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Linear Friction Welding of Aeronautical alloys Modeling and Numerical Simulation

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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

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

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

full 3D, entire process simulation

Forge® solver

(metal forming framework)

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



Material model

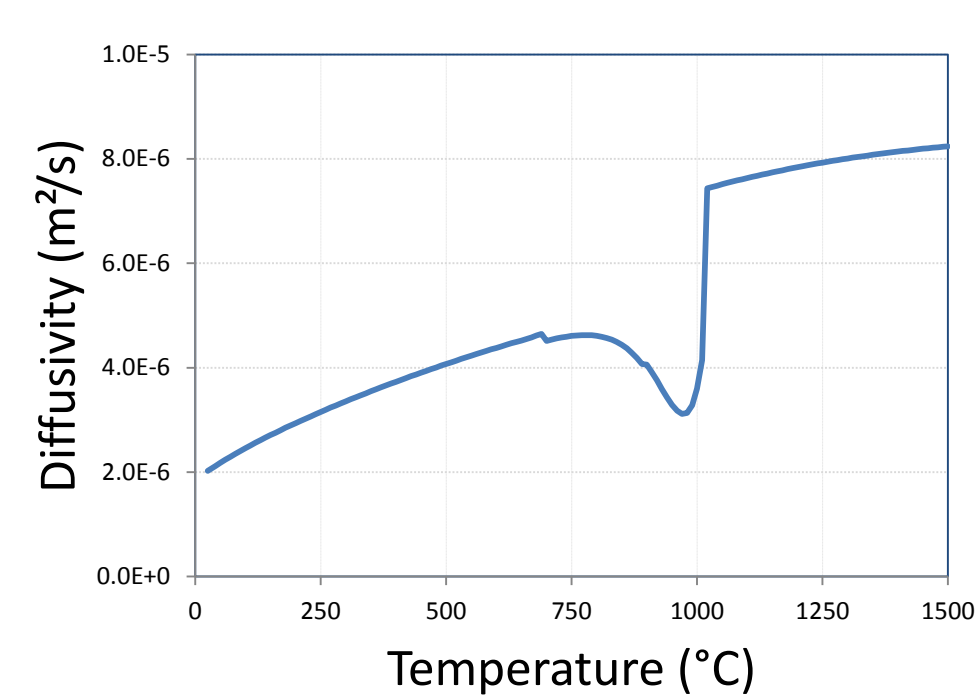
Considered material

Ti6242, TA6V, Ti17, Inconel718

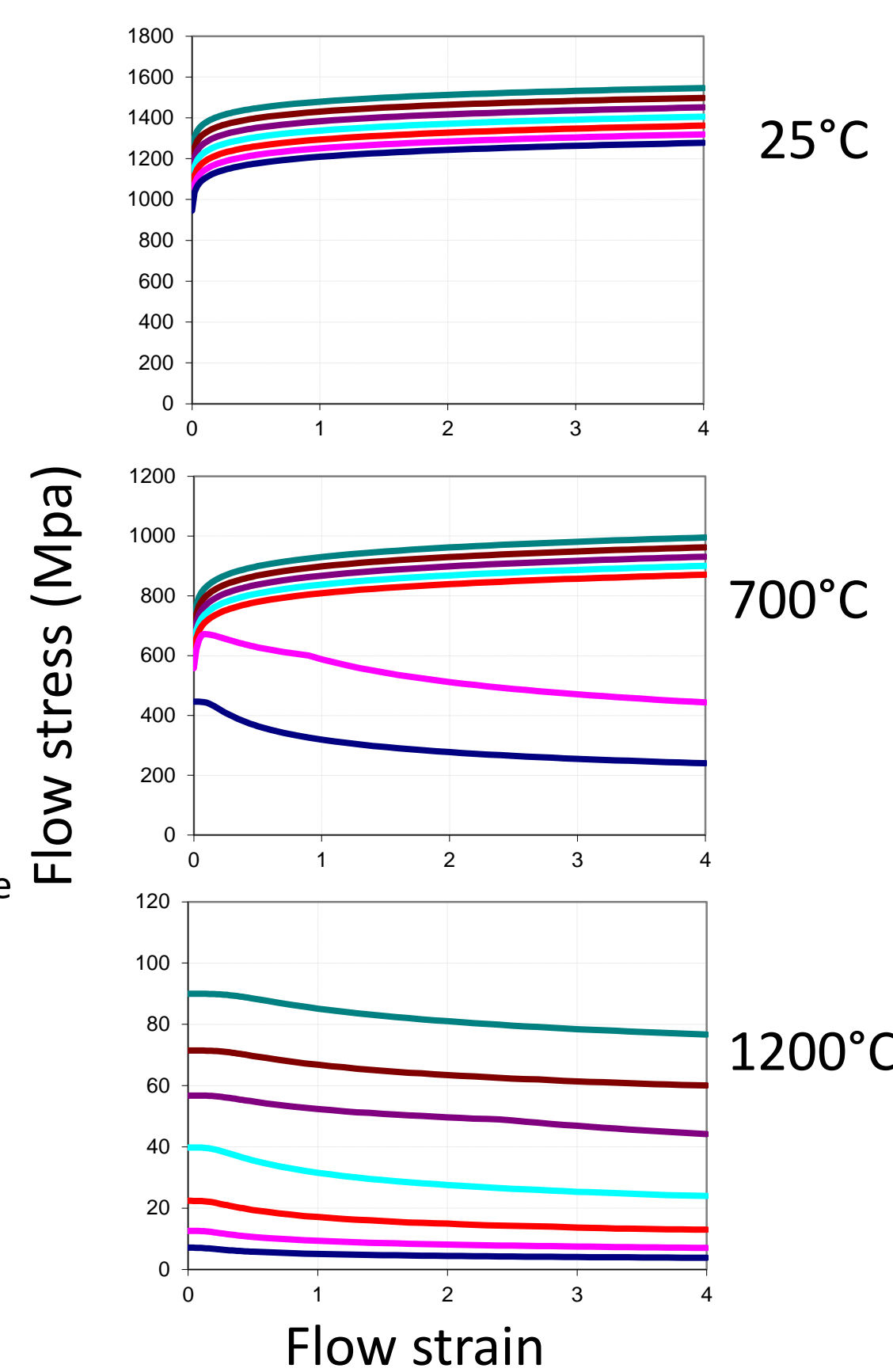
Experimental conditions

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

JMatPro® -based elasto-viscoplastic material



Strain rate (s⁻¹)



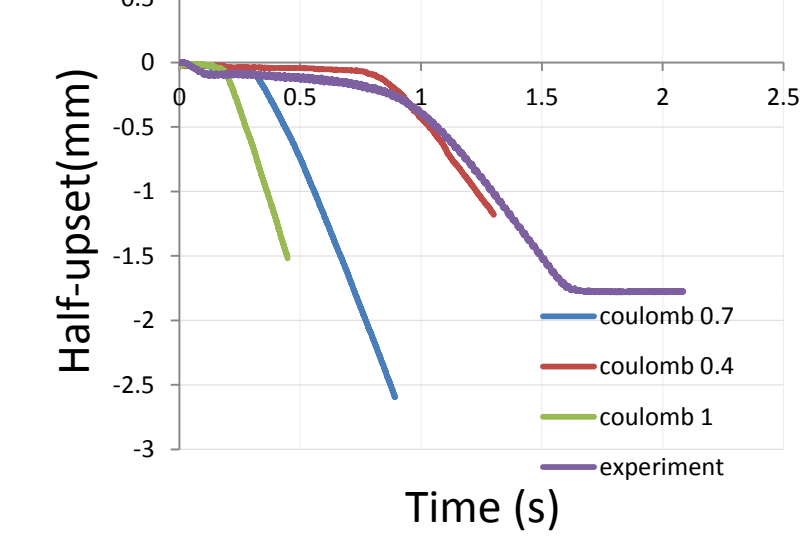
Friction model

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

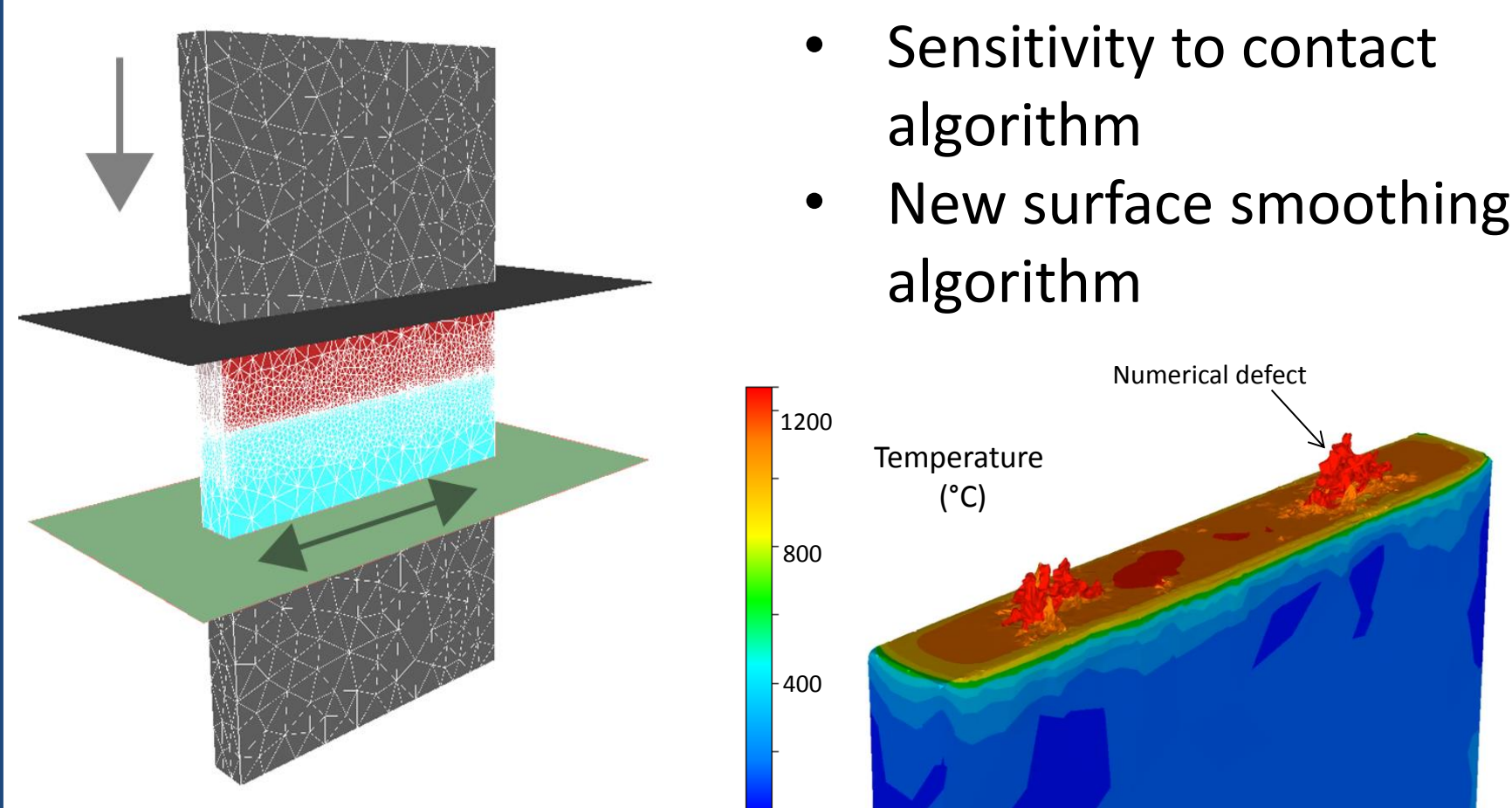
$$\tau = -\mu \sigma_n \frac{\Delta v_t}{|\Delta v_t|}$$



Friction Coulomb coefficient influence On shortening

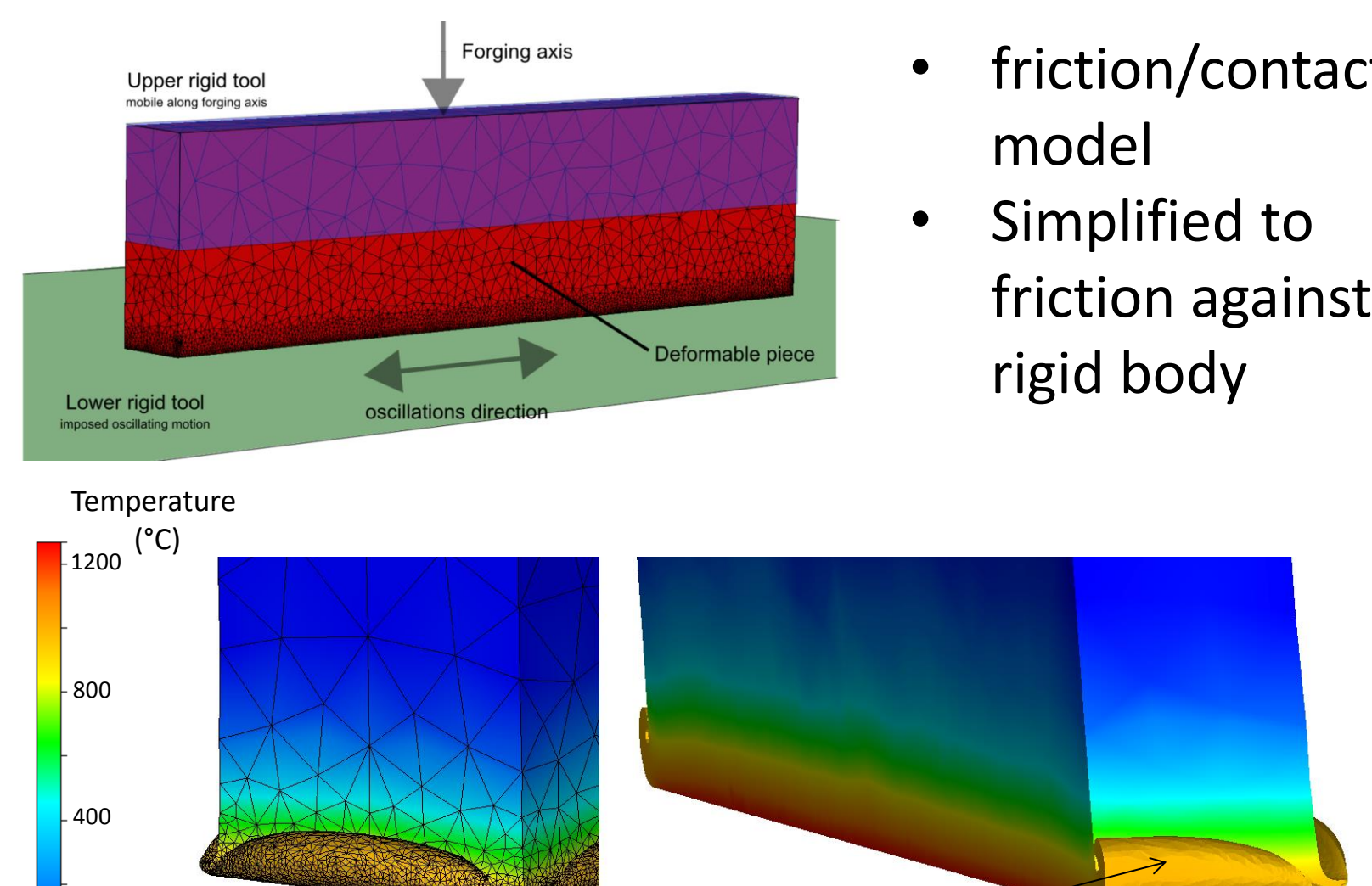
LFW simulation

2 bodies model



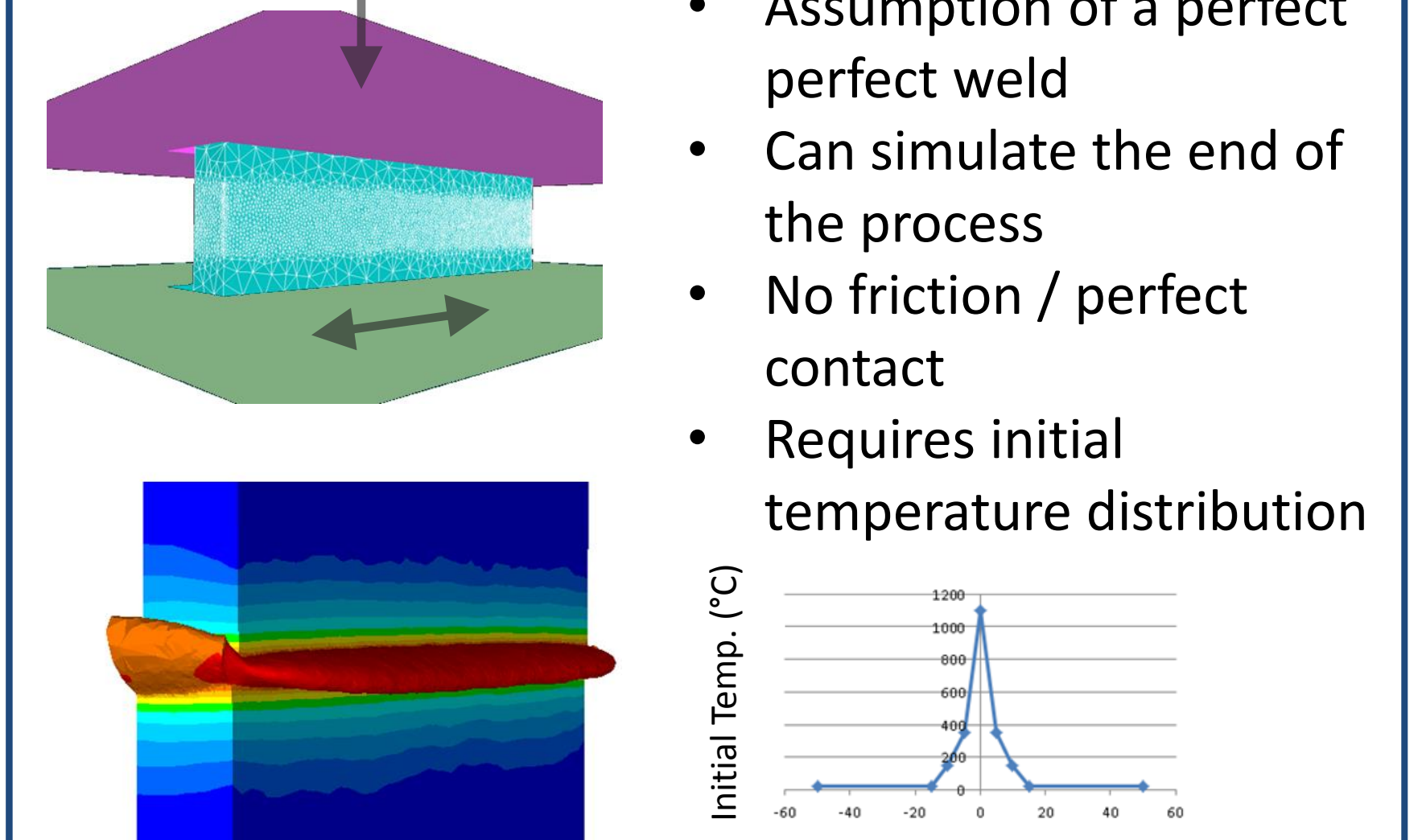
- friction/contact model
- Sensitivity to contact algorithm
- New surface smoothing algorithm

Symmetric bodies model



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

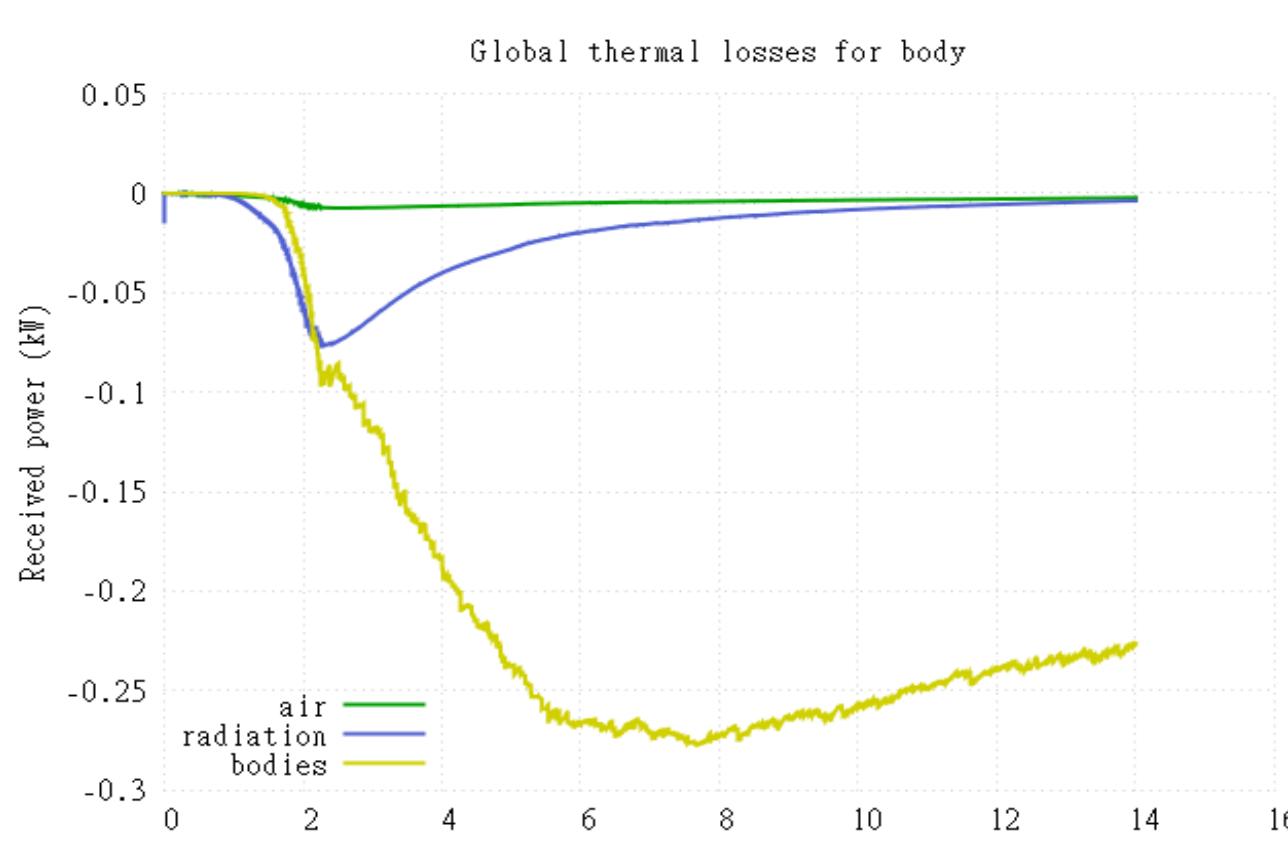
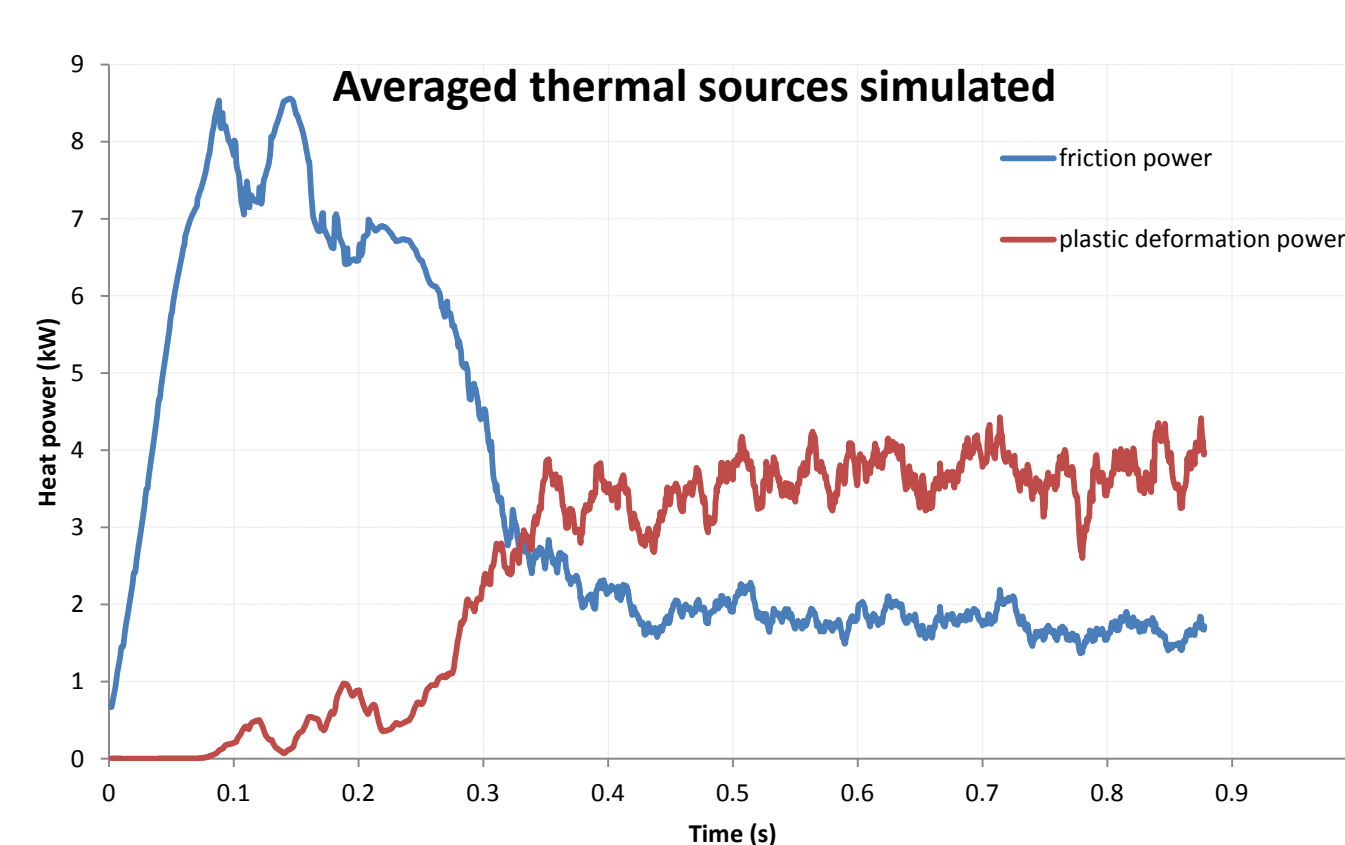
Perfect weld model



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

Process insights

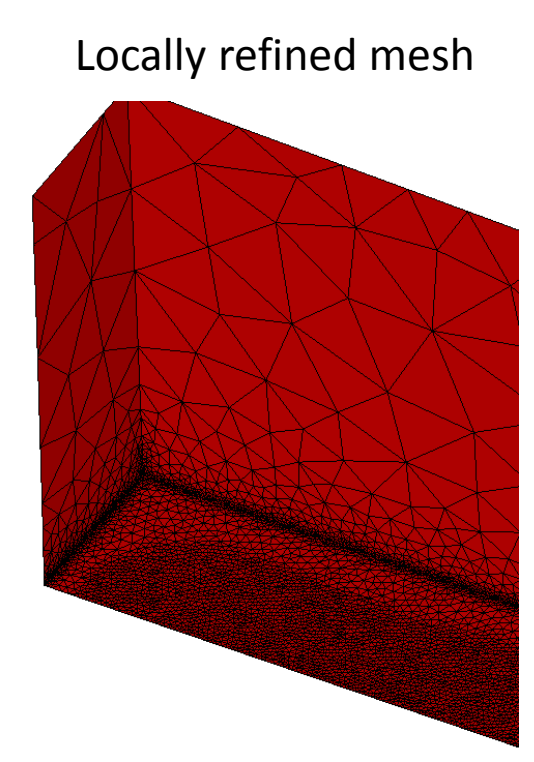
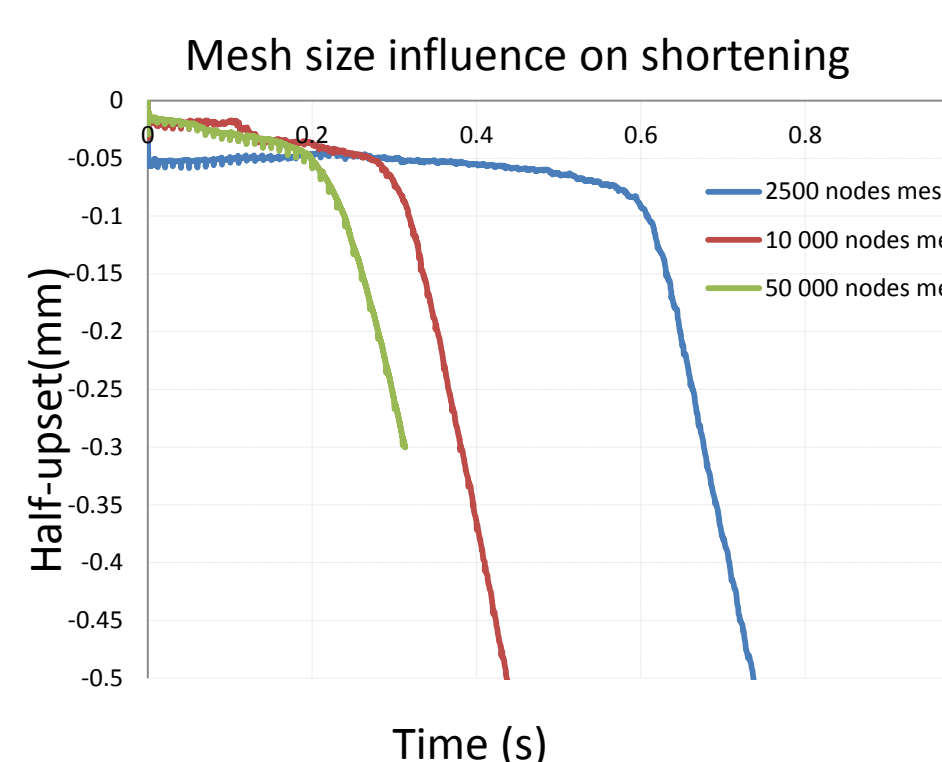
- Purely surfacic to volumic heat generation transition
- Relative irrelevance of heat exchange model with air and clamps



Numerical challenge

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

Proposed solution : Mesh adaptation

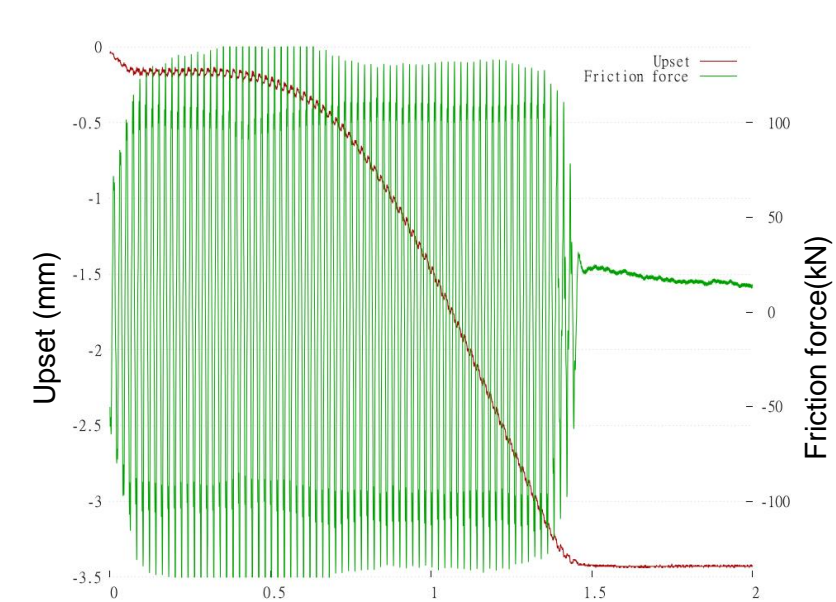


Experimental Measurements

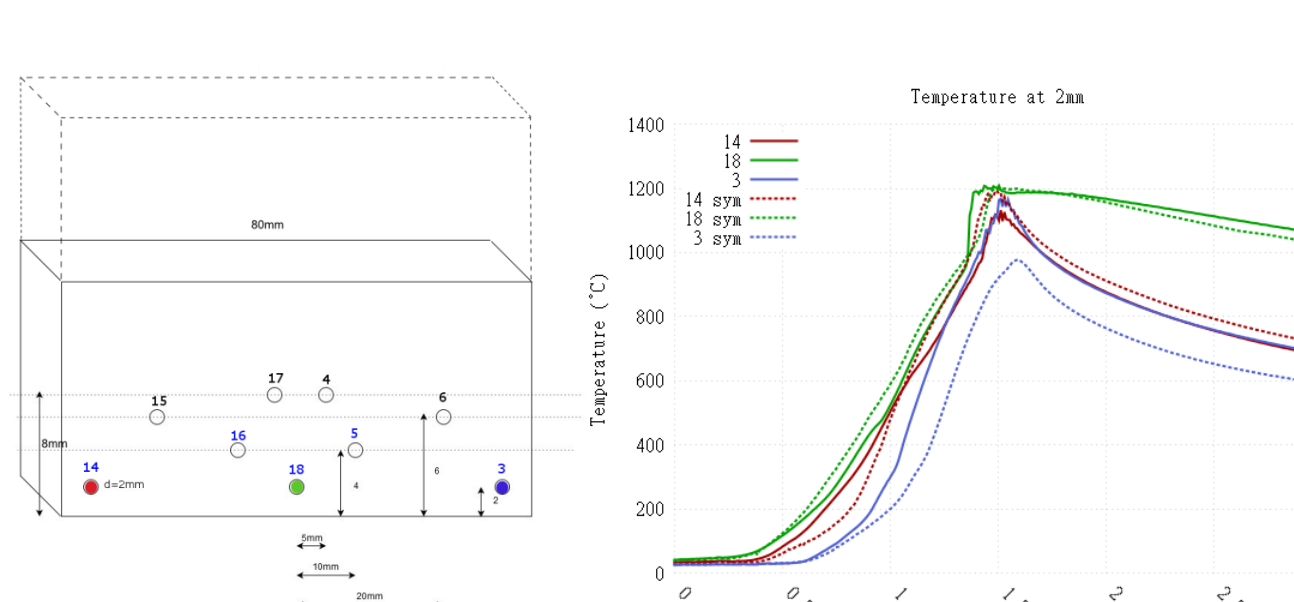
LFW process measures* dedicated to

- 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

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