C3:

LIMMCAST: Modelling of steel casting

S. Eckert[1], R. Schwarze[2]

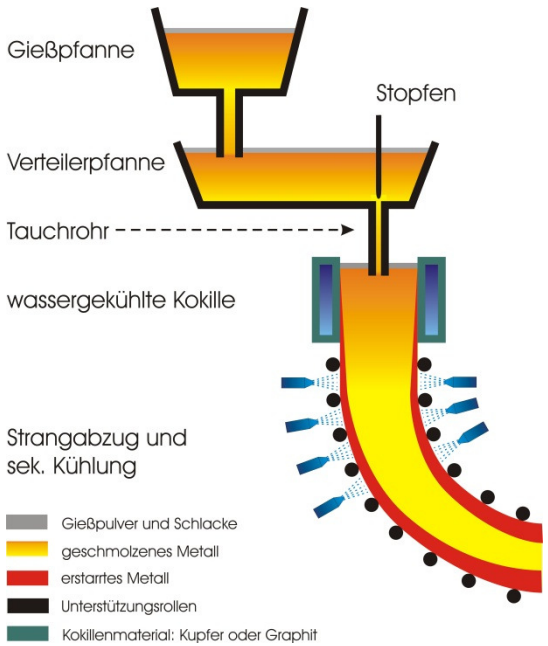
[1]Helmholtz-Zentrum Dresden-Rossendorf (HZDR), D-01314 Dresden
[2]TU Bergakademie Freiberg, Inst. für Mechanik und Fluiddynamik, D-09599 Freiberg

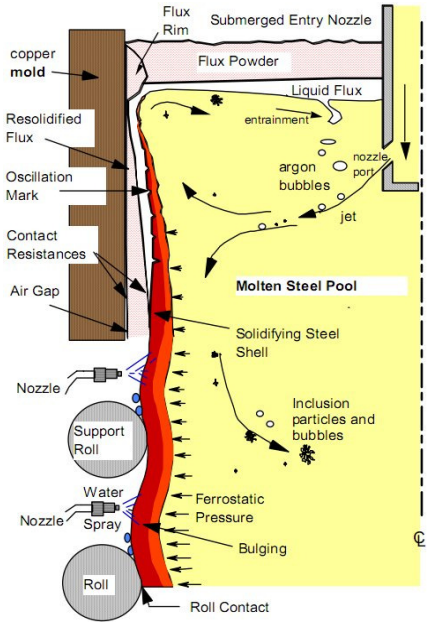
Motivation

The properties of the turbulent flow of the liquid steel influence the quality of the final product and the efficiency of the process.

Problem

- Accidental flow limits the casting speed and causes surface defects and inclusions of impurities ➔ Application of magnetic fields (brakes and stirrers)
- Magnetic fields are in industrial use, but, further improvement of efficiency requires a better understanding of the complex interaction between magnetic field and flow





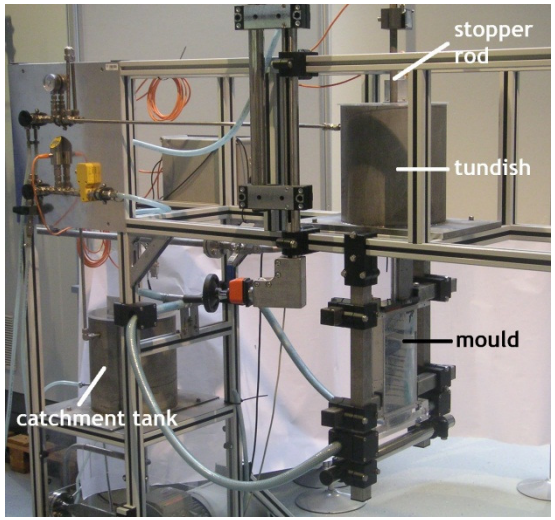
Objectives

- Physical modeling of the continuous casting using low-melting metal alloys (HZDR)
- Corresponding numerical modeling (TU-BAF)

- Flow measurements in the mould, submerged entry nozzle (SEN) and tundish
- Impact of various magnetic fields
- Development of suitable numerical models, code validation
- Optimal configurations for magnetic systems for melt flow control

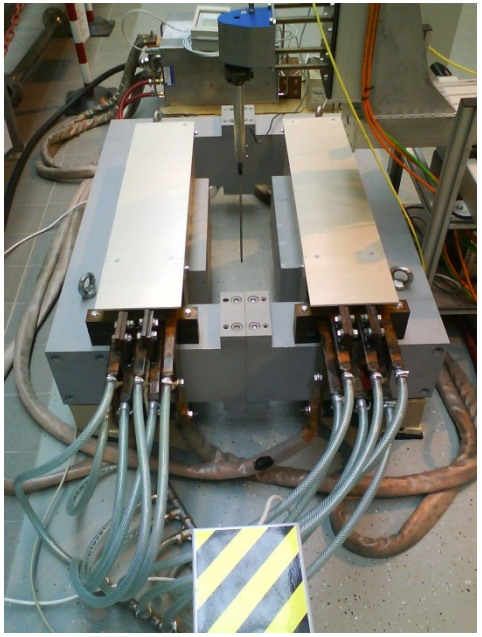
LIMMCAST- Program (HZDR)

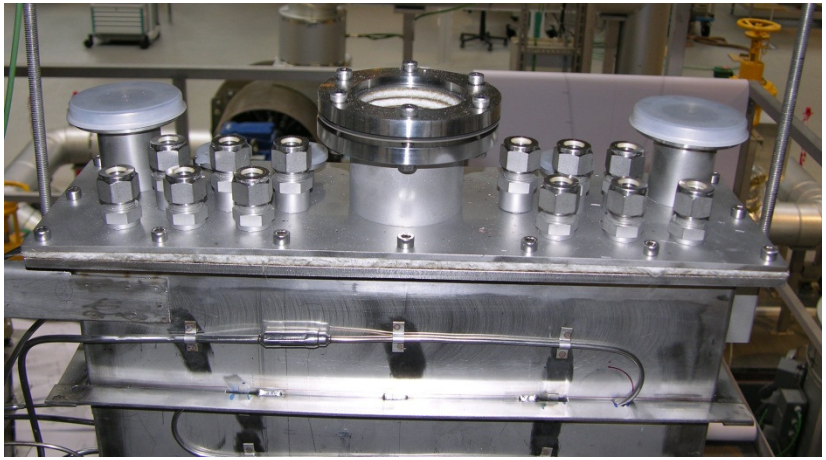
- Three experimental facilities (LIMMCAST, mini-LIMMCAST, X-LIMMCAST)



LIMMCAST

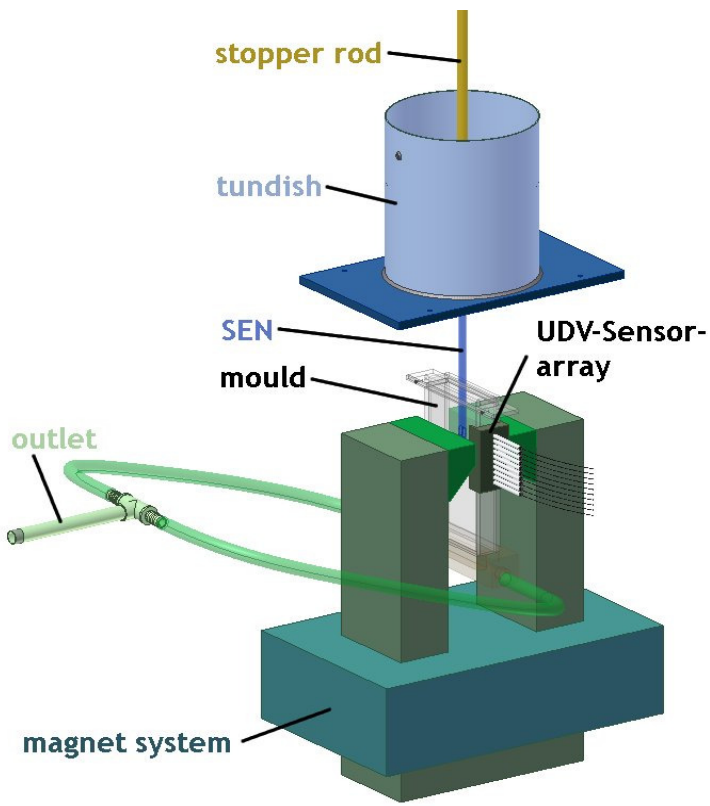
- Simplified model of the continuous casting process
- Use of Sn60Bi40 alloy as model fluid (T_{Liq} = 170 °C)
- Operating temperature at 200 °C up to 350 °C
- Flow rate 2.5 l / s
- Velocity in nozzle 1.3 m / s





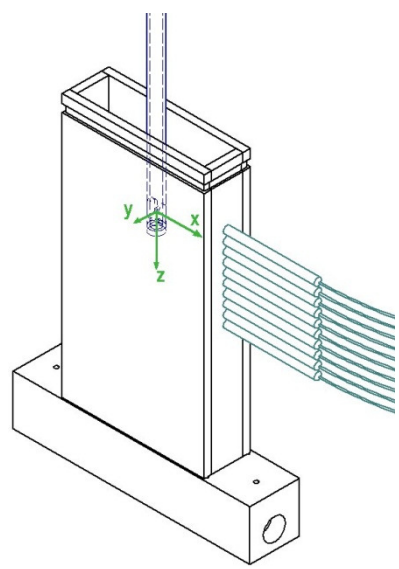
mini-LIMMCAST

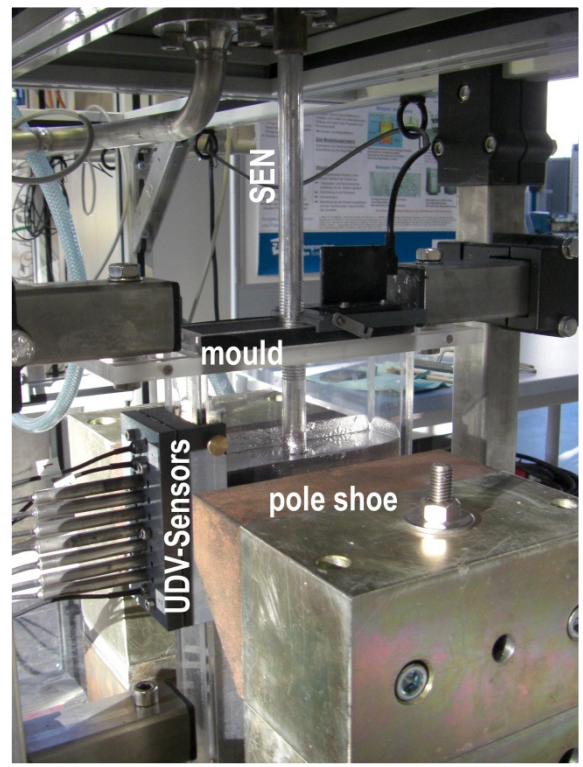
- Two-dimensional velocity mapping in the mould
- Influence of the wall conductivity (0.5 mm brass plates)
- B_{max} = 310 mT (Ha = 460), pole face: 180 x 40 mm²
- Magnetic field covers the whole mould width (level configuration)



Hartmann number

$$Ha = B_0 R \sqrt{\frac{\sigma}{\rho \nu}}$$

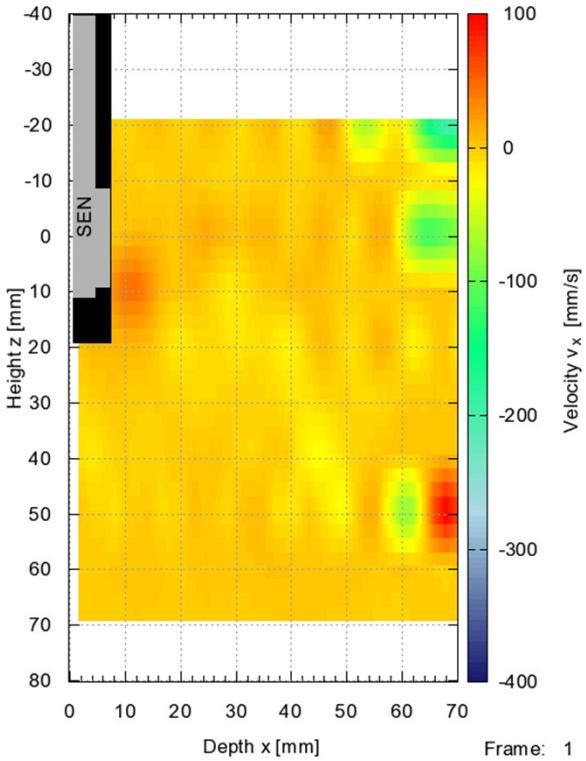




US measurements of the mould flow

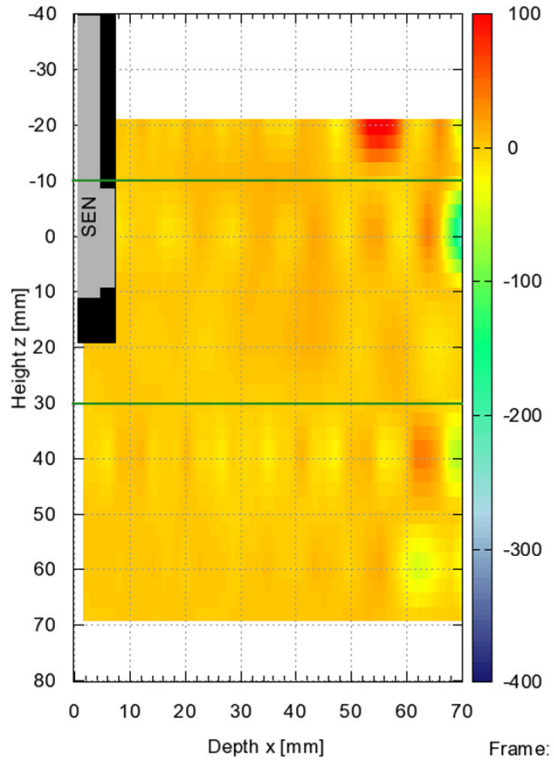
- 10 sensors in multiplexer mode
- Time resolution ~ 5 Hz

B = 0mT



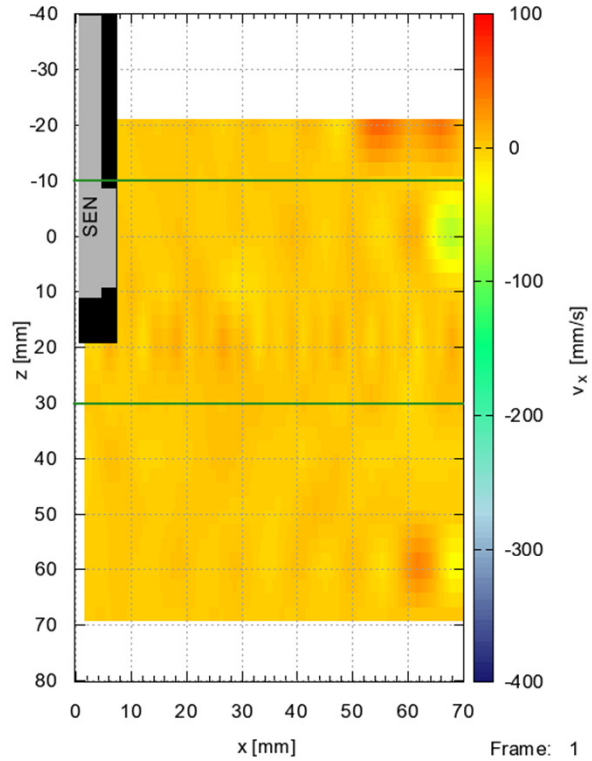
No magnetic field: B = 0 mT

B = 310mT,
Non-conducting mould



Steady magnetic field: B = 310 mT with isolated walls

B = 310mT,
Conducting mould



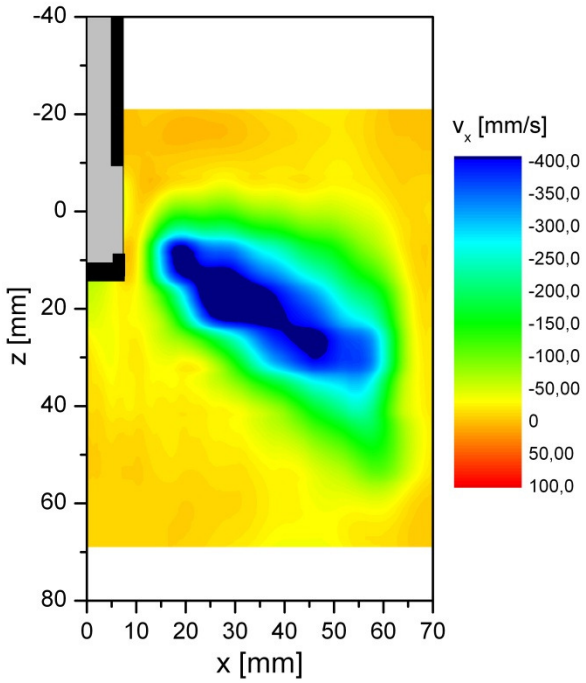
steady magnetic field - B = 310mT + cond. wall

US measurements of the mould flow

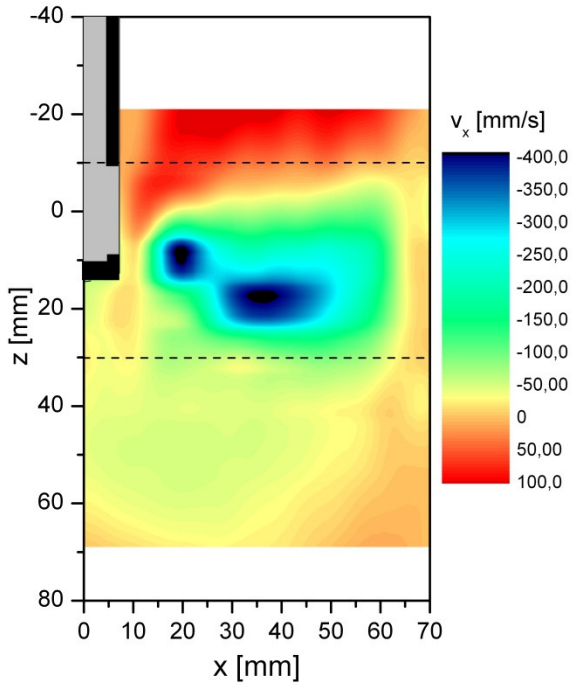
Magnetic field influence on the flow:

- Change of the jet angle
- Formation of strong recirculation zones

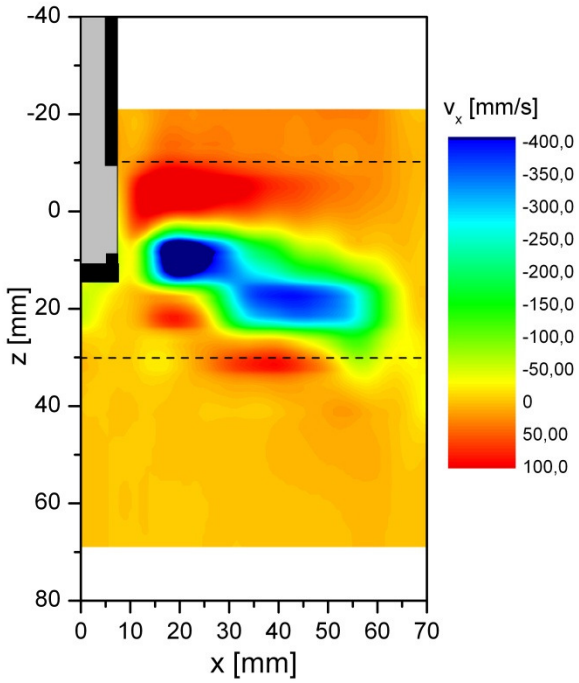
B = 0mT



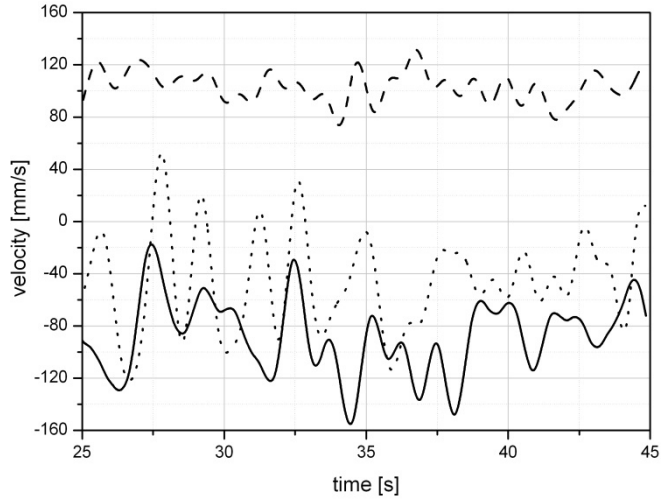
B = 310mT,
Non-conducting mould



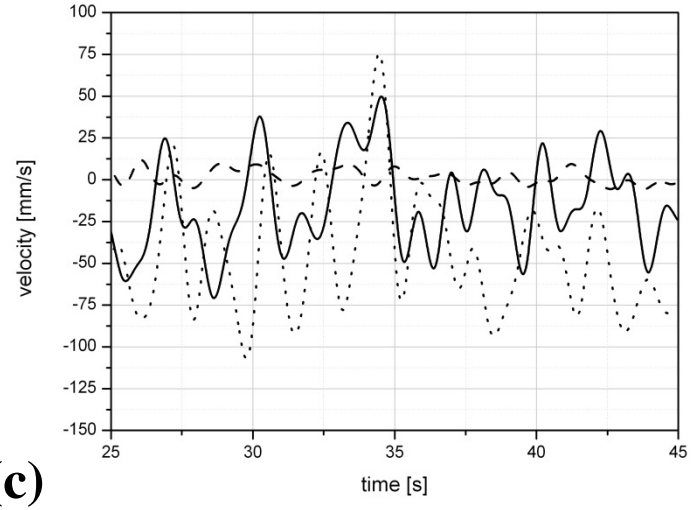
B = 310mT,
Conducting mould



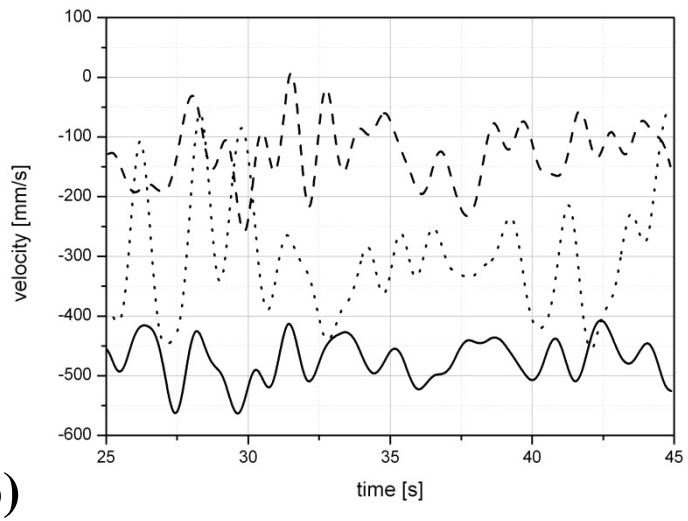
Local time series of the mould flow



(a)



(c)



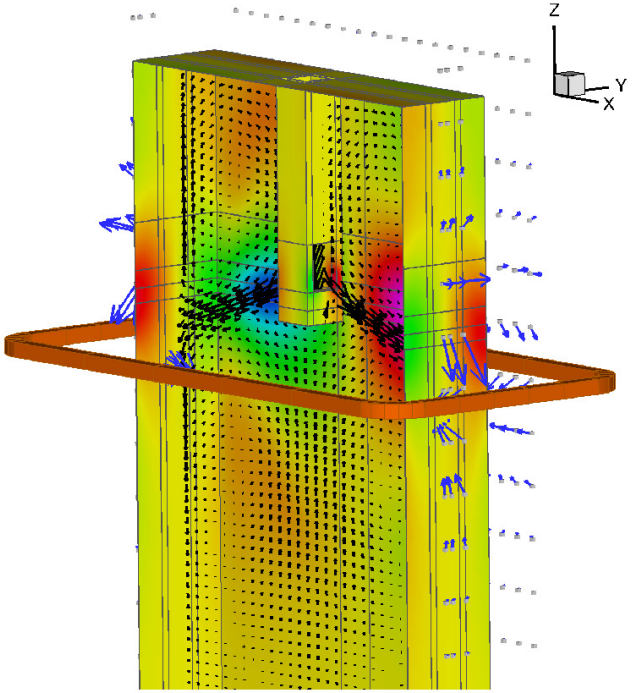
(b)

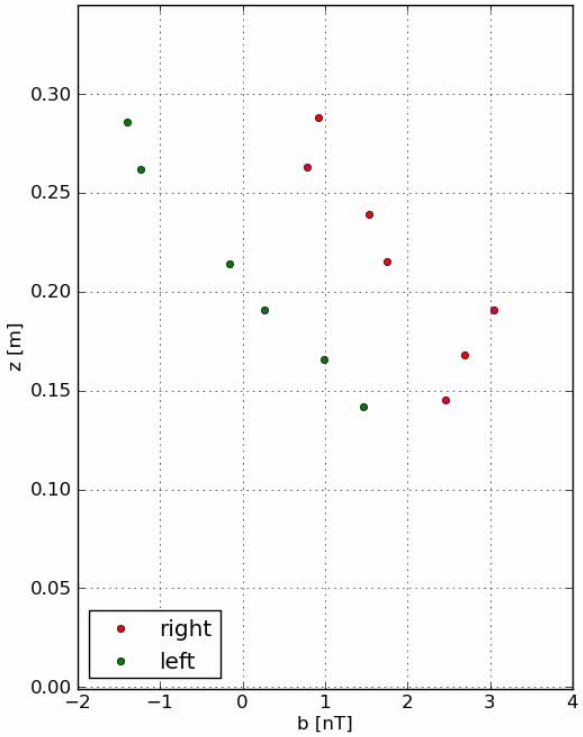
Time series of the horizontal velocity for:

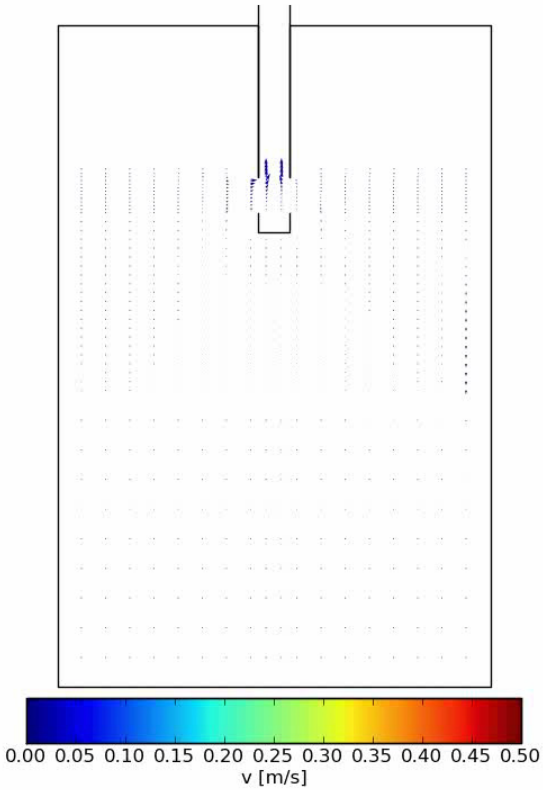
- B = 0 (solid lines),
- B = 310 mT in the non-conducting mould (dotted lines) and
- B = 310 mT in the conducting mould (dashed lines)

Recorded at x = 24.5 mm and **(a)** z = -1 mm, **(b)** z = 19 mm, **(c)** z = 49 mm.

CIFT at mini-LIMMCAST

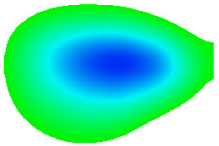






velocity

induced field



electric potential

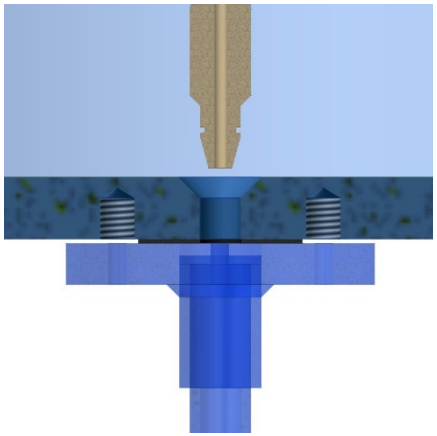
Flow reconstruction in the mould from 2x7 fluxgate sensors at the narrow faces:

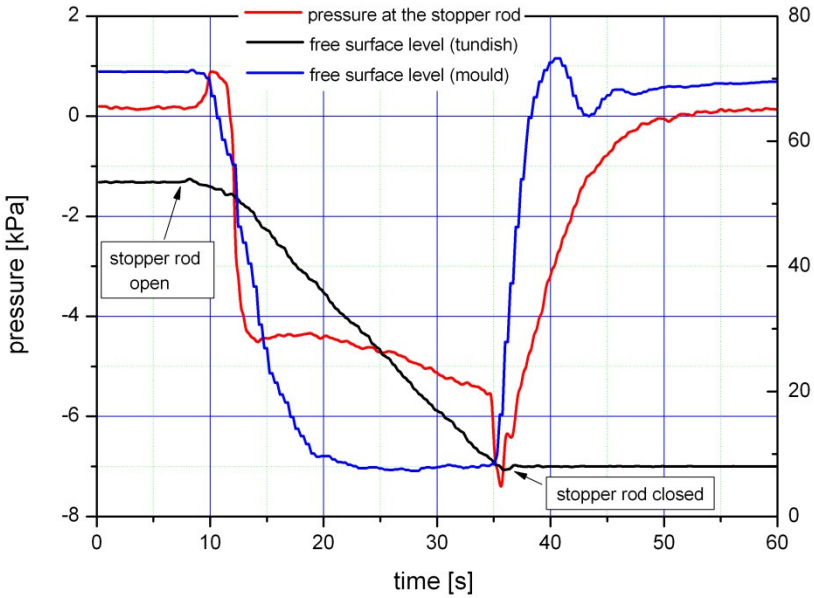
Very intermittent two-phase flow behaviour

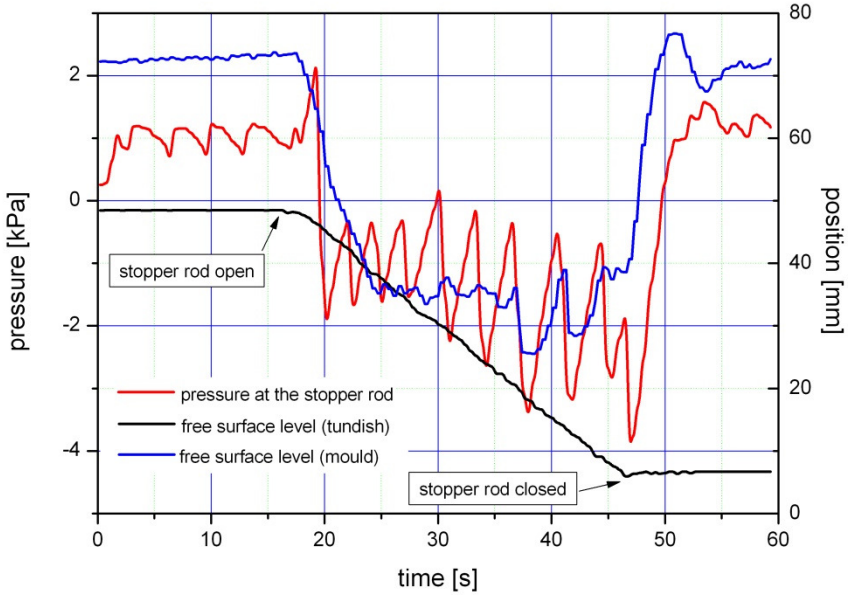
Two-phase flow

Open questions:

- Flow regime in the nozzle
- Bubble distribution in the mould
- Flow instabilities

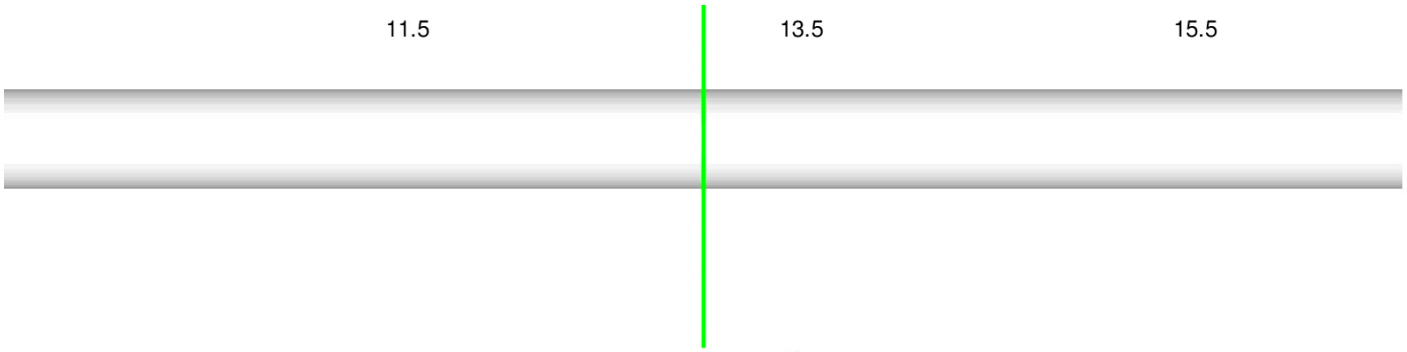


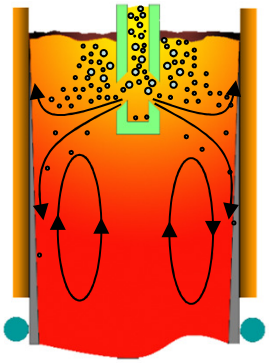


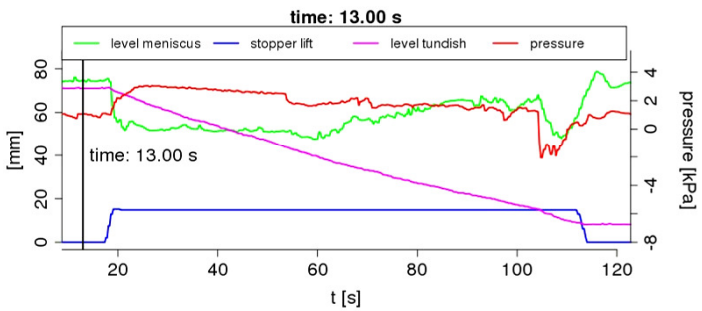


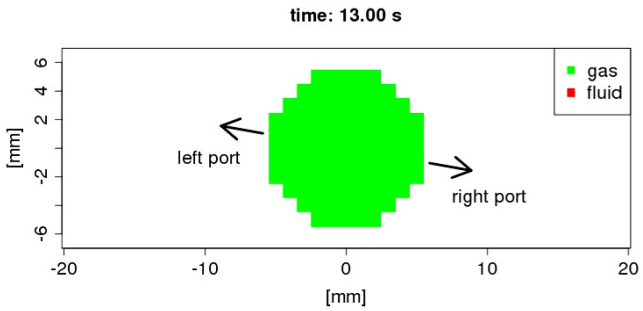
Two-phase flow in nozzle and mould

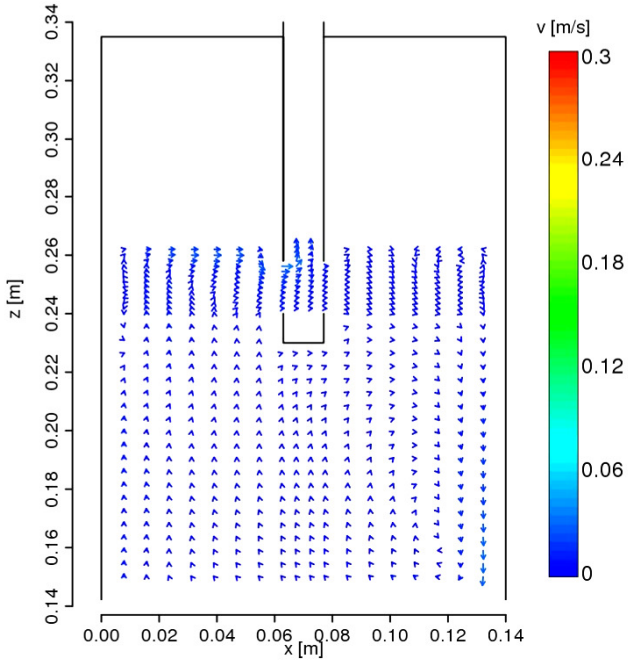
Complex measurements possible:
MIT in nozzle + CIFT in mould + pressure in SEN







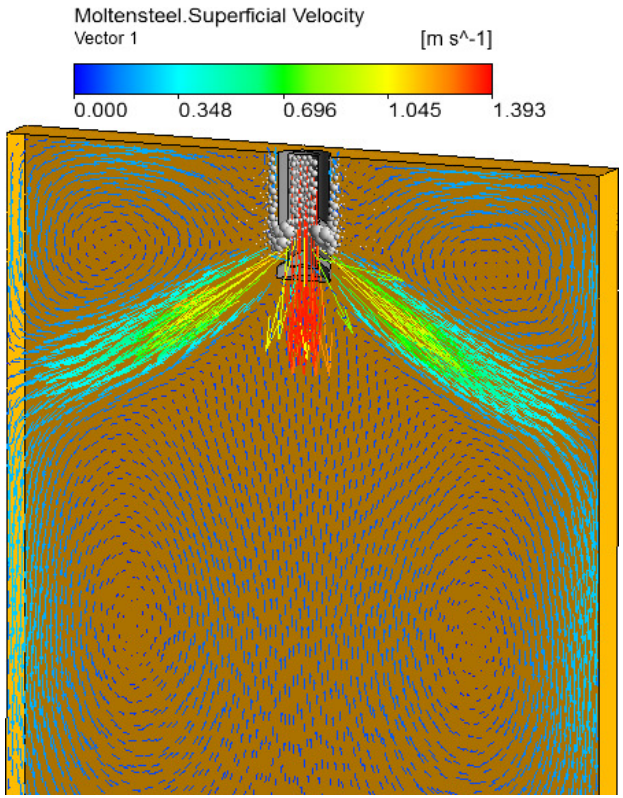




Numerical simulations (TU-BAF)

Previous work

- Flow investigations in continuous casting machines for steel (several projects: DFG, industrial partners, cooperation with HZDR)
- Simulation of flow and solidification in steel melts (SFB 799, TP C1)



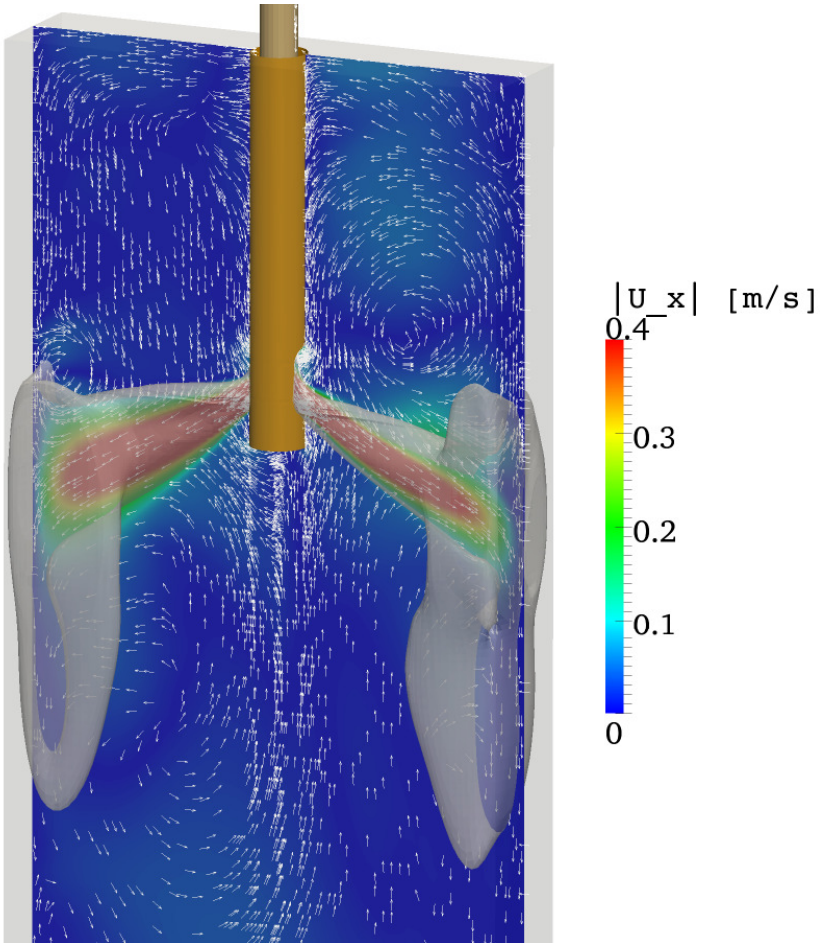
Current issues

- RANS/URANS model for mini-LIMMCAST
- FVM method, OPEN FOAM
- Turbulence models:
  SST k-ω, Reynolds stress
- Validation using experimental data

Numerical simulations (TU-BAF)

Status

- Qualitative features of the flow
- Complex interaction submerged jet – vortices



Next steps

- URANS
- Validation of the Reynolds stress model
- Extension of the turbulence model

Work packages

- Flow measurements wit DC-field (variations: magnetic field parameters, flow rate, SEN geometry, wall conductivity,…)
- Two-phas flow: flow regime inside the SEN, influence of the gas injection on the onset of instabilities
- Numerical simulations: MHD turbulence modeling, validation using the experimental data obtained at LIMMCAST

Links to other projects within LIMTECH

- A3, A4, A5, C1, C4 and YIG

Staffing issues

- S. Eckert, K. Timmel (HZDR)
- R. Schwarze, C. Kratzsch (TUBAF)