FEM Simulation of Thin Plate Deformation During Edge Welding

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Introduction

• Could FEM analysis be used with confidence for prediction of deformation of thin plates under the influence of heat input during edge welding?

• This presentation compares the FEM analysis results with experimental results for extremely high heating input values which destroy the plate for amplifying the effects.
Plate Edge Welding

- MAG 1,2 mm wire
- MAG 1,0 mm wire
- MIG Brazing 1,6 mm wire
- TIG without filler material

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FEM Simulations

Welding speed: \( v = 80 \text{ cm/min} = 13.33 \text{ mm/s} \)

Convection coefficient: \( a = 15 \text{ W/m}^2/\text{K} = 15 \cdot 10^{-3} \text{ N/mm/s/K} \)

Heat input: \( Q = 136.51 \text{ J/mm} = 136510 \text{ Nmm/mm} \)

Power: \( P = Q / t = 136510 \times 13.33 = 1.82 \cdot 10^6 \text{ Nmm/s} \)

- Nonlinear thermal analysis: thermal properties are variable with the unknown temperature.
- Nonlinear structural analysis: large displacements and elastoplastic material (von Mises plasticity, kinematic hardening).
- Material: low carbon steel; mechanical properties are variable with the temperature.

Ansys FE mesh:
- 3876 nodes
- 3864 finite elements
  - SHELL57 finite element for thermal analysis
  - SHELL181 finite element for structural analysis
  - BEAM188 finite elements were added to model stiffeners along short sides

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FEM Simulations

Detail:

Temperature distribution in the plate at $t=60$ s

Variation of point A temperature in time

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Transient Structural Analysis

\[ \sigma_y \text{ versus time: blue curve – point A (midpoint of left side), red curve – point B (midpoint of right side)} \]

Final permanent \( \sigma_y \) stress (after cooling down at room temperature)

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At the end of welding process and after cooling down of the plate at room temperature, two plastic strips of width $g$ are formed. In the case of elastic-ideal plastic material, in these strings are developed a permanent compressive stress equal to $\sigma_y = \sigma_{yield}$ and a permanent strain $\varepsilon_y = \varepsilon_o = \frac{\sigma_{yield}}{E}$.

The two plastic strips are subjected to tension and therefore the plate is compressed: as a consequence a buckling phenomenon can occur.
Results

Experimental Results

Deformation of "K" design HT plate couple

Ansys results.

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Conclusions

• FEM analysis agree reasonably well with experimental results.

• FEM analysis can be used with confidence for predictions of deformation within the material during welding process
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• This paper is not meant for using its findings and its conclusions for any design and/or production work or any other practical purposes.