EVALUATION OF DIFFERENT THERMAL SOURCES' TEMPERATURE DISTRIBUTION AND ANALYSIS OF RESIDUAL STRESS IN WELDED JOINT

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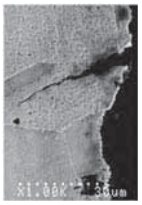
OVERVIEW

Residual stress can affect both the static strength and the fatigue endurance of the welded joints. In particular, a deep understanding of the manufacturing process is needed to achieve safety and quality requirements for parts and components. In this work, the finite element method is used to assess the capability of different thermal methods used to simulate the welding process in reproducing the temperature distribution around the weld. Moreover, residual stress is evaluated for a pipe-to-plate welded joint made of S355JR carbon steel. The manufacturing process is studied from both the thermal and mechanical point of view through ***thermal-structural uncoupled finite element analysis*** made by **ANSYS® Mechanical**.


Clarin [1]


Vanboven et al. [2]

METHODS

- Real specimen

- FE-simulation

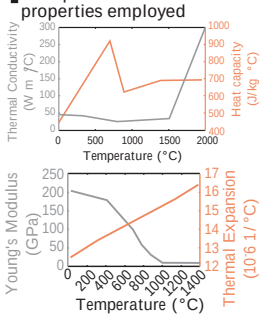
Thermal-Structural non linear uncoupled simulation

1 - THERMAL
- 3D 8-Nodes thermal solid
- Different heat sources models
- Temperature dependent material properties

2 - STRUCTURAL
- 3D 8-Nodes structural solid
- Elastic-plastic material
- Temperature dependent material properties

- FE-model
  - The 3D model was used because of the heat distribution asymmetry caused by the welding process in hoop direction

- Material properties
  - Example of some of the material properties employed

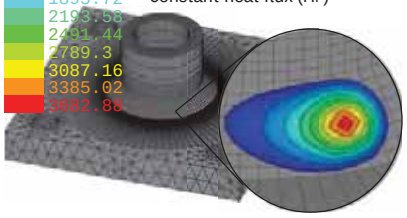


THERMAL ANALYSIS

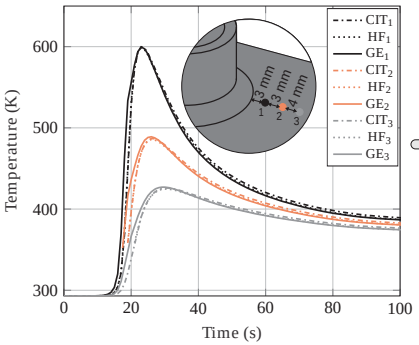
Result: the welding process can be simulated by means of a simplified heat source technique (CIT)

- Thermal heat sources FE-modelling

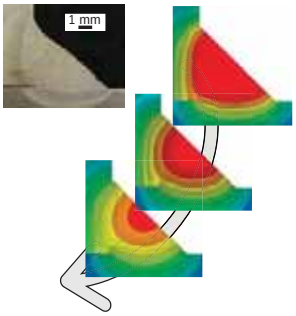
HEAT SOURCE MODELS EMPLOYED:
- ***Constant initial temperature (CIT)***
- Goldak's double ellipsoid (GE), Goldak et al. [3]
- Constant heat flux (HF)



- Heat source models comparison
  - Temperature Vs. Time in different points of the plate



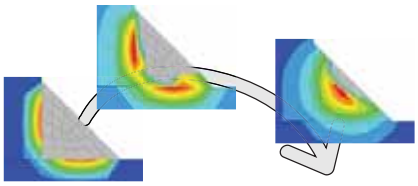
- Heat source models validation
  - Weld pool shape validation
  - Weld pool shape evolution



STRUCTURAL ANALYSIS

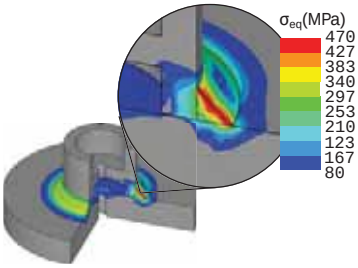
Result: relaxed strains were compared among numerical results and experimental tests, showing a good agreement.

- Weld seam cooling simulation



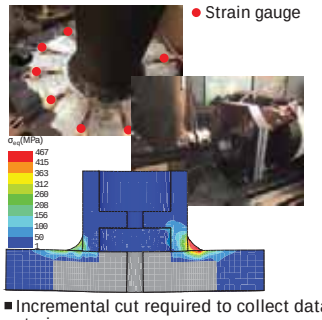
- Deactivation of liquified elements
- Element birth and death method

- Welding process simulation



- Thermal load resulting from thermal simulation
- Evaluation of stress and strain fields

- Relaxed strains comparison



- Incremental cut required to collect data from strain gauges

CONCLUSION

In conclusion, three different methods for the simulation of thermal heat source were applied. The methods require a different number of starting-set parameter. In particular, it was shown that even the most simple numerical model (CIT) can be used to reasonably reproduce the thermal history nearby the weld. Consequently, the CIT method was adopted as the main procedure to simulate the welding process. The temperature field obtained from the thermal analysis was then used as a thermal load for the structural one. From a mechanical point of view, the welding process is simulated taking care of the right stiffness of the component caused by the molten metal. Besides, relaxed strains calculated experimentally were compared with those resulting from simulation, showing a good agreement.

References:

[1] M. Clarin, High strength steel : local buckling and residual stresses (2004)

[2] G. Vanboven, W. Chen, R. Rogge, The role of residual stress in neutral pH stress corrosion cracking of pipeline steels. *Part I: Pitting and cracking occurrence*, Acta Materialia 55, 29 (2007)

[3] Goldak, J.; Chakravarti, A.; Bibby, M. A new finite element model for welding heat sources. *Metallurgical 275 Transactions B* 1984, 15, 299–305.