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Title:

THE PRACTICAL ANALYSIS OF WELDING PROCESSES USING FINITE ELEMENT ANALYSIS

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The Practical Analysis of Welding Processes Using Finite Element Analysis

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Introduction:

With advances in commercially available finite element software and computational capability, engineers can now model large-scale problems in mechanics, heat transfer, fluid flow, and electromagnetics as never before. With these enhancements in capability, it is increasingly tempting to include the fundamental process physics to help achieve greater accuracy (Refs. 1-7). While this goal is laudable, it adds complication and drives up cost and computational requirements. Practical analysis of welding relies on simplified user inputs to derive important relativistic trends in desired outputs such as residual stress or distortion due to changes in inputs like voltage, current, and travel speed.

Procedure:

Welding is a complex three-dimensional phenomenon. The question becomes how much modeling detail is needed to accurately predict relative trends in distortion, residual stress, or weld cracking? In this work, a HAZ (Heat Affected Zone) weld-cracking problem was analyzed to rank two different welding cycles (weld speed varied) in terms of crack susceptibility. Figure 1 shows an aerospace casting GTA welded to a wrought skirt. The essentials of part geometry, welding process, and tooling were suitably captured to model the strain excursion in the HAZ over a crack-susceptible temperature range, and the weld cycles were suitably ranked.

Results and Discussion:

The main contribution of this work is the demonstration of a practical methodology by which engineering solutions to engineering problems may be obtained through weld modeling when time and resources are extremely limited. Typically, welding analysis suffers with the following unknowns: material properties over entire temperature range, the heat-input source term, and environmental effects. Material properties of interest are conductivity, specific heat, latent heat, modulus, Poisson's ratio, yield strength, ultimate strength, and possible rate dependencies. Boundary conditions are conduction into fixturing, radiation and convection to the environment, and any mechanical constraint. If conductivity, for example, is only known at a few temperatures it can be linearly extrapolated from the highest known temperature to the liquidus temperature. Over the liquidus to solidus temperature the conductivity is linearly increased by a factor of three to account for the enhanced heat transfer due to convection in the weld pool. Above the liquidus it is kept constant. Figure 2 shows an example of this type of approximation. Other thermal and mechanical properties and boundary conditions can be similarly approximated, using known physical material characteristics when possible. Sensitivity analysis can show that many assumptions have a small effect on the final outcome of the analysis.

In the example presented in this work, simplified analysis procedures were used to model this process to understand why one set of parameters is superior to the other. From Lin (Ref. 8), mechanical strain is expected to drive HAZ cracking. Figure 3 shows a plot of principal tensile mechanical strain versus temperature during the welding process. By looking at the magnitudes of the tensile mechanical strain in the material's Brittle Temperature Region (BTR), it can be seen that on a relative basis the faster travel speed process that causes cracking results in about three times the strain in the temperature range of the BTR.

Conclusion:

In this work, a series of simplifying assumptions were used in order to *quickly and accurately* model a real welding process to respond to an immediate manufacturing need. The analysis showed that the driver for HAZ cracking, the mechanical strain in the BTR, was significantly higher in the process that caused cracking versus the process that did not. The main emphasis of the analysis was to determine whether there was a mechanical reason whether the improved weld parameters would consistently produce an acceptable weld. The prediction of the mechanical strain magnitudes confirms the better process.

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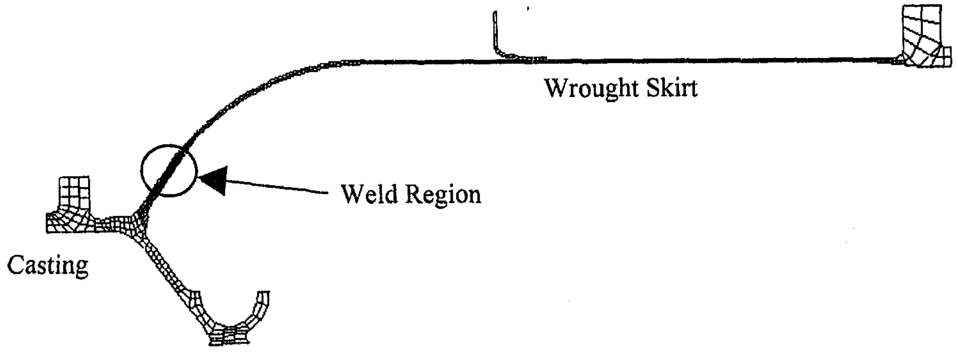

Figure 1: Axisymmetric Mesh for Casting to Skirt Weld

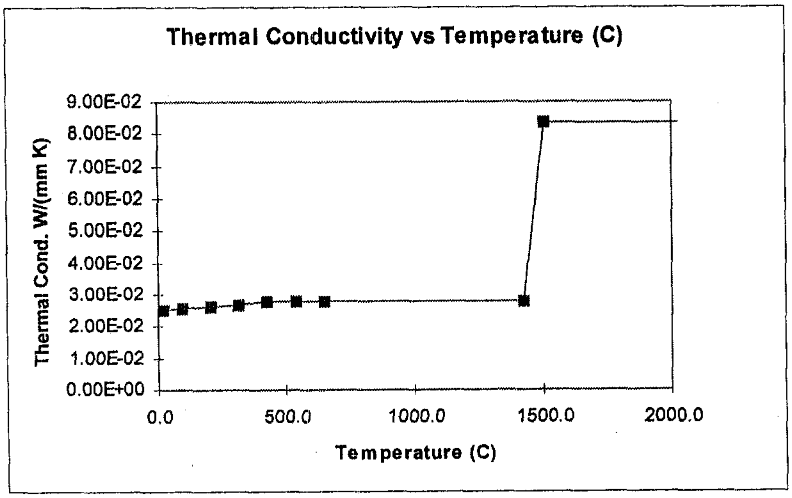

Figure 2: Extrapolated Thermal Conductivity Curve

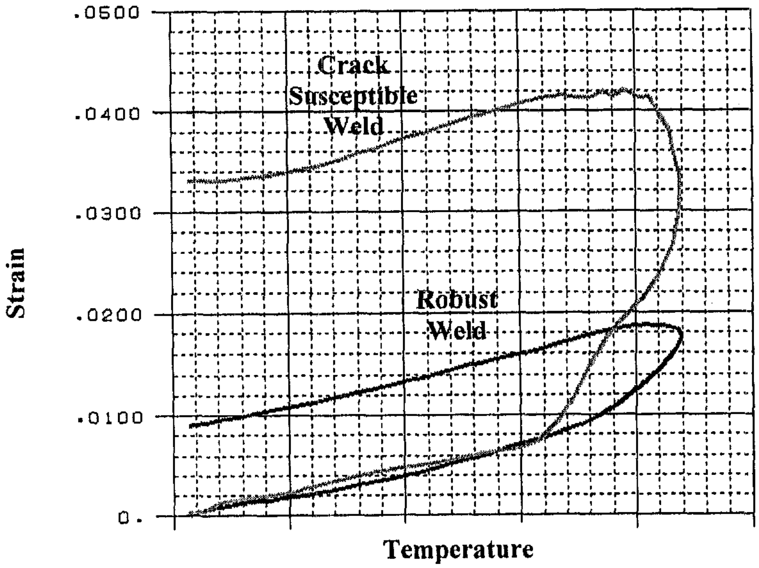

Figure 3: Principal Tensile Mechanical Strain Calculations for casting to skirt weld