# Element activation strategy for Additive Manufacturing, based on the element deletion algorithm

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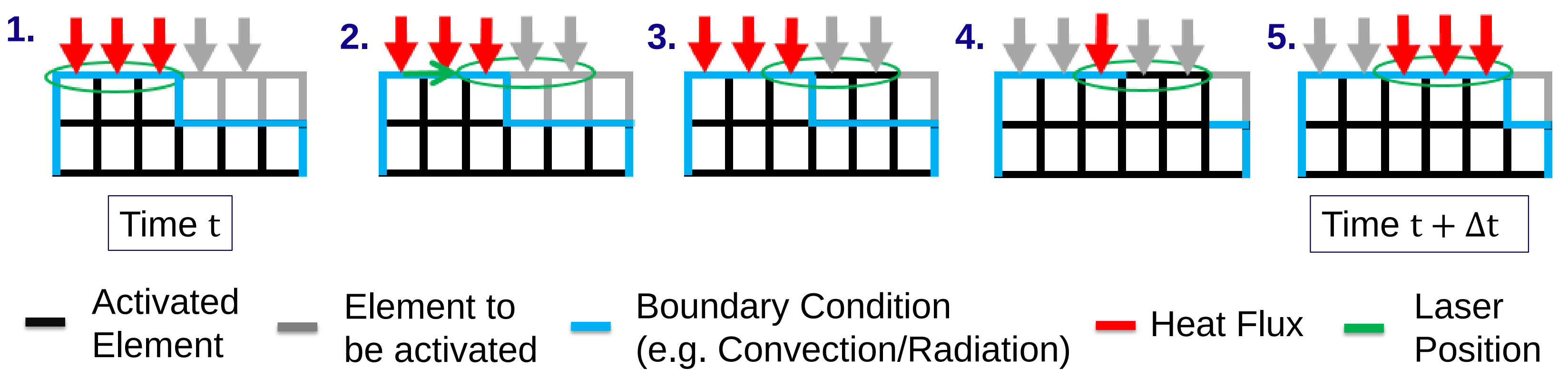
## Context and challenges

- ❑ This work consists in improving the **3D thermal Finite Element Analysis** of a **additive manufacturing process** in the fully **implicit** in-house Finite Element code "**Metafor**" [1].
- ❑ The **challenges** of such a simulation come from multiple sources:
  - ➢ The nature of the process requires a **large deformation thermo-mechanical simulation**;
  - ➢ The modeling of the material law is complex.
  - ➢ The geometry imposes a **very fine discretization** for accurate results.
  - ➢ The process requires **altering the mesh geometry of the model during the simulation** to model the addition of matter.
- ❑ **This work consisted in implementing an element activation method in Metafor inspired by the element deletion algorithm used in crack propagation.**

## Mesh management technique

- ❑ **Finite elements and boundary conditions** (convection/radiation/laser heat flux) are all created at the **start of the simulation** but only enter the computation after their activation (**born-dead elements**).
- ❑ Elements and boundary conditions are **activated/deactivated** based on the **current laser position/mesh geometry** (see below).
- ❑ The method used is **adapted from** the deactivation of elements and boundary conditions used in **crack propagation [2],** instead of having a "crack propagation criterion" we have an **"element activation criterion"** which is for now based on a pre-defined laser position throughout the simulation.

### Computation of new active mesh and boundary conditions

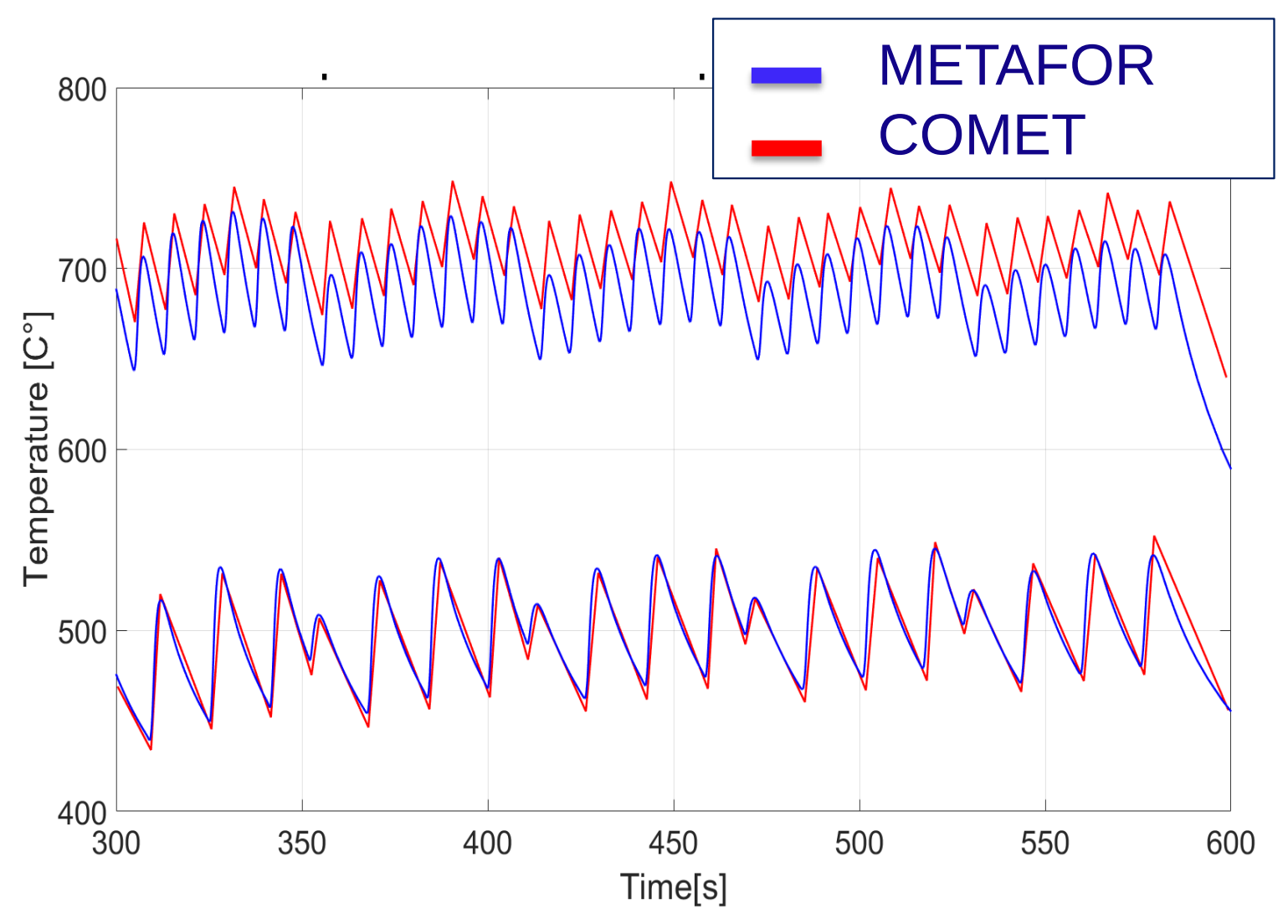


1. Known configuration at time t.
2. Computation of laser position at time t + Δt .
3. Activation of finite elements based on the new laser position.
4. Deactivation of boundary conditions and heat flux based on the new mesh geometry and laser position.
5. Activation of boundary conditions and heat flux based on the new mesh geometry and laser position.

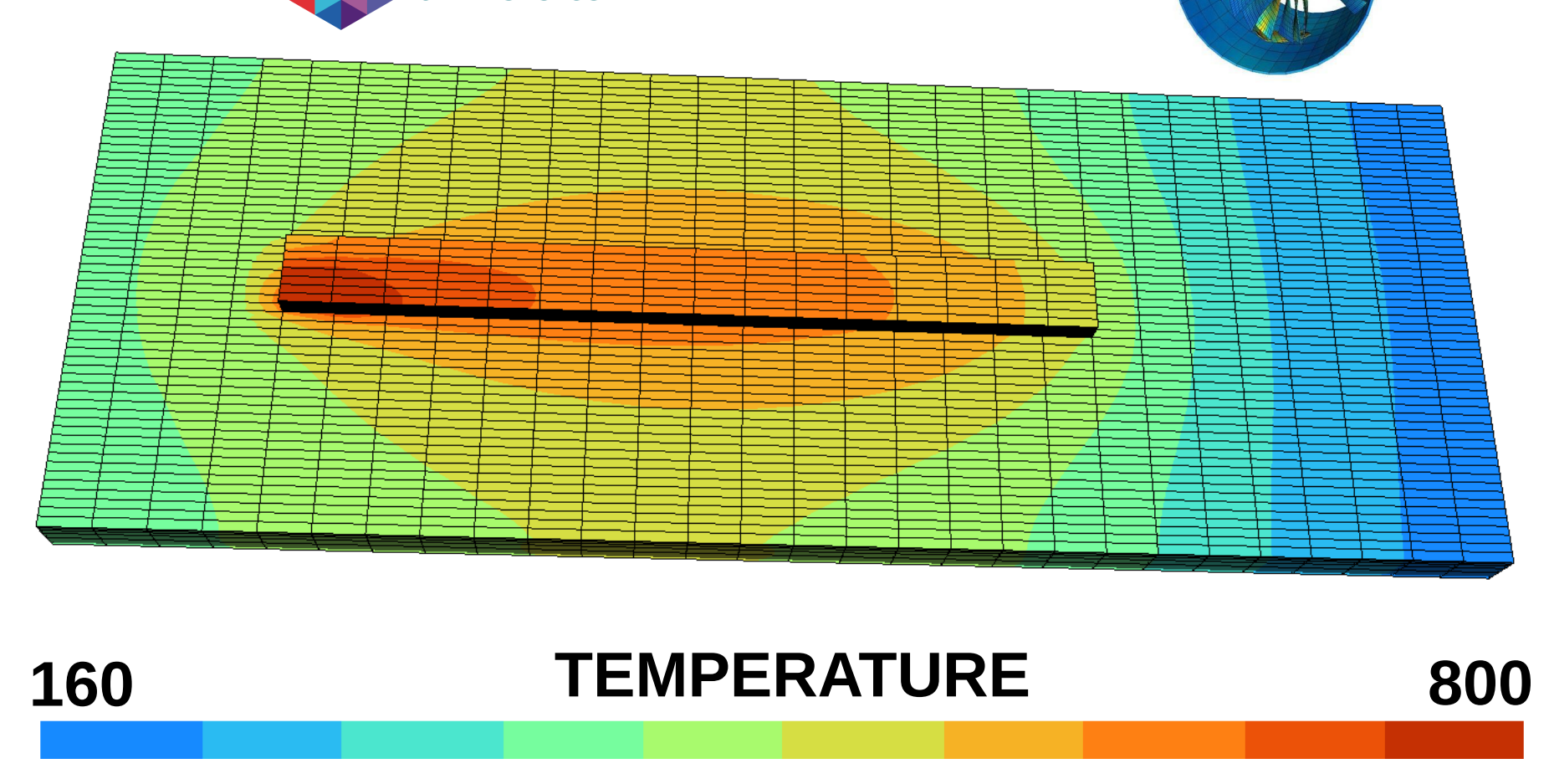
➡ **The user simply needs to define the laser position over time and the software handles the activation.**

## Verification: Test from Chiumenti et al.[3] (Soft: COMET)

### Temperature evolution at 2 Thermocouples: Metafor/COMET

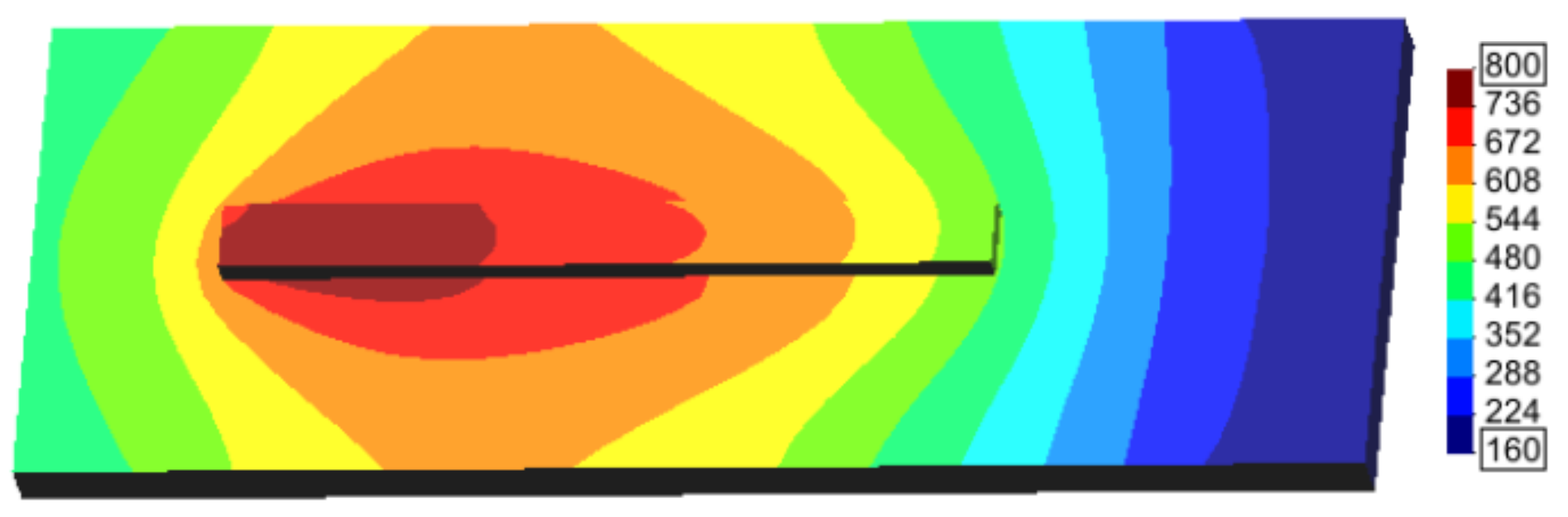


### Final temperature distribution: Metafor



Thermal study of an AM process using Laser Solid Forming of Ti-6Al-4V metal powder

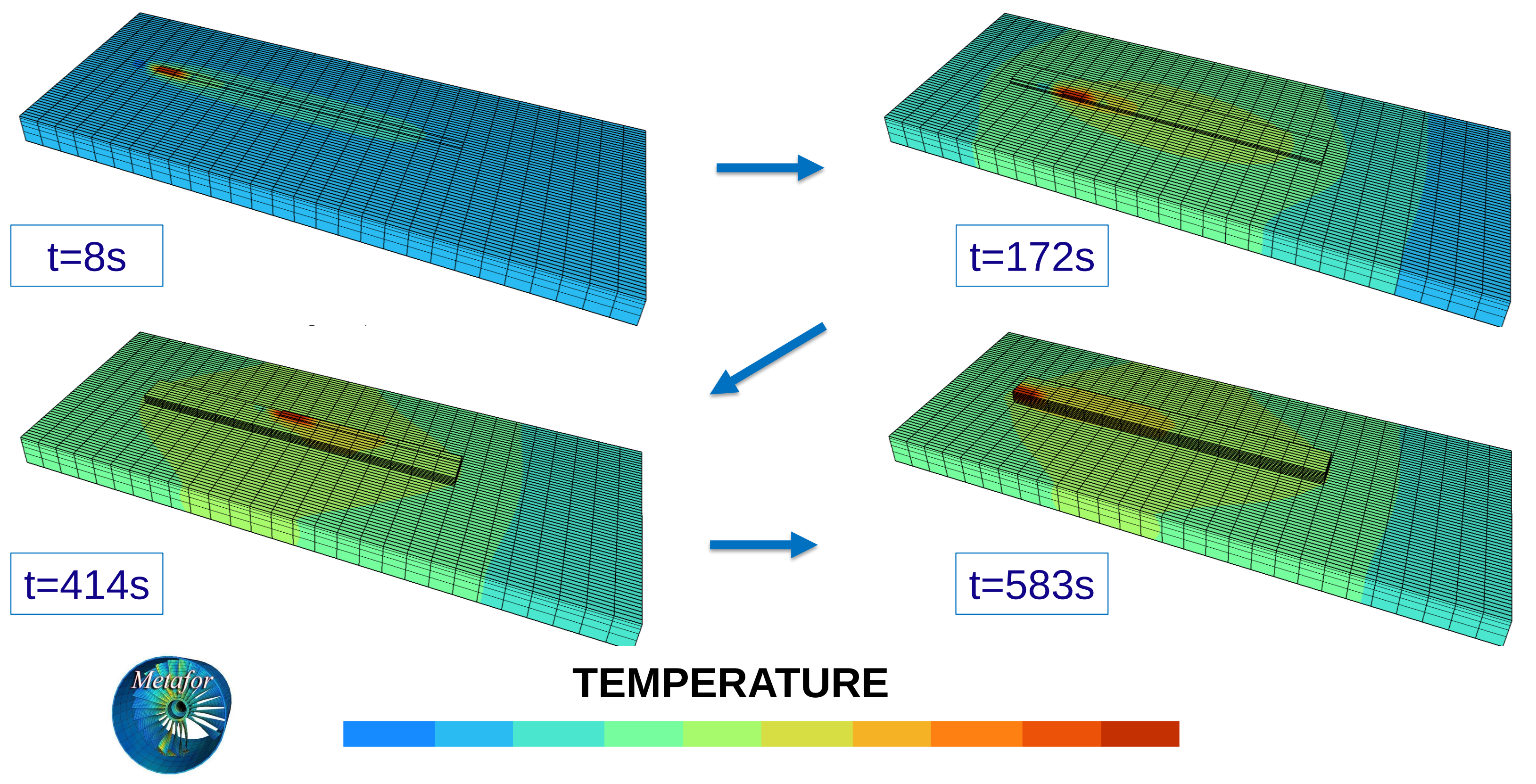
### Final temperature distribution: COMET [3]



**Good agreement of the temperature evolution between COMET and Metafor.**

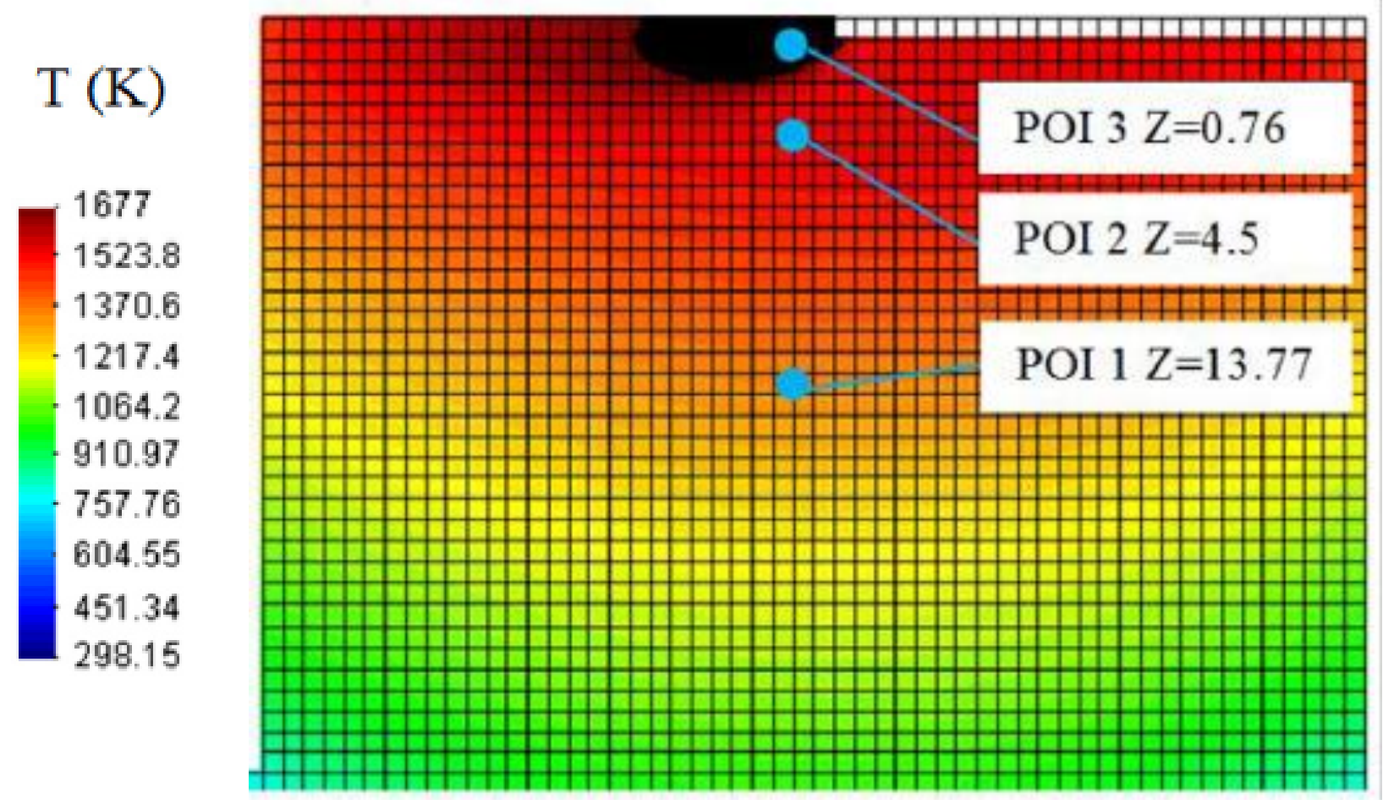
**Both Metafor and COMET could predict the experimental oxidation zone.**

## Time evolution of the process



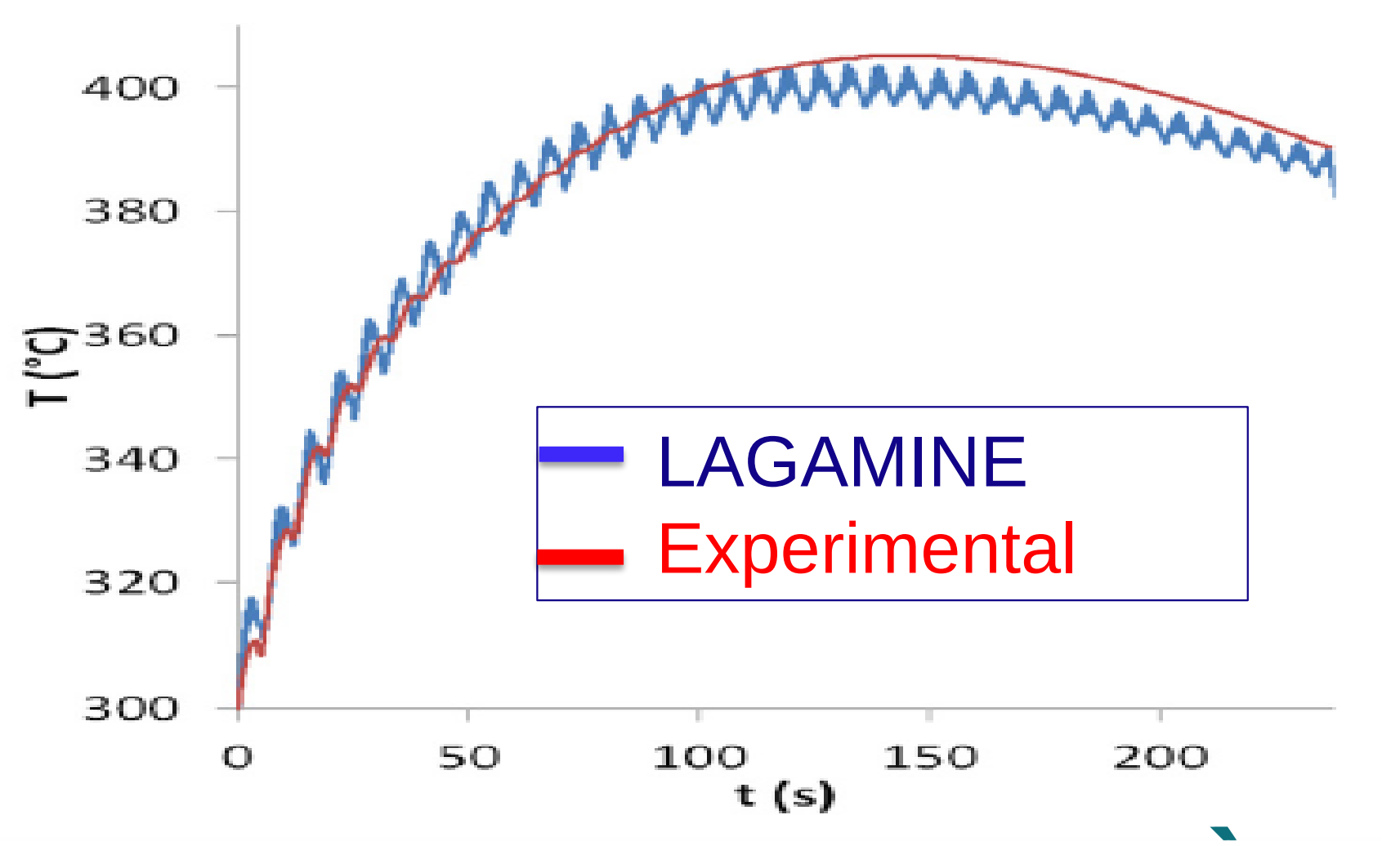
## Ongoing: Test from Jardin et al.[4] (Soft:Lagamine)

### Temperature Distribution [4]

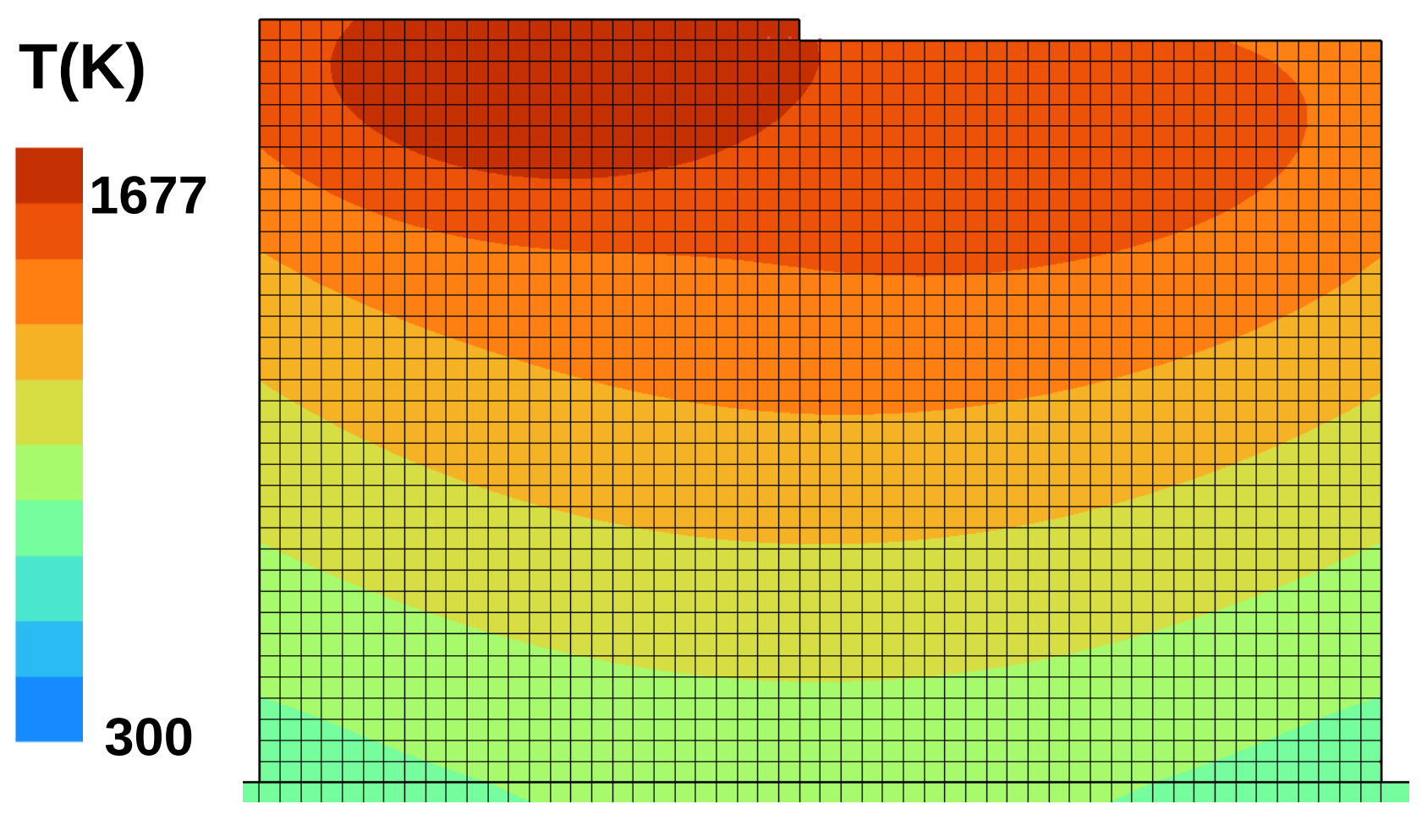


LAGAMINE Software

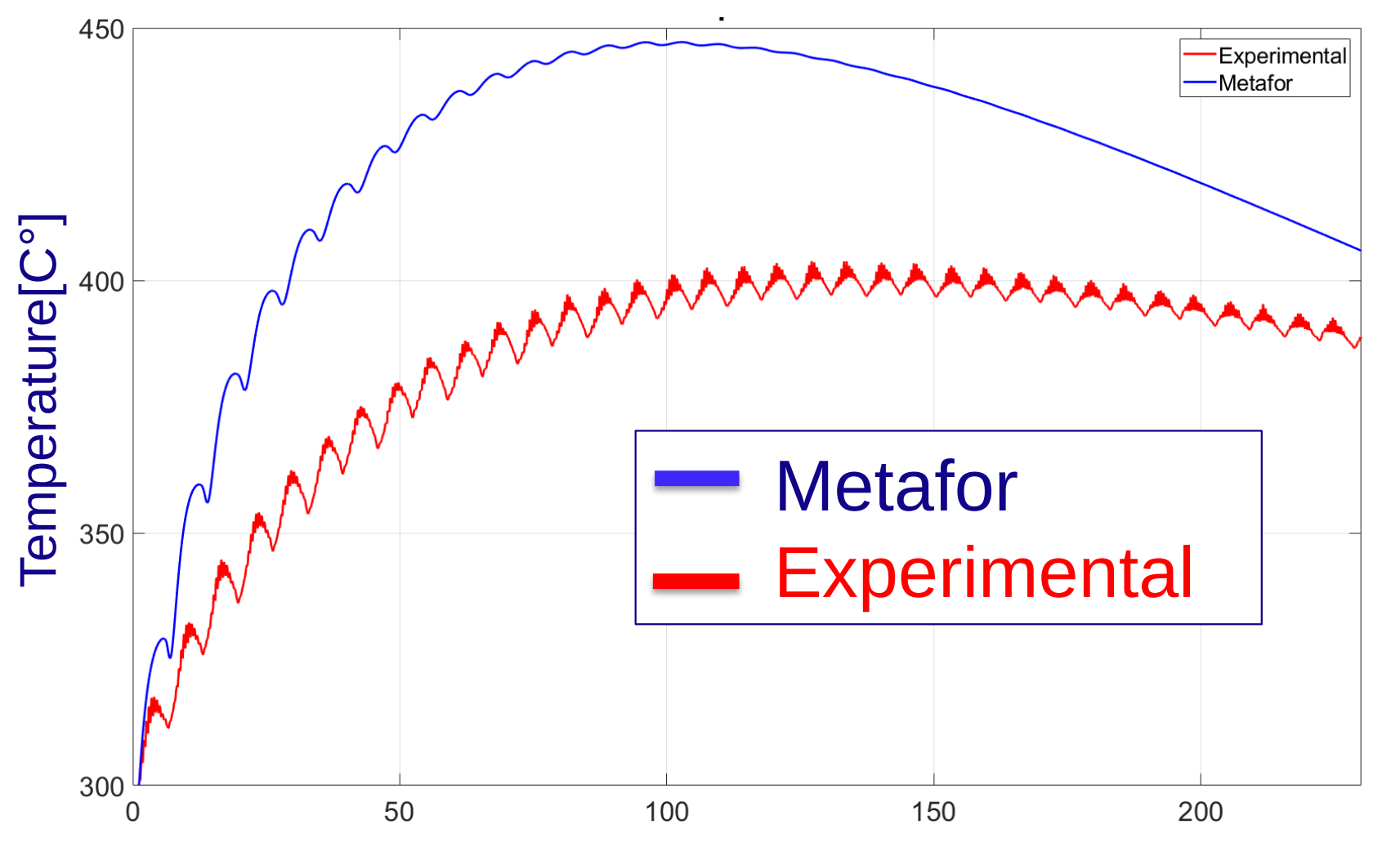
### Temperature evolution [4]



### Temperature Distribution: Metafor



### Temperature evolution: Metafor

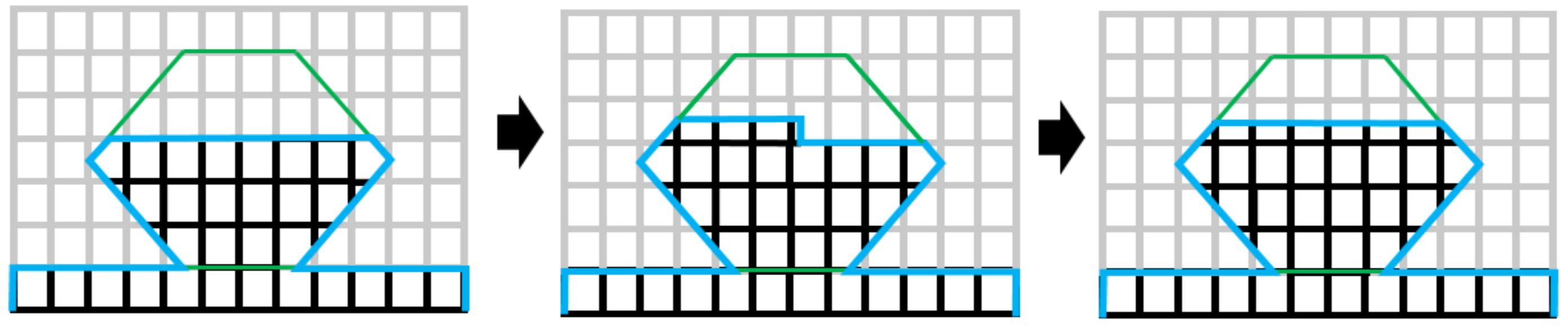


**An investigation of the differences between Metafor and Lagamine is underway**

## Plan for future research

- ❑ **Realise thermomechanical simulations:**
  - ➢ First thermomechanical simulations have already been made.
  - ➢ More implementation is required before validating the model against the literature (e.g. the implementation of a relaxation/annealing temperature in Metafor is required,…)
- ❑ **Improve of the FEM modeling of the mesh/geometry for AM:**
  - ➢ **Implement X-FEM to model the geometry of additive manufacturing processes** to remove the constraint of a very fine mesh imposed by the layer height without loss of accuracy:

**X-FEM for AM:**



## References

[1] J.-P. Ponthot, "Unified stress update algorithms for the numerical simulation of large deformation elasto-plastic and elasto-viscoplastic processes", International Journal of Plasticity. 18 (2002) 91-126.
[2] J.-P. Ponthot, R. Boman, P.-P. Jeunechamps, L. Papeleux, G. Deliége, "An implicit erosion algorithm for the numerical simulation of metallic and composite materials submitted to high strain rate", Proceedings of the Indian National Science Academy. 79/4 (2013) 519-528
[3] M. Chiumenti, X. Lin, M. Cervera, W. Lei, Y. Zheng, W. Huang, "Numerical simulation and experimental calibration of Additive Manufacturing by blown powder technology. Part I: thermal analysis", Rapid Prototyping Journal 23 (2) (2017) 448–463.
[4] Tomé Jardin, R. A., Tchuindjang, J. T., Duchene, L., Tran, H. S., Hashemi, S. N., Carrus, R., Mertens, A., & Habraken, A. (2019), "Thermal histories and microstructures in Direct Energy Deposition of a High Speed Steel thick deposit. Materials Letters,236, 42-45.

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