Numerical simulation in welding process: Optimizing structures with sequence and inertial study
OBJECTIVES:
To design and test a numerical simulation methodology, which can to use in industrial applications in shipbuilding sector.

STRUCTURE OF THE WORK:

- Study of experimental and simplified cases
- Numerical model validation in simple cases
- Validation in complex cases
- Simplification of numerical models
- Validation of simplified numerical models
- Parametric studies and optimization
Design specifications - PREVIAS

- 90% of joints in a ship
- Stiffeners
- “Tee” joints
- Different thickness between flange/web
- Different length
- Not clear a sequence methodology
- Structural importance

Material selection

- Naval A/AH36
- Ferritic structural steel
Worktest’s planetscape

- High geometry variability
- High adaptability and flexibility
- Low efficient and standardization

- 4 geometric variables
  - Flange (height – thickness)
  - Web (height – thickness)

- 16 specimens
Battery test

- Flange
  - Height 120-220
  - Thickness 12-20

- Web
  - Height 350-500
  - Thickness 8-12

16 cases

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Battery test conditions

- Same longitude
- Same loads
- Same conditions

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Numerical simulation

- General thermo-mechanic code
- Thermo-metallurgy coupling
- Sequential thermometallurgy-mechanical calculation
- Elastic-plastic with *kinematic hardening* and *Von Mises* formulation
- Transient calculation
- Material properties changing with temperature and phase
Test 1

- Geometry: 8x350 – 12x120 – 6000mm
- Heat input: Goldak approximation – double sided welding
- Clamp condition: free
- Cooling: convection and radiation
Numerical simulation in welding process

Test 1

- Solid mesh highly optimized, but dense
- Hexahedral elements, 56000
- Good thermal trend, thermocam validation
- Good trend, saddle shape
Test 1

- Solid mesh highly optimized, but dense
- Hexahedrons elements, 56000
- Good thermal trend, thermocam validation
- Good trend, saddle shape

- Over one week CPUclock
Numerical simulation in welding process

Model simplification necessary

Thermometallurgic-elasticplastic

- Transient evolutive analysis
- Non linear
  
  Geometry
  Material properties
  Loads & boundaries

Distortion

- Temperatures & phase proportion
- Stress
- Strain
- Plasticity
- Displacements = Distortion

Simplified method

- Macrosteps formulation
- Elastic linear or non linear geometry
- Shell elements: connector or whole model
- No thermal calculation

Distortion

- Sub-structuring
- Inherent strains
- Local-Global
- Shrinkage
Numerical simulation in welding process

Sequence of modeling

Geometry models for 1-16 cases

Assembly

Calculation

Global geometry models for 4 cases (no-thickness)

Thermal calculation

Mechanical calculation

Postprocessing
Solid VS simplified Shell methodology comparison

- Vertical deflection comparison
  - Right Solid, left Shell
  - 56000 Vs 5000 elements

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Numerical simulation in welding process
Results

Vertical deflection comparison

\[ f = 0.335 \times \eta \times \left( \frac{q}{v} \times \frac{\alpha}{pc} \times \frac{y}{J} \times \frac{L^2}{8} \right) \]
Numerical simulation in welding process

Results

Vertical deflection linearization

\[ y = 6 \times 10^6 x + 0.7481 \]

\[ R^2 = 0.8731 \]

Okerblom model

\[ f = \frac{Q}{J} \]
Numerical simulation in welding process

Sequence results
Deflection comparison

Sequence comparison

Maximum vertical deflection [mm]

Transversal deflection and maximum transversal deflection [mm]
Conclusions

1.- After the performed studies, the selected mathematical models can get the distortion's effect in a right way.

2. – The complex model can not be used in big assemblies due to high time of computation.

3.- Due to economization of time, a simplified method is used. Their accuracy after calibrations is good and it become useful with their low time of computation.

4.- The results compared, under the fixed conditions, shows a great agreement between three methodologies. The trends are similar showing a good behaviour.

5.- The Okerblom analytical model shows a great performance but it is limited to simple joints.

6.- Sequence study is possible in simulation methodology.

7.- Simultaneous welding is useful because it improves the time process.

8.- The welding with a bead in continuous reverse welding is a better choice, showing less vertical deflection, low transversal deflection as well as easy and quickly process for two welders.
Thank you for your attention