



National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation

Date: September 14, 2012

In reply refer to: A-12-52 (Urgent) and
A-12-53 (Urgent)

The Honorable Michael P. Huerta
Acting Administrator
Federal Aviation Administration
Washington, D.C. 20591

In this letter, the National Transportation Safety Board (NTSB) recommends that the Federal Aviation Administration (FAA) take urgent action to address safety issues that have been identified in the NTSB's ongoing investigation of a fan midshaft (FMS) fracture and crack in zero-time General Electric (GE) GEnx-1B engines on Boeing 787 airplanes and a possible FMS fracture on a low-time GEnx-2B engine on a Boeing 747-8F airplane.

On July 28, 2012, a Boeing 787-8 airplane experienced a loss of thrust in the right engine—a General Electric (GE) GEnx-1B turbofan, engine serial number (ESN) 956-121—during a pre-first flight, low-speed taxi test at Charleston International Airport, Charleston, South Carolina.¹ As the airplane was accelerating through 40 knots, the No. 2 engine's N_1 ² speed rolled back and the pilots retarded the throttles to abort the test. The airplane taxied back to the ramp, where the engines were shut down. A visual inspection of the engine during the NTSB's investigation revealed the low pressure turbine (LPT) rotor had shifted aft and extensive damage to the LPT blades and vanes. Further examination of the engine revealed the forward end of the FMS was separated at the rear of the threads. The fractured end of the FMS with the retaining nut still in place was removed from the engine and sent to GE, Cincinnati, Ohio, for dimensional inspection and metallurgical examination. The engine was subsequently removed from the airplane and also sent to GE in Cincinnati for disassembly and examination. The engine had not yet been operated in flight, having only been operated during post-production tests at GE and post-installation ground runs at Boeing in Charleston.

As a result of the ongoing investigation into the FMS separation that occurred on ESN 956-121 at Charleston, GE developed an ultrasonic inspection to scan the forward end of the FMS under the threads where the fracture occurred. On August 13, 2012, a GEnx-1B engine,

¹ Preliminary information about this incident, DCA12IA114, can be found at the NTSB's website at <http://www.ntsb.gov/aviationquery/index.aspx>.

² N_1 is the low pressure rotor speed.

ESN 956-175, installed on a 787-8 airplane that had not yet flown was found to have an indication of a similar crack on the FMS. Like ESN 956-121, this engine had not been operated in flight and had only operated during post-production tests at GE and post-installation ground runs at Boeing in Seattle, Washington. The engine was removed from the airplane and shipped to GE, Durham, North Carolina, for disassembly and further ultrasonic tests that confirmed the crack. The FMS was removed from the engine and shipped to GE in Cincinnati for further inspection and examination.

Examination of the FMS from ESNs 956-121 and 956-175 revealed that they conformed with the engineering drawing's requirements. Metallurgical examination of the FMS from ESN 956-121 revealed a progressive fracture³ that had initiated from multiple origins around the outer circumference of the FMS at the root of the rearmost thread. The progressive fracture covered about half of the fracture face.

Although the fracture in the ESN 956-121 FMS was progressive in nature, the examination of the fracture surface in the scanning electron microscope (SEM) did not reveal any striations that would be typical of a fatigue fracture. Rather, the SEM examination revealed a faceted, quasi-cleavage fracture morphology that is typical of environmentally assisted cracking⁴ of certain high strength steel alloys such as that used on the GENx FMS. The metallurgical examination of the FMS from ESN 956-175 revealed several progressive cracks that had initiated around the outer circumference at the root of the rearmost thread. The morphology of these fracture surfaces was consistent with what had been observed on the FMS from ESN 956-121. The investigation into the cause of the environmentally assisted cracking that occurred in the ESN 956-121 and -175 FMSs is continuing.

On September 11, 2012, a Boeing 747-8F (operated by Air Bridge Cargo, a Russian certificated air cargo carrier) equipped with GE GENx-2B turbofan engines experienced a loss of power in the No. 1 engine, ESN 959-228, during the takeoff roll at Shanghai Pudong International Airport, Shanghai, China. The pilots reported that as the airplane was accelerating through 50 knots, the No. 1 engine's N_1 indication dropped. The pilots rejected the takeoff and returned to the ramp, where an inspection of the No. 1 engine's LPT revealed extensive damage. Further examination of the engine is pending, but photographs of the LPT show damage that is similar to that which was observed on GENx-1B engine ESN 956-121 at Boeing in Charleston. Although other failure modes could cause an N_1 rollback and broken blades, the damage noted on the photographs of ESN 959-228 is consistent with that observed on the engine that failed at Charleston. ESN 959-228 is reported to have accumulated approximately 1,200 hours and 240 cycles since new.

GENx-1B engines are used on Boeing 787 airplanes and GENx-2B engines are used on Boeing 747-8 airplanes. The GENx-1B FMS is slightly longer than that in the -2B engine. However, the threaded end of the FMS; the manner in which it is clamped with the retaining nut;

³ A progressive fracture is the result of a crack that grows in length under the influence of time under continuous or variable stress prior to final fracture.

⁴ In this process, crack initiation and growth occurs in the material at a comparatively low stress level as a result of interactions that occur within the environment. As a product of galvanic corrosion in a moist environment, hydrogen is suspected of causing environmentally assisted cracking in high strength steel.

and the assembly procedures, material specifications, and operating environment are similar between the two models. Therefore, the FMS in GENx-2B engines may be susceptible to the same type of failure observed with the GENx-1B FMS.

Because of the short time to failure and the fact that all of the engines on any single airplane, whether the 787 or the 747-8, have all operated for the same period of time, the NTSB is not only concerned about the potential for further fractures occurring, but also the possibility that multiple engines on the same airplane could experience an FMS failure. Although the FMS fracture that occurred on the 787 at Charleston and the incident that occurred on the 747-8 at Shanghai both happened on the runway and the pilots were able, respectively, to abort the test and the takeoff, the NTSB is concerned about the possibility of an FMS fracture occurring in flight at the limits of an airplane's extended twin-engine overwater operations, or ETOPS,⁵ range and the airplane having to operate with one engine inoperative for up to 5 1/2 hours.

The NTSB notes that, after the FMS fracture at Charleston, GE was very expeditious in assisting 787 operators with inspecting their GENx-1B engines using the newly developed ultrasonic inspection, which is capable of detecting cracks once they reach 0.050 inch in length. To date, all in-service and spare GENx-1B engines have been inspected. In addition, all GENx-2B engines on passenger airplanes and spares have been inspected. The NTSB is aware that about 47 on-wing GENx-2B engines remain uninspected and is concerned that they continue to operate while potentially susceptible to FMS failure. Because of the immediate threat of multiple engine failures on a single aircraft and the availability of an appropriate inspection procedure, there is an urgent need for the FAA to act immediately. Therefore, the NTSB recommends that the FAA issue an airworthiness directive to require, before further flight, the ultrasonic inspection of the FMS in all GE GENx-1B and -2B engines that have not yet undergone inspection.

In addition, the nature of the cracking that was noted on the FMS from ESNs 956-121 and 956-175 did not provide a predictable crack propagation rate that a typical fatigue crack would have. The NTSB believes that repetitive inspections are necessary to ensure that, once an initial inspection has been performed, new or sub-detection-level cracks do not propagate and cause additional failures. Therefore, the NTSB recommends that the FAA require operators to accomplish repetitive inspections of the FMS in all (on-wing and spare) GE GENx-1B and -2B engines at a sufficiently short interval that would permit multiple inspections and the detection of a crack before it could reach critical length and the FMS fractures.

⁵ According to Advisory Circular 120-42B, "Extended Operations (ETOPS and Polar Operations)," the FAA "may authorize ETOPS with two-engine airplanes over a route that contains a point farther than 60 minutes flying time from an adequate airport at an approved one-engine inoperative cruise speed under standard conditions in still air....The FAA may also authorize ETOPS with passenger-carrying airplanes with more than two engines over a route that contains a point farther than 180 minutes flying time from an adequate airport at an approved one-engine inoperative cruise speed under standard conditions in still air."

Therefore, the National Transportation Safety Board makes the following recommendations to the Federal Aviation Administration:

Issue an airworthiness directive to require, before further flight, the ultrasonic inspection of the fan midshaft in all General Electric GENx-1B and -2B engines that have not yet undergone inspection. (A-12-52) Urgent

Require operators to accomplish repetitive inspections of the fan midshaft (FMS) in all (on-wing and spare) General Electric GENx-1B and -2B engines at a sufficiently short interval that would permit multiple inspections and the detection of a crack before it could reach critical length and the FMS fractures. (A-12-53) Urgent

In response to the recommendations in this letter, please refer to Safety Recommendations A-12-52 and -53. We encourage you to submit updates electronically at the following e-mail address: correspondence@ntsb.gov. If a response includes attachments that exceed 10 megabytes, please e-mail us at the same address for instructions. To avoid confusion, please do not submit both an electronic copy and a hard copy of the same response.

Chairman HERSMAN, Vice Chairman HART, and Members SUMWALT, ROSEKIND, and WEENER concurred in these recommendations.

Sincerely,

[Original Signed]

Deborah A.P. Hersman
Chairman