C3:
LIMMCAST: Modelling of steel casting

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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 ($T_{\text{Liq}} = 170^\circ C$)
- 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)
- \( B_{\text{max}} = 310 \text{ mT (Ha = 460)}, \) pole face: 180 x 40 mm²
- Magnetic field covers the whole mould width (level configuration)

Hartmann number

\[
\text{Ha} = B_0 R \sqrt{\frac{\sigma}{\rho \nu}}
\]
US measurements of the mould flow

- 10 sensors in multiplexer mode
- Time resolution \(\approx 5\) Hz

- \(B = 0\) mT
- \(B = 310\) mT, Non-conducting mould
- \(B = 310\) mT, Conducting mould
US measurements of the mould flow

Magnetic field influence on the flow:
- Change of the jet angle
- Formation of strong recirculation zones

**B = 0mT**
- Non-conducting mould

**B = 310mT**
- Conducting mould
Local time series of the mould flow

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

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 $k-\omega$, 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 with DC-field (variations: magnetic field parameters, flow rate, SEN geometry, wall conductivity, …)
– Two-phase 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)