National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation

Date: February 12, 2002
In reply refer to: A-02-03 and -04

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

On January 12, 2002, a model 568F propeller blade, manufactured by Hamilton Sundstrand,[1] separated adjacent to the propeller hub on the No. 2 (right) engine of an Avions de Transport Regional (ATR) ATR42-500 airplane, operated by ACES Colombia and registered in Bermuda as VP-BVE, shortly after takeoff from Cartagena, Colombia.[2] The domestic flight was destined for Bucaramanga, Colombia. The pilots reported that about 5 minutes after takeoff, they felt high vibrations in the airplane, and the No. 2 engine's low oil pressure warning light illuminated. When the pilots attempted to shut down the No. 2 engine with the fuel lever, the lever jammed. They then shut down the engine by pulling the fire handle. The airplane returned to Cartagena for an emergency landing. The 2 pilots, 2 flight attendants, and 37 passengers on board were uninjured. The airplane sustained minor damage to the No. 2 engine's cowling.

The blades of the model 568F propeller assembly have metallic bases made from low alloy steel forgings. The base, also referred to as a "tulip" because of its shape, incorporates the pitch change mechanism, a flange for attaching blade counterweights, and a flared portion for attaching the airfoil. A composite airfoil that is made with a graphite fiber-reinforced epoxy spar surrounded by structural foam and covered by a Kevlar®[3]-reinforced epoxy outer shell is attached to the tulip. The graphite spar and Kevlar shell are adhesively bonded to the outside of the tulip immediately outboard of the counterweight flange fillet radius and are further secured by a circumferential fiberglass composite "compression" wrap. The entire area of the fillet radius is concealed from external view by the compression wrap and additional sealant material.

The initial examination by Colombian Aeronautica Civil investigators of the No. 2 engine's propeller assembly revealed one of the six blades had separated through the metal base just outboard of the propeller hub. An adjacent blade was fractured through the composite airfoil

[1] Although the propeller is certificated by Hamilton Sundstrand in the United States, the blades are manufactured by Ratier Figeac, a Hamilton Sundstrand subsidiary in France.
[2] The National Transportation Safety Board is assisting the Colombian Aeronautica Civil's investigation under the provisions of Annex 13 to the Convention on International Civil Aviation.
[3] Kevlar is the trademarked name of a family of polymers first produced by DuPont in 1971.

at about the midspan area. The examination of the engine revealed that both of the forward engine mounts had broken, and the engine sagged to the bottom of the engine cowling.

The inboard portion of the fractured propeller blade,[4] serial number FR341, containing the majority of the tulip was examined in the National Transportation Safety Board's materials laboratory at the request of the Colombian Aeronautica Civil. Examination of the fractured blade end revealed that blade separation resulted from a fatigue fracture of the tulip originating in an area of widespread corrosion.[5] The fatigue had initiated at multiple corrosion pits on the outer surface of the tulip in the radius immediately outboard of the counterweight flange. The fracture surface bisected corrosion pits that ranged from 0.006- to 0.010-inch deep. The fatigue crack grew through and around about 75 percent of the tulip before tensile overstress separation occurred. Red rust and other evidence of corrosion were visible on the outer diameter surface of the tulip adjacent to the fracture and on the counterweight flange. The examination and metallurgical analysis revealed that the fractured tulip's dimensions and material properties conformed to the manufacturer's specifications. Records for the fractured propeller blade indicate that it was produced on December 12, 1995; had been in service about 6 years; and had accumulated about 11,700 service hours since new.

The tulips from the five other propeller blades installed in the accident airplane's right propeller assembly were examined at the Safety Board's materials laboratory and at Hamilton Sundstrand's Windsor Locks, Connecticut, facility. The examinations revealed that four of the blade tulips (all produced in 1996) had varying degrees of rust and corrosion pitting in the fillet radius but no visual cracking. The remaining blade tulip (produced in 1997) had no rust or corrosion pitting in the fillet radius.

In accordance with Hamilton Sundstrand's Federal Aviation Administration (FAA)-accepted maintenance program, the 568F propeller blades must undergo a major inspection every 8,000 flight hours. This inspection involves a detailed visual examination of the blade but does not involve removal of the compression wrap or nondestructive inspections (NDI) to detect corrosion or cracks in the fillet radius. The fractured blade underwent a major inspection on February 22, 1999, about 5,939 hours before the blade separated, with no corrosion noted. However, the area of the tulip under the compression wrap (including the fillet radius) was not exposed, nor was it required to be, during this inspection.

In a January 23, 2002, presentation to Safety Board staff, Hamilton Sundstrand reported finding rust and corrosion pitting in the tulip fillet radius under the compression wrap of several high service-time blades that had undergone analytical inspections in conjunction with the major inspections[6] beginning in 1998. Hamilton Sundstrand indicated that, in 2000, it inspected 40 additional high service-time blades and reported finding random and isolated corrosion pits up to 0.014-inch deep, but no cracks, on the tulip fillet radius on 34 of the blades inspected (about 85 percent). Hamilton Sundstrand stated that the rust and corrosion pitting uncovered by

[4] The outboard portion of the blade was not recovered.
[5] The area of the fatigue crack would not be visible during a visual inspection.
[6] As part of a continuing airworthiness program, Hamilton Sundstrand performed additional in-depth inspections on selected blades during major inspections. These inspections included removal of the compression wrap, which is not normally performed during major inspections, and inspections of the fillet radius.

the analytical inspections had likely been occurring since the blades were new and were unrelated to operational or environmental conditions.

Hamilton Sundstrand indicated that as a result of the early findings of rust and corrosion pitting, it modified the design of the 568F propeller blade in 1998 so that the adhesive layer applied to the tulip extended farther inboard past the end of the compression wrap, fully covering the fillet radius. The tightly adherent adhesive layer was intended to act as a barrier to deter corrosion; thus, the modification would protect the fillet radius. All 568F propeller blades with serial numbers 1,699 and greater are manufactured with this modified design.

According to Hamilton Sundstrand, about 2,500 568F propeller blades are currently in service, 1,353 of which are blades with serial numbers 1 through 1,698. The blades are installed in a six-bladed propeller assembly that is used on ATR42-410 and -500 and ATR72-500 airplanes. According to ATR, about 151 ATR42-410 and -500 and ATR72-500 airplanes are in service with 35 operators worldwide. Twelve ATR72-500 airplanes with this propeller assembly, all operated by Simmons Airlines as American Eagle,[7] are registered in the United States.

The Safety Board is concerned that all 568F propeller blades without the modified design are susceptible to, and some may already have, corrosion pitting and fatigue cracks, particularly those that have been in service the longest. The Board notes that the visual examination of the blades that occurs every 8,000 hours as part of the major inspection is not sufficient to detect corrosion and cracking in the fillet radius because it does not involve exposing the tulip fillet radius area where the corrosion pitting and cracks have occurred.

On February 1, 2002, Hamilton Sundstrand issued Alert Service Bulletin 568F-61-A33, "Propellers—Blades—Removal of 568F Propeller Blades from Service," for remedial action on 568F propeller blades with serial numbers 1 through 1,698 to require the removal of the oldest blades from service for inspection and repair[8] according to the following schedule: serial numbers 1 through 182 within 150 flight hours or February 15, 2002, whichever occurs first; serial numbers 183 through 265 within 300 flight hours or February 28, 2002, whichever occurs first; serial numbers 266 through 341 within 450 flight hours or March 15, 2002, whichever occurs first; and serial numbers 342 through 428 within 600 flight hours or March 31, 2002, whichever occurs first. The service bulletin contains no information about repetitive inspections or a terminating action for this safety issue. Further, Hamilton Sundstrand is in the process of developing an ultrasonic inspection to detect cracking in the fillet radius without removing the compression wrap.

The Safety Board is extremely concerned that Hamilton Sundstrand's proposed removal and repair schedule is not aggressive enough and is inadequate to prevent another fatigue fracture because of the uncertainties in the failure mechanism. Specifically, it is unknown when the

[7] It is unknown which propeller blades (modified or unmodified) are installed on these airplanes.

[8] Hamilton Sundstrand indicated that the intended repair procedure would include removal of the compression wrap, removal of corrosion, an NDI for cracks, shot peening of the radius, and installation of corrosion protection and adhesive coating (as was installed on propeller blades with serial numbers 1,699 and greater). (Shot peening is a metallurgical surface treatment to improve resistance to cracking.)

corrosion pits originate, what the growth rate for the corrosion pits is, what effect the distribution and density of the corrosion pits have on fatigue crack initiation, what the critical spacing is for microcracks initiating at two adjacent pits to join and form a fatigue crack, and what the overall fatigue crack propagation rate is. The Board is concerned that Hamilton Sundstrand's proposed removal and repair plan would have permitted the failed blade, serial number 341, on the accident airplane to remain in service for 450 flight hours or until March 15, 2002, before requiring its removal and repair.

The Safety Board notes that, when failure mechanisms are known and clearly defined, standard industry practice is to use a safety margin that allows two complete inspection cycles before the observed failure time. However, when uncertainties exist in the failure mechanism, such as in this case, standard industry practice is to use a greater safety margin to conservatively determine an appropriate inspection and repair threshold or schedule.

Although the accident flight crew in this case was able to perform a safe emergency landing after the blade separated, propeller blade separations can quickly cause the flight crew to lose control of the airplane, which could result in injuries or death and damage to the airplane.[9] Because the sample population of blades examined suggests that a large percentage of blades with serial numbers 1 through 1,698 have rust and corrosion pitting on the tulip fillet radius, immediate action is warranted to prevent another blade separation. Therefore, the Safety Board believes that the FAA should, for all Hamilton Sundstrand 568F propeller blades with serial numbers 1 through 1,698, (1) require the immediate inspection and repair (including removal of the compression wrap and any existing corrosion, an NDI for cracks, shot peening of the radius, and installation of an appropriate corrosion protection system) of all blades that have been in service more than 6 years or 11,700 hours; (2) immediately determine a conservative threshold for the inspection and repair of the remaining blades that is appropriately less than 6 years or 11,700 hours in service, taking into account the uncertainties in the failure mechanism (including the initiation and growth rate for the pitting and fatigue cracking); (3) require the immediate inspection and repair of those propeller blades that have already reached or exceeded the threshold determined as a result of (2), above; and (4) for those propeller blades that are not immediately inspected and repaired in accordance with (1) and (3), above, require that they be inspected and repaired as soon as possible, but no later than the threshold determined as a result of (2), above.

The Safety Board notes that although Hamilton Sundstrand modified the model 568F propeller blade design such that blades with serial numbers 1,699 and greater include an adhesive layer that extends over the fillet radius on the tulip, Hamilton Sundstrand indicates that it has not yet examined any of these modified propeller blades to determine if the new design does, in fact, prevent corrosion in the fillet radius. Therefore, the Safety Board believes that the

[9] The Safety Board notes that a propeller blade separation caused the August 21, 1995, crash of Atlantic Southeast Airlines flight 529 in Carrollton, Georgia. A blade from the left propeller separated, causing loss of control of the airplane and a forced landing. The captain and 7 passengers were killed; the first officer, the flight attendant, and 11 passengers sustained serious injuries; and 8 passengers sustained minor injuries. The airplane was destroyed by impact forces and a postcrash fire. For more information, see National Transportation Safety Board. 1996. *In-flight Loss of Propeller Blade, Forced Landing, and Collision with Terrain, Atlantic Southeast Airlines, Inc., Flight 529, Embraer EMB-120RT, N256AS, Carrollton, Georgia, August 21, 1995.* Aircraft Accident Report NTSB/AAR-96/06. Washington, DC.

FAA should require Hamilton Sundstrand to perform additional analytical examinations and testing, including removal of the compression wrap so that the tulip can be fully examined, of a sample of high service-time 568F propeller blades with serial numbers 1,699 or greater to determine if rust and corrosion pitting are occurring in the fillet radius, and, on the basis of the results of those examinations, require additional inspections, modifications, or repairs as appropriate.

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

> For all Hamilton Sundstrand 568F propeller blades with serial numbers 1 through 1,698:
> (1) Require the immediate inspection and repair (including removal of the compression wrap and any existing corrosion, a nondestructive inspection for cracks, shot peening of the radius, and installation of an appropriate corrosion protection system) of all blades that have been in service more than 6 years or 11,700 hours;
> (2) Immediately determine a conservative threshold for the inspection and repair of the remaining blades that is appropriately less than 6 years or 11,700 hours in service, taking into account the uncertainties in the failure mechanism (including the initiation and growth rate for the pitting and fatigue cracking);
> (3) Require the immediate inspection and repair of those propeller blades that have already reached or exceeded the threshold determined as a result of (2), above; and
> (4) For those propeller blades that are not immediately inspected and repaired in accordance with (1) and (3), above, require that they be inspected and repaired as soon as possible, but no later than the threshold determined as a result of (2), above. (A-02-03) (Urgent)
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> Require Hamilton Sundstrand to perform additional analytical examinations and testing, including removal of the compression wrap so that the tulip can be fully examined, of a sample of high service-time 568F propeller blades with serial numbers 1,699 or greater to determine if rust and corrosion pitting are occurring in the fillet radius, and, on the basis of the results of those examinations, require additional inspections, modifications, or repairs as appropriate. (A-02-04)

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

Original Signed

By: Marion C. Blakey
Chairman