

Repair Techniques for Fusion Reactor Applications

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Introduction/Background

Fusion reactors, such as the planned International Thermonuclear Experimental Reactor, will require repair during their lifetime. These repairs will require welding on material irradiated during operation of the reactor. Considerable work done previously on the weldability of irradiated 304 stainless steel for fusion reactor applications has shown that welding on irradiated material causes cracking in the weld heat-affected zone due to helium present from irradiation. The extent of this cracking is a function of the amount of helium present, the welding process used (the time and temperature), and the material being welded.

Procedure

The present study compares the weldability of 304 and 316LN stainless steel containing helium. A comparison of the weldability of this "old" high carbon 304 material with the weldability of "ITER Grade" 316 stainless steel was made. Previous studies on 304 were performed on material containing helium from both irradiation and from decay of tritium. The present study used material charged with tritium and aged to produce approximately 90 appm helium. Plates of each material, 0.5 inches thick by 4.0 inches long and 1.25 inches wide were charged and aged. Charging was done at 350°C for two weeks to achieve a level distribution of tritium throughout the plates. The charged plates were then aged for approximately nine months to achieve the desired level of helium. The plates were then outgassed at 490°C for three weeks to diffuse most of the tritium from the plates.

Results

Results of the present study show that less cracking occurs in the "ITER Grade" 316LN stainless steel than in the "old" high carbon 304 stainless steel. This is good news for the fusion reactor community since 316 stainless steel is a candidate material of construction for future reactors.

Plates were assembled with uncharged run-on and run-off plates on either side, and both GMA overlay welds and GTA stringer beads were made across the plates. Low heat input overlay welding was identified previously as a preferred technique to minimize cracking when welding irradiated material. Resulting welds were evaluated by surface examination for toe cracks, by examination of metallographic sections, and by TEM examination of selected locations near and remote from the welds. Welds in the uncharged plates served as controls to confirm that cracks were the result of helium and not some other phenomenon.

Crack counts in the charged plates indicated over twice the number and length of cracks in the “old” 304 material compared to the “ITER Grade” 316 material. Bubbles, from helium release, existed in the weld metal of each material and were more extensive in the 304 material. Analysis of helium content in the two materials indicated approximately the same content in each.

Conclusions

In conclusion, 316 stainless steel is the preferred material compared to 304 stainless steel for construction of reactors at locations where welded repair of irradiated components may be necessary. By comparison to the extensive data available on weldability of 304 stainless steel, further conclusions can be reached regarding the choice of welding conditions for repair of irradiated 316 stainless steel.