Culminating years of work aimed at preventing aging airliners from being flown with widespread fatigue damage (WFD), the U.S. Federal Aviation Administration (FAA) has issued a rule requiring the development of an inspection program for transport category airplanes.[1]

The FAA's final rule governing the inspections took effect Jan. 14. It gives design approval holders between 18 months and five years, depending on the airplane, to develop inspection programs. Operators then have an additional 2½ to six years to implement the inspection requirements.

A framework assembled by the Taiwan Aviation Safety Council holds wreckage from a China Airlines Boeing 747 that crashed near Taipei in 2003, killing 225. Investigators found extensive fatigue damage in the fuselage.

BY LINDA WERFELMAN

Crackdown on Fatigue

The FAA aims for new inspection programs to keep airplanes with widespread fatigue damage out of the air.

The FAA characterized the problem as increasingly likely as the airplane ages.

The campaign to address the problem of WFD began in the aftermath of an April 28, 1988, accident in which an Aloha Airlines Boeing 737-200 experienced an explosive decompression and separation of an 18-ft (5-m) section of the upper portion of the cabin fuselage (see "There Was Blue Sky," p. 39).[2]

The U.S. National Traffic Safety Board blamed the accident on the failure of the airline's maintenance program to detect "significant disbonding and fatigue damage" that led to the failure of a lap joint and the subsequent separation of the upper section of fuselage. The safety recommendations generated by the accident investigation set in motion the years-long effort to develop protections against WFD.

Over the years, the NTSB has investigated a number of accidents and incidents involving airliners with WFD (see "Airplanes Damaged by WFD," p. 40), and the FAA has issued about 100 airworthiness directives intended to address WFD.

Defining the Terms

WFD is defined by the FAA as the "simultaneous presence of fatigue cracks at multiple structural locations that are of sufficient size and density that the structure will no longer meet the residual strength requirements of [U.S. Federal Aviation Regulations] Section 25.571(b)," which discusses damage tolerance evaluations.

WFD is largely a result of the repeated pressurization and depressurization of airplanes during years of flight. In the final rule, the FAA characterized the problem as "increasingly likely as the airplane ages, and … certain if the airplane is operated long enough."

WFD is difficult to detect because when the cracks first form, they are very small; eventually, however, they grow quickly and join together, possibly causing structural failure before they are detected in an inspection.

The FAA characterized as "fortuitous" that many cases of WFD have been discovered by workers performing routine aircraft maintenance.

"Cracks have been found by workers while stripping and painting an airplane," the FAA said in the final rule. "Cracks have also been found by mechanics conducting unrelated inspections of skin anomalies on the external fuselage; further investigation revealed multiple cracks in stringers and circumferential joints."

In other cases, however, fatigue cracking has gone unnoticed, and "undetected multiple site damage in wing or fuselage structure has eventually led to catastrophic failure of the structure in flight," the FAA said.

Two Types

WFD takes one of two forms:

- Multiple site damage is defined by the FAA as "the simultaneous presence of fatigue cracks at multiple locations that grow together in the same structural element, such as a large skin panel or lap joint."
- Multiple element damage is "the simultaneous presence of fatigue cracks in similar adjacent structural elements, such as frames or stringers."

In some instances, both types of WFD occur at the same time.

'Broad Safety Net'

Summarizing the comments submitted after the rule was proposed in 2006, the FAA noted that some operators and aviation organizations questioned the need for the new rule, arguing that it was not justified in terms of safety.

The FAA said that some had noted that the Aloha Airlines accident was the last major accident in the United States to be attributed to WFD — and that the NTSB had concluded that WFD was a contributing factor rather than the sole factor in the accident.

Boeing commented, however, that the rule would "cast a broad safety net on airframe structural performance for those types of details the industry has determined may be susceptible to

Continued on p. 40

'There Was Blue Sky'

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The in-flight structural failure of an Aloha Airlines Boeing 737-200 during an April 28, 1988, flight from Hilo, Hawaii, U.S., to Honolulu is widely described as the defining event in the development of programs to address issues associated with aging aircraft.

The airplane had accumulated 89,680 flight cycles, and 35,496 flight hours, when the accident occurred — an explosive decompression and the separation of an 18-ft (5-m) section of the upper cabin fuselage — from the main cabin entrance door aft.

Of the 95 people in the airplane, one flight attendant was swept out of the airplane and presumably killed. Another flight attendant and seven passengers were seriously injured.

The final report on the accident by the U.S. National Transportation Safety Board (NTSB) noted that the two pilots had said that they heard a loud clap or "whooshing," followed by the sound of wind behind them and that the captain had said that, when he looked back, he saw that the cockpit entry door was gone and "there was blue sky where the first-class ceiling had been."[1]

He said that the airplane rolled slightly left and right and that the controls felt "loose" as he began the emergency descent to Kahului Airport on the Hawaiian island of Maui, using hand signals to communicate with the first officer because of the continuing roar of the wind. He stopped the airplane on the runway, where the cabin crew conducted an emergency evacuation.

Afterward, one passenger said that, as she boarded the airplane, she had seen a longitudinal fuselage crack located, the report said, "in the upper row of rivets along the S-10L lap joint, about halfway between the cabin door and the edge of the jet bridge hood." The passenger had not mentioned her observation to the crew or to ground personnel.

A post-accident examination of the airplane revealed that the fuselage skin had separated along a line that followed the upper rivet line.

The NTSB cited as the probable cause of the accident "the failure of the Aloha Airlines maintenance program to detect the presence of significant disbonding and fatigue damage which ultimately led to failure of the lap joint at S-10L and the separation of the fuselage upper lobe."

Among the contributing factors identified by the NTSB were "the failure of Aloha Airlines management to supervise properly its maintenance force" and "the failure of the FAA [U.S. Federal Aviation Administration] to evaluate properly the Aloha Airlines maintenance program and to assess the airline's inspection and quality control deficiencies."

—LW

Note

1. NTSB. Aircraft Accident Report NTSB/AAR-89/03, *Aloha Airlines, Flight 243, Boeing 737-200, N73711; Near Maui, Hawaii; April 28, 1988*.

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WFD," pave the way for establishing safe operational limits and prescribe maintenance actions to help avert WFD in airplanes that have not yet reached those limits.

Airbus added its support for the "intent … to address the potential risks of [WFD] by requiring that appropriate maintenance requirements be imposed to preclude aircraft operations in the presence of [WFD]."

The FAA characterized the rule as "essential to prevent future accidents or incidents."

The agency added that "the potential for catastrophic structural failure is significant."

In the past, manufacturers developed "some level of understanding of structural fatigue characteristics up to the design service goal, but not beyond it," the FAA said. "A significant number of airplanes being operated currently have already accumulated a number of flight cycles or flight hours greater than the original design service goal. As the existing fleet continues to age, the number of such airplanes will increase."

The FAA noted that airplane structural fatigue characteristics are understood "only up to a certain point consistent with the analyses performed and the amount of testing accomplished." Airplanes should not be operated beyond that point because "in the absence of intervention, the likelihood of WFD increases with the airplane's time in service."

The FAA noted that some airlines had said in their public comments that existing programs — including elements of the Aging Aircraft Program, established after the Aloha Airlines accident — served the same purposes as an airplane inspection program designed specifically to identify WFD. Nevertheless, the FAA said that the existing programs were intended to address structural degradation in specific aircraft and not to focus on WFD. This new rule, however, specifically addresses WFD, and the programs that will be implemented as a result of the rule are intended to be the last element of the Aging Aircraft Program, the FAA said.

The agency said that maintenance programs typically include inspections to detect "obvious damage and irregularities," but "WFD, by

Airplanes Damaged by WFD

In its final rule, the U.S. Federal Aviation Administration (FAA) discussed about a dozen cases since the 1988 Aloha Airlines accident involving widespread fatigue damage (WFD) in transport category airplanes, including:

- The discovery, during maintenance in 1998, of two cracks growing from beneath a Boeing 727 lap joint. "Disassembly of the joint revealed a 20-in [51-cm] hidden crack from multiple site damage on the lower row of rivet holes in the inner skin," the FAA said.
- The discovery in July 2003 of cracking along a lap joint in a 737. The FAA described "extensive multiple site damage with up to 10 in [25 cm] of local link-up of cracks in one area."
- The discovery in June 2003 of cracking of the aft pressure bulkhead on a McDonnell Douglas DC-9 following a rapid decompression at 25,000 ft. A subsequent inspection found multiple site damage and "extensive link-up of cracks," the FAA said.
- An investigation that blamed fatigue cracks in the right wing of a Lockheed C-130A for the August 1994 in-flight separation of the wing as the airplane was responding to a forest fire near Pearblossom, California, U.S. Similar cracks were blamed for the in-flight separation of the wing of another firefighting C-130A in June 2002 near Walker, California, the FAA said.
- The discovery, during maintenance in 2005, of missing skin fasteners in the upper deck area of a 747. The subsequent inspection revealed that the fuselage frame was severed. Substantial cracking was found in two adjacent fuselage frames.
- Testing, service experience and analysis of an Airbus A300 in 2002 revealed cracking in adjacent fuselage frames. The FAA said the fatigue cracks "could result in multiple element damage."

— LW

its nature, is usually hidden and not readily detectable."

Specifics of the Rule

The new rule applies to turbine-powered transport category airplanes with a maximum takeoff gross weight of more than 75,000 lb (34,020 kg) that are operated under U.S. Federal Aviation Regulations Part 121 or Part 129 and have type certificates issued after Jan. 1, 1958. It also applies to all transport category airplanes that will be certificated in the future, regardless of their maximum takeoff gross weight or how they are operated. Some 4,198 U.S.-registered airplanes are affected by the rule, the FAA said.

The rule requires design approval holders to "evaluate the structural configuration of each model for which they hold a type certificate to determine its susceptibility to WFD and, if it is susceptible, to determine that WFD would not occur before the proposed LOV" — the "limit of validity" — the number of flight hours or flight cycles that an airplane can be operated before undergoing mandatory inspections for fatigue damage.

Design approval holders and operators also would be required to incorporate into their maintenance programs an LOV for the affected airplanes. The rule includes an option for extending an LOV, with maintenance actions designed to support the extension. No airplane could be operated beyond its extended LOV, the FAA said.

Determining an LOV

The rule says the evaluation of an LOV must be based on test evidence — described as data from full-scale fatigue testing, either of the entire airplane or of major sections of the airplane or both — and analysis — including fatigue and damage tolerance analyses. New airplane models pending approval should undergo testing to produce data on all structural parts of an airplane that are susceptible to WFD, the rule says.

The test data for some older airplanes may involve only the fuselage, the rule says.

"This is because the pressurized fuselage has been considered to be the most fatigue-critical part of the airplane," the rule says. "The wing and empennage have typically been considered less critical, and, as a result, relevant test data may not exist. However, for these same airplane models, significant service experience does exist."

Because of the availability of data, the rule says that, for these airplanes, the FAA would accept a combination of data from test evidence and analysis, along with service experience to show compliance with the rule.

"For example, in the case of one [of the earlier] airplane models, significant numbers of airplanes both in service and in storage have accumulated flight cycles in excess of the design service goal," the rule says. "For this model, there is significant existing test evidence for the fuselage but very little for the wing. In this case, the FAA expects that demonstrating freedom from WFD for the wing would be based primarily on service experience; for the fuselage, it would be based primarily on service experience and test evidence."

In the rule, the FAA established "default LOVs" for dozens of airplane models; for most, the default LOV was the same as the model's previously established design and extended service goal. For example, the default LOV for Airbus A319-series airplanes is 48,000 flight cycles/60,000 flight hours. The design and extended service goal also is 48,000 flight cycles; the goal is not expressed in flight hours.

The FAA estimated the benefits of implementing the rule at $4.8 million and the cost at $3.6 million.

The FAA said it is working with the European Aviation Safety Agency, which currently is developing rules to address WFD, and other national aviation authorities to harmonize WFD regulations.

'WFD, by its nature, is usually hidden and not readily detectable.'

Notes

1. FAA. "Aging Airplane Program: Widespread Fatigue Damage." *Federal Register* Volume 75 (Nov. 15, 2010): 69745–69789.

2. NTSB. Aircraft Accident Report NTSB/AAR-89/03, *Aloha Airlines, Flight 243, Boeing 737-200, N73711; Near Maui, Hawaii; April 28, 1988.*