NTSB Accident Investigations Involving Fatigue Fractures Initiating from Subsurface Defects

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Abstract

The U. S. National Transportation Safety Board has investigated accidents involving fatigue fractures that initiated at subsurface anomalies including (1) a fatigue fracture that initiated from a ceramic inclusion in a turbocharger turbine wheel from a Piper PA-46-350P airplane which contributed to a forced landing, (2) a fatigue fracture of a railcar axle that initiated from a casting void that resulted in a derailment and crude oil explosion, and (3) a fatigue fracture of a high-pressure turbine stage 2 disk on a Boeing 767-300 airplane that initiated from a discrete dirty white spot and resulted in an uncontained engine failure, engine fire, and aborted takeoff. Processes used by the NTSB Materials Laboratory to analyze the fracture mechanisms and characterize the initiating defects will be discussed.

1. Introduction

The National Transportation Safety Board (NTSB) is an independent U. S. government agency responsible for investigating civil transportation accidents in all modes of transportation including aviation, rail, pipeline, highway, and marine. The focus of NTSB accident investigations is to determine the probable cause and to make recommendations to prevent future accidents. The NTSB Materials Laboratory, located in Washington, DC, USA, conducts failure analysis of components to determine fracture mechanisms and to provide NTSB accident investigators with information that is incorporated into the overall investigation. The NTSB Materials Laboratory sees 50 to 100 fatigue fractures annually, and in most cases the fatigue origin is found at the surface of the part. However, fatigue initiation from subsurface manufacturing anomalies or defects have been observed, and several of these cases are presented below. [1-3]

2. Results

(1) A Piper PA-46-350P airplane experienced a partial loss of engine power during climb due to failure of the right turbocharger. The pilot elected to shut down the engine during the landing approach and crashed short of the runway. A subsequent examination of the turbocharger wheel showed one of the blades fractured at the root due to fatigue that initiated from an inclusion shown in figure 1. The defect was characterized using scanning electron microscopy (SEM) and energy dispersive x-ray spectroscopy (EDS) on the fracture surface and in a metallurgical section through the origin area. Additional information was obtained using a focused ion beam to mill into the inclusion on the metallographic section.

(2) A train car hauling grain derailed due to a fractured axle, obstructing an adjacent track. A train hauling crude oil on the adjacent track collided with the derailed train car, resulting in the release and ignition of crude oil. The axle on the derailed grain car fractured due to fatigue that initiated from an internal casting void shown in figure 1. In addition to characterizing the fracture mechanism, the initiating void was analyzed using a coordinate measurement device to obtain a three-dimensional representation of the void. This data was then incorporated into a finite element model to study the stresses associated with the specific void geometry under axle loading conditions.

(3) American Airlines flight 383 had started its takeoff ground roll at Chicago O'Hare International Airport when an uncontained engine failure and subsequent fire occurred in the right engine from a high pressure turbine (HPT) stage 2 disk fatigue fracture as shown in figure 1. The fatigue crack initiated at a subsurface

anomaly known as a discrete dirty white spot. Characterization of the failure included striation counting, metallographic examinations, microhardness measurements, and compositional analysis using EDS and wavelength dispersive x-ray spectroscopy (WDS).

3. Conclusion

A defect can be defined as a discontinuity whose size, shape, orientation, or location makes it detrimental to the useful service of the part in which it occurs. [4] In each of these cases, an undetected anomaly that was incorporated into the part early in the manufacturing process led to early fatigue initiation, which significantly reduced the expected lifetime of the part. The NTSB used a variety of techniques to characterize the defects to better understand the source of the initiating defect and to prevent future failures.

4. References

1. M. Fox, Accident Docket ERA11LA224, Materials Laboratory Factual Report 11-122, National Transportation Safety Board (2011).

2. E. Mueller, Accident Docket DCA14MR004, Materials Laboratory Factual Report 14-020, National Transportation Safety Board (2014).

3. D. Kramer, Accident Docket DCA17FA021, Materials Laboratory Factual Report 17-034, National Transportation Safety Board (2017).

4. J. Davis, ASM Materials Engineering Dictionary, ASM International (1992).

Figure 1. Turbocharger turbine wheel fractured blade (left images), rail car axle fracture with central void (middle images), and HPT stage 2 disk fracture surface (right image).