



National Transportation Safety Board Aviation Accident Final Report

Location:	DFW Airport, TX	Accident Number:	FTW01FA127
Date & Time:	05/23/2001, 1504 CDT	Registration:	N1419D
Aircraft:	Fokker F28 Mk 0100	Aircraft Damage:	Substantial
Defining Event:		Injuries:	92 None
Flight Conducted Under:	Part 121: Air Carrier - Scheduled		

Analysis

During landing touchdown, following a stabilized approach, the right main landing gear failed. The airplane remained controllable by the pilots and came to a stop on the runway, resting on its right wing. The DFW Fire Department arrived at the accident site in 35 seconds and, following communication between the airplane's Captain and Fire Department's Incident Commander, it was decided that an emergency evacuation of the airplane was not necessary. Examination revealed that the right main gear's outer cylinder had fractured allowing the lower portion of the gear (including the wheel assembly) to separate from the airplane. Research, examination & testing of the cylinder revealed that a forging fold was introduced into the material during the first stage of its forging process. The first stage is a hand operation, therefore the quality is highly dependent on the person performing the hand operation. Following the first landing, the forging fold became a surface breaking crack, due to the normal loads imposed during landing. Although growth of the fatigue crack was suppressed by crack blunting, high load landings resulted in growth of the fatigue crack. Subsequently, the landing gear failed when the crack had reached a critical length. Additionally, the airplane's maintenance records were reviewed and no anomalies were found.

Probable Cause and Findings

The National Transportation Safety Board determines the probable cause(s) of this accident to be: A forging fold that was introduced during the manufacture of the right main landing, which resulted in a fatigue crack in the right main landing gear cylinder, and its subsequent failure during landing.

Findings

Occurrence #1: AIRFRAME/COMPONENT/SYSTEM FAILURE/MALFUNCTION
Phase of Operation: LANDING - FLARE/TOUCHDOWN

Findings

1. (C) LANDING GEAR,MAIN GEAR
2. (C) MATERIAL DEFECT - MANUFACTURER
3. (C) LANDING GEAR,MAIN GEAR - CRACKED
4. (C) LANDING GEAR,MAIN GEAR - FATIGUE
5. (C) LANDING GEAR,MAIN GEAR - FAILURE

Occurrence #2: GEAR COLLAPSED
Phase of Operation: LANDING - ROLL

Factual Information

HISTORY OF FLIGHT

On May 23, 2001, at 1504 central daylight time, a Fokker F28 Mk 0100 airplane, N1419D, operating as American Airlines (AA) flight 1107, was substantially damaged when the right main landing gear failed during landing (touchdown) at the Dallas-Fort Worth International Airport (DFW), Texas. The airplane was registered to and operated by American Airlines Inc., of Fort Worth, Texas. The captain, who holds an airline transport pilot certificate, the first officer, who holds an airline transport pilot certificate, two flight attendants, and 88 passengers were not injured. Visual meteorological conditions prevailed, and an instrument flight rules (IFR) flight plan was filed for the 14 Code of Federal Regulations Part 121 scheduled passenger flight. The flight originated from Charlotte, North Carolina (CLT), at 1228 and was scheduled to arrive DFW at 1507.

According to the captain and first officer, the first officer was the flying pilot for the CLT-DFW leg. The flight departed CLT, flew to DFW, and was cleared for a visual approach to runway 17C. Both flight crew members reported that the approach was flown visually, backed up with the localizer and Precision Approach Path Indicator (PAPI). They stated the approach was "stable and the touchdown was normal." The captain reported, just after initial touchdown a "loud bang" was heard, the right wing dropped, and the aircraft started to move to the right. The pilots were initially able to maintain directional control of the airplane with rudder and brake inputs; however, as speed decreased the Captain used "gentle" tiller (nose wheel steering control) inputs to assist in aligning the airplane with the runway centerline. The airplane came to a stop upright, with the right wing tip resting on the ground. The captain immediately consulted with the flight attendants and the DFW Fire Department Incident Commander, and determined that an emergency evacuation was not necessary. Subsequently, mobile stairs met the airplane and the passengers deplaned.

PERSONNEL INFORMATION

The captain holds an airline transport pilot certificate and is type rated in the F-100. At the time of the accident he had accumulated a total of 14,000 flight hours, of which 3,600 were in the F-100. He held a Federal Aviation Administration (FAA) first class medical certificate with no limitations or waivers that was issued on March 29, 2001.

The first officer holds an airline transport pilot certificate and is type rated in the F-100. At the time of the accident he had accumulated a total of 6,700 flight hours, of which 302 were in the F-100. He held an FAA second class medical certificate with no limitations or waivers that was issued on July 1, 2000.

The number one flight attendant was hired, and initially qualified in the F-100, on July 6, 2000. The number two flight attendant was hired, and initially qualified in the F-100, on May 11, 2000.

AIRCRAFT INFORMATION

The airplane was delivered new to American Airlines on June 30, 1992, and maintained in accordance with American Airlines' FAA approved airworthiness inspection program (AAIP). The airplane's maintenance records were reviewed, and there was no recent maintenance work performed that was related to the failure of the landing gear.

At the time of the accident, the airframe, to include the right main landing gear had accumulated a total of 21,589 hours (total ship time) and 15,380 cycles (total ship cycles) during its 8 years and 11 months of service.

The F28 Mk 0100 is equipped with one nose landing gear and two main landing gear; one under the inboard section of each wing. Each main landing gear was manufactured by Messier-Dowty Limited of the United Kingdom, from a forged block of grade 77-aluminum alloy (the equivalent to grade 7014-aluminum alloy in the United States). Each main landing gear is a two-wheel gear that has three support points; the forward attach, the aft attach, and the side stay strut attach. The landing gear is operated through a hydraulic system.

AERODROME INFORMATION

DFW airport is located at north 32 degrees 47.042 minutes latitude and west 097 degrees 15.205 minutes longitude, and at an elevation of 603 feet msl. The airport has two parallel runways on the west side of the airport and three parallel runways on the east of the airport, all of which are oriented north-south. The airport also has two parallel runways oriented northwest-southeast. Runway 17C is located on the east side of the airport, concrete (grooved), is equipped with a 4-light PAPI on the left side of the runway, and is 11,388 feet long and 150 feet wide.

METEOROLOGICAL INFORMATION

At 1511, the weather observation facility at DFW reported the following weather conditions: sky clear, visibility 10 miles, wind from 220 degrees at 10 knots, temperature 91 degrees Fahrenheit, dew point 54 degrees Fahrenheit, and an altimeter setting of 29.86 inches of mercury.

FLIGHT RECORDERS

The airplane was equipped with a Fairchild Model A-100A cockpit voice recorder (CVR). The CVR consisted of 34 minutes of good quality audio information on four channels, which included the accident. The CVR information confirmed that the First Officer was flying the airplane during the approach and landing. During the final approach, just prior to touchdown, the cockpit area microphone (CAM) channel captured the electronic voice announcing "50" "40" "30" "20" "10" in one second intervals. Three seconds later a bang followed by rattling sounds lasting approximately .26 seconds appeared on the CAM channel. One second later a lighter bang followed by rattling sounds lasting .34 seconds appeared on the CAM channel. Approximately 4 seconds later the FO remarked that "something [was] not right." One second later the CAM channel picked up the sounds of a "loud" bang and a rumble followed by a narrowband high pitched sound lasting approximately 36.5 seconds. Seven seconds later the Captain observed that the right main landing gear had collapsed. Fifty-six seconds after the "loud" bang, the Captain called for engine shut-down.

The airplane was equipped with an L-3 Communications Fairchild Model F-2100 digital flight data recorder (DFDR). Examination of the DFDR data confirmed that the approach was stable. The airplane initially landed with a vertical speed of less than 1 foot per second in a nose up and left wing down attitude. The airplane then became airborne a second time for a short moment and the second touchdown was in a right wing down attitude. When the air/ground switch changed from air to ground the vertical acceleration reached a maximum of 1.32 g, longitudinal acceleration reached a minimum of -0.11 g and lateral acceleration reached a maximum of 0.11 g. The longitudinal acceleration decreased to a minimum of -0.28 g and the

lateral acceleration decreased to a minimum of -0.37 g.

WRECKAGE AND IMPACT INFORMATION

On scene examination of the airplane and runway revealed that the lower portion of the right main landing gear assembly separated from the airplane. A runway survey crew estimated the gear failure point to be abeam taxiway echo juliet (EJ). The first significant fractured portions of the outer case of the gear strut assembly were found on the runway at the intersection of taxiway echo kilo (EK), 776 feet from the approximate gear failure point. The right wing tip touched down 2,200 feet from the gear failure point and 65.5 feet west (right) of the runway centerline. Witness marks from the right wing tip extended from this point 2,100 feet, to the final resting position of the airplane. The inner piston of the right main landing gear, with the scissor and wheel assembly attached to it, was found 2,500 feet from the gear failure point, along the east edge of taxiway mike two (M2). The airplane came to rest 4,300 feet from the gear failure point with the nose oriented 12.5 feet to the west (right) of and parallel to the runway centerline. The right wing sustained structural damage. The forward spar of the right wing, between stations 12,375 and 13,550, was damaged.

Additionally, two runway edge lights, located on the west side of the runway, between taxiway EK and taxiway M2, were damaged.

The portion of the right main landing gear that remained attached to the airframe, and its separated portions found on/near the runway, were sent to the NTSB Materials Laboratory in Washington, D.C., for further examination.

AIRPORT EMERGENCY RESPONSE

At 1504, the DFW Fire Department was notified of the accident by air traffic control tower personnel via the emergency phone network and responded with 6 crash fire rescue (CFR) units, 2 command units, 4 police units and 4 emergency medical service (EMS) units. The first two units arrived on-scene 35 and 38 seconds after the accident occurred. All units arrived on-scene within 2 minutes of the accident. The CFR units, that were equipped with 9,000 gallons of extinguishing agent, were positioned around the airplane ready to apply agent if necessary. Contact was made between the fire department's Incident Commander and the airplane's Captain via the dedicated emergency frequency. The Incident Commander reported to the Captain that there was no fire, no fuel leak and a small amount of hydraulic fluid leaking from the right main landing gear assembly area. The Captain elected not to initiate an emergency evacuation of the airplane.

MEDICAL AND PATHOLOGICAL INFORMATION

On May 23, 2001, both pilots were tested for the presence of drugs and alcohol, and the tests were negative.

TESTS AND RESEARCH

The right main landing gear was examined at the NTSB Materials Laboratory in Washington D.C. All of the landing gear components were accounted for except for the outstop ring (part number 201072334). The steel outstop ring was later found with the use of metal detectors during the third organized search of the accident site at DFW Airport. The outstop ring was examined at the NTSB Materials Laboratory and no features were noted on the ring that indicated the condition of the ring was related to the failure of the landing gear.

The right main landing gear's outer cylinder fractured into five pieces. Visual examination of the pieces revealed the fractures contained a river pattern that emanated from the forward face of the gear, above the dowel pin bushing and forward of the up-stop damper abutment. The fracture origin at the upper face of the fracture was not damaged; however, the fracture origin at the lower face was obliterated by post-fracture mechanical damage. The fracture origin area of the upper face was excised and ultrasonically cleaned in a detergent solution. Scanning electron microscope (SEM) examination of the excised fracture revealed a band of fatigue striations. The fatigue band measured 31 micrometers (0.0012 inch), and contained roughly 65 striations. The fracture features outside of the fatigue area displayed ductile dimple features typical of an overstress separation. Paint was removed from the external face of the excised fracture piece with a commercial paint thinner. No evidence of mechanical damage was found on the external surface. A section (cut) was made through the mid-span of the fracture origin area and perpendicular to the length of the crack. Examination of the section revealed distorted grain flow associated with the fracture origin that was irregular, radiating out and away from the fracture origin and aligned parallel with the fracture origin area. Line features, typical of a forging lap or fold, emanated from the fracture origin. The length of distorted microstructure was 0.08 inch (2mm) and was noticeable to a depth of 0.16 inch (4mm). A forging fold is a discontinuity in the material resulting from the material folding over onto itself during the forging process.

A segment was cut from the cylinder at the top of the main fitting and drag arm just above the fracture. The segment chemistry and microstructure were examined at the Messier Dowty Materials Laboratory, Gloucester, England under supervision of the Air Accidents Investigation Branch of the United Kingdom. The segment chemical analysis, hardness, fracture toughness, and fatigue strength were calculated and no anomalies were noted. An eddy current inspection of the remainder of the main fitting was also conducted and no additional cracking or forging folds were revealed.

Research by Messier-Dowty revealed that the forging fold was produced during the forging of the gear, during the preform stage. At this stage the major change in the section at the base of the drag arm is formed by taking a number of "bites." There are two situations which could result in a forging fold at this stage. First, production of sharp, uneven or deep bites can lead to folds if the bites are overlapping. Any smearing of the metal as a result of the forging bites is prone to lap or fold over. Secondly, a lack of die lubrication may also give rise to metal smearing, and a forging fold may occur. Preforming is a "hand operation," therefore the occurrence of folds is partially dependant on the operator. A review of the manufacturing process revealed that there have been no changes to the forging process that would relate to the development of a fold.

Further testing by Fokker and Messier-Dowty revealed that a fold will open and become surface breaking after the first landing, due to the loads imposed during touchdown. A fold that is subjected to 50-100 Mpa of stress will become a surface breaking crack. The lightest landing of an airplane will result in a fold becoming surface breaking. Following the first landing, when the fold became a surface breaking crack, fatigue growth was suppressed by "crack blunting." Crack blunting is a phenomenon in which only high load levels result in growth of the crack.

Research was conducted regarding the detectability of forging folds/cracks. Prior to leaving the factory, each landing gear is subjected to four inspections, which present the opportunity

for forging folds to be detected: 1. Inspections are carried out after etching between each pressing stage 2. There is a detailed visual inspection at the finished stage 3. Etch penetrant inspection of the finished forging is carried out after heat treatment of the finished forging 4. Further penetrant and etch penetrant inspections are carried out during machining at Messier-Dowty. The detectability of a fold, utilizing either the eddy current or etch penetrant inspection method, is dependant on the amount of die lubricant present in the forging (the folds are not detectable if the die lubricant is not present). Once the fold is opened, both etch penetrant and eddy current methods are similar in their capability to detect a fold. Regardless of the presence of die lubricant, an open fold/crack is easily detectable using the eddy current and etch penetrant inspection methods.

The following main landing gear components were examined during the course of the investigation, with nominal results: torque link dampers, brake control valve assembly, brake shut-off valve assembly, brake assemblies, wheel speed sensors, dual skid control valve assemblies, and the skid control unit.

ADDITIONAL INFORMATION

On June 5, 2001, AA initiated a fleet campaign on their F-100 airplanes. The campaign consisted of an eddy current inspection of the cylinder's main fitting area, where the crack was found on the accident gear. Three additional AA landing gear were found to have positive crack indications when the eddy current inspections were performed. One of these main landing gear was examined at the NTSB Materials Laboratory and the two other by Messier-Dowty. All three examinations revealed similar size cracks and forging defects as the accident landing gear exhibited.

On June 18, 2001, Messier-Dowty and Fokker Services issued concurrent service bulletins (SB), F100-32-100 and SBF100-32-128, respectively, regarding the main landing gear on Fokker F28 Mk 0100 airplanes. The service bulletin required a one-time eddy current inspection of the landing gears' main fitting. If a crack was detected, the operator was required to rework the main landing gear and, submit to Fokker Services, a questionnaire detailing the crack. Messier-Dowty reported that the service bulletin fleet wide inspections revealed seven gears with defective forgings. The seven gears, and the accident gear, were manufactured during one of two time periods: April-June 1990 and April-August 1991. There were no gears reported with defective forgings between October 1985-March 1990 and between September 1991-September 2001. The Civil Aviation Authority (CAA) Netherlands then issued an Airworthiness Directive (BLA 2001-080), which made the inspections outlined in Messier-Dowty's and Fokker Services SB's mandatory.

On August 20, 2001, the NTSB issued the following four Urgent Safety Recommendations (A-01-30 through -34) to the FAA:

1. 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 initial 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.
2. 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 from propagating to failure between inspections.

3. Require all operators of Fokker F-100 series airplanes equipped with the 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 and/or fatigue cracks, as described in the most recent revision of Fokker Services SBF100-32-128, at an interval that will prevent forging folds or resulting structural cracks from propagating to failure between inspections. This interval should be determined on the basis of crack propagation rates, including the propagation rates of the MLG cracks that have been discovered to date.

4. Require Fokker Services to review the current forging processes and inspection procedures for the 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 MLG that are to be installed on its airplanes.

In October 2001 Messier-Dowty and Fokker Services issued concurrent SBs, F100-32-101 and SBF100-32-131, respectively. The SBs established repeat eddy current inspections of the main fitting area of the cylinder. The repeat inspections were an effort to raise the confidence level of detection of small discontinuities (cracks). No additional cracks have been reported as a result of these SBs. The CAA Netherlands issued an Airworthiness Directive (BLA 2001-141), which made the inspections outlined in Messier-Dowty's and Fokker Services SB's mandatory.

On December 20, 2001, the FAA issued Airworthiness Directive (AD) 2001-24-10. The AD required an initial eddy current inspection of the MLG main fittings cited in Fokker SB F100-32-100, within 1,000 total landings or 30 days, whichever occurs later. The AD further required operators to repeat the inspection every 500 landings or 6 months, whichever occurs first.

In March of 2003, Messier-Dowty and Fokker Services issued concurrent service bulletins, F100-32-102 and SBF100-32-134, respectively. These service bulletins detailed terminating action inspections. The bulletins require that the repeat inspections (a minimum of two) are completed and then a final, independent etch penetrant inspection is accomplished at the next overhaul. After the final inspection at overhaul, full safe life of the gear is restored and additional repeat inspections are not necessary. If a crack is identified, the SB requires that the gear be reworked or replaced.

Subsequently, the CAA Netherlands issued an AD (BLA 2003-140), which made the actions listed in the March 2003 SB's that were published by Messier-Dowty and Fokker Services, mandatory. As of the writing of this report the FAA had not yet issued final terminating action ADs.

Pilot Information

Certificate:	Airline Transport; Commercial	Age:	45, Male
Airplane Rating(s):	Multi-engine Land; Single-engine Land	Seat Occupied:	Left
Other Aircraft Rating(s):	Helicopter	Restraint Used:	Seatbelt, Shoulder harness
Instrument Rating(s):	Airplane; Helicopter	Second Pilot Present:	Yes
Instructor Rating(s):	None	Toxicology Performed:	Yes
Medical Certification:	Class 1 Valid Medical--no waivers/lim.	Last Medical Exam:	03/29/2001
Occupational Pilot:		Last Flight Review or Equivalent:	02/20/2001
Flight Time:	14000 hours (Total, all aircraft), 3600 hours (Total, this make and model), 7100 hours (Pilot In Command, all aircraft)		

Co-Pilot Information

Certificate:	Airline Transport; Commercial; Flight Engineer	Age:	36, Male
Airplane Rating(s):	Multi-engine Land; Single-engine Land	Seat Occupied:	Right
Other Aircraft Rating(s):	None	Restraint Used:	Seatbelt, Shoulder harness
Instrument Rating(s):	Airplane	Second Pilot Present:	Yes
Instructor Rating(s):	None	Toxicology Performed:	Yes
Medical Certification:	Class 2 Valid Medical--no waivers/lim.	Last Medical Exam:	07/01/2000
Occupational Pilot:		Last Flight Review or Equivalent:	09/03/2000
Flight Time:	6700 hours (Total, all aircraft), 302 hours (Total, this make and model), 4000 hours (Pilot In Command, all aircraft)		

Aircraft and Owner/Operator Information

Aircraft Manufacturer:	Fokker	Registration:	N1419D
Model/Series:	F28 Mk 0100	Aircraft Category:	Airplane
Year of Manufacture:		Amateur Built:	No
Airworthiness Certificate:	Transport	Serial Number:	11402
Landing Gear Type:	Retractable - Tricycle	Seats:	94
Date/Type of Last Inspection:	04/17/2001, Continuous Airworthiness	Certified Max Gross Wt.:	98000 lbs
Time Since Last Inspection:	251 Hours	Engines:	2 Turbo Fan
Airframe Total Time:	21589 Hours	Engine Manufacturer:	Rolls-Royce
ELT:	Not installed	Engine Model/Series:	TAY650-15
Registered Owner:	American Airlines Inc.	Rated Power:	15100 lbs
Operator:	American Airlines Inc.	Air Carrier Operating Certificate:	Flag carrier (121)
Operator Does Business As:	N/A	Operator Designator Code:	AALA

Meteorological Information and Flight Plan

Conditions at Accident Site:	Visual Conditions	Condition of Light:	Day
Observation Facility, Elevation:	DFW, 603 ft msl	Observation Time:	1511 CDT
Distance from Accident Site:		Direction from Accident Site:	
Lowest Cloud Condition:	Clear	Temperature/Dew Point:	33° C / 12° C
Lowest Ceiling:	None	Visibility	10 Miles
Wind Speed/Gusts, Direction:	10 knots, 220°	Visibility (RVR):	
Altimeter Setting:	29.86 inches Hg	Visibility (RVV):	
Precipitation and Obscuration:			
Departure Point:	Charlotte, NC (CLT)	Type of Flight Plan Filed:	IFR
Destination:	DFW Airport, TX (DFW)	Type of Clearance:	IFR
Departure Time:	1228 EDT	Type of Airspace:	Class B

Airport Information

Airport:	Dallas-Fort Worth Intl (DFW)	Runway Surface Type:	Concrete
Airport Elevation:	603 ft	Runway Surface Condition:	Dry
Runway Used:	17C	IFR Approach:	Visual
Runway Length/Width:	13388 ft / 150 ft	VFR Approach/Landing:	Full Stop; Straight-in

Wreckage and Impact Information

Crew Injuries:	4 None	Aircraft Damage:	Substantial
Passenger Injuries:	88 None	Aircraft Fire:	None
Ground Injuries:	N/A	Aircraft Explosion:	None
Total Injuries:	92 None	Latitude, Longitude:	32.896389, -97.879167

Administrative Information

Investigator In Charge (IIC):	Jason A Ragogna	Adopted Date:	11/25/2003
Additional Participating Persons:	Eric West; Federal Aviation Administration (AAI-110); Washington, DC Clayton B Titus; Federal Aviation Administration (AMR CMO); DFW Airport, TX Sean Mulholland; American Airlines Inc.; DFW Airport, TX Arthur Reekers; Stork (Fokker Services B.V.) Ian D Mowat; Messier-Dowty Michael D Michaelis; Allied Pilots Association; Fort Worth, TX Lonny Glover; Association of Professional Flight Attendants; Eules, TX		
Publish Date:			
Investigation Docket:	NTSB accident and incident dockets serve as permanent archival information for the NTSB's investigations. Dockets released prior to June 1, 2009 are publicly available from the NTSB's Record Management Division at pubinq@ntsb.gov , or at 800-877-6799. Dockets released after this date are available at http://dms.nts.gov/pubdms/ .		

The National Transportation Safety Board (NTSB), established in 1967, is an independent federal agency mandated by Congress through the Independent Safety Board Act of 1974 to investigate transportation accidents, determine the probable causes of the accidents, issue safety recommendations, study transportation safety issues, and evaluate the safety effectiveness of government agencies involved in transportation. The NTSB makes public its actions and decisions through accident reports, safety studies, special investigation reports, safety recommendations, and statistical reviews.

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