

Fatigue Crack Propagation of Austenitic Stainless Steel Welds

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Introduction

Austenitic stainless steels, both of the conventional and superaustenitic varieties, are being investigated as viable alternatives to the low alloy steels for Advanced Double Hull surface combatants. One of the driving factors for the change is to reduce the magnetic signature of the ships. In stainless steel welds, magnetic δ -ferrite can form upon solidification depending on the nominal compositions of nickel and chromium in the material. Therefore, there are concerns that during the design of such ships, which require welding throughout, δ -ferrite may form and increase the magnetic signature of the ship. The purpose of this research is to use different austenitic stainless steels to vary the amounts of δ -ferrite in the weld metal of both gas metal arc and laser welds in order to subsequently determine the influence of δ -ferrite on the fatigue crack propagation behavior of the welds.

Experimental Procedure

Austenitic stainless steels, 316L and 309S, and superaustenitic stainless steel, AL6XN, were used as base materials. Multi-pass gas metal arc and laser welds were fabricated from these base metals. The weld metal δ -ferrite content was determined for both types of welds.

Compact-tension test specimens, conforming to ASTM Standard E647, were removed from the parent welds in such an orientation that allows for fatigue crack growth either across the weld metal (in a direction normal to the welding direction) or completely within the weld metal (parallel to the direction of welding). Fatigue crack propagation tests were conducted in order to conform to ASTM Standard E647.

Results and Discussion

In order to decouple mechanical from microstructural influences on the weld crack propagation behavior, a stress ratio that overcame possible influences, such as compressive residual stresses and crack closure, on crack growth during testing was determined on specimens with the crack growth orientation perpendicular to the weld metal. This orientation allowed for the consideration of the different residual stress distributions expected from the base metal into the weld metal. Additional metallurgical influences on fatigue crack growth, such as material composition and grain size, have been investigated by conducting fatigue crack propagation tests on wrought specimens. With these influences being considered, the remaining influential factor influencing the crack growth is the δ -ferrite content in the weld metal, which has been investigated by growing the fatigue crack perpendicular to the direction of welding. This effect is more observable due to the wide range of δ -ferrite that accompanies the chosen stainless steels. The combination of the aforementioned fatigue crack propagation results allowed for direct observation of the influences of δ -ferrite on the crack propagation behavior of stainless steel weldments.

Conclusion

The mechanical effects of fatigue crack propagation of austenitic stainless steels have been decoupled from the microstructural effects by determining a stress ratio that overcomes the aforementioned mechanical influences during testing. Such a procedure is vital for determining the microstructural influences, such as δ -ferrite content, that can influence the fatigue crack propagation behavior of such welds. Such knowledge is important if some δ -ferrite remains during the fabrication of the Advanced Double Hull surface ships.