Reduction of Weld Residual Stress in Alloy 22 by Pro-Active Thermal Management

Hanbing Xu, Zhili Feng*, Lawrence Bower** and Stan A. David**
**Oak Ridge National Laboratory, Oak Ridge, TN 37831*
*** Joseph Oat Corporation, Camden, NJ 08104*

Introduction

High tensile residual stresses associated with welding have been a major source of concern for the safety and integrity of welded structures. This study was to investigate an approach for in-process control of the weld residual stress, by means of in-process proactive thermal management during welding. The concept of the proactive thermal management is to intentionally interrupt the normal cooling sequence during welding through various cooling and heating techniques, to produce a different residual stress profile in the weld region.

Technical Approach

A proactive "in-process" welding thermal management procedure was applied in conjunction with the gas tungsten arc welding (GTAW) process. Although water can be a more effective thermal-management media, it is prohibited in certain applications. Liquid argon was used in this study. Welding trails were made on 12" long by 3" wide by 1" thick plate made of Alloy 22 (UNS N06022), a Ni-Cr-Mo alloy that provides outstanding resistance to corrosion. The single pass bead-on-plate weld with liquid argon surface quenching and one baseline sample without quenching were made. Blind hole drilling measurements was made to determine the residual stresses at two locations: at the weld centerline and the fusion line. To determine the non-uniform weld residual stress distribution in the thickness direction of a plate, the incremental holing drilling technique and integral method were used. The principal residual stresses have been calculated as the function of depth from the plate surface. These samples were evaluated for residual stresses to determine if the argon cooling system achieved the goal of reduced residual stresses in the as-welded condition.

Results

For the baseline sample, the highest maximum principal residual stress (which is responsible for stress corrosion cracking) in the surface layer is located at the fusion line, which is as high as 491 MPa. The maximum principle residual stress at the center of the weld is 85 MPa. The residual stress measurement results of baseline sample and liquid argon surface quenched sample are compared in Fig.1. The results showed that substantial residual stress suppression was achieved with this more aggressive thermal management parameter clearly. At the weld centerline, the maximum principal stress is reduced from 85MPa to 37MPa. More importantly, the highest maximum principal stress at the fusion line of the weld is reduced from 491MPa to 76MPa, a reduction of 85 percent. The resultant 76MPa tensile stress is also substantially lower than the nominal yield strength (365MPa) and tensile strength (772MPa) of the solution annealed Alloy 22.

Conclusion

It can be concluded that the liquid-argon based approach was very effective to reduce the maximum tensile residual stresses at the weld surface. The pro-active in-process welding thermal management technique would require different welding conditions than the conventional GTAW process to maximize the residual stress suppression effects.

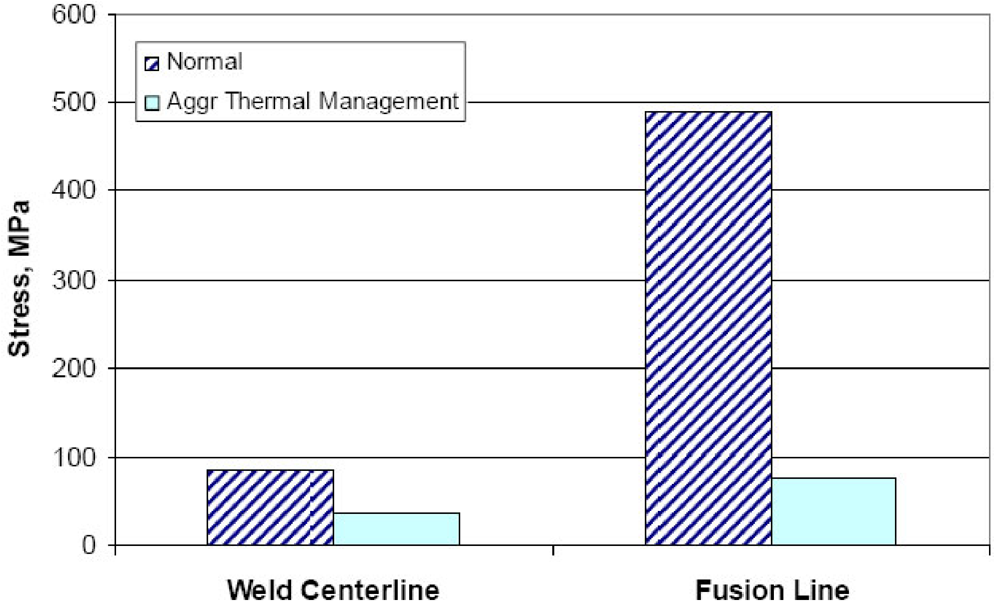

Fig. 1. Comparison of maximum principal weld residual stresses of the single pass bead-on plate weld at two locations: weld centerline and weld fusion line. The maximum stress is located at the fusion line. The proactive thermal management resulted in considerable reduction of the maximum principle stress at the fusion line. All residual stresses were at the surface of the weld sample.