Success Story
COMET

K1-MET
Competence Center for Excellent Technologies in Advanced Metallurgical and Environmental Process Development
Programme: COMET – Competence Centers for Excellent Technologies
Programme line: K1-Centres
COMET subproject, duration and type of project:
Unsteady Flows in Continuous Casting, 07/2012 –06/2015, multi-firm

Revealing the source of clogging

During continuous casting of steel non-metallic inclusions deposit on the inner walls of the Submerged Entry Nozzle (SEN), leading to clogging and restricted operation. In this project we developed a comprehensive model for the simulation of the onset of clogging. Thereby, particle deposition is pictured by a lattice Boltzmann (LB) magnification lens, which is embedded into a classical CFD simulation. Furthermore, the stability of attached particles is governed by a new re-suspension criterion which is based on fluid flow, material properties and wall roughness. Our simulations reveal the source of clogging and enable the design of future SENs.

Numerical simulation of fluid flow and particle deposition

From a physical point of view clogging in Submerged Entry Nozzles (SENs) can be associated with (i) particle trajectories and particle deposition as well as (ii) the stability of particle-wall attachment and the possible particle re-suspension.

Numerical simulation of the trajectories of non-metallic inclusions requires the resolution of turbulent length and time scales which are significantly smaller than the dimensions of the secondary vortices within a SEN's geometry. Consequently, this requires a fine grid resolution in combination with a local, scale resolving turbulence model. High efficient Large Eddy Simulation (LES) on regular grids inevitably require a fine grid resolution of the whole computational domain, while a locally refined grid resolution might be sufficient for a dedicated investigation of secondary vortex formation in SEN flow.

In this project we therefore developed a hybrid simulation methodology, which embeds a highly efficient lattice Boltzmann based Large Eddy Simulation (LES) model on a regular grid into a classical finite volume simulation. Thereby the lattice Boltzmann co-simulation acts as a magnification lens in an interesting sub-region of the global SEN simulation.

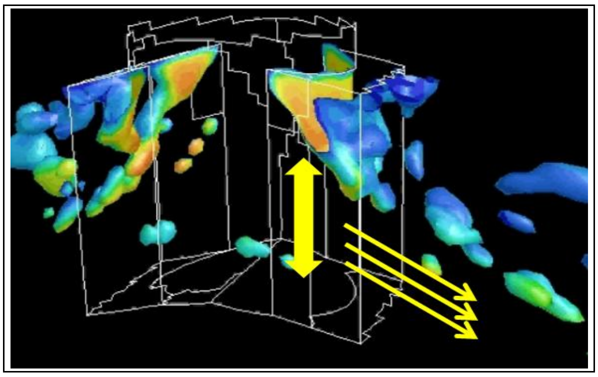

Fig. 1: Embedded lattice Boltzmann simulation of large gas bubbles formation; gas bubbles coloured by velocity

Federal Ministry of Science, Research and Economy

Austrian Ministry for Transport, Innovation and Technology

Further model extensions considered the formation of large gas pockets in the upper port openings (Figure-1), which might alter the SEN's outflow profile.

In turbulent flows, particle deposition is known to be governed by diffusion, interception or impaction, depending on the particles' Stokes regime. In this project we studied the influence of large scale turbulent vortices on particle trajectories and particle deposition by help of the lattice Boltzmann magnification lens.

Particle re-suspension and the onset of clogging

The present study aims at describing the clogging onset in SENs by means of a model for the stability of accreted particles of arbitrary wettability on rough walls. Thereby, our model development is based on two hypotheses. First, we assume that non-metallic particles almost always experience contact with a gas phase during secondary metallurgy processing (e.g. by gas purging). Especially in the case of a non-wetting particle this leads to the formation of gas pockets at cavities on the particle's surface, which might still exist in the SEN.

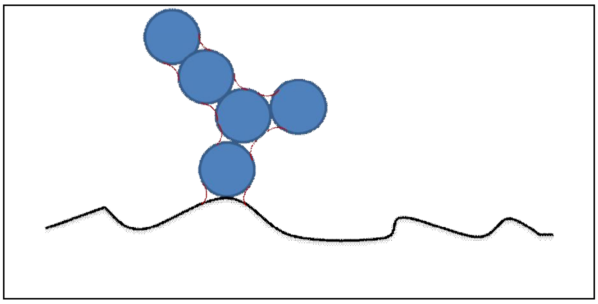

Fig. 2: Non-metallic inclusion with gas pockets contacting a rough wall

Second, we presume that this amount of particle attached gas forms a gaseous neck upon particle-wall contact, which subsequently exerts a strong attractive force to the wall (Figure-2). Based on these two hypotheses, we studied study incipient clogging in the lower deflection region of a bifurcated SEN in dependence on fluid flow, particle wettability and wall roughness (Figure-3).

Impact and effects

In this project we successfully developed and implemented a lattice Boltzmann magnification lens, which enables highly efficient simulations of multi-scale flows. This methodology by its own is generally applicable in different disciplines beyond metallurgy.

A deeper metallurgical understanding of the phenomenon of clogging, in turn, enables the design of alternative SEN geometry which will be less prone to heterogeneous clogging.

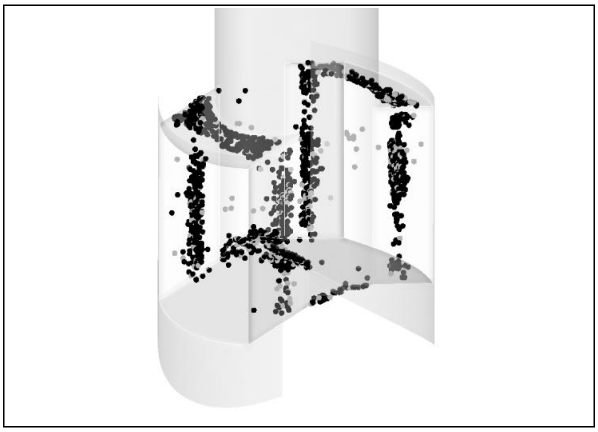

Fig. 3: Incipient particle deposition pattern in a bifurcated SEN geometry

Contact and information
K1MET

Johannes Kepler University
Altenbergerstr. 69, 4040 Linz
T ++43/732/2468-6477
E stefan.pirker@jku.at, www.particulate-flow.at

Project coordinator
Stefan PIRKER

Project partners

Organisation	Country
Johannes Kepler University	Austria
Montan University Leoben	Austria
Primetals	Austria
RHI	Austria