Additive Manufacturing of Metal Matrix Composites

F. Wirth, K. Wegener
ETH Zurich, Institute of Machine Tools and Manufacturing, Zurich, Switzerland

INTRODUCTION:

Laser cladding allows the additive manufacturing of metal matrix composites (MMC) by mixing carbide particles into the metal powder. Depending on their density, the carbide particles tend to segregate inside the melt pool. Simulations help to understand the process and to achieve a homogeneous particle distribution.

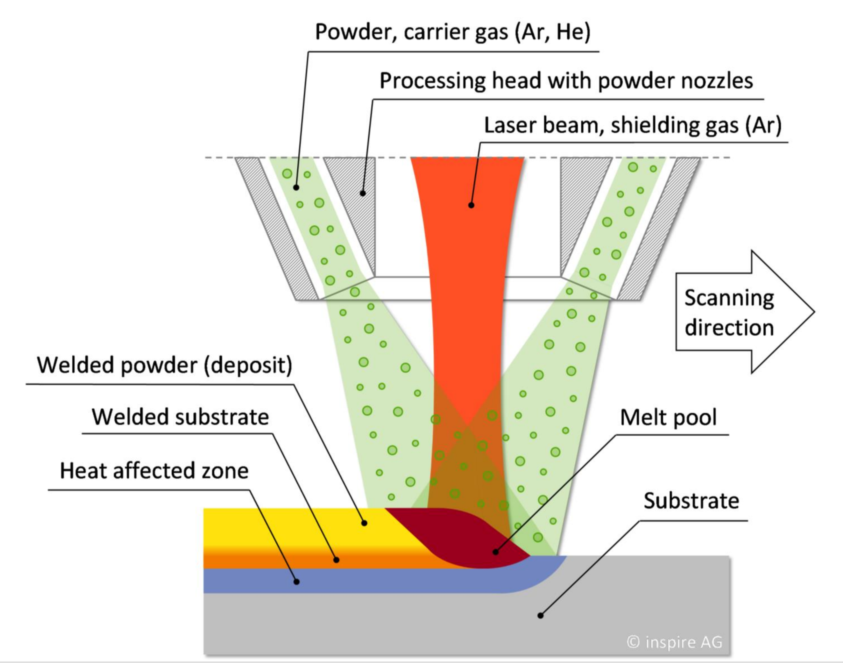

Figure 1. Laser cladding process principle

Figure 2. MMC coating on conveyor screw (courtesy of Oerlikon Metco)

COMPUTATIONAL METHODS:

- Powder nozzle
  - One sixth of the three-jet powder nozzle and the space below is modeled
  - First the gas flows are calculated based on: Turbulent flow k-ε model, transport of concentrated species
  - Then the particle tracing module is used to simulate powder particle movement inside the powder jet
- Melt pool [1]
  - The powder jet characteristics obtained from the powder nozzle simulation are required as input data
  - First the melt pool is calculated based on: Heat transfer, laminar flow, deformed geometry, boundary PDE (to describe the free surface

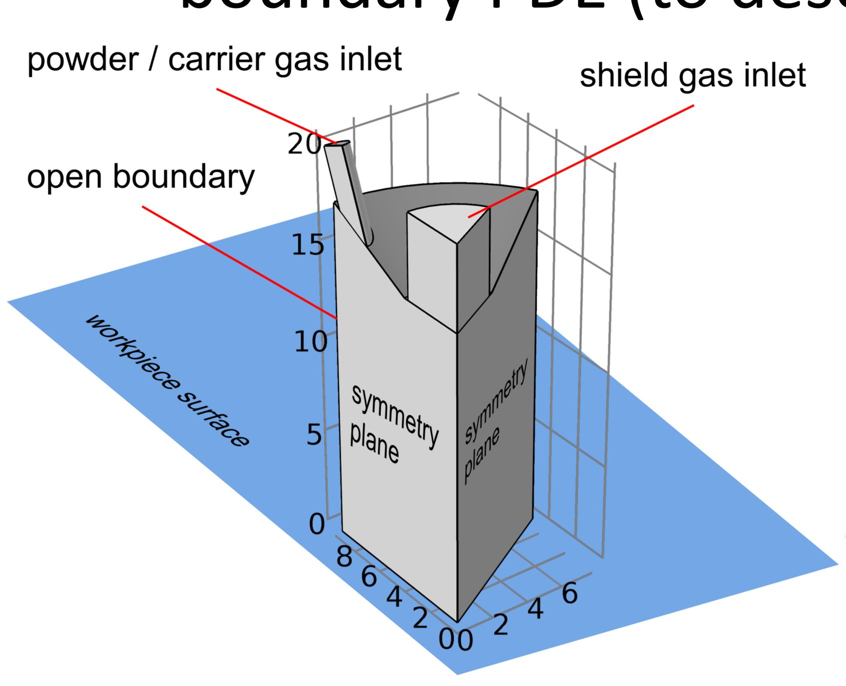

Figure 3. Powder nozzle model geometry

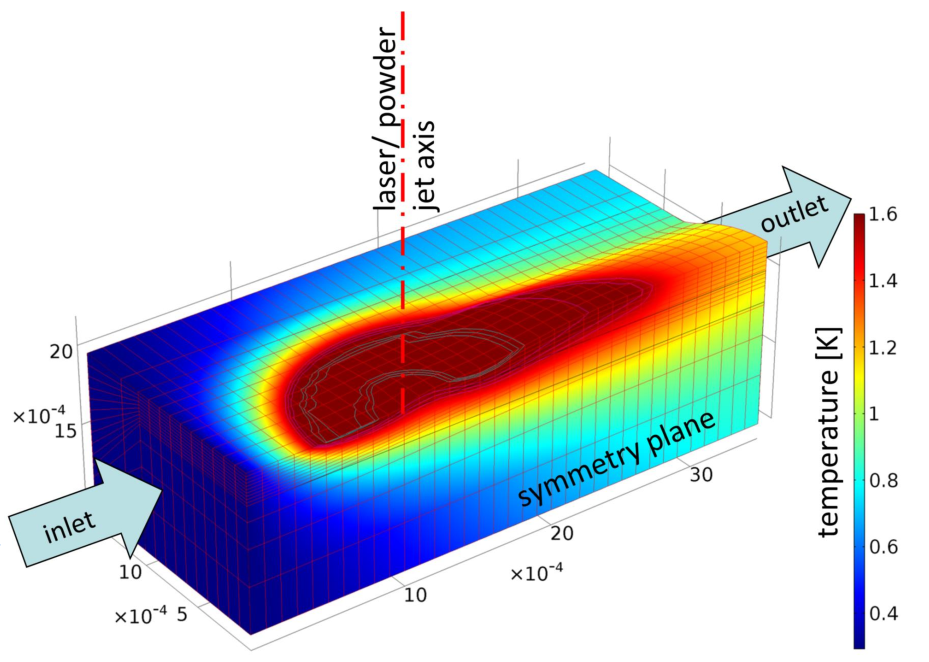

Figure 4. Melt pool simulation scheme

RESULTS:

- Shield gas atmosphere can be optimized regarding gas types, gas flow rates and nozzle design

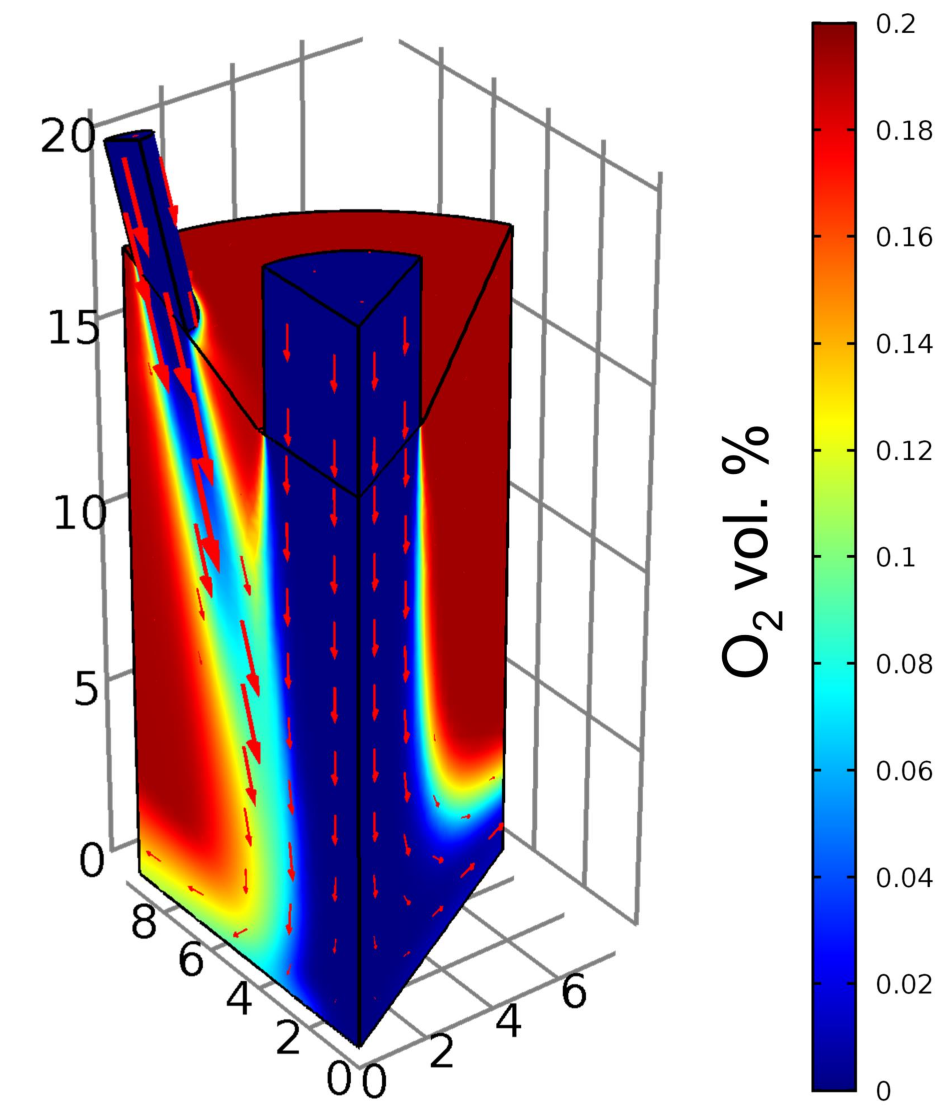

Figure 5. Gas flow

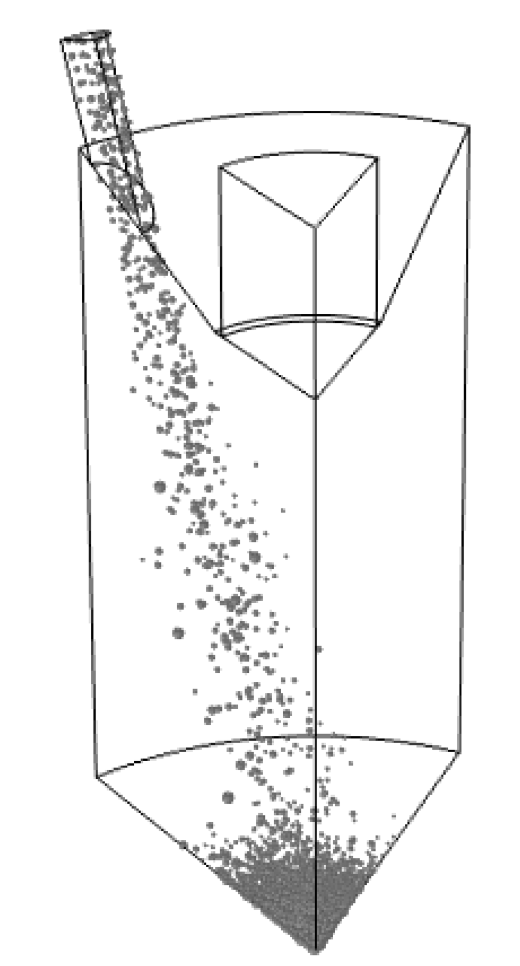

Figure 6. Powder jet

- The melt pool flow has only a minor effect on the carbide particle distribution

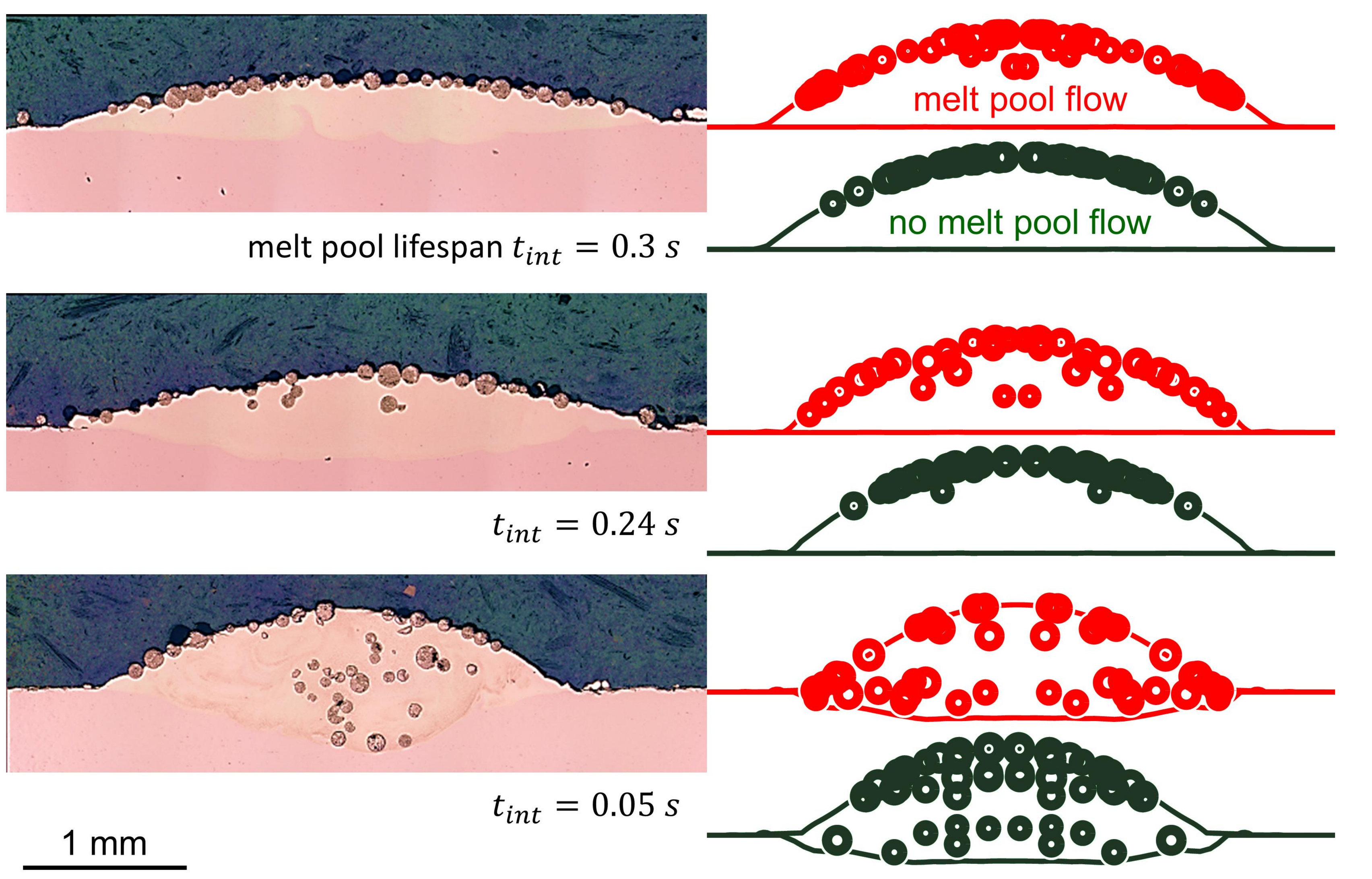

Figure 7. Experimental cross sections vs. simulation results

CONCLUSIONS:

The homogeneity of the carbide particle distribution in MMCs can be improved by a shorter melt pool lifespan and a proper choice of the particle size. Thus the wear resistance of MMC coatings can be improved.

REFERENCES:

1. F. Wirth, K. Wegener, A physical modeling and predictive simulation of the laser cladding process, Additive Manufacturing, 22, 307-319 (2018)