FEM Simulation of Thin Plate Deformation During Edge Welding

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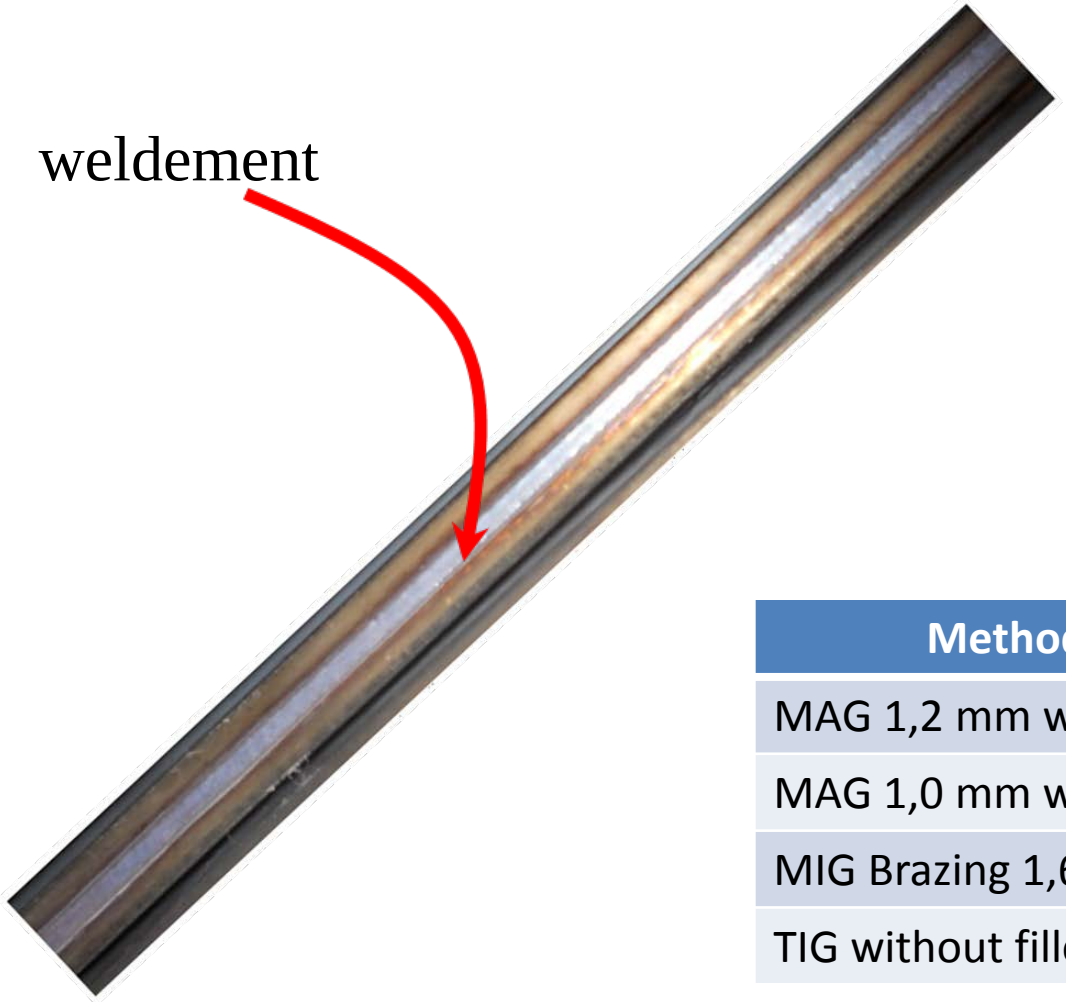
Introduction

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

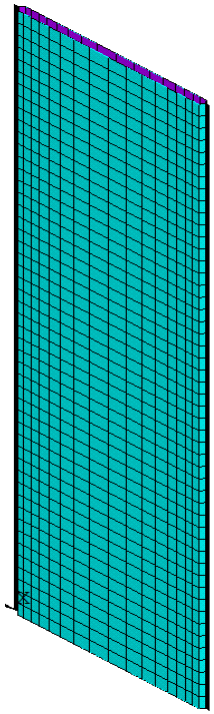
- This presentation compares the FEM analysis results with experimental results for extremely high heating input values which destroy the plate for amplifying the effects.

Plate Edge Welding



Method of Welding
MAG 1,2 mm wire
MAG 1,0 mm wire
MIG Brazing 1,6 mm wire
TIG without filler material

FEM Simulations



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

Welding speed: v=80 cm/min = 13.33 mm/s

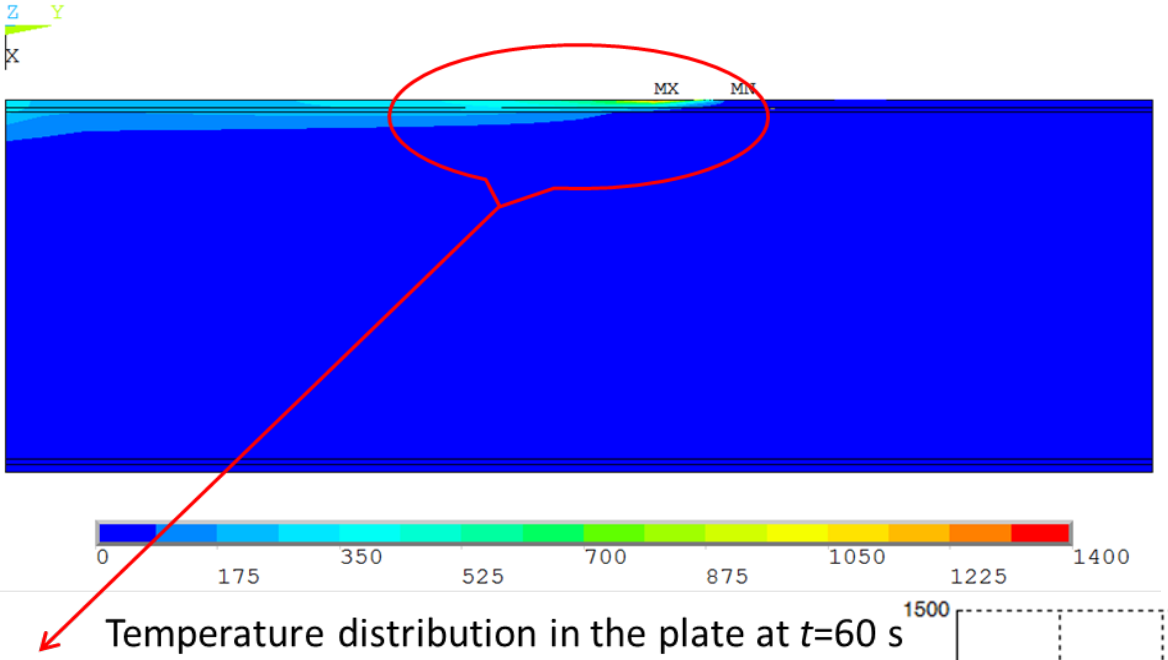
Convection coefficient: α=15 W/m^2/K = 15·10^{-3} N/mm /s /K

Heat input: Q=136,51 J/mm = 136 510 Nmm/mm

Power: $P = Q/t$ = 136 510 x 13.33=1.82·10^6 Nmm/s

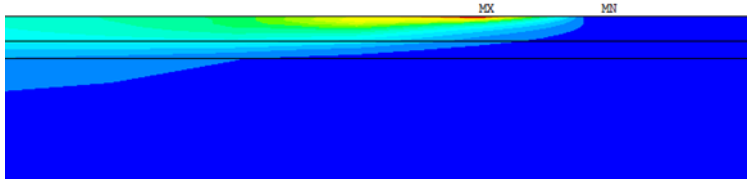
- Nonlinear thermal analysis: thermal properties are variable with the unknown temperature.
- Nonlinear structural analysis: large displacements and elastoplastic material (von Mises plasticity, kinematic hardening).
- Material: low carbon steel; mechanical properties are variable with the temperature.

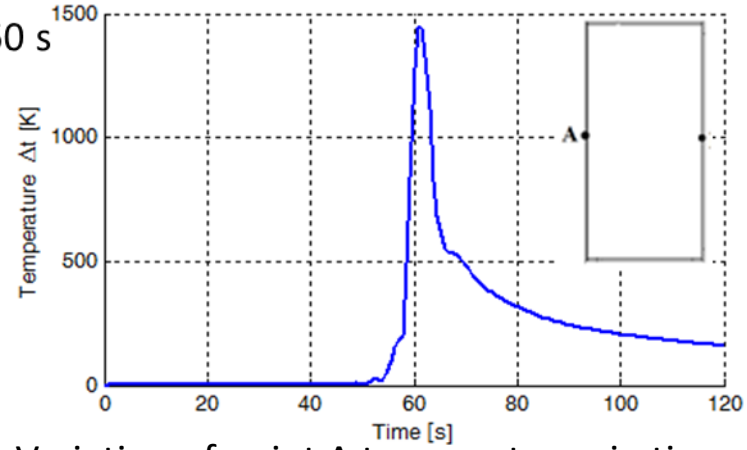
FEM Simulations



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

Detail:





Variation of point A temperature in time

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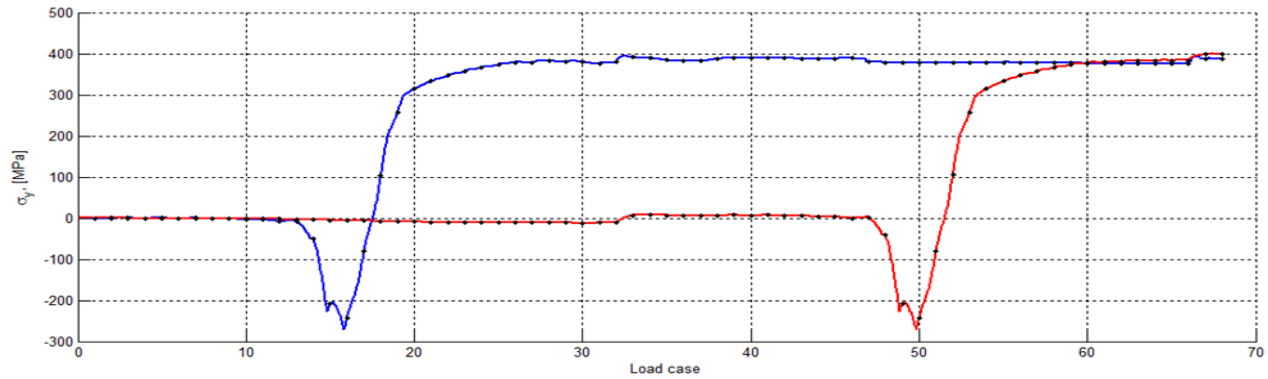
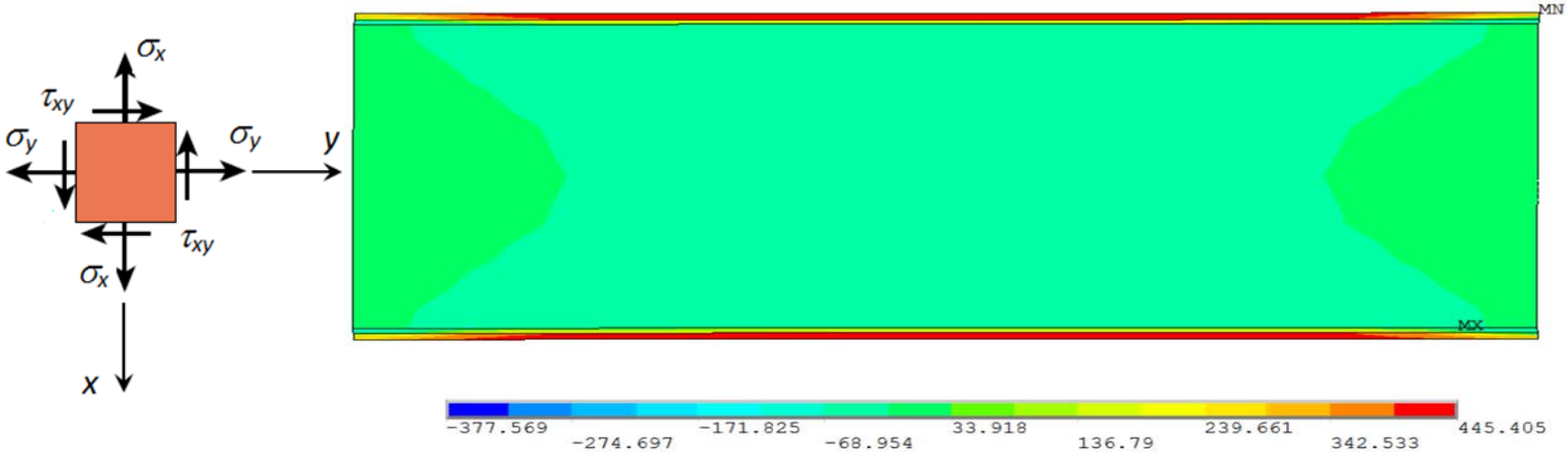
Transient Structural Analysis

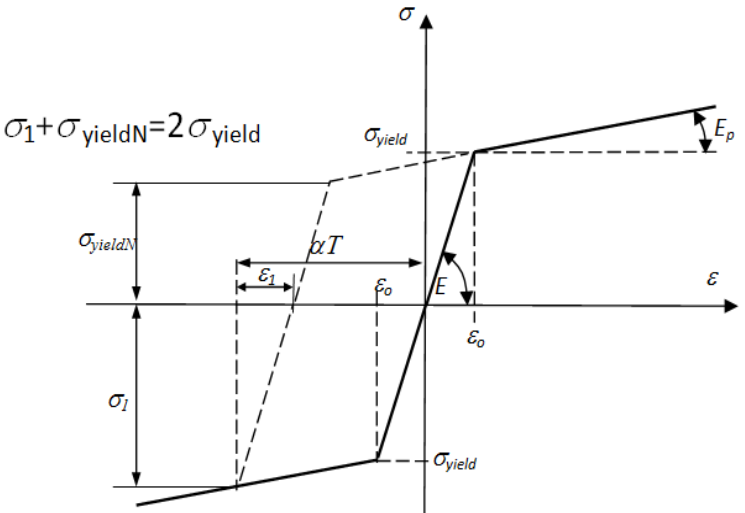


σ_y versus time: blue curve – point A (midpoint of left side),
red curve – point B (midpoint of right side)

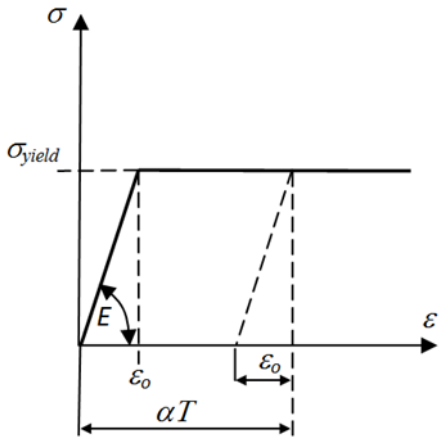


Final permanent σ_y stress (after cooling down at room temperature)

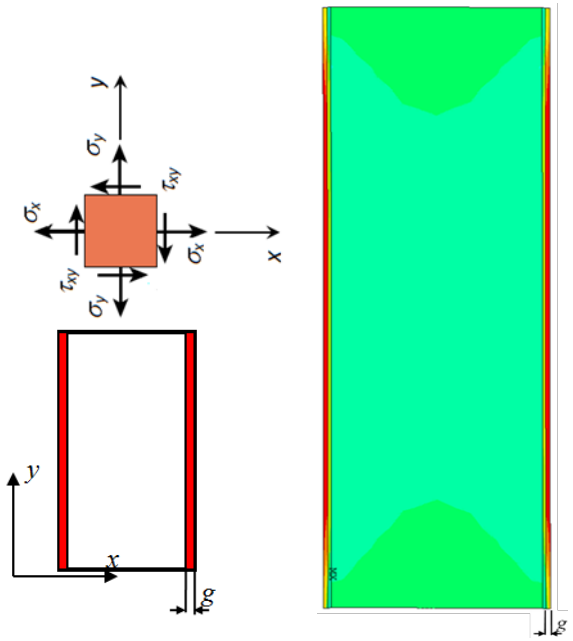
Results



Kinematic hardening)



Particular case:
elastic – ideal plastic material



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 $\sigma_y = \sigma_{yeld}$ and a permanent strain $\varepsilon_y = \varepsilon_o = \sigma_{yeld}/E$.

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

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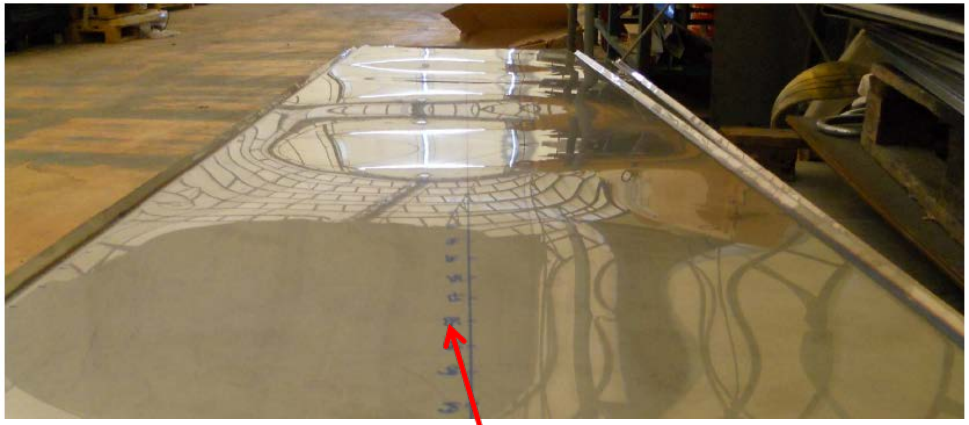
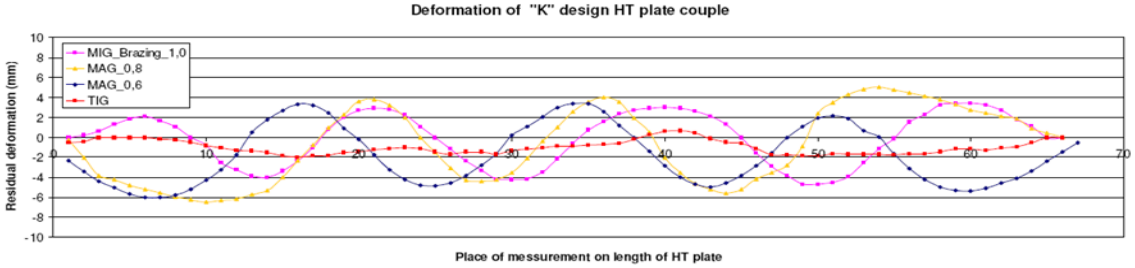
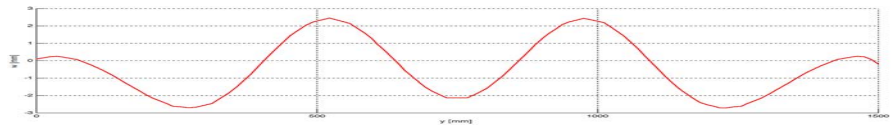
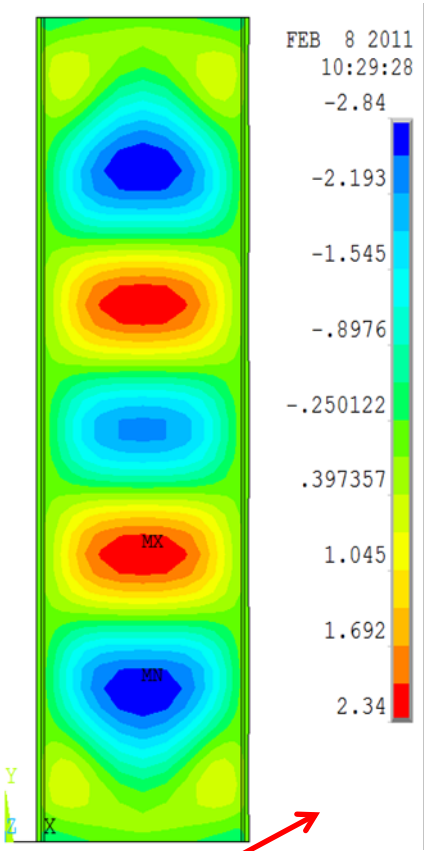
Results

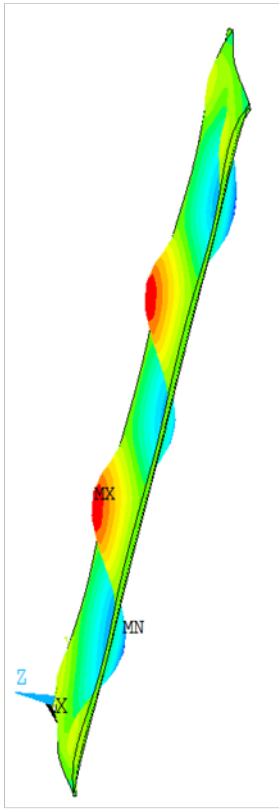


Experimental Results









Ansys results.

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

Disclaimer

- This paper is not meant for using its findings and its conclusions for any design and/or production work or any other practical purposes.