

Analytical Thermal Solutions for Moving Arc and Lumped-Heating Procedures in Complex Welded Structures

By Z. Cao, F. W. Brust, Y. P. Yang, and J. C. Kennedy, Battelle Memorial Institute

Introduction

In manufacturing industry, there are more and more needs for numerical thermal analyses (such as finite element analysis, FEA) of complex welded structures. However, one of the major impediments using numerical methods is that the overall computational speed may be very slow and sometimes even unacceptable, especially when a complex welded structure is involved. Experiences have demonstrated that the thermal solutions can be significantly simplified without jeopardizing the solution accuracy.

Many investigations have been studied on analytical thermal solution modeling. However, these solutions are having troubles to deal with multiple pass welds, curved welds, various of weld joints, and different boundary conditions. Also, all the transient solutions have to numerically solve an integral, which can be troublesome and slow down the computation and reduce accuracy.

Solution Description

Transient, explicit, and closed-form comprehensive thermal solution procedures (CTSP) for moving arc cases are developed to simulate the thermal process of welding in a complex welded structure. Also, the solution procedures are expanded to handle lumped-heating procedures in huge and complex structures since it is time-consuming to perform a thermal analysis when using FEM-based lumped-heating procedure for such structures. The solution procedures can deal with not only multiple-pass and curved welds, but also different types of complex welded structures and their boundary conditions. All weld features are permitted, including weld start/stop effects, multiple passes, arbitrary weld joint, base plate cut-outs and holes, and trailing and heating sources.

Results and Discussion

A series of examples has been calculated for the practical welded structures. The predicted results have been compared with the experimental measurements. A good agreement has been achieved between prediction and measurement. The CTSP is 100 to 1000 times faster than a numerical solution, and it greatly reduces both input time and the computational resources required. Accuracy of the solution is very competitive to that from the FEM and usually better when very coarse meshes are used because of its mesh independence.

The analytical lumped-heating solutions are compared with the analytical moving arc and ABAQUS lumped-heating solutions in terms of temperature histories and final weld distortions. There is a good agreement between the analytical and ABAQUS lumped-heating procedures. Also, the comparison between analytical lump-heating and moving arc procedures are reasonably closed to each other.

Conclusion

Analytical thermal solutions for moving arc and lumped-heating procedures have been developed to simulate temperature history for different type of joints in complex welded structures: (1) The CTSP has been successfully used for V-groove, T-fillet and lap joints. (2) There is a good agreement between prediction and experimental measurements. (3) Compared with FEM, the CTSP thermal analysis has saved tremendous computational time. (4) The CTSP can be used for rather coarse meshes and still provide good accurate results. (5) CTSP provides good temperature prediction for thermal-mechanical analysis.