# Additive manufactturing in construction requires reliable high fidelity models.

**Modelling and Simulation of Shotcrete 3D Printing**

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## In Short

- Thixotropy modeling with cumulant LBM
- Simulation of rehological behavior of fresh concrete
- Simulation of multiphase turbulent jet

This project is concerned with the simulation of additive manufacturing processes in civil engineering as being developed in the TRR 277. More specifically we focus on the modelling of the automated shotcrete process used in large scale printing of concrete structures. Its future development depends heavily on the understanding and control of the flow patterns in the jet used for the deposition of the materials. This jet is a complex turbulent three phase flow comprised of liquid cement, solid aggregates and ambient air. The air may not only interact with the fluid and solid components of the concrete during the deposition but can become a permanent part of it by forming voids. The distribution of the aggregates, the voids and the adhesion to previously deposited layers is a function of the spatial distribution of the different components of the jet and their kinetic energy at the time of impact. Any attempt to optimize this process will depend on an in-depth understanding of the physical behavior of the jet. The high ejection velocity leads to a phenomenon called atomization in which the jet breaks up in many small fragments that deposit individually. An atomizing jet spreads laterally and may lead to an inhomogeneous distribution of the material components and their impact velocity with obvious implications on the quality of the result. However, direct measurement of component densities and their impact velocities are apparently difficult. Hence, we aim at determining such data numerically.

The project is structured into two work packages. In the first work package, we will calibrate and validate the rheological model for concrete based on Roussel [1]. The model will be adapted for our massively parallel simulation framework VirtualFluids [4] based on the cumulant lattice Boltzmann method [3]. Experimental reference data is provided by our project partners of TRR277 project A04 (i.e. the group of Prof. Dirk Lowke TU-Braunschweig). In order to validate the numerical accuracy of the so obtained model, we will perform empirical convergence analysis by repeating simulations at three different resolutions from which we compute the order of convergence and the Grid Convergence Index. In the second work package, the conservative Allen-Cahn phase field equation in velocity/pressure formulation [4] will be applied to the simulation of the turbulent shotcrete jet at realistic density ratios between concrete and air.

## WWW

https://www.tu-braunschweig.de/trr277/projects/amc-structure/b-projects/b03

## More Information

[1] Roussel, N. (2006). A thixotropy model for fresh fluid concretes: theory, validation and applications. Cement and concrete research, 36(10), 1797-1806.

[2] Amirshaghaghi, H. Hassan Rahimian, M., Safari, H. Krafczyk, M. "Large Eddy Simulation of liquid sheet breakup using a two-phase lattice Boltzmann method." Computers & Fluids 160 (2018): 93-107

[3] Fakhari, A, Geier, M., Lee, T., "A mass-conserving lattice Boltzmann method with dynamic grid refinement for immiscible two-phase flows." Journal of Computational Physics 315 (2016): 434-457.

[4] Geier, M., Fakhari,A. Lee, T., "Conservative phase-field lattice Boltzmann model for interface tracking equation." Physical Review E 91.6 (2015): 063309.

[5] Kutscher, K., Geier, M., & Krafczyk, M. (2019). Multiscale simulation of turbulent flow interacting with porous media based on a massively parallel implementation of the cumulant lattice Boltzmann method. Computers & Fluids, 193, 103733.

## Project Partners

TRR277 project A04 (i.e. the group of Prof. Dirk Lowke TU-Braunschweig)

## Funding

DFG SFB/Transregio TRR 277

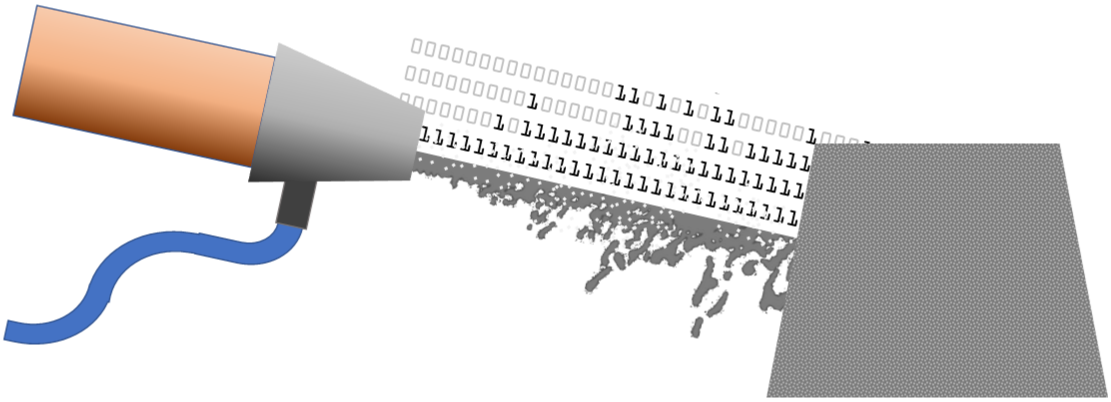

***Figure 1:*** *The final goal of the project is the numerical simulation of the atomizing jet including solid particles, the comparison to experiment from A04 and the construction of a simplified surrogate model describing the distribution of different phases and their kinetic energy in the jet.*