MATERIALS **MATTER**

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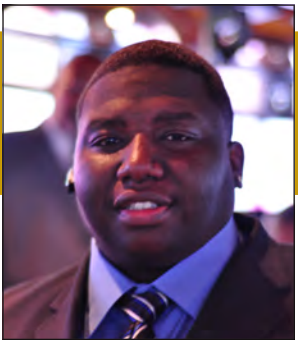


# GEAR CORROSION IN THE MANUFACTURING PROCESS

Corrosion in the gear manufacturing process is a significant issue that must be corrected to avoid premature failure.

**NO MATTER HOW WELL GEARS ARE** designed and manufactured, gear corrosion can occur during the manufacturing process, which may, in turn, result in catastrophic failure. To further complicate matters, corrosion can easily go undetected during normal visual inspection especially in the difficult-to-observe areas. Corrosion can appear in different forms such as pitting, crevice, and intergranular corrosion. All forms can lead to catastrophic failure. As such, preventing corrosion or, if necessary, repairing, is critical to avoiding the failures that corrosion can cause.

## PITTING CORROSION

Pitting corrosion is one of the most treacherous forms of corrosion; it can cause failure by perforation while the weight loss on the metal is minimal. Pits are generally small and often remain undetected. A small number of isolated pits on a generally non-corroded surface may be disregarded. However, a large number of small pits on a generally non-corroded surface may not be identified by visual examination, or their potential for damage may be miscalculated. When pits are accompanied by slight or moderate general corrosion, the corrosion products may mask them, further reducing the likelihood of detection. The corroded region below the surface can be much larger than indicated by the surface area of the pit. As per ASTM G46-94, "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" [1].

Figure 1 shows a chart from this standard that depicts some of the varying shapes that pitting corrosion can take. Consequently, only one seemingly narrow pit could ultimately lead to bending fatigue failure.

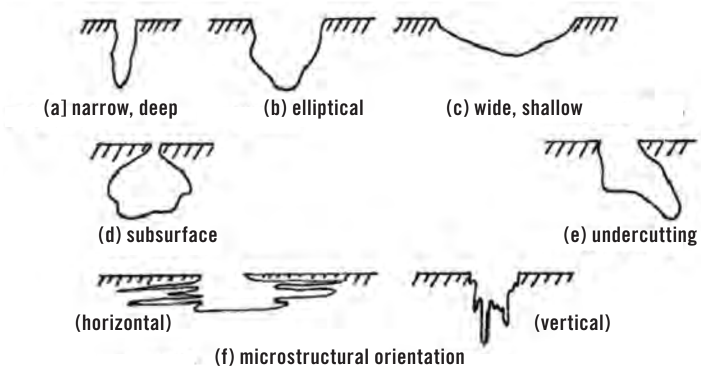


Figure 1: Examples of pitting corrosion [1]

## 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 buildup 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.

## INTERGRANULAR CORROSION

Intergranular (IGA) corrosion happens when a small volume of metal is preferentially removed from paths that follow the structural dissimilarities along grain boundaries to produce crevices or cracks. In this, a small volume of metal is removed in preferential paths that proceed across or through the grains. Intergranular corrosion is sometimes accelerated by tensile stress. In extreme cases, the cracks proceed entirely through the metal, causing perforation. This condition is known as stress corrosion cracking (SCC).

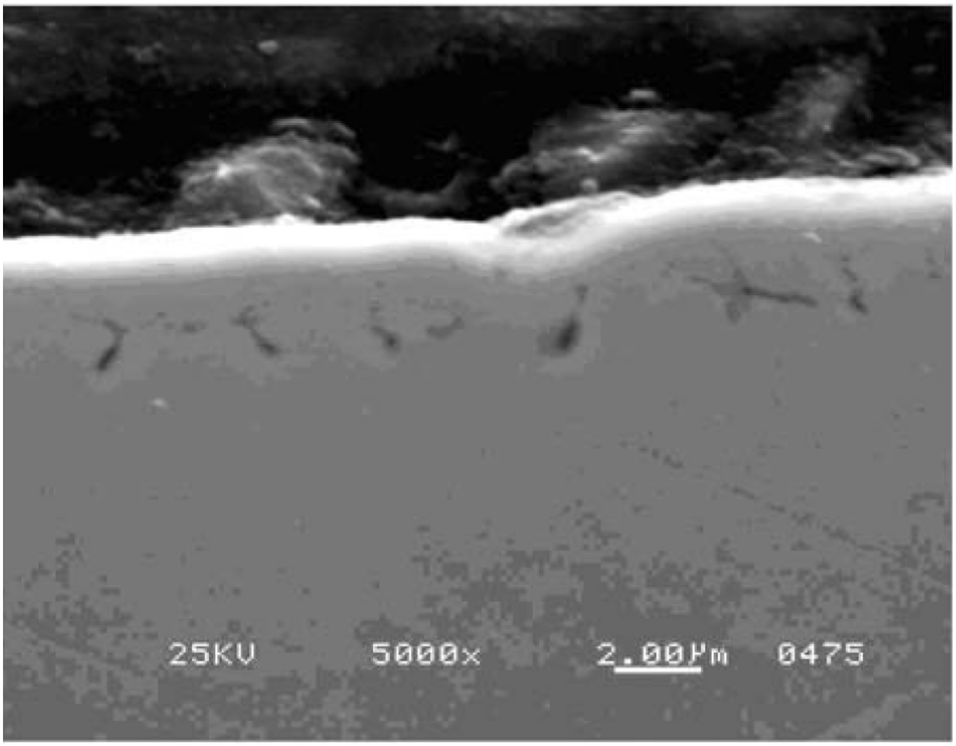


Figure 2: Example of IGA at 5000 [2]

## CORROSION AND BENDING FATIGUE

One of the many detrimental effects of corrosion in gearing is low-cycle bending fatigue failure. Corrosion pitting in the root fillet area has been identified as one of the ways low-cycle bending fatigue failure can occur. The source of this fatigue failure is quite simply, that corrosion pitting weakens the area in which it is located. As the load from each cycle is applied, these weak points propagate and can result in low-cycle bending fatigue and premature gear failure.

## CORROSION IN THE MANUFACTURING PROCESS

Gears are susceptible to corrosion during the manufacturing process. As EH&S initiatives have reduced the use of the oil-based rust preventatives and rust-inhibiting machining coolants in the interest of employee safety, this risk has grown. The gear manufacturing process is complex and consists of many steps including machining, plating, carburizing, and so on. This level of complexity makes it harder to control or mitigate corrosion from entering the process due to the many opportunities for corrosion initiation. Serious corrosion can be observed in little over an hour [2], and given this fact, there is a clear need to be able to effectively repair corrosion.

## CORROSION REPAIR VIA ISOTROPIC SUPERFINISHING

Glass beading is the most common method of repairing corrosion. However, studies have shown chemically accelerated vibratory finishing (CAVF), a form of isotopic superfinishing, is also an effective method for removing corrosion [2]. As previously noted, corrosion can reside below the gear surface. Therefore, if the corrosion recovery step does not completely remove the surface asperities formed during machining operations, any residual, sub-surface corrosion can easily return and grow. However, CAVF can be used to more effectively and reliably eliminate surface asperities while simultaneously removing corrosion, thereby fully repairing and improving the gear in one step.

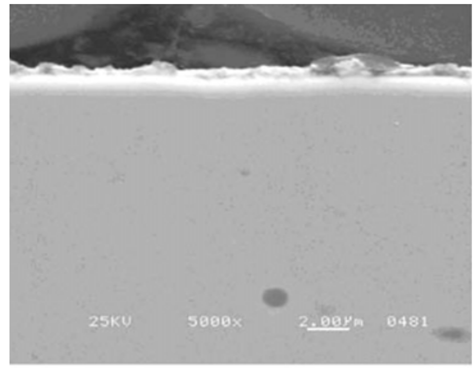
## INCREASED CORROSION RESISTANCE OF ISOTROPICALLY SUPERFINISHED SURFACES

In addition to being a preferred method of repairing corrosion, CAVF has been studied relative to its impact on corrosion resistance. The Gear Research Institute conducted a study comparing standard gear steels as well as hardened stainless steels including 440C, Pyrowear® 675, and CSS-42L™ in both ground and isotropically superfinished states [3]. As expected, the newer, more advanced gear steels were superior to the more standard gear steels. However, the somewhat less expected result was that, in general, the isotropically superfinished surfaces improved the corrosion resistance of the gear steels as compared to the ground versions. It has been hypothesized that this may be a result of the unique surface texture of these surfaces.

## CONCLUSION

Corrosion in the manufacturing process is probable if the gears are not properly handled. Corrosion can lead to premature and catastrophic gear failure. Isotropic superfinishing in the form of CAVF has been shown to be an effective method of removing corrosion. Studies have even shown improvements in corrosion resistance as a result of the use of CAVF. Clearly removing corrosion that occurs in the manufacturing process is critical. Given the advantages offered by CAVF, it would seem to be a preferred method of correcting corrosion in the manufacturing process.

Area A




Area B

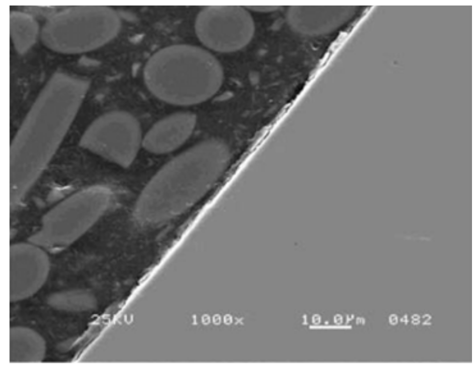



**Figure 3: Examples of previously corroded surface repaired via CAVF [2]**

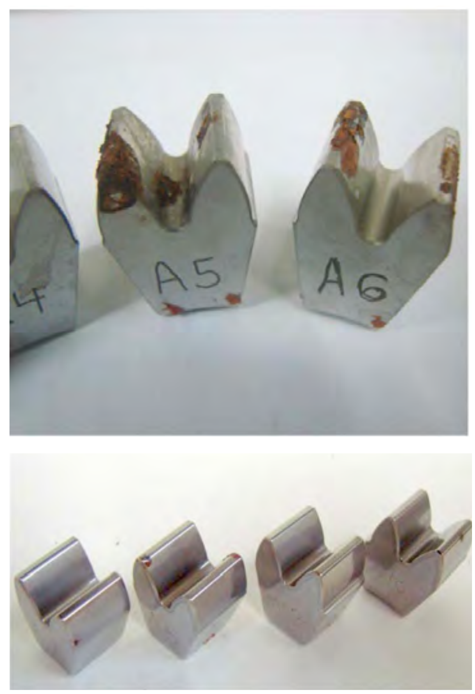



**Figure 4 – Pyrowear® 675 corrosion testing samples: ground (top) and isotropically superfinished (bottom) [3]**

## REFERENCES

1. ASTM G46-94, "Standard Guide for Examination and Evaluation of Pitting Corrosion," 2013.
2. Omer El-Saeed and Gary Sroka, REM Chemicals, Inc. and Gregory Blake, Rolls-Royce Corporation, "Gear Corrosion during the Manufacturing Process," AGMA Fall Technical Meeting, San Antonio, TX, 2008, 08FTM18.
3. Suren Rao, Doug McPherson, and Gary Sroka, "Comparative Corrosion Characteristics of Ground and Superfinished Gear Steels," Gear Solutions, January, 2013.

**ABOUT THE AUTHOR:** David Idlebird has been a research process engineer with REM Surface Engineering since 2013 where he has developed new processes and applications, aided in safety and quality initiatives, and assisted in corporate lean efforts. He has experience and expertise in engineering, safety, quality, maintenance, and process development. Idlebird graduated from Prairie View A&M University with a bachelor's degree in Mechanical Engineering and a minor in Business Administration. He can be reached at didlebird@remchem.com.