

## Advice & Counsel

Frank Altmayer, CEF AESF Technical Director Scientific Control Laboratories, Inc. 3158 Kolin Avenue Chicago, IL 60623-4889

Corroding Away-Part I

he last month seems to have ⊥ yielded a spate of corrosionrelated problems. The first problem came very close to home when I visited my boat and found a turnbuckle snapped (Fig. 1). It seems the boatyard installed a nickel-chromiumplated brass turnbuckle on my "baby stay" (a small cable that runs from about the middle of the mast of a sailboat to the deck). Brass is a poor choice of material for any application involving high tensile stress and a corrosive environment, because of its high sensitivity to stress corrosion failures. Sure enough, this brass turnbuckle evidenced intergranular brittle failure (Fig. 2) typical of stress corrosion. The correction is to replace the part with a material more suitable to the high seas (stainless steel).

The same day I discovered my boat's corrosion problem, I also got involved with others that were more interesting:

Dear Advice and Counsel. We utilize a chromium-plated steel mold that needs to be cleaned frequently. Our cleaning procedure is to soak the mold in a proprietary alkaline cleaning solution for 10–15 min, followed by the application of ultrasonics for approximately 2–3 hr or more. (The "stuff" in this mold is really hard to remove.) After a few months of repeated cleaning cycles, we have noticed corrosion of the mold that appears to be limited to recessed areas and cavities. We have been told that the problem may be stray currents or bimetallic corrosion. Can you give an opinion?

## Signed, Zapped

## Dear Zapped,

Further investigation into your operation revealed that the attack was localized and not limited to chro-



Fig. 1-Snapped turnbuckle.

mium-plated areas. Etching of metal became evident only after several months of tooling processing and repeated cleaning. The "corrosion" appeared to be concentrated to areas that were cavities or recessed areas on the tooling, whether chromium-plated or not (Fig. 3). A definite line of demarcation was visible where the tooling was mounted into the molding plate, with no etching present on areas where the tooling was mounted into the plate, but severe etching immediately above the joint between the plate and the tooling.

Current operating practice is to use a proprietary cleaner in the ultrasonic tank, under the following conditions:

1. The concentration of the cleaner is approximately 8 oz/gal.



Fig. 3-Concentrated corrosion



Fig. 2—Granular brittle failure.

- 2. The operating temperature is approximately 180 °F.
- 3. The cleaning tank is an ultrasonic cleaning tank, 200 gal in size, and operated at an ultrasonic power density of 40 watts/gal.
- 4. Gentle agitation/tank turnover is provided by a recirculating pump on a cartridge filter.
- 5. Tank temperature is maintained with heating coils mounted on the bottom of the tank, along with the ultrasonic transducers.

## Was this Caused

By Stray Currents? Stainless steel and chromium plating are soluble in alkaline solutions, when subjected to anodic DC current. Stray current could therefore cause attack of the metals. The attack, however, would be concentrated on sharp edges and ridges, which is the opposite of the observed attack (at crevices). Further, company efforts at measuring stray currents failed to detect significant levels.

Was this Chemical Attack? Stainless steels and chromium plating are not subject to chemical attack by alkaline cleaning solutions, in the absence of stray currents or dissimilar metals. Further, chemical attack would manifest itself uniformly, while the experienced attack was very localized. Was this Caused By the Ultrasonics? Stainless steels and chromium electroplate are resistant to corrosive attack by alkaline solutions, as long as a thin oxide film (which forms instantly when cleaned stainless steel or chromium is exposed to air) is present on the surface of these metals. It is possible to apply an excessive amount of cavitation intensity\* in an ultrasonic cleaning tank, resulting in the destruction of the protective oxide film. The resulting erosion of the metal will occur over a long period of time, and would be concentrated at cavities, where sonication is at a maximum concentration.

Cavitation intensity is dependent upon:

• Temperature—Changes in temperature also change the viscosity, solubility of gases, diffusion rates of dissolved gases, and vapor pressure, thereby affecting cavitation intensity. In water-based solutions, the cavitation effect is optimized at about 60 °C. Viscosity should be minimized, as syrupy liquids retard the formation of cavitation bubbles. Dissolved gases reduce cavitation effects by discharging and absorbing energy that would otherwise create implosion of cavities. Increased temperature minimizes gas solubility, maximizes the diffusion rates of dissolved gases, and brings the liquid closer to its vapor pressure. Vaporous cavitation is the most effective method of ultrasonic cleaning.

• Cavitation Intensity—The intensity of cavitation is also related to the applied ultrasonic power. As the power is increased above the cavitation threshold, cavitation intensity turns "flat," and no further increase in cleaning efficiency can be obtained by increasing applied power. The ultrasonic power must be adequate to create cavitation around the entire part being cleaned. This power is rated in "watts per gallon." As tank volume goes up, the power required to achieve cavitation goes down. Too much power applied to a part in a large tank can cause cavitation erosion, which looks like corrosion. In tanks above 100 gal in capacity, the maximum power applied should be 20 watts/gal, while tanks below 100 gal utilize exponentially increasing power densities, going from 20 watts/gal all the way up to 130 watts/gal. Cavitation intensity is also inversely related to ultrasonic frequency. As the frequency is increased, the cavitation intensity is decreased. Power and frequency, therefore, need to be balanced.

We suspect that the current operating practice of applying 40 watts/gal, for a 200-gal cleaning tank is producing an erosion of the metal in areas of maximum cavitation (recessed areas and cavities). The ultrasonic power applied to the tooling in this tank should be reduced to 20 watts/gal. *PasF* 

\*"Ultrasonic Cleaning, Fundamental Theory and Application," F. John Fuchs, Precision Cleaning, 1994.