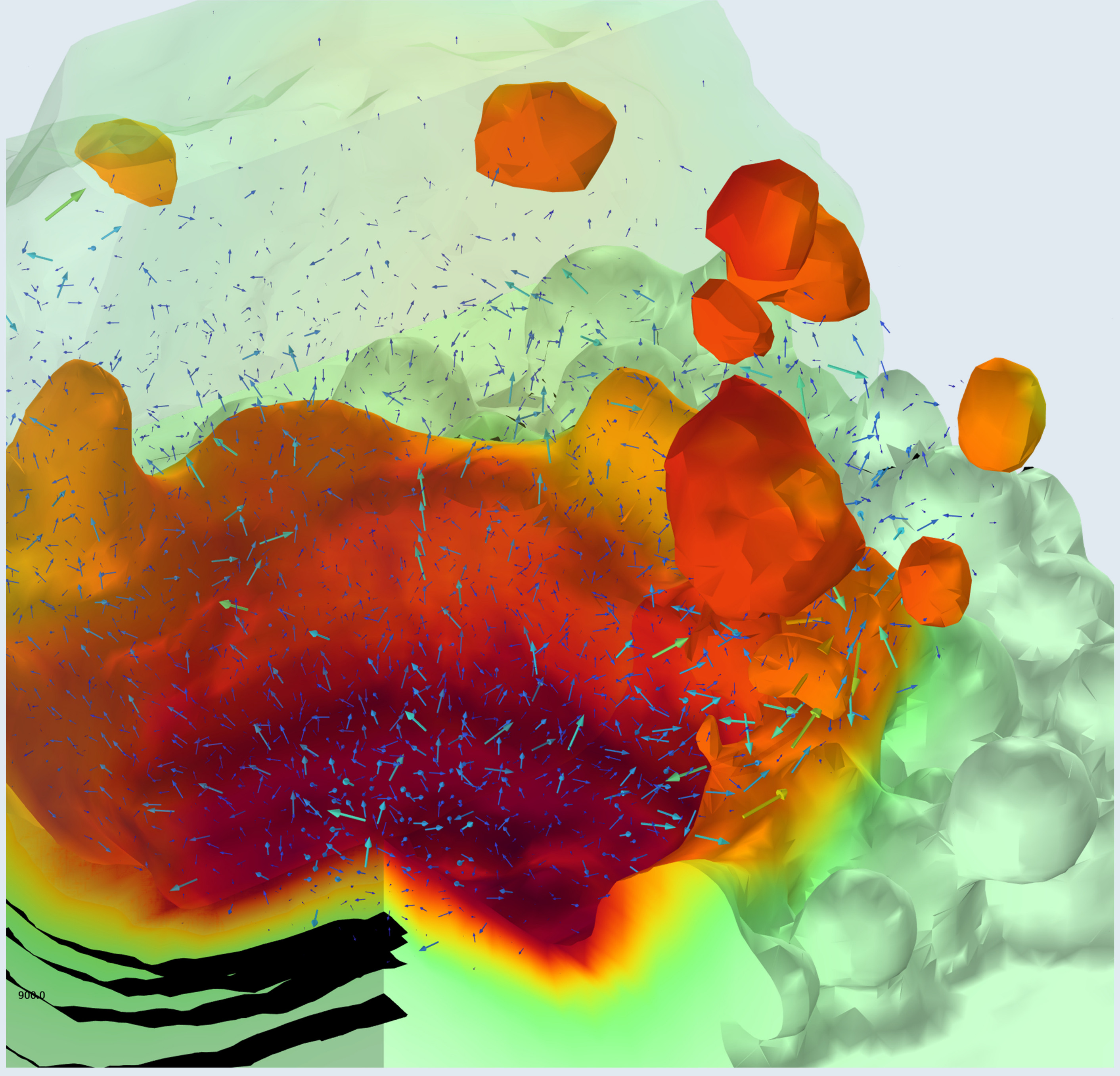

Benefit of Vapor Consideration for LPBF Additive Manufacturing Process Simulation

To investigated the stability of LPBF process, the meso-scale simulation is a powerful tool. The present work aims to prove the effect of the vapor jet, usually neglected but strongly sensitive.

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Abstract

Simulation of laser processes is more and more efficient. In some cases, as welding and **additive manufacturing**, the physical phenomena are complex, multi-physics and multi-phases, thus some assumptions have to be done.

For **Laser Powder Bed Fusion**, a laser beam melts and vaporizes the substrate and powder materials. In literature, the **vaporization process** is supposed to produce a **recoil pressure** at the surface of the liquid, but the momentum created on the gas is usually neglected.

In the present paper, authors focus on this part of the model in order to prove the benefit of such consideration. The whole model is described (heat transfers, fluid flows, phase field) and the vapor consideration is detailed physically and numerically for **two assumptions: pressure model and momentum model**. After having shown some numerical comparisons illustrating the benefit of this method, a a short physical analysis is made to conclude on the sensitivity of the vaporization phenomenon on the process.

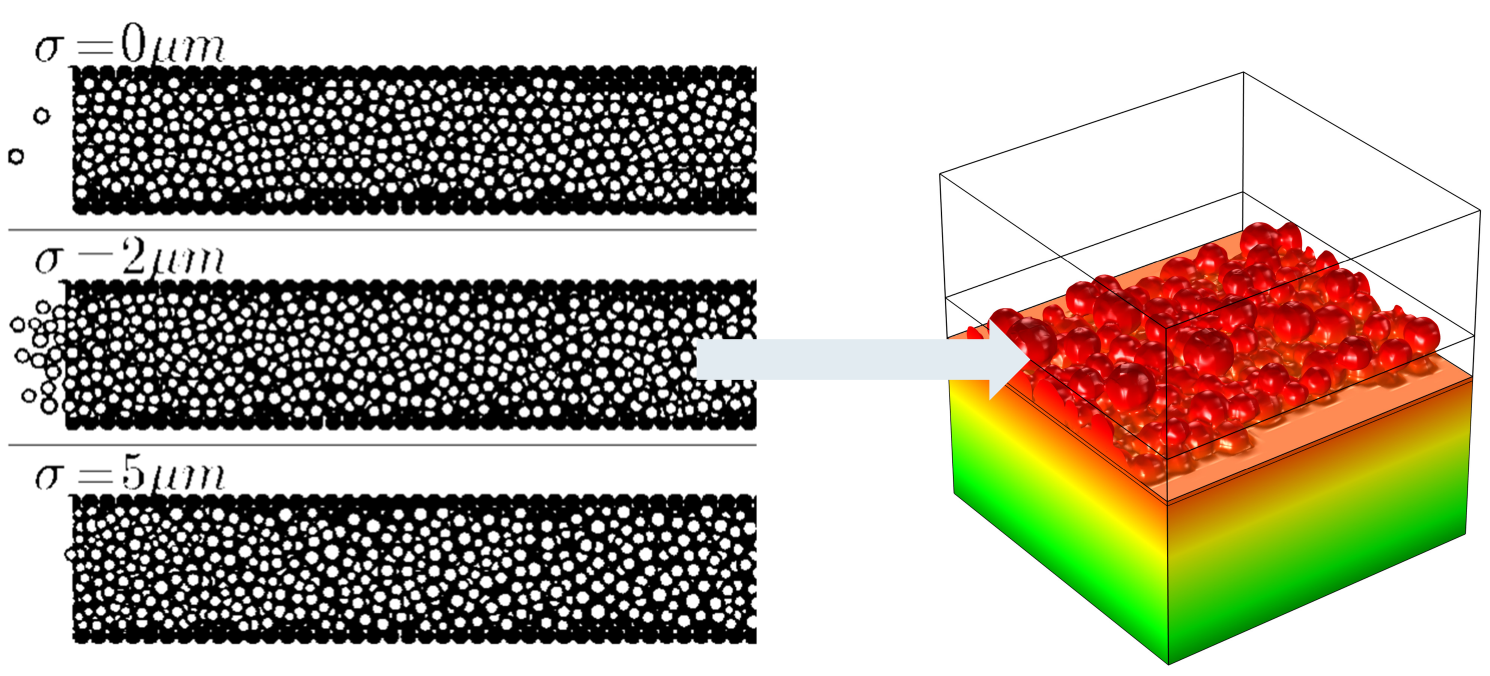


Figure 1: Left, DEM computing for different powder characteristics, right, Transferred powder bed from DEM to FEM.

Methodology

A common **thermo-hydrodynamic** model of static laser welding is developed [Dal, Daligault, Mayi] for **LPBF** (Figure 1) **on 316L** stainless steel and with a Eulerian front tracking method (Phase Field).

Two approaches are applied to simulate the vapor effects: the **pressure** {... | and **momentum** | ...} formulations.

$$\text{N.S. : } \rho_\emptyset \left[\frac{\partial \vec{v}}{\partial t} + (\vec{v}.\vec{\nabla})\vec{v}\right] = \vec{\nabla}.\left(pI + \mu_\emptyset(\vec{\nabla}\vec{v} + (\vec{\nabla}\vec{v})^T)\right) + (\sigma\kappa + \{\boldsymbol{p_{rec}}|\boldsymbol{0}\}).\delta\phi$$

$$\text{Mass cons. : } \quad \vec{\nabla}.\vec{v} = \left\{\boldsymbol{0}\middle|\dot{\boldsymbol{m}}\left(\frac{1}{\rho_v} - \frac{1}{\rho_l}\right)\boldsymbol{\delta\phi}\right\}$$

$$\text{Phase Field : } \quad \frac{\partial \phi}{\partial t} + \vec{v}.\overrightarrow{\nabla\phi} - \vec{\nabla}.\vec{v} = \left\{\boldsymbol{0}\middle|\dot{\boldsymbol{m}}\left(\frac{V_{\phi 1}}{\rho_v}\right)\boldsymbol{\delta(\phi)}\right\} = \vec{\nabla}.\frac{\gamma\lambda}{\varepsilon^2}\overrightarrow{\nabla\psi}$$

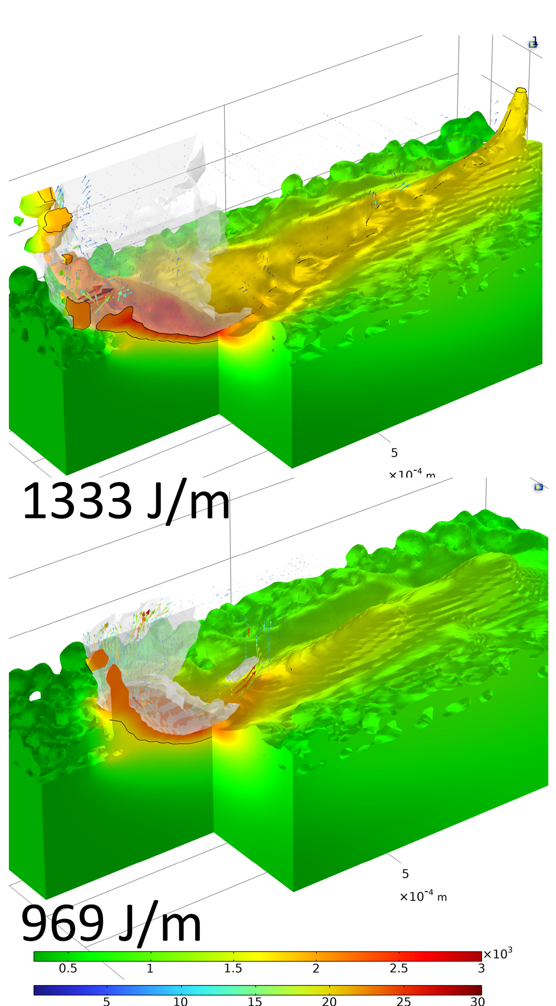
Results

The approaches give the **same macroscopic melt pool behaviors** (size).

The gas and liquid velocities are **much more realistic** (close to 200 m/s – Figure 2) with the momentum formulation than with the recoil pressure.

The shearing produced by the vapor produces **spatters** all around the melt pool.

Applications with **real process** parameters produce realistic **instabilities**.



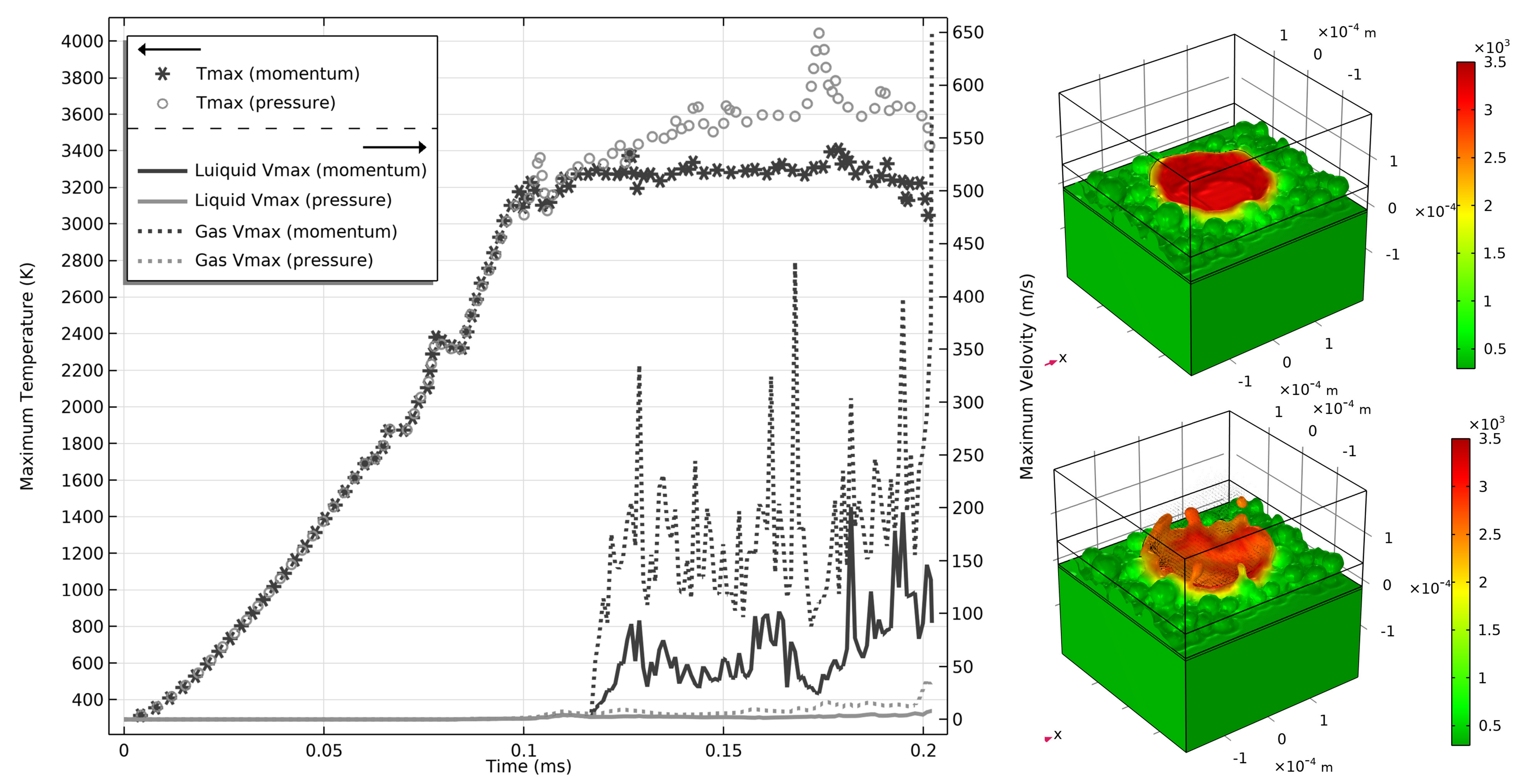


Figure 2: Left, Maximum velocities and temperatures, right, Thermal field and deformation of liquid boundary.

REFERENCES

Dal, M., "Powder Consideration for Additive Manufacturing Simulation", Comsol Conference, 2020.

Mayi, Y. A. ,"Transient dynamics and stability of keyhole at threshold in laser powder bed fusion regime investigated by finite element modeling", JLA 33, 2021.

Daligault, J., "Combination of Eulerian and ray-tracing approaches for copper laser welding simulation", JLA 34, 2022.

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