Development of a Laser Cladding Process Model

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Introduction: Laser Cladding is one of the processes in the growing field of additive manufacturing. A laser beam creates a melt pool, into which powder is blown and molten. Thereby a layer can be produced track by track and a volume part is built layer by layer. But one key problem preventing a wide application is the prediction of the built height.

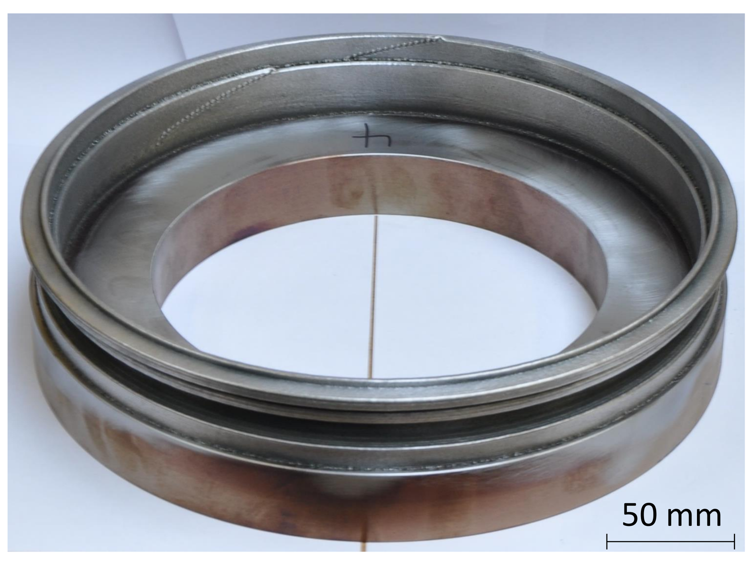

Figure 1. Demo part, provided by Oerlikon Metco

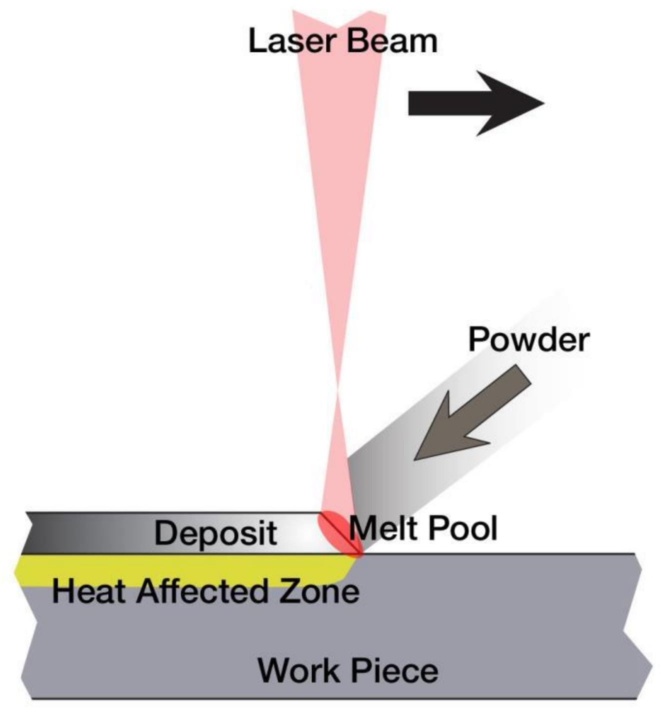

Figure 2. Laser Cladding principle

Computational Methods: Beside the heat transfer equation

$$\rho c_p \left(\frac{\partial T}{\partial t} + \vec{\boldsymbol{u}}\, \nabla T \right) = \nabla(\lambda \nabla T) + Q$$

and the Navier-Stokes equations

$$\rho \left(\frac{\partial \vec{\boldsymbol{u}}}{\partial t} + \vec{\boldsymbol{u}} \cdot \nabla \vec{\boldsymbol{u}} \right) = \nabla[-p\boldsymbol{I} + \mu(\nabla \vec{\boldsymbol{u}} + (\nabla \vec{\boldsymbol{u}})^T)] + \vec{\boldsymbol{F}}$$

$$\rho \nabla \cdot \vec{\boldsymbol{u}} = 0$$

a modified height function equation [1]

$$\frac{\partial h}{\partial t} + \begin{pmatrix} u \\ v \\ 0 \end{pmatrix} \cdot \nabla h = w + v_{clad}$$

has to be solved on a moving mesh. Herein v_{clad} is the weld bead height growth velocity respecting the physical conditions for powder transfer into the melt pool. The laser surface heat source model takes the different absorption conditions into account.

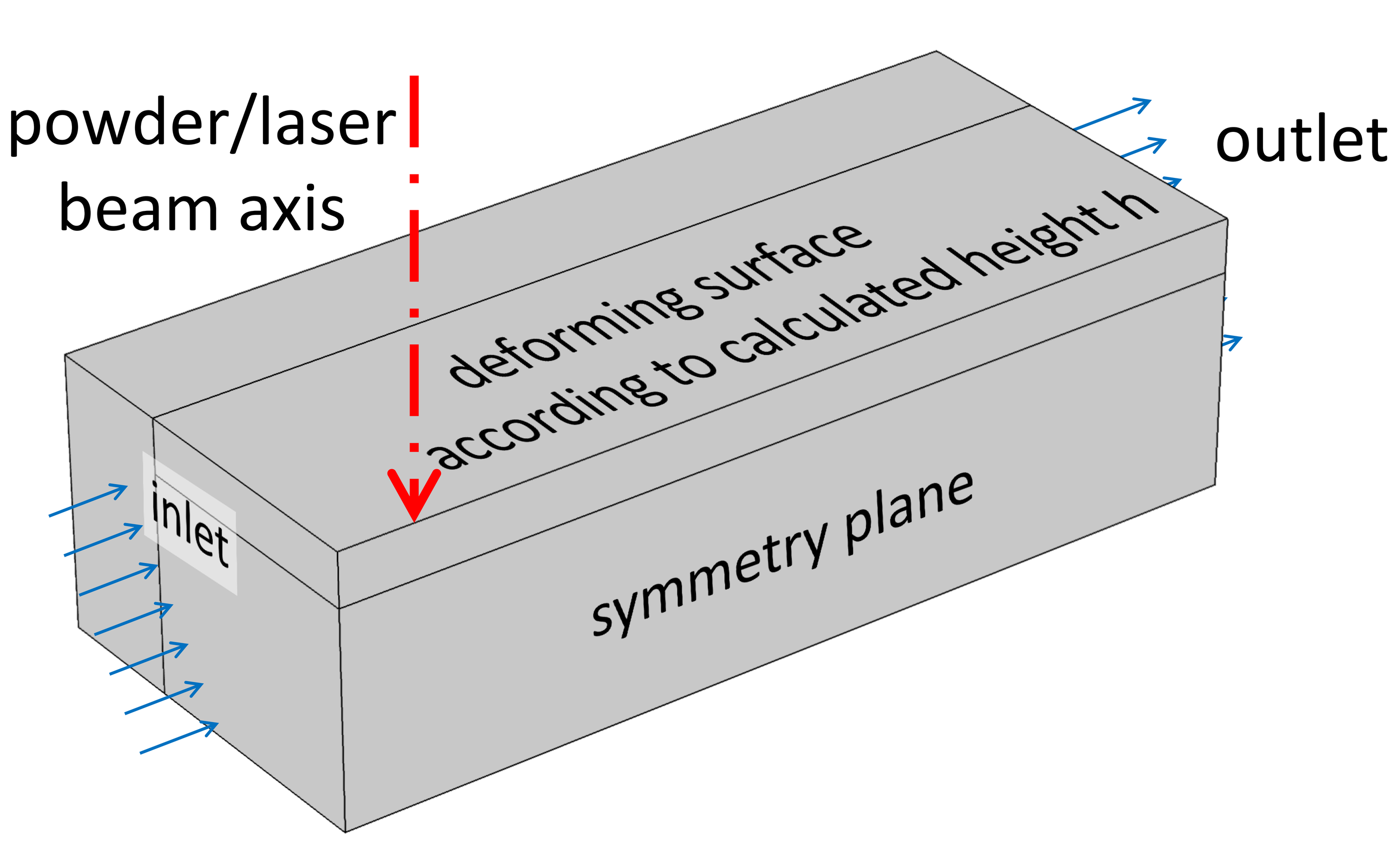

Figure 3. Model geometry

Results: The thermal field (fig. 4), the melt pool flow (fig. 5) and the surface contour (fig. 6,7) can be simulated. The simulated cross section of a single track shows good agreement with the experimental results (fig. 6).

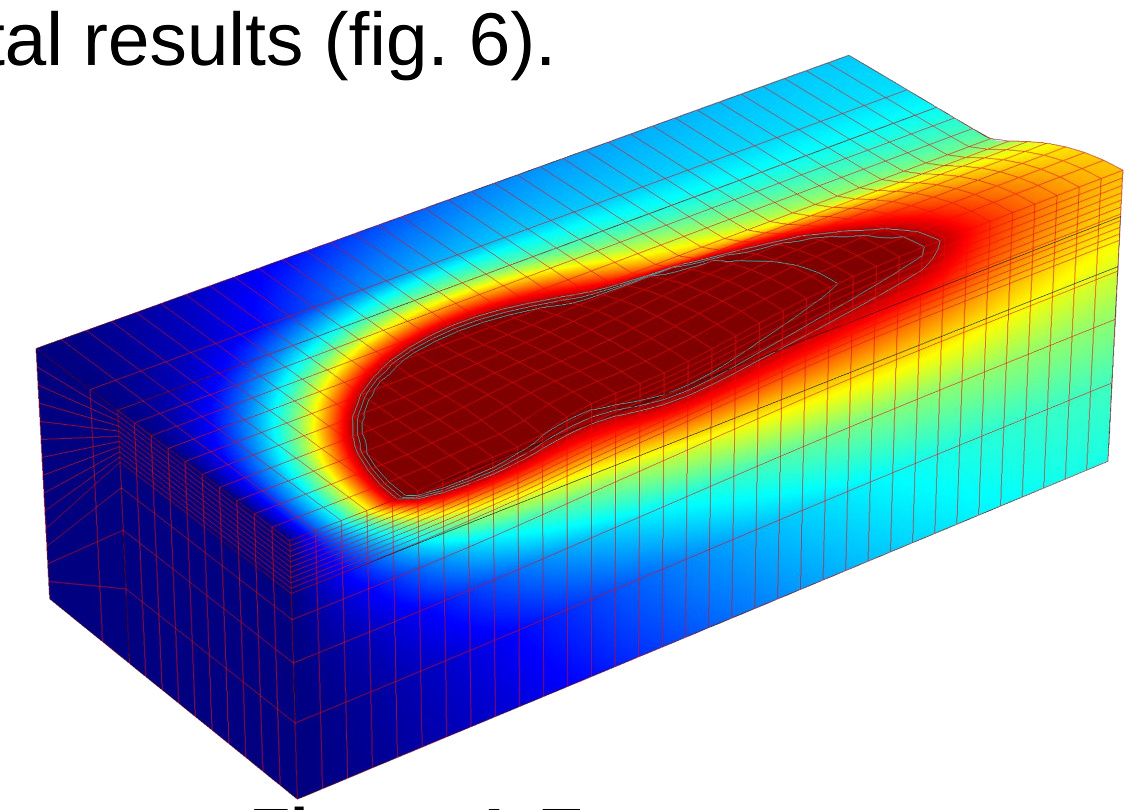

Figure 4. Temperature

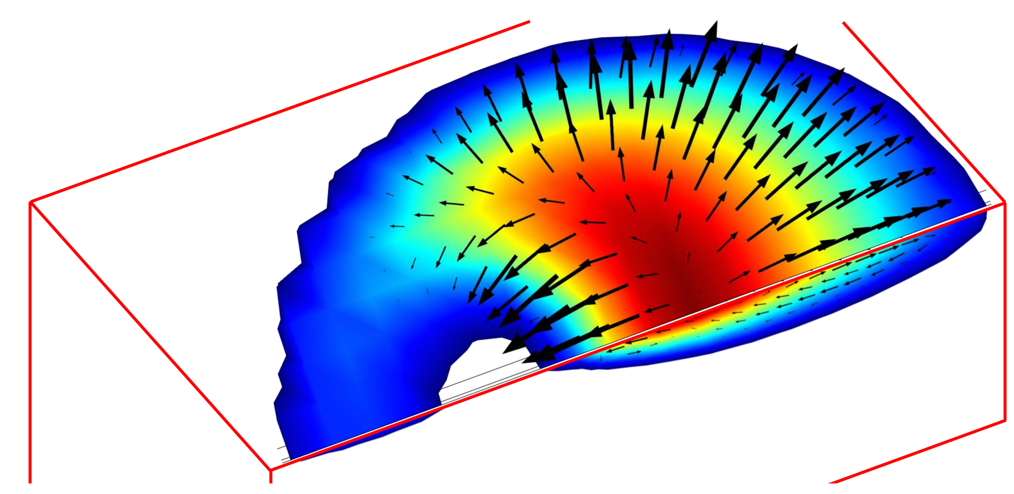

Figure 5. Melt pool flow

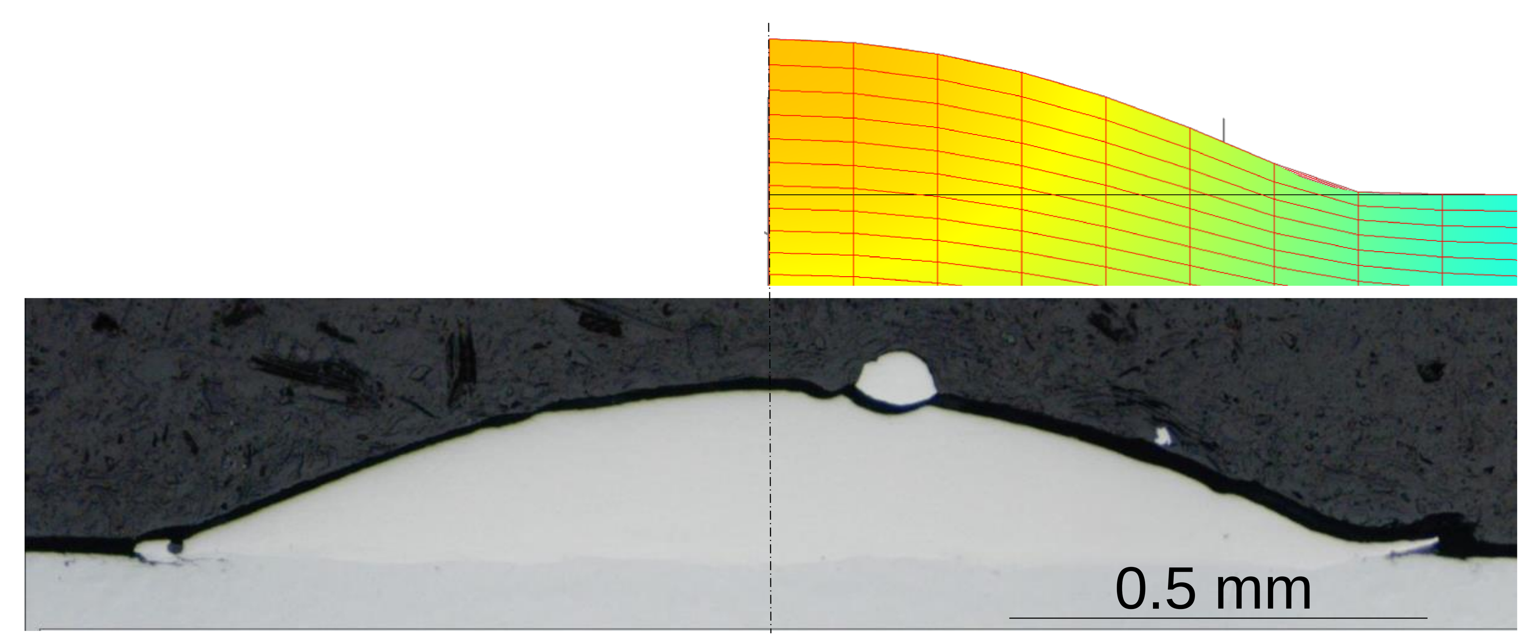

Figure 6. Single track cross section

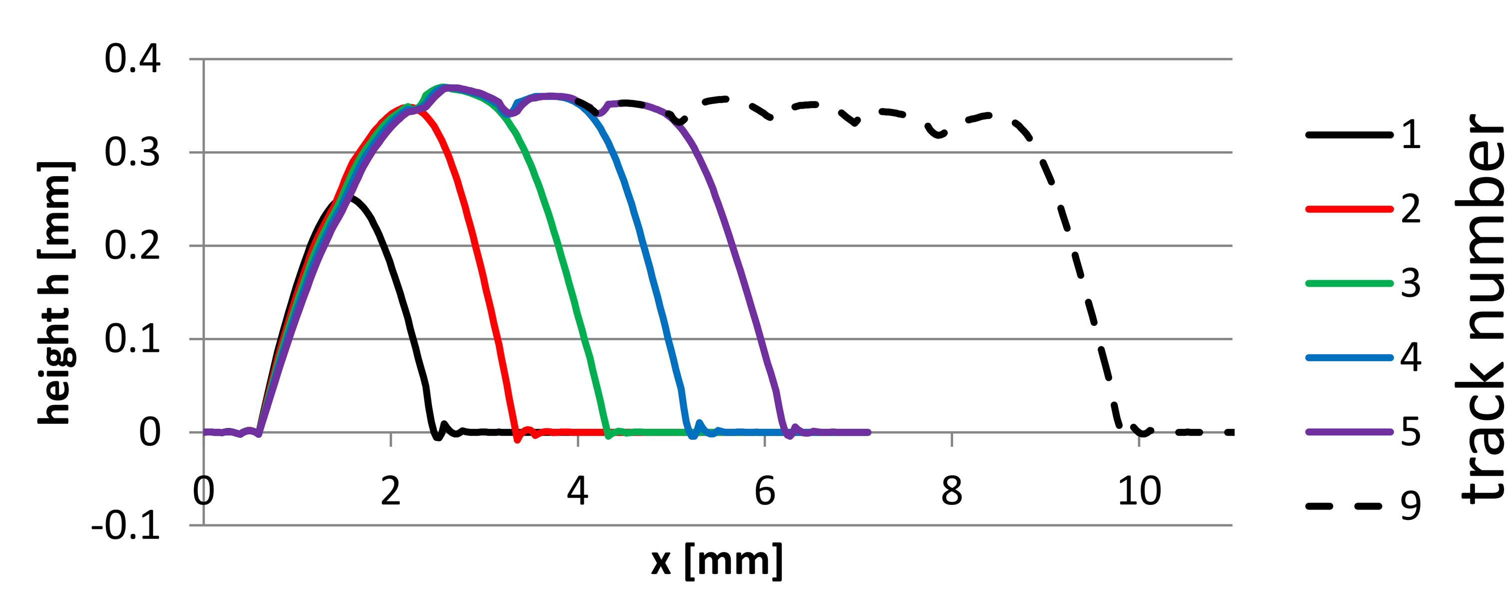

Figure 7. Simulated multi track cross section

Conclusions: After successful simulation of single and multiple tracks the model will be extended towards complex geometries and (hot) crack susceptibility estimation. These results can be useful for the development of a CAM tool enhancing the application of laser cladding.

References:

1. Nichols, B. D., Hirt, C. W., Calculating Three-Dimensional Free Surface Flows in the Vicinity of Submerged and Exposed Structures, Journal of Computational Physics, 12, pp. 234-246 (1973)