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Gear Corrosion During the Manufacturing Process

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[The statements and opinions contained herein are those of the author and should not be construed as an official action or opinion of the American Gear Manufacturers Association.]

Abstract

No matter how well gears are designed and manufactured, gear corrosion can occur that may easily result in catastrophic failure. Since corrosion is sporadic and a rare event and often difficult to observe in the root fillet region or in finely pitched gears with normal visual inspection, it may easily go undetected. This paper presents the results of an incident that occurred in a gear manufacturing facility several years ago that resulted in pitting corrosion and intergranular attack (IGA). It showed that superfinishing can mitigate the damaging effects of IGA and pitting corrosion, and suggests that the superfinishing process is a superior repair method for corrosion pitting versus the current practice of glass beading.

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Introduction

Pitting corrosion

Pitting is one of the most insidious forms of corrosion; it can cause failure by perforation while producing only a small weight loss on the metal. Also, pits are generally small and often remain undetected. A small number of isolated pits on a generally uncorroded surface are easily overlooked. A large number of very small pits on a generally uncorroded surface may not be detected by visual examination, or their potential for damage may be underestimated. When pits are accompanied by slight or moderate general corrosion, the corrosion products often mask them. [1]

Surface pitting is often barely visible even at 10–30 X magnification, and can therefore often go undetected. The corroded region below the surface can be much larger than indicated by the surface area of the pit. ASTM G46–94, *Standard Guide for Examination and Evaluation of Pitting Corrosion*, states: “Pits may have various sizes and shapes. A visual examination of the metal surface may show a round, elongated, or irregular opening, but it seldom

provides an accurate indication of corrosion beneath the surface. Thus, it is often necessary to cross section the pit to see its actual shape and to determine its true depth.” [2] For example, the G46 standard presents a chart of possible variations in the cross-sectional shapes of corrosion pits. See figure 1.

Consequently, only one insignificantly appearing narrow pit could ultimately lead to bending fatigue failure.

Crevice corrosion

Crevice corrosion is a localized form of corrosion that occurs in narrow openings or spaces where the localized chemical environment is different than that of its surroundings. The change in the crevice chemical environment can be caused by a depletion of the inhibitor or the oxygen, a shift to acid conditions or a build up of aggressive ion species in the crevice. Crevice corrosion commonly occurs under washers, seals, threads and surface deposits. When the chemical environment within the crevice is different than that of its surroundings, an electrochemical cell is created resulting in corrosion that can be as damaging as pitting corrosion.

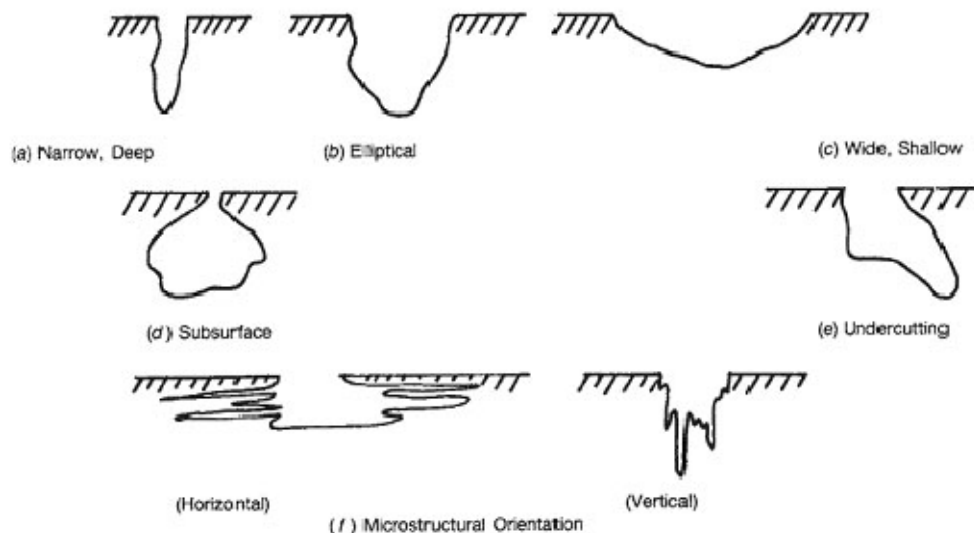


Figure 1. Variations in cross-sectional shapes of corrosion pits [2]

Intergranular corrosion

Another type of corrosion attack is intergranular or intercrystalline corrosion, during which a small volume of metal is preferentially removed from paths that follow the structural dissimilarities along grain boundaries to produce fissures or cracks. The same kind of subsurface fissures can be produced by transgranular or transcrySTALLine corrosion. In this a small volume of metal is removed in preferential paths that proceed across or through the grains. Intergranular and transgranular corrosion sometimes are accelerated by tensile stress. In extreme case the cracks proceed entirely through the metal, causing rupture or perforation. This condition is known as stress corrosion cracking (SCC). [3]

Nguyen et al.[4], in an earlier paper discussed why gears are very susceptible to corrosion during the manufacturing process. In order to protect workers and the environment, the use of oil-based rust preventives and rust-inhibiting machining coolants have been minimized. The gear manufacturing process is complex, and requires machining, plating, carburization, grinding, plating removal, and nital etch inspection often followed by glass beading or shot peening. During this entire process, gears are often left exposed to the environment for several weeks without the use of rust preventives. They are handled by a number of personnel, and experience many back and forth trips between the shop floor and the metrology laboratory.

Aerospace gears require state-of-the-art design and precision manufacturing to meet the needs of today's performance demands. Having said that, all of the efforts can be for naught if pitting and intergranular corrosion occur. Such corrosion can lead to disastrous, premature failure. The severity of the problem will be illustrated with two actual experiences described in detail in Part I and Part II of this paper. Part I is a short experiment to answer the question whether or not one drop of sweat inadvertently falling on an aerospace gear could result in serious damage. Part II discusses a study of IGA

and pitting corrosion that was detected on aerospace gears, and the ability of superfinishing to remove this damage.

Part I: Unexpected low cycle bending fatigue failure

Introduction

Recently, the Aerospace Research Bloc at the Gear Research Institute of The Pennsylvania State University conducted a study of bending fatigue performance of AMS 6308 test gears.¹⁾ (AMS 6308 is commercially available as Carpenter's Pyrowear[®] 53 and Latrobe's Lesco 53.) Several gears experienced unexpected low cycle bending fatigue failure, and the root cause was determined to be corrosion pits in the root fillet region. The disturbing part of this finding is that the pitting was not visible to the naked eye, and could only be seen at 30X magnification. Consequently, these pits escaped the manufacturer's as well as the testing laboratory's inspections.

Since aerospace gears lack rust preventives during portions of the manufacturing cycle, one might question whether or not one drop of sweat inadvertently falling on a gear could cause major corrosion problems—leading to premature bending fatigue failure.

Test procedure

Test specimens: Because of their ready availability, Falex AMS 6260 (E-9310) Steel V-Blocks (Part #000-502-024) having a 58-60 HRC were chosen as test specimens. These were cleaned of their rust preventive using a non-chlorinated solvent (carburetor cleaner) followed by acetone as recommended by Falex. A drawing of the V-Block is shown in Figure 2.

One of the V-Blocks was left in the ground (as-received) condition. See Table 1 for the surface roughness values of the ground V-Block, and Figure 3 for the surface profile.

¹⁾ This was an unpublished study completed by the Aerospace Research Bloc whose sponsors include Avio Group (Italy), Boeing (Mesa and Philadelphia), Curtiss Wright Controls, Honeywell International, Pratt & Whitney (East Hartford, CT and Quebec, Canada), REM Chemicals, Rolls Royce, Sikorsky Aircraft and Timken.