Linear Friction Welding of Aeronautical alloys: Modeling and Numerical Simulation

A. Potet*, K. Mocellin, L. Fournier
*antoine.potet@mines-paristech.fr
MINES ParisTech, PSL Research University, CEMEF, CNRS UMR 7635

Purpose

Providing an efficient LFW thermomechanical simulation tool

Challenges

- Predictive simulation (friction force, shortening, temperature)
- Complex geometries (L and T shapes)
- Welding of dissimilar materials

Intended usages of simulation tool

- Process design
- Microstructure prediction from thermomechanical history

Thermo-mechanical coupled process

\[ \rho \frac{d\dot{v}}{dt} = -\nabla p + \nabla s \]
\[ \rho c \frac{dT}{dt} = \nabla \cdot \dot{\gamma} \dot{V} + r \]

Full 3D, entire process simulation

Forge® solver
- (metal forming framework)
- Implicit formulation
- Updated lagrangian
- (v-p) based formulation
- Remeshing

Material model

Considered material

T6244, TA6V, Ti17, Inconel 718

Experimental conditions

- Temperature: 20 – 1200°C
- Strain: 0 – 50
- Strain rate: 0 – 500 s⁻¹

JMatPro®-based elasto-viscoplastic material

Friction model

Modeling challenge

- Friction model is critical but unknown

Proposed solution: Inverse analysis from recorded real-process data

Results presented here are based on a Coulomb model

\[ \tau = -\mu \Delta \frac{\Delta \tau}{\Delta \sigma} \]

LFW simulation

2 bodies model

- Friction/contact model
- Sensitivity to contact algorithm
- New surface smoothing algorithm

Symmetric bodies model

- Friction/contact model
- Simplified to friction against rigid body

Perfect weld model

- Assumption of a perfect weld
- Can simulate the end of the process
- No friction / perfect contact
- Requires initial temperature distribution

Process insights

- Purely surfacic to volumic heat generation transition
- Relative irrelevance of heat exchange model with air and clamps

Numerical challenge

- Surface phenomena are dominant
- Locally refined mesh must be used to ensure accuracy

Proposed solution: Mesh adaptation

Experimental Measurements

- LFW process measures* dedicated to:
  - Friction model calibration
  - Model validation
  - Machine built-in upset and global friction force monitoring
  - K-type thermocouple measurements

*Processes were realized with ACB machine and expertise

Acknowledgements

Authors would like to thank UPMC/UMI project partners - ACB, Airbus Group, LTC and CDM for their implication and support.

Bibliography