Uncontained Engine Failure of Delta Airlines Flight 1288

Patrick Carroll

Embry Riddle University

SFTY 375

Table of Contents

Abstract

On July 6th 1996 a McDonnel-Douglas operated by Delta Airlines experienced and uncontained engine failure while accelerating for takeoff which was safely aborted. There were two fatalities and two other passengers were seriously injured. A portion of the fan hub had separated and penetrated the fuselage damaging the airframe and killing the passengers. It was determined that a manufacturing defect caused a fatigue crack to form causing the fan hub to fail and a contributing factor to the accident was the failure of the maintenance department to detect the cracks during routine inspections.

Introduction

On July 6th, 1996 Delta flight 1288 suffered an uncontained engine failure while accelerating for takeoff, the crew brought the aircraft to a stop and evacuated the passengers (National Transportation Safety Board, 1998). The damage to the engine started a fire that was extinguished by emergency crews arriving on the scene, this delayed the evacuation slightly but not enough to cause a concern for the flight crew (National Transportation Safety Board, 1998). Two passengers were killed when uncontained debris penetrated the fuselage at seat row 37 on the left side; this also caused injuries to two more passengers on the right side in the same row (National Transportation Safety Board, 1998). Uncontained engine failures are a rare occurrence in transport category aircraft and to have the parts penetrate the fuselage is almost unheard of but it does happen. Federal Aviation Administration (FAA) advisory circular 20-128A lists the methods of compliance to reduce the chances of an uncontained engine failure (Federal Aviation Administration, 1997). The mass of rotating parts and the amount of energy contained within them while at high power settings can still breach the engine case when a failure occurs.

Cause of the Failure

The National Transportation Safety Board (NTSB) determined that the cause of the uncontained engine failure was that the fan hub had developed fatigue fractures and split apart during high power operation on the takeoff roll (National Transportation Safety Board, 1998). This separation also caused the inlet cowl to detach from the engine and debris to penetrate the fuselage (National Transportation Safety Board, 1998). Additional factors in the incident were the failure of Delta’s maintenance department and inspection procedures to detect the crack within the material (National Transportation Safety Board, 1998).

Further metallurgical analysis determined that the crack was detectable by fluorescent penetrant inspection methods in use by Delta at the time of its last shop visit (National Transportation Safety Board, 1998). The NTSB further determined that the cause of the failure was a problem that occurred during the machining of the forging (1998).

Titanium alloys require special manufacturing processes, because of this; many companies such as engine manufacturers will outsource the production of the individual parts to reduce infrastructure and production costs. The fan hub that failed was initially forged in Milwaukee WI and then had the machining operations performed by Volvo in Sweden (National Transportation Safety Board, 1998). This machining process is where the hub was damaged which eventually led to its failure. The previous machining process used by Volvo per Pratt & Whitney instructions required multiple steps to complete (Federal Aviation Administration, n.d.) The drilling operation required the hole to be completed in steps and that after the drill progressed .20 inches in the hole it was to be removed and the chips flushed with coolant and the process repeated (Federal Aviation Administration, n.d.). Volvo initiated a request to use a coolant channel drill that had internal passages which speeded up the process and was supposed to automatically flush out the chips created during the machining process, this request was approved by Pratt & Whitney and classified as an “insignificant” change in the process (Federal Aviation Administration, n.d.). Since the change was classified as insignificant by Pratt & Whitney’s own review process, it did not require further investigation by their engineering department and metallurgical tests that would be required if it was deemed to be a significant change to the machining processes (Federal Aviation Administration, n.d.). It was discovered during the investigation that this change in the drilling procedures is what damaged the grain boundary in the hole that allowed fatigue cracks to form (Federal Aviation Administration, n.d.)

Contributing Failures

Fan hubs for a Pratt & Whitney engine are only inspected during the overhaul process, the primary means of inspection is by fluorescent penetrant but this type of inspection can only reveal cracks that are open to the surface (National Transportation Safety Board, 1998). The fan hub is life limited to 20,000 cycles and is not inspected unless it is removed from the engine during overhaul, total cycles on the fan hub at the time of accident was 13,835 (National Transportation Safety Board, 1998). It was removed and inspected during heavy maintenance at 12,693 cycles where it underwent fluorescent penetrant inspection, the process used by Delta at the time was found to be deficient by the NTSB when inspecting the tierod bolt holes due the depth and the magnifying lens used in the process (1998). It was also discovered that when the developer was applied to the fan hubs that it would not sufficiently enter into the bolt holes because of their depth and diameter thus causing problems with detection of cracks (National Transportation Safety Board, 1998).

In addition to the failure of Delta's inspection process to indicate the crack, Pratt & Whitney also had inadequate procedures when receiving new parts. During the investigation, the company revealed that they do not inspect incoming parts from their suppliers for airworthiness but only for shipping damage and to ensure the serial numbers match the paperwork (National Transportation Safety Board, 1998). This is a failure on Pratt & Whitney's part as they failed to ensure that the part conformed to their standards and instead relied on the blind faith they put in their parts supplier. Volvo may have been a trusted an approved partner in the manufacturing of the parts but the nature of the turbine engine and how it operates requires increased scrutiny of even newly produced parts due to their exotic materials and use on transport category passenger aircraft.

Safety Initiatives

As with any aviation incident, one of the most important processes after the causes are found are the safety initiatives enacted to address any findings. The fan rotor that failed revealed problems that could occur during the manufacture of a new part and a lack of inspection procedures when Prat &Whitney received parts from its suppliers. Regulations were amended, advisory circulars were produced, and an industry team was formed between the Federal Aviation Administration and engine manufacturers (Federal Aviation Administration, n.d.). 14 CFR 33.70 was created to enhance oversight of the production process and to have the manufacturer develop plans to ensure the serviceability of the part throughout its life (Federal Aviation Administration, n.d.). 14 CFR Part 193 was established so that when a company voluntary submits safety related information to the FAA, it will remain confidential (Federal Aviation Administration, n.d.). In addition to the regulations, four advisory circulars were produced related to the inspection process and damage tolerances for turbine rotors (Federal Aviation Administration, n.d.).

The Rotor Manufacturing Project (ROMAN) formed after the investigation concluded and was a partnership between the FAA, parts suppliers, and engine manufacturers to address the issues that were discovered by the NTSB (Federal Aviation Administration, n.d.). The ROMAN group has sponsored research into advanced manufacturing techniques, inspection procedures, research and development in nondestructive testing procedures, and enhanced engine inspection procedures when the part is exposed or removed to increase the reliability of detection and to prevent uncontained failures (Federal Aviation Administration, n.d.). The engine manufacturers working together with the FAA increases reliability and safety for the all involved.

Conclusion

The fan disc failed because of a microstructure flaw that was introduced during the manufacturing process into a tierod bolt hole. The microstructures were harder than the surrounding material that allowed stress fractures to form within the grain boundaries of the surrounding crystalline structure of the metal. Over the life of the part these fractures developed into fatigue cracks that although were detectable by inspection procedures at the time it was removed for overhaul, were not detected by Delta's maintenance personnel. This altered grain structure was most likely caused by a change of drilling procedures by Volvo that was approved by Prat &Whitney that failed to conduct an engineering review. During the drilling process the coolant flow may have been interrupted or the tool feed speed may have been too fast which did not alloy the drill chips to clear properly from the hole. This would have created increased friction and temperature, which produced a localized area of work hardened material and altered the microstructure of the tierod bolt hole wall eventually causing the failure of the rotor a significant time after its initial manufacture.

References

Federal Aviation Administration. (1997). *Design considerations for minimizing hazards caused by uncontained turbine engine or auxillary power unit failure , AC 20-128A.* Washington D.C.: U.S. Department of Transportation, Federal Aviation Administration.

Federal Aviation Administration. (n.d.). *Delta flight 1288 accident overview*. Retrieved from http://lessonslearned.faa.gov/ll_main.cfm?TabID=3&LLID=60&LLTypeID=2

National Transportation Safety Board. (1998). *Uncontained engine failure, Delta air lines flight 1288.* Washington, D.C.: National Transportation Safety Board.