

Ductility-Dip Cracking Mechanism Development in Austenitic, Nickel-Base Weld Metals

Ductility-dip cracking (DDC) is a solid-state, elevated temperature phenomenon occurring in the vicinity of the recrystallization temperature. The susceptible temperature range usually resides between the solidus and approximately $0.5T_m$. Crystallographically, it has been shown in weld metal that DDC preferentially occurs along migrated grain boundaries. Therefore, single-phase weld metals with low amounts of impurities, grain boundary precipitates and/or second phases may have a higher susceptibility to DDC as these weld metals have little resistance to grain boundary movement. In austenitic stainless steels and nickel base alloys, there appears to be strong grain size dependence with coarser grain sizes promoting a higher susceptibility to DDC. Additionally, grain boundary shearing and the relative orientation of a grain boundary to an applied strain have been shown to increase susceptibility to DDC in some materials.

In recent years, Alloy 690 base material and Filler Metals 52 and 82 have become the materials of choice for commercial nuclear steam generator applications. Recent studies have shown these materials to be susceptible to DDC in both the fusion zone and heat affected zone (HAZ) using both the transverse and “double-spot V-restraint methods. In addition to the aforementioned test methods, a Gleeble-based DDC test technique developed by Nissley and Lippold has been employed to develop DDC strain-temperature susceptibility curves for Filler Metals 52 and 82. Results from the aforementioned test techniques will be presented, including metallographic and SEM characterization. Additionally, weld metal grain orientation relationships on migrated grain boundary formation and subsequent DDC susceptibility will be addressed based on results obtained through the utilization of the SEM equipped with Orientation Imaging Microscopy (OIMTM) software. Furthermore, DDC susceptibility effects of weld metal interstitial additions will be summarized.

A mechanism for DDC, including compositional and microstructural effects, will be presented. This mechanism provides valuable insight into filler metal selection and/or development to avoid DDC in highly restrained weld metals.