time.

The Safety Board notes that the need for repetitive inspections is also supported by 14 CFR 25.571, which outlines damage-tolerance[10] and fatigue (or safe-life)[11] evaluation requirements for transport-category aircraft structure. Section 25.571(a), which describes the general requirements for damage-tolerance evaluations, states that inspections or other procedures must be established, as necessary, to prevent catastrophic failure of principal structural elements. This section also states that inspection intervals are to be "established based on crack growth analyses and/or tests, assuming the structure contains an initial flaw of the maximum probable size that could exist as a result of manufacturing or service-induced damage." However, section 25.571(c), "Fatigue (safe-life) evaluation," states that compliance with damage-tolerance requirements is not required if it would be "impractical," in which case the structure must be shown "to be able to withstand the repeated loads of variable magnitude expected during its service life without detectable cracks."

The MLG design for Fokker F.100s was originally certified using the fatigue (safe-life) evaluation provided in section 25.571(c). However, the MLG failure at DFW and the findings of the inspections conducted after the accident demonstrate that the MLGs do not meet the criteria of section 25.571(c). Consequently, inspection intervals must be established as soon as possible to ensure that the structure remains damage-tolerant. The Board is concerned, however, that crack propagation rates and critical crack lengths for these MLGs are still unknown. Therefore, the Safety Board believes that the FAA should require Fokker Services to immediately determine a repetitive inspection interval that will prevent structural cracks in MLGs that are identified in Messier-Dowty SB F100-32-100 Revision 1 from propagating to failure between inspections.

---

[8] National Transportation Safety Board. 1998. *Uncontained Engine Failure, Delta Air Lines Flight 1288, McDonnell Douglas MD-88, N927DA, Pensacola, Florida, July 6, 1996.* Aircraft Accident Report NTSB/AAR-98-01. Washington, D.C.

[9] For more information, see the discussion on pp. 68-69 of the Delta flight 1288 report.

[10] According to the FAA's *Damage Tolerance Assessment Handbook, Volume I*, issued in February 1999, "damage tolerance refers to the ability of the design to prevent structural cracks from precipitating catastrophic fracture when the airframe is subjected to flight or ground loads. Transport category airframe structure is generally made damage tolerant by means of redundant ("fail safe") designs for which the inspection intervals are set to provide at least two inspection opportunities per number of flights or flight hours it would take for a visually detectable crack to grow large enough to cause a failure in flight."

[11] According to the FAA's *Damage Tolerance Assessment Handbook, Volume I*, issued in February 1999, "for safe life, the design objective [is] to make the time needed to form a crack longer than the operational life of the structure." Advisory Circular 25.571-1C states that the "safe-life of a structure is that number of events such as flights, landings, or flight hours, during which there is a low probability that the strength will degrade below its design ultimate value due to fatigue cracking."

The Safety Board further believes that the FAA should require all operators of Fokker F.100 series airplanes equipped with the MLGs that are identified in Messier-Dowty SB F100-32-100 Revision 1 to periodically conduct eddy current inspections of MLG cylinders for forging folds or fatigue cracks, as described in the most recent revision of Fokker Services SBF100-32-128, at the interval identified in response to Safety Recommendation A-01-31.

In addition, to prevent additional flawed landing gear on F.100s from entering service, the Safety Board believes that the FAA should require Fokker Services to review the current forging processes and inspection procedures for the MLGs that are identified in Messier-Dowty SB F100-32-100 Revision 1 and to modify those processes and procedures, as appropriate, to ensure that forging folds do not occur in MLGs that are to be installed on its airplanes. Finally, because of the number of flawed landing gear identified during the inspections conducted after the accident at DFW and because Messier-Dowty uses similar manufacturing processes to make landing gear for other aircraft manufacturers, the Safety Board is concerned that additional defective gear could enter service on other airplane models. Therefore, the Board believes that the FAA should review the processes by which Messier-Dowty manufactures and inspects its landing gear and require modification of these processes as necessary.

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

Require all operators of Fokker F.100 series airplanes equipped with the main landing gear (MLG) that are identified in Messier-Dowty Service Bulletin (SB) F100-32-100 Revision 1 to immediately conduct an eddy current inspection of the MLG cylinders for forging folds and fatigue cracks as described in the most recent revision of Fokker Services SBF100-32-128 and to remove from service all landing gear in which such forging folds or cracks are found until they are returned to an airworthy condition. (Urgent) (A-01-30)

Require Fokker Services to immediately determine a repetitive inspection interval that will prevent structural cracks in main landing gear that are identified in Messier-Dowty Service Bulletin F100-32-100 Revision 1 from propagating to failure between inspections. (Urgent) (A-01-31)

Require all operators of Fokker F.100 series airplanes equipped with the main landing gear (MLG) that are identified in Messier-Dowty Service Bulletin (SB) F100-32-100 Revision 1 to periodically conduct eddy current inspections of MLG cylinders for forging folds or fatigue cracks, as described in the most recent revision of Fokker Services SBF100-32-128, at the interval identified in response to Safety Recommendation A-01-31. (A-01-32)

Require Fokker Services to review the current forging processes and inspection procedures for the main landing gear (MLG) that are identified in Messier-Dowty Service Bulletin F100-32-100 Revision 1 and to modify those processes and procedures, as appropriate, to ensure that forging folds do not occur in MLGs that are to be installed on its airplanes. (A-01-33)

Review the processes by which Messier-Dowty manufactures and inspects its landing gear and require modification of these processes as necessary. (A-01-34)

Acting Chairman CARMODY and Members HAMMERSCHMIDT, GOGLIA, and BLACK concurred in these recommendations.

[Original Signed]

By: Carol J. Carmody
Acting Chairman