

Smoothed Particle Hydrodynamics (SPH) Simulation for Continuous Castings

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Short Introduction to SPH

General Idea of the SPH method:

- mesh-free Lagrangian method used for simulating fluid flows,
- represent the fluid by particles,
- the physical property of a particle i is only affected by surrounding particles within a certain smoothing length h , where \mathbf{r}_i denotes the position of particle i .

The smoothing kernel:

- Physical properties are *smoothed* since only particles which lie within the range of the kernel function W are considered:

$$W(\mathbf{r}_i, h) = \frac{315}{64\pi h^9} \begin{cases} (h^2 - \|\mathbf{r}_i\|^2)^3, & \text{if } 0 \leq \|\mathbf{r}_i\| \leq h \\ 0, & \text{if } \|\mathbf{r}_i\| > h \end{cases}$$

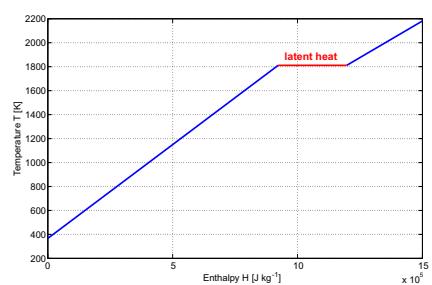


Fig. 1: Fitted Measurements for $T(H)$

Temperature Simulation and Solidification Process

Computation of the Temperature in SPH form:

- Goal: Implement heat transfer simulation
- The following SPH formulation for the enthalpy H has been developed:

$$\frac{dH_i}{dt} = \sum_{j \neq i} \frac{m_j}{\rho_i \rho_j} \frac{4\kappa_i \kappa_j}{\kappa_i + \kappa_j} (T_i - T_j) \frac{\nabla W(\mathbf{r}_{ij}, h) \cdot \mathbf{r}_{ij}}{\mathbf{r}_{ij}^2}, \quad \text{with } \mathbf{r}_{ij} := \mathbf{r}_i - \mathbf{r}_j$$

- Temperature T is calculated from enthalpy, based on fitted experimental properties of the material (see Figure 1)

Milestones of the Solidification Process Implementation:

- Figure 2 shows a benchmark problem comparing the SPH simulation to a well-known fundamental solution of the heat equation,
- Figure 3 presents heat conduction during the dam break experiment with a cold wall at the right-hand boundary (no solidification),
- Figure 4 shows the solidification of the material during the continuous casting process with cooling at the right-hand wall at different time steps.

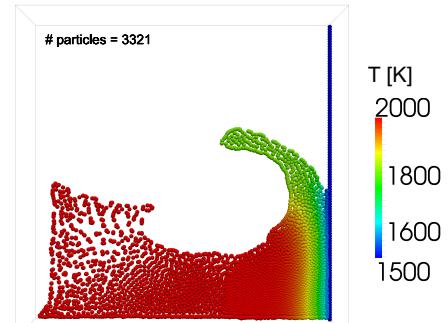


Fig. 3: Simulation of the Dam Break

Numerical Test Calculation

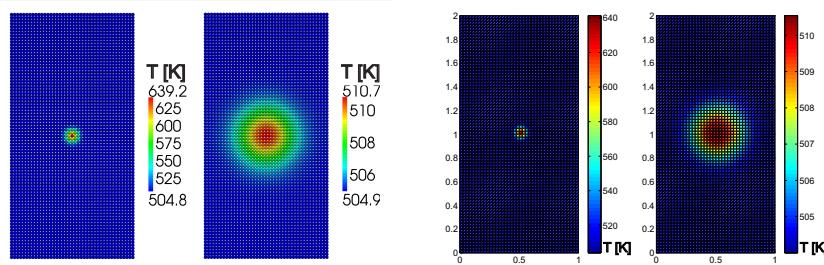


Fig. 2: SPH Simulation (left) and analytic Solution (right)

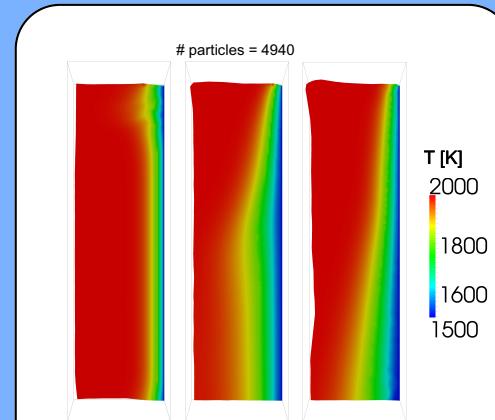


Fig. 4: Continuous Casting Simulation

References

- Novel applications of smoothed particle hydrodynamics (SPH) in metal forming. P.W. Cleary, M. Prakash, J. Ha. J. Mat. Proc. Tech. 177 (2006) 41-48
 Solidification using smoothed particle hydrodynamics. J.J. Monaghan, H.E. Huppert, M.G. Worster. J. Comp. Phys. 206 (2005) 684-705
 Effect of Heat Transfer and Solidification on High Pressure Die Casting. P. Cleary, J. Ha, J. Mooney, V. Ahuja. Monash University (1998) 679-682