**Solidification Cracking Mechanisms in Low Alloy Steel Welds**

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Solidification cracking is generally a function of the composition and it is widely believed that carbon increases cracking in low alloy steel welds. However, unexpectedly high cracking has been reported in low carbon (0.1%C) steel welds [1] intended for oil and gas piping. In these materials, such cracking has serious consequences in terms of providing sites for hydrogen-induced cracking. Recently, a high cracking probability has been predicted for weld metals by Ichikawa et al. [2] using weld cracking data for such steels in the very low carbon range between 0.03-0.15%C. However, the mechanisms for this behavior have not been widely discussed in the literature. A study sponsored by the NSF was undertaken to investigate solidification cracking behavior of Fe-C, Fe-Ni, Fe-B and Fe-C-Ni model alloys prepared from high purity materials. Additionally, a few high strength commercial and experimental weld metals were also investigated. Cracking was studied the varestraint hot cracking test. The tests were also conducted in the transvarestraint mode in order to reveal cracking in these materials of low susceptibility. The test specimens were examined in terms of crack length criteria, optical and scanning electron microscopy.

The results of solidification cracking tests showed that in all the alloys, the cracking was a function of the solute content and the solidification mode. The incremental cracking due to Ni and C addition was greater when delta solidified first from the melt than when austenite was the primary solidifying phase, while an opposite trend was found in Fe-B alloys. In the Fe-C alloys, the cracking behavior was complex and a peak in cracking was observed at 0.1%C, which was equivalent to that in 0.23%C or 5%Ni alloys. Detailed metallographic observation showed that as little as 0.01%C caused the development of cellular solidification in Fe-C alloys. A dendritic or cellular solidification pattern was visible for C > 0.08%. However, no dramatic difference in solute segregation was evident across various C contents from 0.01 to 0.23%. The study shows that enhanced solidification cracking in the vicinity of 0.1%C in Fe-C alloys is not explainable by the solute segregation but on the basis of the additional shrinkage stress imposed by the ferrite-austenite solid state transformation taking place within the temperature zone of solidification brittleness. The study has highlighted that particularly in low C alloys, the mechanical behavior of the solid plays a major role in solidification cracking unlike in stainless steels, where solute segregation is an overriding factor in determining the behavior. Further analytical investigations are in progress to reveal the nature of solute segregation in these alloys.

This work is of great interest to fabrication of high strength steels where the trend has been to reduce C to very low levels while carefully tailoring the alloy content using Ni, B or Mn to achieve high strength and toughness. The relations between composition and solidification cracking developed in this study will provide a basis for a comprehensive model for cracking in high strength steel welds.

## References


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