Linear Friction Welding of Aeronautical alloys Modeling and Numerical Simulation

Antoine Potet, Katia Mocellin, Lionel Fourment

Linear Friction Welding of Aeronautical alloys Modeling and Numerical Simulation

A. Potet*, K. Mocellin, L. Fourment
*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

Project partners

LFW machine designer

Aircraft Manufacturer

Material Science Research Laboratory

Material Science Research Laboratory

Thermo-mechanical coupled process

$$\rho\frac{dv}{dt} = -\nabla p + \nabla . s$$

$$\rho c\frac{dT}{dt} = \nabla . \lambda \nabla T + r$$

full 3D, entire process simulation

Forge® solver
(metal forming framework)

- Implicit formulation
- Updated lagrangian
- (v-p) based formulation
- Remeshing

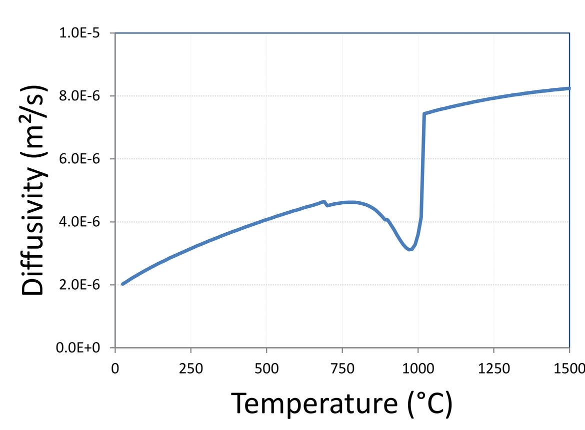
Material model

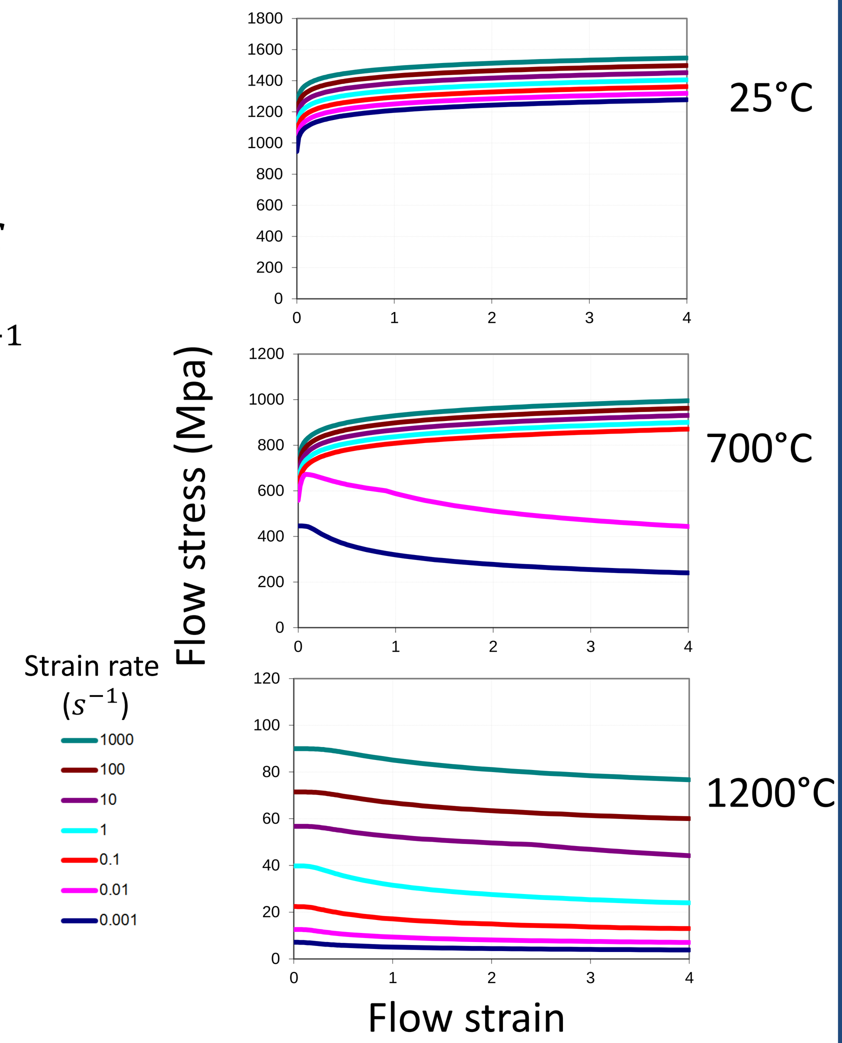
Considered material
Ti6242, TA6V, Ti17, Inconel718

Experimental conditions

- Temperature : $20 - 1200°C$
- Strain : $0 - 50$
- Strain rate : $0 - 500\ s^{-1}$

JMatPro ® -based elasto-viscoplastic material





Friction model

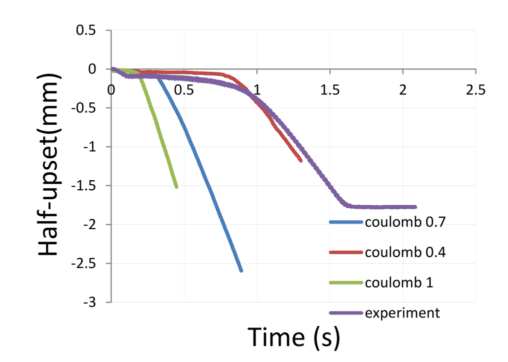
Modeling challenge

- Friction model is critical but unknown

Proposed solution : inverse analysis from recorded real-process data

Results presented here are based on a Coulomb model

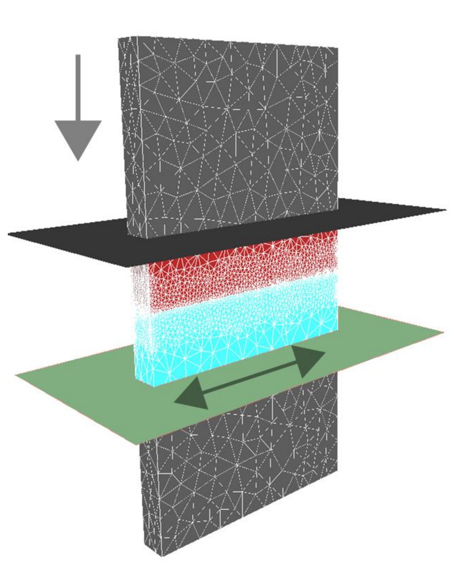
$$\tau = -\mu\sigma_n\frac{\Delta v_t}{|\Delta v_t|}$$



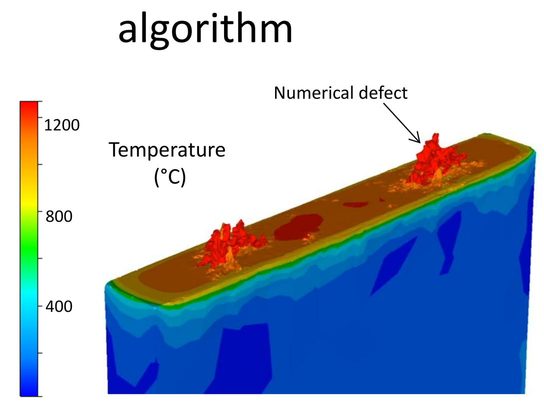
Friction Coulomb coefficient influence
On shortening

LFW simulation

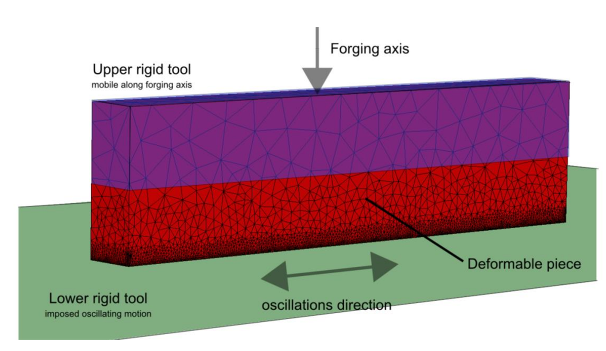
2 bodies model



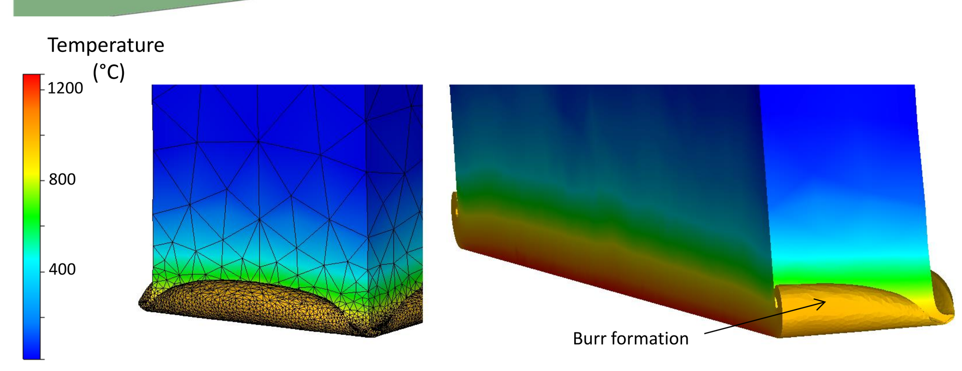
- friction/contact model
- Sensitivity to contact algorithm
- New surface smoothing algorithm



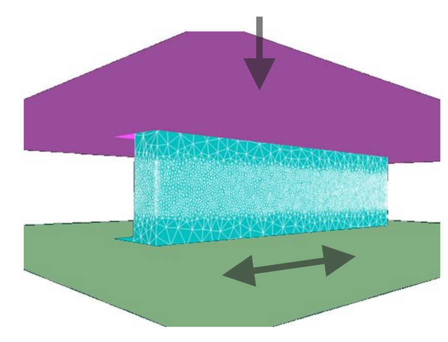
Symmetric bodies model



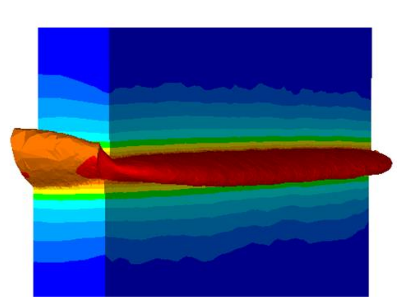
- friction/contact model
- Simplified to friction against rigid body

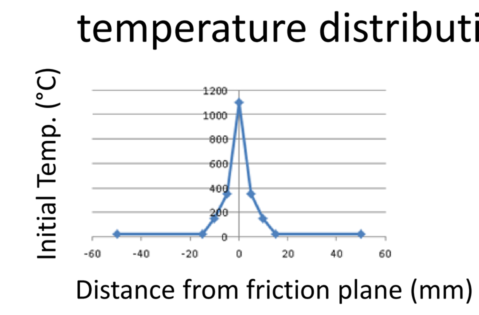


Perfect weld model



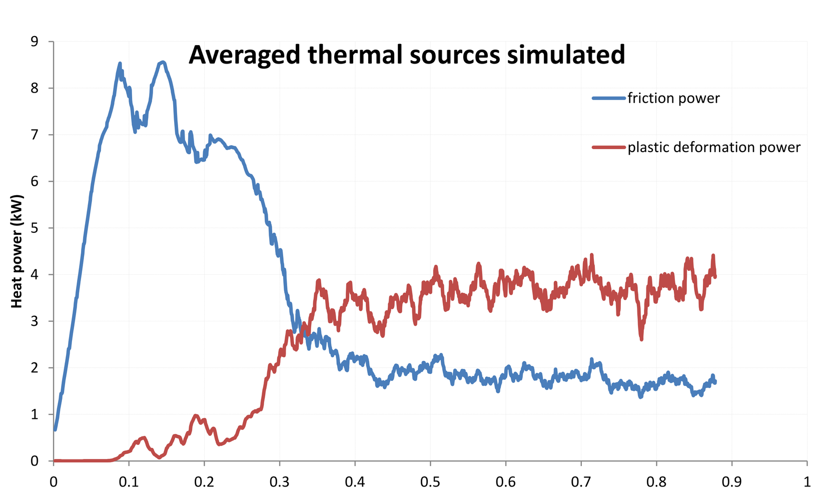
- Assumption of a perfect perfect weld
- Can simulate the end of the process
- No friction / perfect contact
- Requires initial temperature distribution

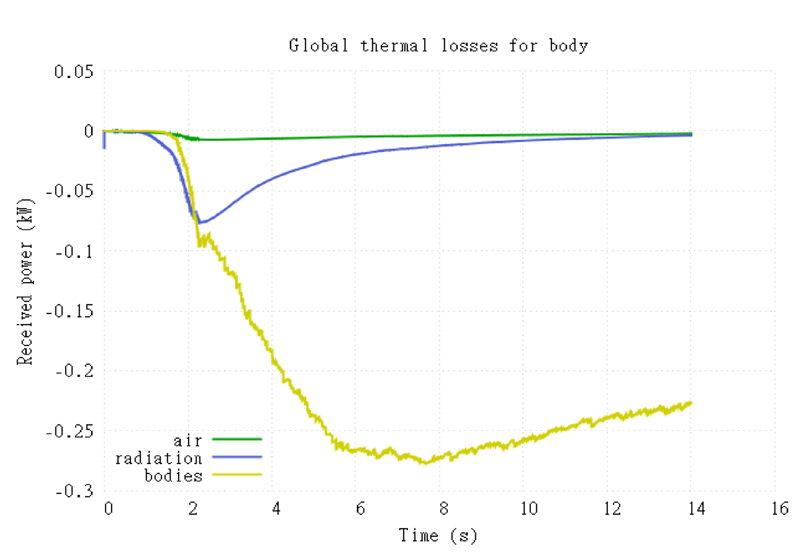




Process insights

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

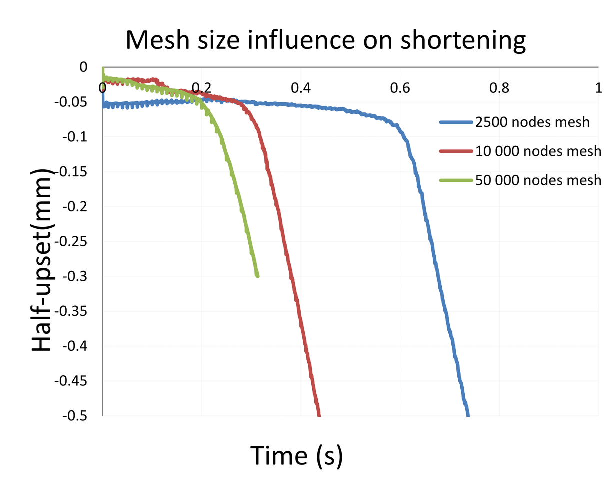




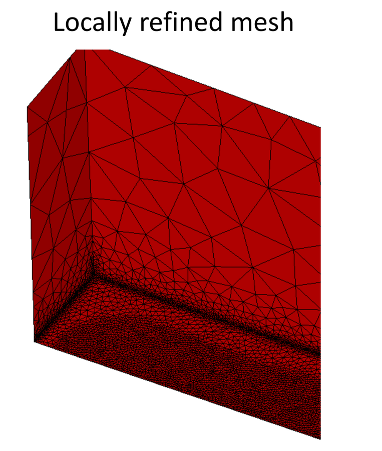
Numerical challenge

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

Proposed solution : Mesh adaptation



Locally refined mesh

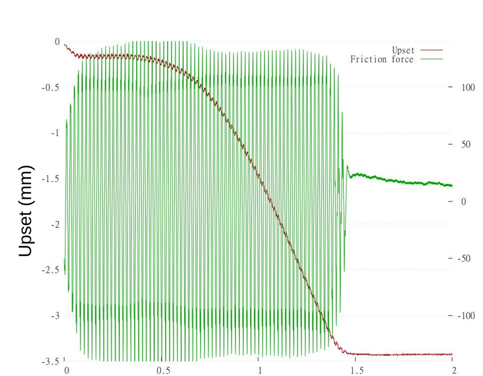


Experimental Measurements

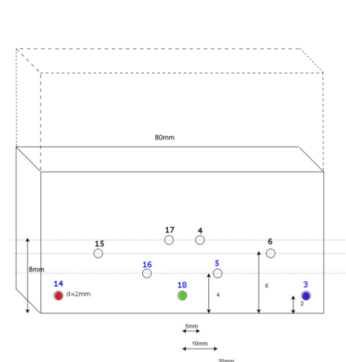
LFW process measures*
dedicated to

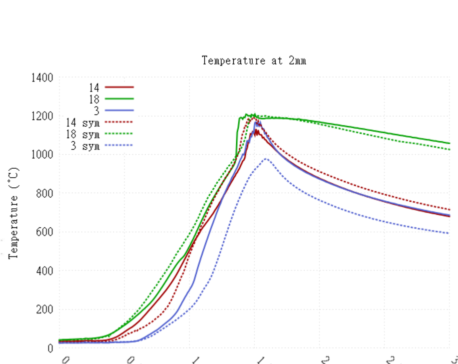
- friction model calibration
- model validation

*Processes were realized with ACB machine and expertise



Machine builtin upset and global friction force monitoring





K-type thermocouple measurements

Bibliography

1. P. Wanjara, and M. Jahazi, , Metallurgical and materials transactions, **36A,8**, 2159-2164 (2005)
2. MTU Aero Engines, Munchen; 'Military Engines', Public Relations, March 1999.
3. A. R. McAndrew, P. A. Colegrove, A. C. Addison, B. C. D. Flipo, M. J. Russell, and L. A. Lee. MATERIALS & DESIGN, **87**, 1087-1099 (2015).
4. R. Turner, J. C. Gebelin, R. M. Ward, and R. C. Reed. Acta Materialia, **59,10**,:3792-3803(2011).
5. A Vairis and M Frost. Wear, **217,1**, 117-131(1998).
6. Garcia, A. M. M. (2011). “Blisk fabrication by linear friction welding advances in gas turbine technology” in *Advances in Gas Turbine Technology* edited by Dr. Ernesto Benini (InTech, 2011). pp. 411-434.
7. Guo,Z.,Turner,R.,DaSilva,A.D.,Sauders,N.,Schroeder,F.,Cetlin,P.R.,and Schille,J.-P. Physical and numerical simulation of materials, **762**, 266-276(2013).
8. A Vairis and M Frost. Materials science and engineering, **292,1**, 8-17(2000).
9. P. Zhao, L. Fu, and D. Zhong. Computational materials, **92**, 325-333(2014).

Aknowledgements

Authors would like to thank OPTIMUM project partners : ACB, Airbus Group, UTC and CDM for their implication and support.