FBG Optical fiber trial at ArcelorMittal INDUSTEEL Belgium.

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Summary.

ArcelorMittal Industeel Belgium is a steel plant producing carbon, low alloy, stainless steels and nickel based alloys through a continuous caster, in combination with a plate mill.
To ease and speed up the developments of new steel grades at the caster, Industeel Belgium has cast during 3 months with a mold equipped with 2 horizontal FBG fibers rows per broad face, containing 43 temperature sensors in each row. The aim of the trial is to verify the quality of the FBG measurements, as well as advantages of increasing in the resolution of the online thermal mapping of the mold during casting. Added to this, Industeel was willing to check the increase of performances in sticker detection. The trial has been done with the company EBDS Engineering, already monitoring the caster with its EMERALD BPS system, based on a thermocouple acquisition system.

Introduction.

The Industeel slab caster is a curved mold caster that can cast 225mm as well as 355mm thick slab. The steel grades being cast are in constant evolution and Industeel is willing to upgrade its mold with more temperature sensors, that have a better reliability, with a better heat response than the classical thermocouples, and not sensitive to possible water disturbance due to a lack of tightness. The target is to have a better “thermal mapping” of the mold, as consequently a better understanding of what is happening into the mold during casting.
In addition, the BPS system must use all these temperatures in order to improve its sticker detection and false alarm ratio.
In 2023, Industeel has awarded EBDS Engineering for a trial with its fiber solution, to evaluate the quality and the performances of this FBG fiber technology.

Layout of the trial.

The copper plates of the Industeel slab caster are 2450mm wide and 700mm high. There are 2 rows of 9 pairs of thermocouples installed in each broad face. These thermocouples are being installed at 286mm and 418mm respectively from the top of the copper, and the plates are nickel coated.

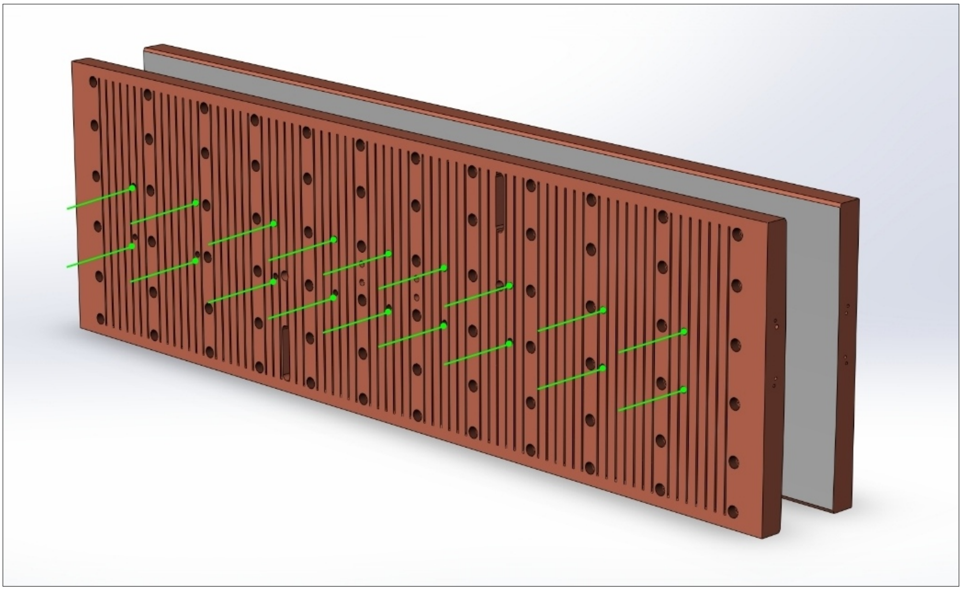

Fig. 1: Plate design and TC positions

As on can see, the 2 rows of thermocouples are evenly distributed on each side of the central horizontal axis of the plates. For the fiber trial, we have equipped 2 newly Ni-coated plates. In order not to destroy the newly installed Ni coating by installing inserts in the plates, we have chosen to drill the plate for the installation of the fibers. The position of the fibers are as the following drawing:

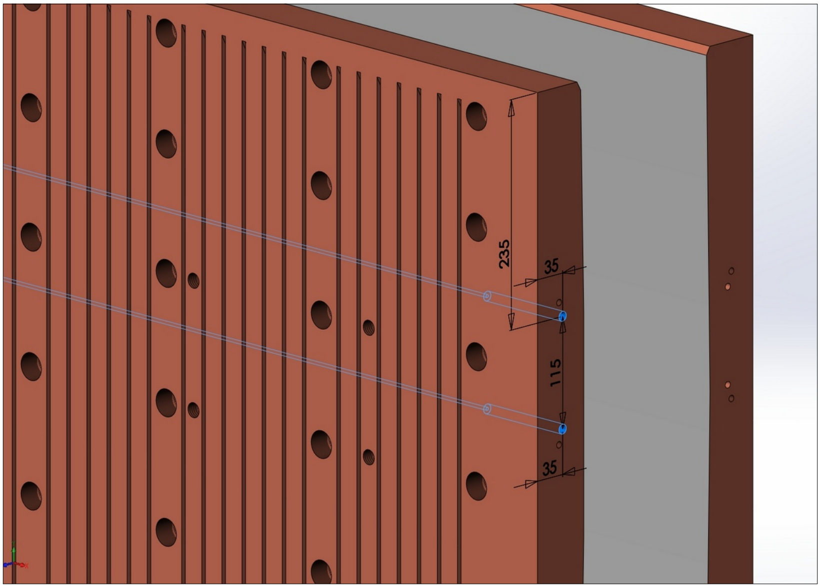

Fig. 2: Fiber positioning in the plates

The upper fiber is at 235mm for the top of the plate and the lower one is 115mm lower (central horizontal axis of the plate). As the length of the broad face plate is quite important (2450mm), we could not be sure to match the drilling from both sides. And so we have decided to use shorter fibers, installed from each sides of the plates.

So we have a total of 8 fibers being installed on the mold (each plate with 4 fibers, installed 2 by 2 from each side). All the optical fibers are being concentrated into a single concentration box installed on the mold, and from this box, a unique industrial optical cable in transferring all the optical signal down to an intermediate connection cabinet.

Each fiber is containing 21 FBG sensors so we have 42 sensors per horizontal row. The distance between each sensor is 50mm.

The following picture shows the general optical layout implemented at the caster.

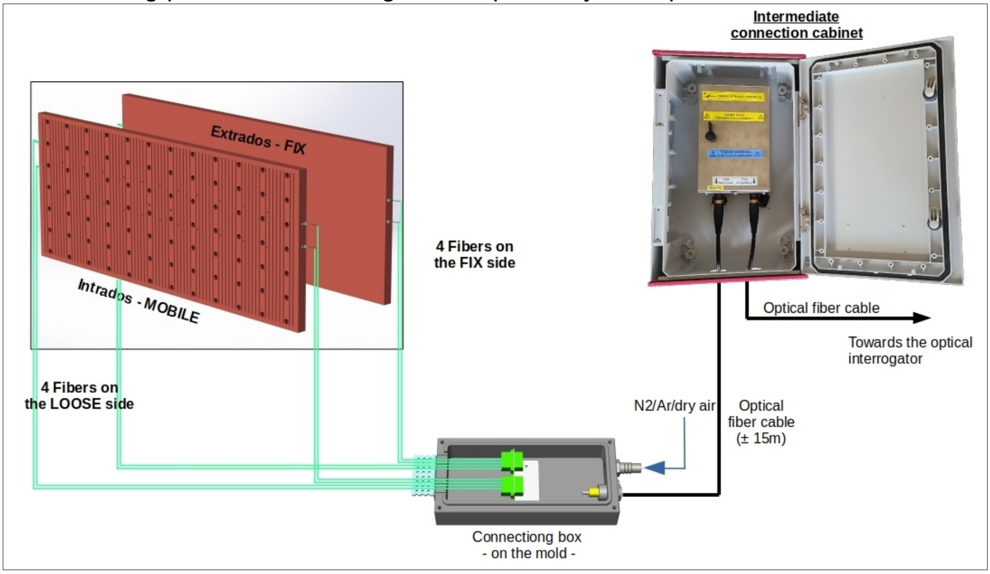

Fig. 3: Optical fiber layout at the caster.

The IT program used for the trial the Emerald BPS-HD, that is including the fiber optical signal treatment/management (optical spectrum management, peak detection, calculation of the temperatures of each individual FBG, using for each fiber its own calibration values).

The interface for the operator, used in the course of the trial is the EMERALD BPS-HD client , which displaying the 4 copper plates thermal exchanges of the mold (in relative T°), as well as the trends of any selected temperature vertical pair.

The TC pairs on the narrow faces were not active during the fiber trial.

Operating results.

1. Mold thermal exchange vision

From a thermal exchange vision point of view, the resolution given by the 2x42 sensors on each broad face is quite impressive and is showing very precisely the events that are occurring in the mold.
The following print screen are showing different situation visible on the screen of the operator.

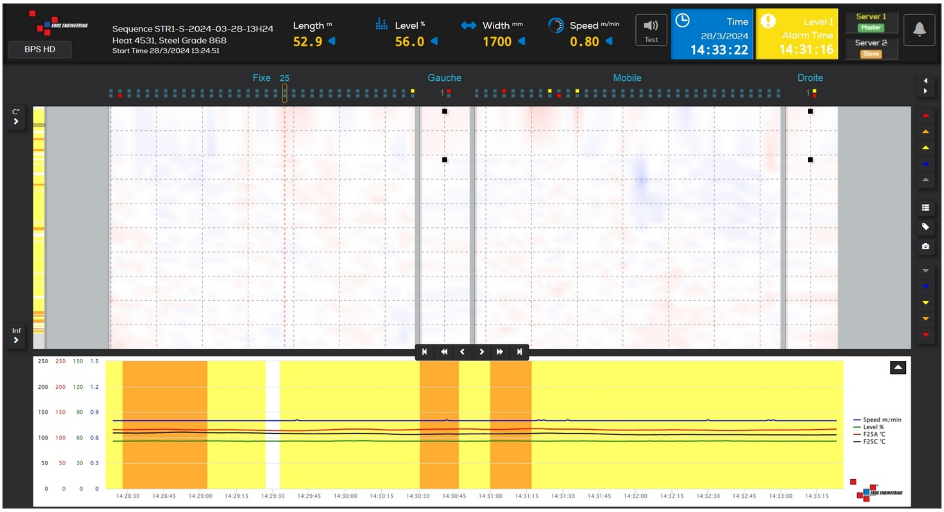

Fig. 6: Calm thermographical view.

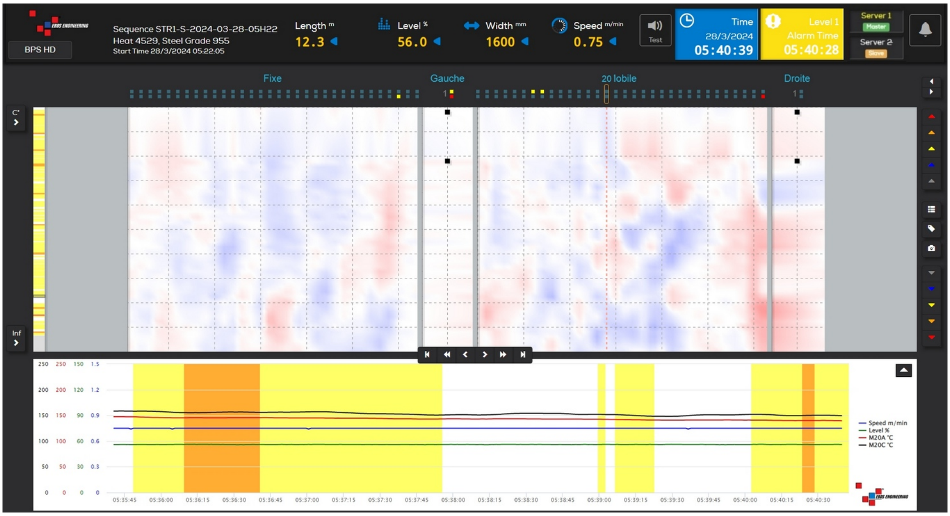

Fig. 7: Slightly agitated view.

Some steel grades, like peritectic can generate quite a lot of disturbances in the mold. For sure, these must be scattered and somehow evenly distributed in the mold. The following print screen shows such a steel grade, perceived by the FBG sensors:

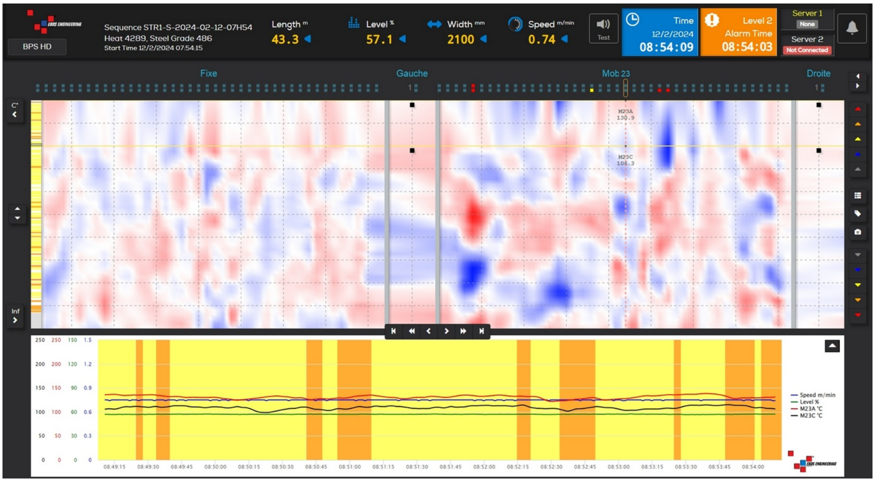

Fig. 8: Peritectic thermographical view

Uneven phenomena can be as well displayed:

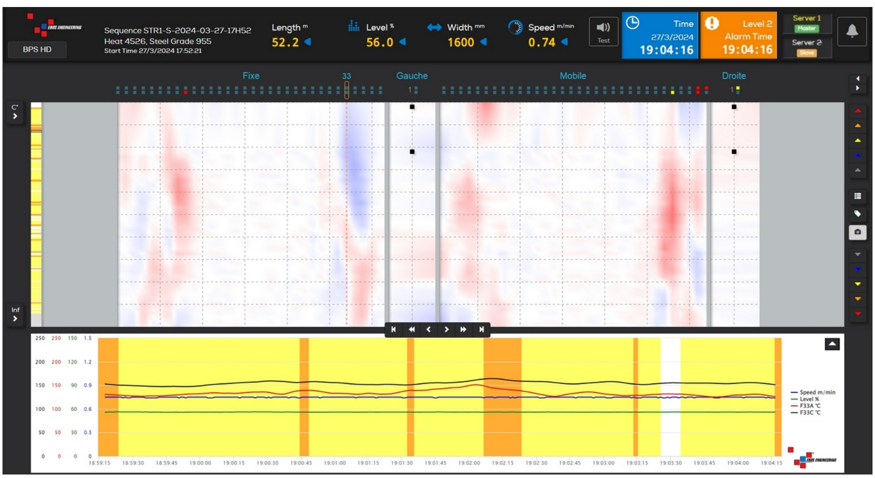

Fig. 9: Thermal agitation close to both narrow faces

For example here below, the fig. 10A and 10b are showing problems that can be seen on special steel grades; we can see that the EMERALD BPS-HD and the slab surface are having a very similar outlook:

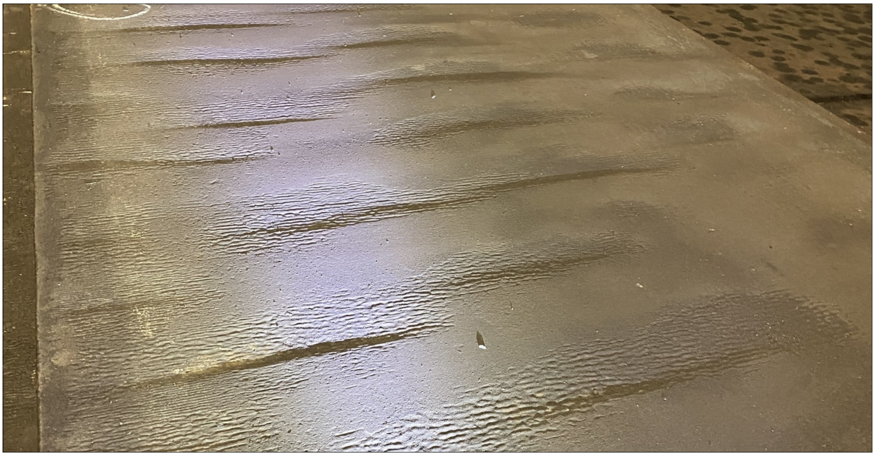

Fig. 10a: Problems on special steel grade generated in the mold – Slab view

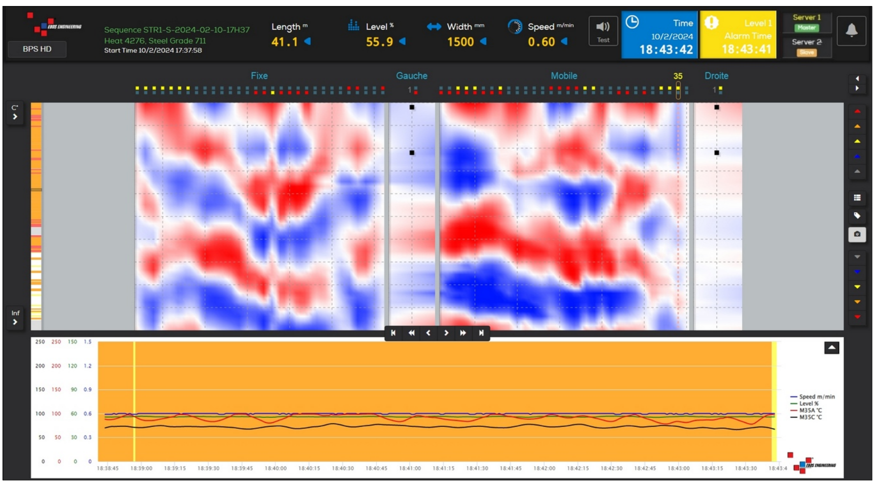

Fig. 10b: Problems on special steel grade generated in the mold – Screen view

These example shows the very fine information that can be obtained from the FBG sensors. If they are shown to the operator in a practical manner, as it is on the Emerald BPS screen for example, it is a precious information for the operator during casting, as well as for steel grade/mold powder developments.

2. Sticker detection

In ArcelorMittal Industeel, thanks to the low casting speeds (typically from 0.4m/min to 0.8m/min), the sticker detection does not need to slow down the caster automatically. The decision to slow down is taken by the operator, based on the vision of BPS screen. In addition to this, most of the stickers situations that are happening in Industeel will un-stick by themselves quite quickly, and do not need a slowdown to un-stick and heal.

In this particular example, we can see 2 stickers, developing on each broad face, due to a intervention in the mold. The left one is not un-sticked yet, but the right one has already un-sticked from the copper.

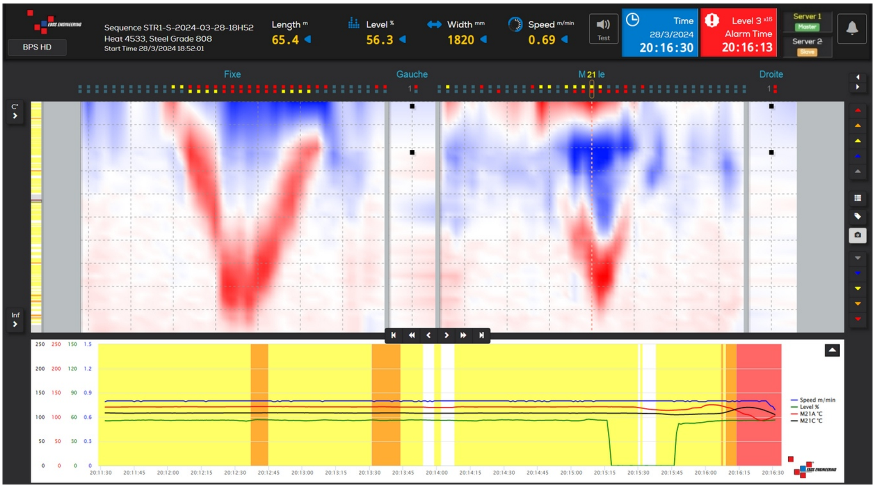

Fig. 11: Double sticking situation

In this particular case, the operator will decide to slow down the caster because of the left sticker. No BO occurred.

Here below an example of another sticking situation:

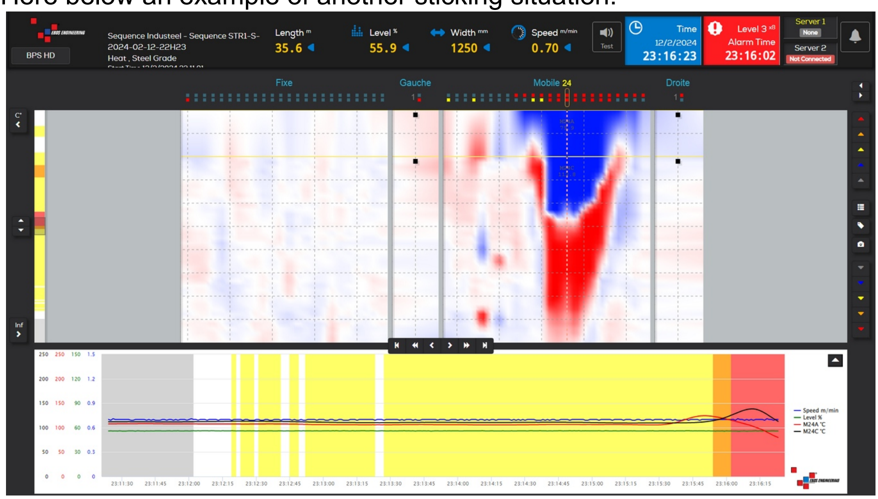

Fig. 12: Sticking situation

Thanks to the high resolution of the fiber sensors, it is also possible to see small sticking-unsticking situation that is not always possible to see/detect with the standard thermocouple view; for example, the figure here below shows a succession of sticking/un-sticking situation:

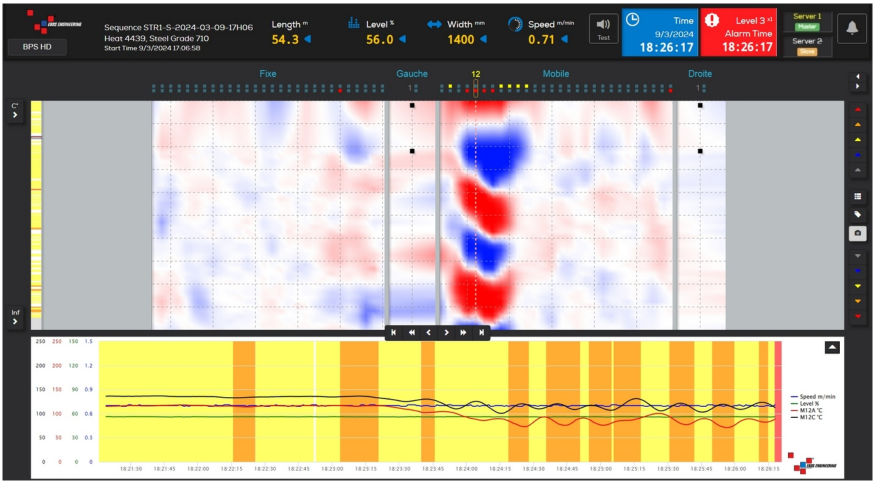

Fig. 13: Several sticking/un-sticking situation

Conclusions.

The use of FBG optical fibers, with sensors distributed every 50mm along the fiber, are showing excellent results, in terms of reliability and precision.
The trial allowed to show that the resolution of a 2 row FBG fiber system, combined with a performing thermographical screen is giving outstanding information to the caster operator on all phenomena happening in the mold, and can help to characterize the mold powder.
Added to this, it was possible to detect sticker formation quite earlier, and with a better confirmation rate than a standard TC based system.