International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2015): 78.96 | Impact Factor (2015): 6.391

Failure Analysis of Some Aerospace Components through Microscopic Examinations

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Abstract: ***Microscopic fracture analysis techniques have been used to find out causes of failure of given aerospace materials. The mode of their fracture and various microscopic and macroscopic features has been thoroughly examined before concluding the actual story of failure.***

Keywords: Beach marks, Fatigue striations, Ratchet Marks, fatigue

1. Introduction

It is a systematic, science-based method employed for investigations of failures occurring during test or in service.

For this analysis, we generally consider a broad spectrum of possibilities or reasons for the occurrence of failure. Like the great detective, we must carefully examine and evaluate all evidence available, then prepare a hypothesis—or possible chain of events—that could have caused the "crime". We may compare ourselves to a coroner performing an autopsy on a person who suffered an unnatural death, except that the failure analyst works on parts or assemblies that have had an unnatural or premature demise.

Figure 1: Observed fractures in one of the parts

2. How this analysis can be done

There are several ways to do this. Some of these are:
- Visual examination
- Nondestructive testing
- Mechanical testing
- Microscopic examination
- Chemical analysis

In this paper, I will be presenting my analysis done through microscopic examinations.

3. Problem Statement

We have few components from aircrafts engine and helicopters wheel hub manufactured from Ni based superalloy or Mg alloy respectively which had failed during service and has to be examined under a Stereo- binocular microscope.

4. Principle Involved

The analyst must be aware of the normal, or expected, location for fracture in any type of part because any deviation from the normal location must have been caused by certain factors that must be discovered.

An all-too-familiar type of fracture is that of the ordinary shoelace. A shoelace will inevitably fail at one of the two top eyelets, adjacent to the bowknot, as shown in Fig. 2

The logic behind this can be:
When the knot is tied, the lace is pulled tightest at the upper eyelets; therefore, the service stress is highest at this location.

Also Most of the sliding motion during tightening occurs at the lace as it goes through the upper eyelets. Therefore, the metal eyelets tend to wear, or abrade, the fibers of the lace.

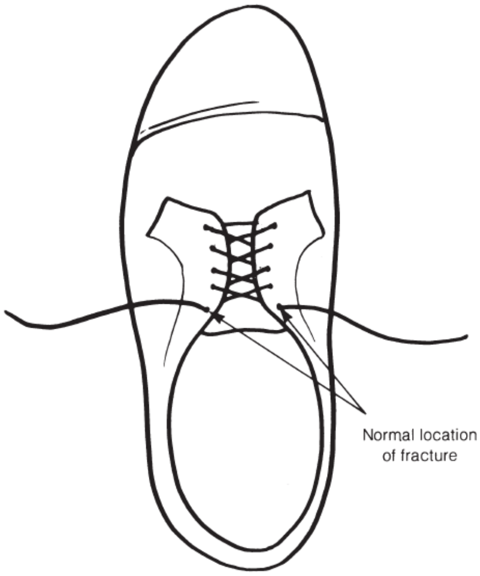

Figure 2: understanding fracture analysis through shoelace

If the shoelace were to fracture at any other location, such as at the lower eyelets or near the free ends, one would have to suspect that, for some reason, the shoelace had substandard mechanical properties at the location of failure. Or, alternatively, the lace could have been damaged—such as by burning from dropped cigarette ashes—thus causing it to be weakened and fractured at an abnormal location.

5. Understanding cause of failure

Metal parts fracture in a much more complex version of the weakest-link principle: the weakest location in a part will not originate a fracture if the stress is below the strength at that location. On the other hand, a high-strength location in a part may suffer fracture if the stress is concentrated at that location.

Other locations of normal fracture in metal parts are at geometric stress concentrations, such as the first engaged thread of a bolt within a nut or other tapped hole, or at a sharp-cornered fillet in a rotating shaft, or at the root fillet of a gear tooth. These represent some of the normal locations of fatigue fractures that may occur after long service

Fractures caused by abnormal events, such as accidents, may occur at locations other than those noted because of the unpredictable forces in an accident.

6. Experimental Verification:

We tested two failed samples under Stereo- binocular microscope which were Aircrafts engine's turbine blade and Helicopter's wheel Hub at National Aerospace Laboratory (Nal), India.

Based on the appearance on the fracture surface and the beach marks on the fracture surface and mode of cracking, fracture was confirmed to be fatigue. By tracing back the beach marks, the origin of crack initiation was identified.
We will be dealing with these samples one by one.

Sample 1: Helicopter wheel hub sample

Figure 3: Figure showing location of wheel hub

After microscopic observations:
1) **Crack initiation**: In the case of wheel hub, the crack initiation was associated with corrosion pit on the surface at the fillet region.

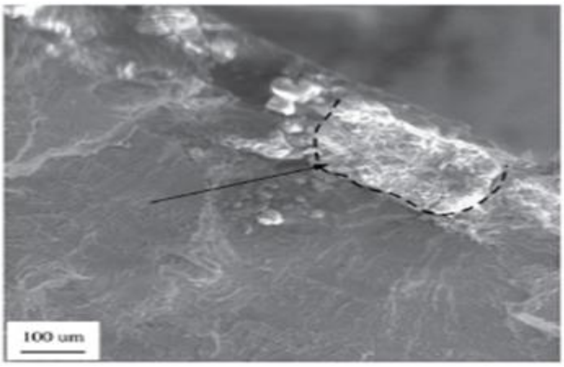

Figure 4: fatigue crack nucleation site from corrosion pit at the specimen surface (marked with black)

Pitting corrosion, or pitting, is a form of extremely localized corrosion that leads to the creation of small holes in the metal. The driving power for pitting corrosion is the depassivation of a small area, which becomes anodic while an unknown but potentially vast area becomes cathodic, leading to very localized galvanic corrosion. The corrosion penetrates the mass of the metal, with a limited diffusion of ions

2) Cause :
Saline environment (after further chemical tests)

3) Generating story of failure:
Since the helicopter to which sample belonged was a naval helicopter so continuous exposure to saline environment of sea may have initiated pits on its surface causing its failure.

Sample 2: Aircrafts engine's turbine blade
We used a cut sample of blade for our investigation.

1) **Crack initiation**: In the case of turbine blade the beach marks were observed to be initiated from leading edge.

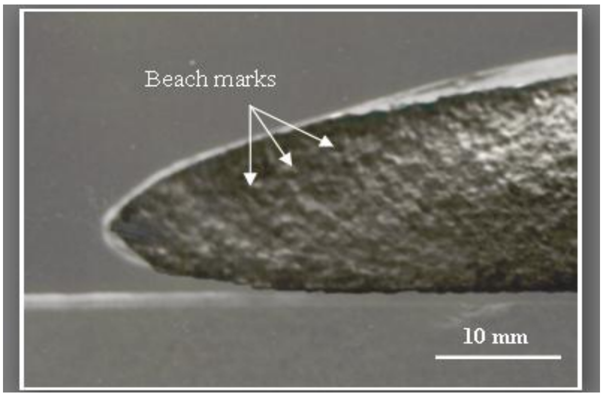

Figure 5: Beach marks seen on the sample

Beach marks are macroscopic progression marks on a fatigue fracture or stress-corrosion cracking (SCC) surface that indicate successive positions of the advancing crack front. They take the form of crescent-shaped macroscopic marks on fatigue fractures representing positions of the crack propagation, radiating outward from one or more origins.

Beach marks are also known as clamshell marks, arrest marks or growth rings.

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Fatigue striations are microscopic features on a fatigue fracture surface that identify one propagation cycle of a fatigue crack. They are not always present and can only be seen under a scanning electron microscope shown in figure 6

In figure 6, **Ratchet Marks** can also be seen, which are actually traces of vertical planes separating fatigue fractures originating from multiple initiation points.

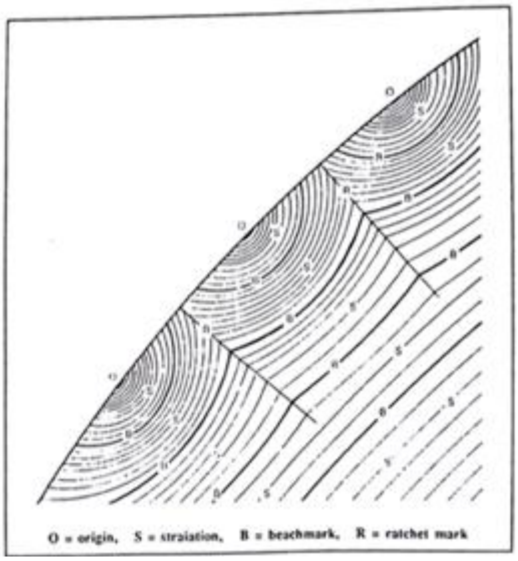

Figure 6: various features seen on given sample

2) Generating story of failure:
Due to high number of cycles crack initiated from leading end of blade from multiple points which propagated further leading to fracture. By tracing back the beach marks, the origin of crack initiation were identified.

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Author Profile

Yogesh Pratap Singh is pursuing his B.Tech in Mechanical Engineering from NIT Raipur and presently is in his third year of undergraduate study (2014-18). Currently He is a Research project student at LPSC, Indian Space Research Organization. He is an Aerospace enthusiast and has also been an Intern at National Aerospace Lab, Helicopter Division Hal And Aircraft Division Hal. His field of interests includes vibrations, failure analysis, Theory of machines etc.