Discussion

Discussion of "Microstructural and Stress Corrosion Cracking Characteristics of Austenitic Stainless Steels Containing Silicon"*

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The authors investigate the effect of Si on the susceptibility of austenitic steels intended for use in nuclear light water reactors to irradiation-assisted stress corrosion cracking. However, regrettably, they admit to inconclusive results. It seems that some other important factor may be over-riding their results. I write to draw attention to the probability that oxide bifilms (oxide films entrained during the original pouring of the steel) seem likely to be the dominant factor in this research, and may have been overlooked.

This writer has recently drawn attention to the effect of bifilms on stress corrosion cracking in Al-Mg alloys.[1] The effect seems to be not confined to light alloys, but appears to be a general metallurgical problem. If the surface film on the original liquid metal is folded into the melt during the pouring of the ingot, the film folds in double, with its dry ceramic surface folded opposed and unbondable, thus acting as a crack in suspension in the liquid. Highly turbulent handling of melts can fill a liquid metal with a huge density of cracks.[2] The cracks are naturally frozen into the solid if solidification is sufficiently rapid.

The experimental technique described by the authors is particularly susceptible to the formation of a generous population of bifilms in their final microstructure. The pouring of the melt in a vacuum induction furnace necessarily involves a significant drop of the melt (by a meter or more) into a mold. The relatively poor industrial vacuum is well known for being highly effective for oxidizing melt surfaces during the pour.[2,3] The mold would have been iron or steel, and so would have rapidly frozen the copious numbers of bifilms in place before they had a chance to float out. The subsequent vacuum arc remelting (VAR) would have introduced a second crop of serious bifilms in the "pancake style" folding of the oxide surface in this extremely inappropriate melting process. The VAR is well known to produce ingots of reactive alloys that are practically unworkable (for instance, VAR ingots of the Ni-base alloy Waspalloy have a reputation for being prone to crack on forging, whereas electroslag remelted ingots, which are naturally relatively free from entrained bifilms, forge like butter).

It is to be expected therefore that the stainless steel specimens used in this interesting work contain a high density of bifilm defects. The steels would have been essentially precracked with a huge density of randomly oriented cracks. It is no surprise therefore to observe clear bifilm signatures in the fracture surfaces. In particular, Figure 13 illustrates a transgranular fracture mode, typical of environmentally assisted cracking (EAC), but is also a clear example of the folds and creases of an oxide film that had originated on a liquid surface. Figure 15 is even more fascinating, revealing both planar and folded areas, which the authors suggest correspond to austenite and ferrite grains. Planar facets are commonly associated with bifilms that have been pushed by advancing dendrites to create crystallographically flat cracks.[2] If this identification of phase is accurate, in this case, it seems that the close-packed austenite pushes the oxide films effectively, forming planar cracks, whereas ferrite is not so effective. Figure 16 shows characteristic traces of bifilms from the EAC area continuing without a break into the ductile final fracture (DFF) area. Figure 18 illustrates a region of intergranular fracture again typical of that created by bifilms that have been pushed by the advancing solidification front into intergranular regions. Such planar intergranular fractures have been identified in turbulently cast but not in Ni-base alloys and steels that have been carefully cast to avoid turbulent entrainment of the liquid surface.[2]

It seems therefore that the authors may have been witnessing in their stress corrosion fatigue testing the advance of corrodant into the pre-existing cracks provided by bifilms. The advance of the initial fatigue crack is rather lengthy, explaining the substantial oxides built up on this portion of the fracture. In contrast, the EAC region had relatively small oxides (the authors have not identified nor suspected the presence of the original bifilm oxide, extending over the entire region, which is probably only nanometers thick, so that the metallurgical structure is seen through the film) as a result of the crack progressing rapidly through the EAC region. Clearly, the DFF region had few if any observable oxides.

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