# The FAA Elevates Shot Peening

Shot peening is used in the manufacturing, maintenance and repair of aircraft components to enhance or restore fatigue properties that are lost in service or repair (welding, blemish removal, etc.) This isn't news as the aerospace market is crucial to many of us in the shot peening industry. What is news is the responsibility the FAA (the U.S. Federal Aviation Administration) is taking for educating its auditors and inspectors on shot peening and proper shot peening processes in airlines, job shops and repair facilities.

An external influence that led to shot peening education for the FAA came from Electronics, Inc. (EI). EI already had comprehensive shot peening training vehicles through its annual workshops and on-site training programs. Building on these well-developed programs, EI became an accredited training supplier to the FAA. Pete Bailey and Jack Champaigne of Electronics Inc. developed the unique training program for FAA inspectors and auditors — it's the first and only program of its kind and was developed specifically for the FAA. EI provides Inspection Authorization renewal courses for Shot Peening Audits; Workshop Level I, II and III; Rotary Flap Peening and Shot Peening Training. EI also provides on-site training and workshop courses that instruct maintenance and repair facilities on how to prepare for and pass a FAA audit. FAA employees regularly attend the EI workshops; Aviation Safety Inspectors from FAA facilities in California, Ohio and Arizona attended the 2003 Scottsdale workshop.

**We are very pleased to have formed this alliance with the FAA. It elevates shot peening training to the level of attention and importance it deserves in the aerospace industry.**

—Jack Champaigne

Because the FAA is raising the standard for shot peening, every OEM, job shop and supplier to the shot peening industry will benefit — the greater the appreciation for the process, the more components that will be shot peened.

When we widen our perspective, flight safety is the biggest winner. Read these examples of how poor (or no) shot peening jeopardizes the integrity of aircraft components… and our safety.

**I received valuable training at the 2003 EI Shot Peening workshop. It was well-worth the time and will enhance our ability to oversee the people and facilities that perform shot peening.**

—Gary Martin
Flight Safety Inspector
Flight Standards Office

**Internal Failure in Engines**

The FAA on July 2, 1998 ordered Operators of CFM 56-7B powered Boeing 737-700's and 800's to immediately check those engines for signs of internal failure.

The telegraphic airworthiness directive followed separate in-flight shutdowns of CFM 56-7B on 737's operated by Transaero and Braathens airlines. Investigations determined the accessory gearbox starter gearshaft in each engine suffered fatigue failure that stemmed from a manufacturing process change.

A vendor for CFM International eliminated shot peening of the gearshaft hub in mid-1996. FAA officials said the lack of shot peening was the primary cause of failures. CFM had the vendor reinstitute shot peening earlier this year and had launched a program to replace roughly 400 gearshaft hubs.

—Edward H. Philips
Aviation Week and Space Technology, July 6, 1998

**Inadequate Shot Peening Cited in Two Failures of Left-Main Landing Gear on Fokker 100**

The Australian Transport Safety Bureau said that the two incidents, which occurred three months apart in the same airplane, involved cracks in parts of the landing gear that had been repaired and in areas where shot peening was faulty.

About 10:30 local time July 4, 1999, the crew of a Fokker 100 experienced a severe vibration from the left-main landing gear when they applied the wheel brakes during the landing roll at Norfolk Island Airport after a domestic flight in Australia. The airplane received minor damage; none of the 43 people on board was injured. Three months later, at 10:40 local time Oct. 9, 1999, the same airplane was being landed at the same airport when the crew experienced a severe vibration throughout the airframe.

The airplane received substantial damage; none of the 84 people on board was injured. The incidents were investigated by the Australian Transport Safety Bureau (ATSB), which issued a technical report on the analysis of the airplane's left-main landing-gear failures and air safety occurrence reports on each incident. ATSB said in its technical report that, in the first incident, the outboard wheel on the left-main landing gear separated from the wheel hub during landing and that the second incident involved the fracture of the left-main landing-gear upper-torque-link attachment lugs.

A similar landing accident in May 2001 involving a Fokker 100 at Dallas-Fort Worth (Texas, U.S.) International Airport resulted in several safety recommendations from the U.S. National Transportation Safety Board. After the first incident, examination of maintenance documents showed that the wheel had accumulated 99.8 hours in service and 77 landings and takeoffs since overhaul. The air safety occurrence report said that during the overhaul, repairs had been performed to remove scoring from the hub that was caused by "rubbing contact with the brake heat shield during service."

The repairs included the reduction of the hub diameter by 0.02 inch (0.51 millimeter). The work was conducted in accordance with requirements of repair no. 15 of the Aircraft Braking Systems Corp.maintenance manual of Sept. 27, 1998, and the Aircraft Systems Corp. authorized an increase of the repair tolerance for the hub-diameter reduction from between 6.41 inches and 6.48 inches (16.28 centimeters and 16.46 centimeters) to between 6.39 inches (16.23 centimeters) and 6.48 inches. Instructions for the repairs said that after material was removed for the hub-diameter reduction, the repaired area was to be shot peened. The air safety occurrence report said that shot-peening parameters were to be "adjusted to produce a specific surface quality".

The technical report said that a comparison of the surface of the repaired area and the original surface of the wheel hub revealed a "markedly different" intensity in the shot peening of each area. The intensity of shot peening was lower on the repaired surface, the report said. "This variation would be expected to lower the resistance of the wheel to fatigue cracking," the air safety occurrence report said. "The lower level of compressive residual stress associated with the less intense shot-peening process applied to the repaired [area] would also increase the likelihood of fatigue failure under normal loading conditions."

Shot peening is a method of strengthening a metal's resistance to fatigue and other types of stress-induced damage, typically by using compressed air or a rotating wheel to hurl round metallic shot at high speed toward the surface of the metal.[1]

The intensity of the shot peening is determined by shot size and air pressure or the speed of the rotating wheel. The result of the process is that residual compressive stress is created on the metal's surface; the presence of the residual compressive stress is designed to delay the initiation or extension of fatigue cracks that otherwise might develop from features on the surface. The U.K. Air Accidents Investigation Branch said, in an explanation of the shot-peening process that was included in a report on a 1995 accident, "Essentially, applied tensile stresses are offset by the residual compressive stress from peening."[2]

Viewed using low-power magnification, effective shot peening appears in the form of small indentations in an even pattern across the surface of the treated metal. The ATSB air safety occurrence report on the July 4 landing incident said that the wheel failed because of fatigue cracking that began at the surface of the metal in the repaired area of the wheel hub.

"No single stress point concentrator had started the cracking," the report said. "It had begun at numerous closely spaced points around the circumference of the hub, known as ratchet marks. This was consistent with sideways flexure of the wheel web and with crack growth from the repaired surface of the hub. There was no indication the growth had started at any crack that had been present prior to the repair."

The fatigue crack spread in a manner consistent with the sideways flexing of the wheel web - flexing that occurs "when a turning moment (torque) is applied to the main landing gear while the wheels [are] rotating, such as during ground turning or crosswind landings," the report said. High crosswind components were typical during takeoffs and landings at Norfolk Island, the flight crew said.

The technical report said that the ability of the main landing-gear wheels to withstand such a turning moment depends on "the resistance of the component and the magnitude and frequency of the alternating stresses created by the applied loads and any geometric stress concentrators."

The final fracture of the wheel occurred just after touchdown, an indication that significant torque was being applied to the left-main landing gear at the time, the report said. The incident investigation also revealed that, during the last overhaul before the landing incident, a portion of the left-main landing-gear shimmy damper had been reassembled incorrectly.

The error had little effect, if any, on the initiation of the fatigue crack or the spread of the fatigue crack, the air safety occurrence report said. (Similarly, the air safety occurrence report on the second landing incident said that the incorrect assembly of the shimmy damper had little effect, if any, on the initiation or development of the fatigue cracks cited in that incident.)

The report on the second landing incident said that the upper torque-link attachment lugs on the left-main landing gear had broken during landing. (The upper torque-link attachment point was an integrally forged double lug with a stiffening web between the two lugs.) Examination of maintenance documents showed that the landing gear had accumulated 658 cycles since overhaul and 16,579 cycles since new.

The technical report said that the upper torque-link attachment lugs had failed because of "the extension of pre-existing cracking in the lug-stiffening web while torque was transmitted through the torque links. The cracking in the stiffening web was caused by stress corrosion." The report said that the extension of the crack was consistent with loading that resulted in sideways flexing of the wheel rim during such situations as crosswind landings.

"The fracture of each lug section occurred as a result of rapid, unstable crack propagation," the report said. "In addition to the fractures in the lug sections, fracture and crack growth had extended from the locking-pin hole in the stiffening web. Initially, cracking from both the upper and lower locking-pin holes extended on a plane approximately 45 degrees to the pivot-pin bore. The cracks branched as they approached the lugs. One branch of the cracking extended around the circumference of the web, approximately parallel with the plane of the lugs; the other branch extended on a plane toward the lugs and arrested at the point of change in cross section between the web and lugs."

The stiffening web, the pivot-pin bore and the locking-pin hole had been "reworked" during the most recent overhaul. "Material had been removed by localized surface grinding in an attempt to remove corrosion," the report said. "The pivot-pin bore surface had been peened and repainted with a chromate-based paint primer. However, the paint film exhibited poor adhesion and the shot-peening coverage was haphazard."

The presence of the stress corrosion crack in the stiffening web reduced the fracture-resistance of the lug during times when tensile stresses existed in the lug, including during crosswind landings, when main landing-gear turning moments were transmitted through the torque links, the report said.

The report said that the inboard lug fractured shortly after touchdown "as a result of the tensile stresses created by torque transmission [during the crosswind landing] and the lowering of the lug fracture resistance by the presence of a stress corrosion crack in the stiffening web. The failure of the inboard lug was followed by the bending fracture of the outboard lug." Both air safety occurrence reports included a recommendation to the U.K. Civil Aviation Authority (U.K. CAA) to review the repair process and the overhaul process for the failed wheel and for the failed torque links that were identified during the ATSB investigation of the second landing incident to ensure that the processes conform to airworthiness requirements.

In response, CAA said that the repair and overhaul processes would be reviewed.

The technical report also included a recommendation for an audit of the company responsible for the repair and overhaul of the left-main landing gear "to establish why the repaired surface of the wheel hub differed from the 'as manufactured' condition'.

The report said, "In particular, it should be established if the specification of the repair was adequate, or if repair instructions were followed. The reasons for any inadequacy or lack of compliance should be established."

"Similarly, the reworking of the torque link attachment lugs of the main-landing-gear fitting should be reviewed to establish why the surface treatment and surface protections schemes were inadequate."

Article printed from the Aviation Mechanics Bulletin, September-October 2001, with permission by the Flight Safety Foundation (FSF). For more information on FSF, visit http://flightsafety.org.

Additional articles from Aviation Mechanics Bulletin are available at: http://flightsafety.org/amb_home.html

[FSF editorial note: This article, except where specifically noted, is based on the Australian Transport Safety Bureau (ATSB) Analysis of left-main landing-gear failures, Fokker 100, VH-FWI, ATSB Air Safety Occurrence Report 199903327 and ATSB Air Safety Occurance Report 199904802. The reports include photographs and diagrams.]

References

1. U.K. Air Accidents Investigation Branch. Report on the accident to Douglas Aircraft Company MD-83, G-DEVR at Manchester Airport on 27 April 1995, Section 1.16 "Tests and Research." Aircraft accident report 1/97 (EW/ C95/4/2).
2. Ibid.

Further Reading From FSF Publications:

FSF Editorial Staff. "Fatigue Crack Leads to MD-83 Left Main Landing Gear Collapse on Rollout." Aviation Mechanics Bulletin Volume 45 (May-June 1997).

FSF Editorial Staff. "Corrosion and Fatigue-crack Detection Remains Critical to the Continued Airworthiness of Aging Aircraft." Aviation Mechanics Bulletin Volume 46 (March-April 1998).

### Propeller Separates from Engine, Causing Fatality

The propeller separated from the right engine during the initial climb. Examination of the wreckage revealed the propeller hub fracture resulted in one of the three propeller blades detaching from the hub.

The rest of the propeller hub then separated striking the right front of the fuselage. Oil was spread across the aircraft nose and windshield. The fuselage right side damage increased aerodynamic drag. Witnesses reported the engine cowling was torn. The aircraft entered a right turn and dive. It impacted the ground in a near inverted attitude. Metallurgical examination of the failed prop hub revealed metal fatigue emanating from the threaded hole for the grease fritting. The threads had been deformed by shot peening, resulting in increased stress concentrations at the threads.

The National Transportation Safety Board determines the probable cause(s) of this accident as follows:

Fatigue of the right propeller hub due to metal fatigue which resulted in catastrophic separation of the propeller. Contributing to the accident was damage done to the aircraft airframe in flight by the separating propeller making the aircraft uncontrollable.

—NTSB Identification: LAX89FA314
The docket is stored on NTSB microfiche number 42375
Accident occurred Friday, September 15, 1989 in Ontario, Canada
Aircraft: Piper PA-31-350
Injuries: One Fatal


Pratt & Whitney employees and EI instructors at a recent shot peening training class in San Antonio, Texas.