Stopper sys [redacted]
mould durin [redacted]

SEN which gives rise to issues related to oxidization such as formation of inclusions which in turn can result in issues related to clogging; where the inclusions attach and accumulate to the surface of the SEN and restrict the flow, and defects; where inclusions become entrapped in the solidifying steel leading to lower quality of the final product. One way to mitigate the low pressures in the system is through addition of argon via the stopper, but this can however have undesirable consequences in increased instability in the mould.

It is necessary to gain further understanding into the pressure behaviour in the stopper and SEN throat region of a continuous caster to ensure increased pressures in the system while minimizing the instabilities in the mould level. The conditions in the corrosive liquid steel held at temperatures above 1500 °C does however severely limit the number of measurements possible to conduct. Previous measurements have been conducted to measure e.g., velocity in liquid metal as reviewed by for example Eckert et al at HDRZ [1] and S Argyropoulos [2] which highlights some methods of measurement. However, the difficulty in making long term reliable measurements has led to the necessity to develop systems similar to that of the continuous caster for measurements, examples of such systems are full- or down-scaled water- and liquid metal models. One such liquid metal model is the Continuous Casting Simulator (CCS) developed at Swerim to simulate the continuous casting process using a eutectic bismuth-tin alloy with properties similar to that of liquid steel.

The focus of this paper is to investigate the pressure distribution in the stopper and SEN throat region in the CCS. Additional measurements of the mould surface level and velocity are conducted to identify how the flow regulation process affects the stability of the system. The goal is to gain further understanding into the effect of the flow regulation of continuous casting on the pressure in the system to identify sources of risk to ultimately find ways to further improve the process- and quality of casting.

EXPERIMENTAL SETUP

Continuous Casting Simulator (CCS)

The CCS located at Swerim, Luleå, which was used during the experiments in this paper uses of the Eutectic Bismuth(52 wt%)-Tin(48 wt%) (EBT) liquid metal alloy circulating in a closed-loop system consisting of tundish-SEN-mould. Fig. 1 below visualizes a conceptual sketch of the CCS with the different subsections highlighted.

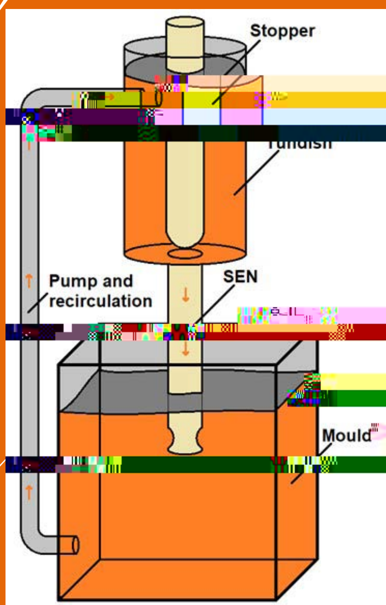
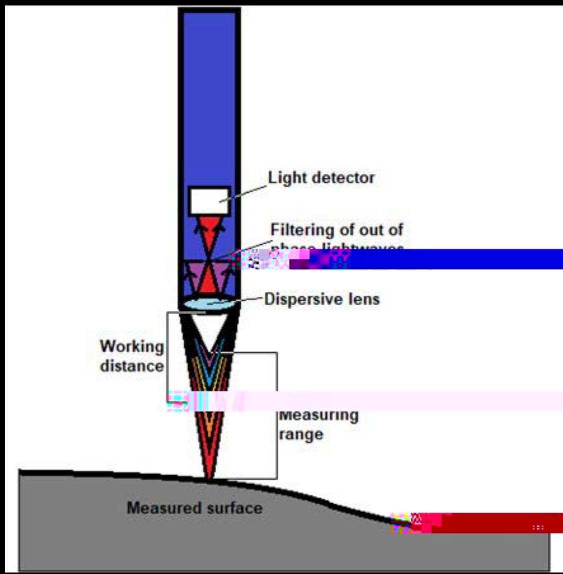


Fig.1 - The Continuous Casting Simulator design with the different subsections highlighted.

The mould is full-scale according to industrial continuous casters to as accurately as possible replicate the flow conditions experienced in the steel industry, with the slab dimensions of 1200x220 [mm]. The different parts of the entire system are manufactured out of steel, including the stopper and SEN used in the trials. The liquid metal is pumped from the bottom of the mould to the tundish to allow for the closed loop.



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[redacted]	[redacted]	0.129	0.236
[redacted]	[redacted]	-0.036	-0.016
[redacted]	[redacted]	0.123	-0.034
[redacted]	[redacted]	0.561	0.545

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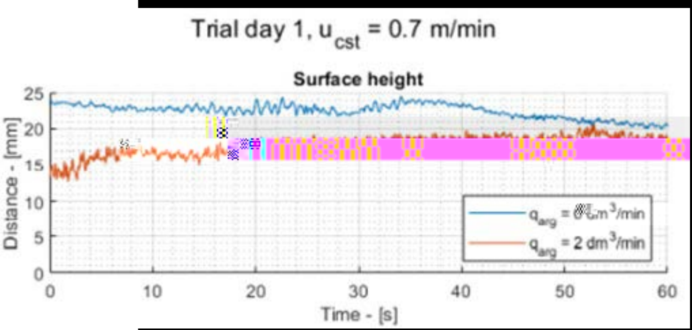

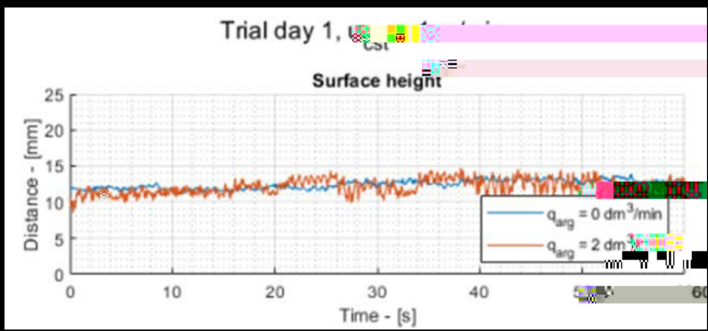

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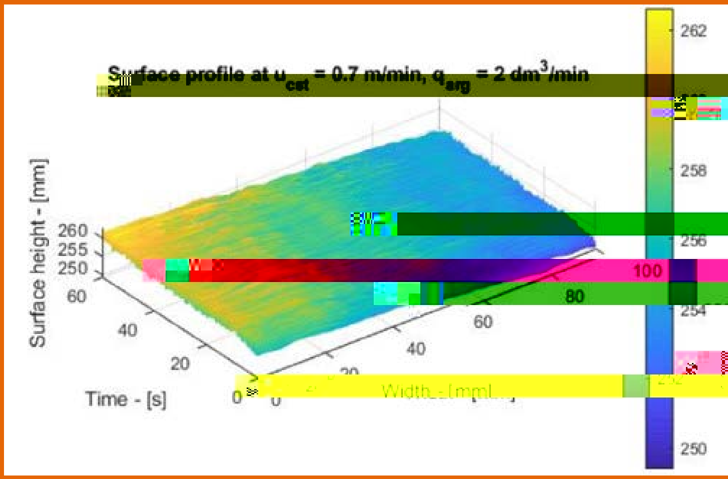

Fig.8 - Surface level measurement with the blue line laser sensor.

It is possible to distinguish higher frequent wave fluctuations at different times (i.e., as y-value increase) in the surface plot as well as a gradual level increase until the end of the measurement.

Velocity measurements

Four sensors were installed in the mould for measurements whereas one of the sensors resulted in consistent measurements over longer time periods. The reason behind the inconsistent measurements of the three other probes is believed to be due to the silicone oil forming an insulating layer on the electrodes of the probes as they are dipped through the mould surface. The resulting velocity measurements from the reliable velocity measurement in the near SEN region of the mould is presented in Fig 9.

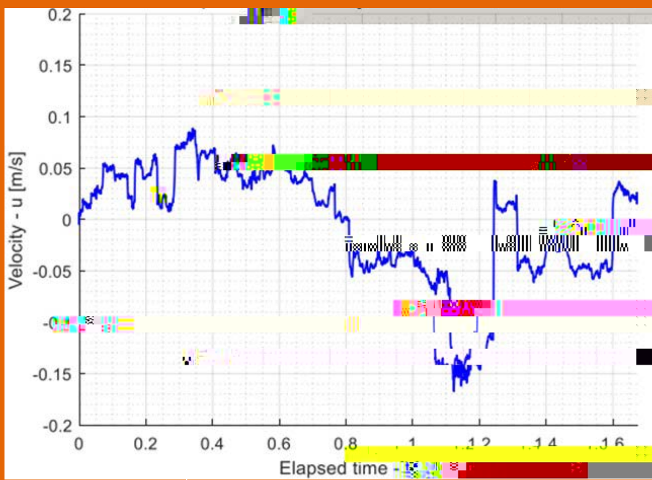

Fig.9 - Velocity measurement from near SEN region.

The velocity overall fluctuates quite a bit in both magnitude and direction. Initially the velocity is in the positive direction (towards the SEN) but then the velocity direction reverses, and the magnitude increases for a time until it reverses again.

DISCUSSION

The absolute pressures which were detected in the system were considerably low and very close to absolute vacuum. At these pressures there is a high likeliness of air infiltration into the system and possibly even that different constituents of the liquid metal may start to vaporize resulting in cavitation. It is however worth considering that the CCS system uses stainless steel which results in a very tightly sealed system which likely results in lower pressures than those which can be realised in the ceramic re-

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position.

Surface measurements were difficult to conduct due to the formation of a foamy layer of argon in the silicone oil. The measurements which were conducted showed a trend towards less stable mould level due to increased