20 years of methodologies applied to the welding of large components

F. Boitout (ESI Group), Ph. Mourgue (ESI France)
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Introduction

Welding simulation: Treasure hunting, Graal quest?

• Welding simulation in its 30ies:

• The needs are there:
  ‣ Worldwide competition
  ‣ The profits are done with added value parts

• The means are almost available
  ‣ Computer power
  ‣ Dedicated software
  ‣ Knowledge (methods)

• Next years challenge: Impact of manufacturing on service life of components and assemblies.
Physics should not be a bottleneck
What is a large object?

From the eyes of a welding simulation persona

- Components size
  - Nuclear component
  - BIW
  - ...

- Welding length
  - Multipass
  - Additive Manufacturing

- Large components with long welds
  - Heat exchanger
  - Turbines
  - Complex designs (Iter Vacuum chamber, ships, cars...)

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What is expensive?

• Model description:
  ‣ CAD 2 Mesh
  ‣ Process definition

• Solution:
  ‣ Physics:
    • Heat transfer
    • Metallurgy
    • Mechanical
    • ...  
  ‣ Numeric
    • Element types
    • Coupling or chaining?
    • Methods
  ‣ Solving

• Analysis of results
  ‣ Extract information: \( G(\text{Stress, strain, temperature, internal var...}) = F(X, t) \)
  ‣ Virtual reality visualization tools
Example: Service life assessment of a welded large component

- Pre-heat to 160°C
- Deposit Cladding Layer
- Deposit Buttering Layer
- Post Weld Heat Treatment for Stress Relief
- Root pass of Groove Weld
- Continue Groove welding until all beads are deposited
- Release Clamps
- Post-weld Machining of Groove weld

**Service Cycle (Temperature, Pressure)**
1: Be simple

Keep It Simple Stupid (KISS)

• 2D models
  ‣ Multi-pass
• Welding of shells 2.5 D
  ‣ Automotive
• (Pass grouping)
  ‣ Multi-pass in 3D
• (Super-elements)
  ‣ Turbines
• Inherent strain and Thermal cycle methods
  ‣ Very Large components
Transient Welding Modeling
Process optimization for Multi-Pass Welding of thick components

Phase III – NGNN Analysis Results

Baseline

Alternative Design 1

Alternative Design 2

Alternative Design 3
Welding of shells 2.5D

Simplified methodologies (automotive)

Detail Design
10 Hours
DMP 10 CPU

Early feasibility
15 Minutes
DMP 10 CPU

Distortion Comparison
2: Be specific
Usage of the welding process specificities

• Stationary process
  ‣ Steady state computation
    • Ariane tank

• Local process: Local-global methods
  ‣ DSIGN project 1998-2001:
Local-Global method
ITER Vacuum chamber
Fig. 1 The fusion reactor and the vacuum vessel with zone for the full-scale model

Fig. 3 The PS1 main manufacturing sequences

Fig. 4 The PS2 main manufacturing sequences

Fig. 6 PS2 (inner shell) local and global models

Fig. 7 PS2 (outer shell) local and global models
Fig. 8 Comparison of measured and computed shrinkages after PS1 welding

Fig. 9 Comparison of measured and computed shrinkages after PS2 outer shell welding

Fig. 10 Comparison of measured and computed shrinkages after PS2 inner shell welding

Fig. 5 PS1 local and global models
3: Be an applied mathematician

Use numerics

- Explicit formulation
  
  IMPLICIT: CPU \sim 2h DMP8

- Multiscale
  - Local mesh refinement

Mathematical expressions:

- \textbf{Phase de soudage}
  - Facteur échelle temps mécanique $\times 1000$
  - CPU : DMP32 = 35min
  - Memoire = 14Mb

- \textbf{Phase de soudage}
  - Facteur échelle temps mécanique $\times 10\,000$
  - CPU : DMP32 = 10min
  - Memoire = 14Mb
4: Be a computer power user

Moore law

• Parallelization
  ‣ SMP/DMP
    • Speed-up
  ‣ Solvers (direct/iterative)
    • “robustness” vs RAM consumption
  ‣ GPU
  ‣ ...

Mechanical Computation
Don’t forget the analysis..
Virtual reality 3D for Assembly
Conclusion

• Remark 1:
  ‣ All models are made more and more complex until they reach the limits. *Engineers have a tendency to try to push the envelop (even if it is not necessary).*

• Remark 2:
  ‣ The limit of a chain is the limit of the weakest part. Welding of large components limitation is not necessarily the *solving* limit.

• Remark 3:
  ‣ Welding simulation has greatly improved in 30 years, the challenge is not anymore simulate the welding operation, but the full manufacturing itself. The skill of the engineer is still a *must-have* to select methods and assumptions with a global vision.
THANKS
Papers

• Modelization of Residual stresses in Aluminum welded joints, J.P. Bonnafé, C. Destandau, Aérospatiale Les Mureaux, France, 25-28 September 1995