Sensitization and Environmental Cracking of 5xxx Aluminum Marine Sheet and Plate Alloys

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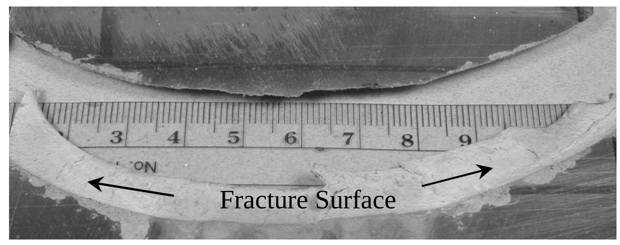
The current demand for fast sea transportation in both commercial and military applications has accentuated the need for lightweight materials that can provide a challenging combination of material property requirements. The high strength-to-weight characteristics of aluminum alloys are particularly attractive for use in these new high performance vessels. The aluminum sheet and plate alloys used for marine applications are the 5xxx alloys in which the principal alloying element is magnesium. The 5xxx alloys are non-heat-treatable alloys that are strengthened by strain hardening. Therefore, these alloys achieve their properties through the combined effects of alloy composition as well as thermal and mechanical processing.

The excellent corrosion resistance of the 5xxx alloys is one of their most important characteristics. They are resistant to industrial and marine atmospheres and can be used in these environments without additional protective measures such as painting or sacrificial anodes. Welds of these alloys are normally as corrosion resistant as the parent alloy. However, under certain conditions of elevated temperature exposure, alloys containing higher amounts of magnesium (>3%Mg) may become susceptible to intergranular forms of corrosion (i.e. intergranular corrosion, exfoliation, and/or intergranular stress corrosion cracking). Exposure to certain unsuitable combinations of time at elevated temperature either during the fabrication of the sheet and plate products or in service can cause precipitation of the β-phase (Mg_2Al_3), which forms preferentially on the grain boundaries. The β-phase precipitate is electrochemically more active than the aluminum matrix and the susceptibility of the 5xxx materials to intergranular forms of corrosion increases with the continuity of the grain boundary precipitation. [1,2]

Recent experiences with environmental cracking incidences in the field and in laboratory tests have demonstrated that the degree of recrystallization of the microstructure[3] and the loading mode are also influential in the stress corrosion performance of these materials. Laboratory tests with uniaxial loading have shown that, when sensitized, 5xxx alloys are particularly susceptible to SCC when tested in the short transverse (ST) orientation but are not susceptible to SCC when tested in the longitudinal (L) or long transverse (LT) orientations unless the material is fully recrystallized. In order to meet the mechanical property requirements the microstructure of these strain-hardened materials will generally be at least partially unrecrystallized.

In marine applications (e.g. 5 or 6 mm thick hull plate) these materials experience mixed mode loading in service. The mixed mode loads induce sufficient tensile stresses on the short transverse plane to propagate stress corrosion cracks through unrecrystallized segments of partially recrystallized microstructures resulting in intergranular fractures that propagate macroscopically in a mixed or slant (shear) fracture mode. The appearance of a typical fracture is illustrated in Figure 1.

The SCC susceptibility of these materials under mixed mode loading conditions has therefore been evaluated in lab tests using modified double cantilever beam (DCB) type specimens. The results of these mixed-mode SCC tests will be compared with standard uniaxial (ST) SCC and standard (plane strain) DCB test results on thicker plate materials as a function of the degree of sensitization (i.e. continuity of grain boundary precipitation) as determined by nitric acid mass loss tests (ASTM G67). [4] The consistency of SCC test results with mass loss criteria in ASTM G67 will also be evaluated.



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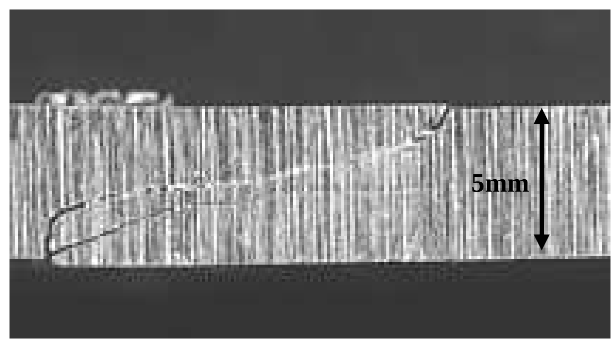

b.

Figure 1. Macroscopic photos of slant (shear) fracture surface on sensitized 5mm thick 5083 hull plate; a. top surface view, b. transverse section view.

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