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THE THIRD DIMENSION OF MOLD MEASUREMENT – CASTING PROCESS BENEFITS WITH THE 3D TREND[1]

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Abstract

How can a properly adjusted mold increase productivity and product quality in the continuous casting process on slab casters? By measuring the 3-dimensional contour of a mold, it is possible to observe the wear during its lifetime, estimate the lifetime of the mold and to measure and properly adjust the foot rolls. By knowing the exact taper of narrow face and broad face, you can prevent breakouts and detect a dangerous gap between narrow face and broad face. With information about the deviation from the set point geometry and scratches, you can determine the best time to exchange mold plates to prevent breakouts and save money. Until now, making a 3D measurement of the slab mold has not been possible, but newest laser technology has made it possible to acquire all the mold relevant data with only one measurement device that measures contactless and fully automatically.

Key words: Mold wear; Laser; Life-time; Slab quality.

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1 MEASUREMENT DEVICE

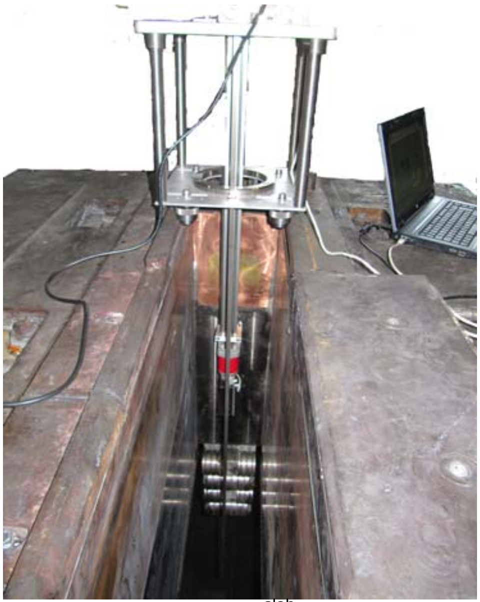

Figure 1. Mold.checker^{slab} in mold.

The mold.checker^{slab} consists of a measurement unit with laser and the evaluation PC.
The measurement unit is positioned in the corner region of the mold. It automatically calibrates its position in reference to the mold and the vertical axis.
A menu-driven HMI guides the operator through the measurement of the mold. The operator only has to enter data like mold number, mold width and number of casts and start the measurement.
The measurement itself is done completely automatically, so the operator is not prevented from doing other tasks.
For each cross section, more than 6,000 measurement points are taken in less than 6 sec.

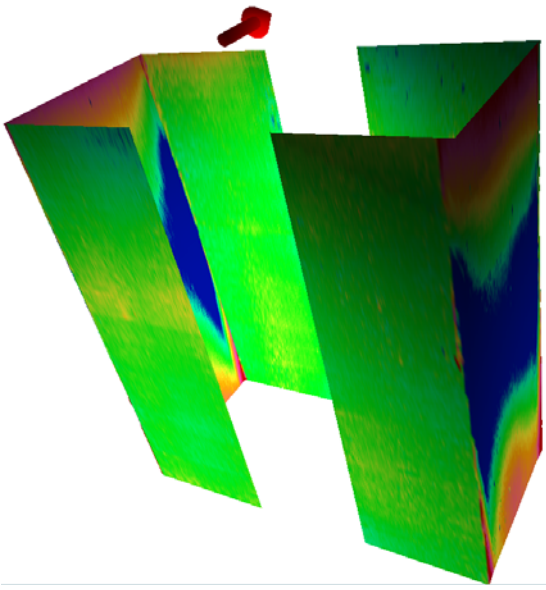

Figure 2. Measurement of mold corners.

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With the mold.checker[slab], both corner regions can be measured and visualized. Like in a 3d-CAD program, the result can be turned around arbitrarily to take an optimum view at each region.
The red arrow points in casting direction and the colors show the deviation of the set-point surface.
Different surfaces can be chosen as set-point surfaces:

- a plain surface;
- a more sophisticated one, e.g. with parabolic shape that is often used for narrow faces;
- an older measurement of the same mold to evaluate mold wear;
- a different mold to compare different shapes (e.g. a pure copper mold and a plated mold, but both with the same number of heats).

2 MEASUREMENT RESULTS

2.1 Scratches

Scratches may be a severe problem and in the worst case, they can result in breakouts.
Generally, there are two different kinds of scratches:

- horizontal scratches: caused by particles that have not properly been cleaned from the edges behind the narrow faces; that causes horizontal scratches in broad faces when narrow faces are moved;
- vertical scratches: Can result from bad insertion of the dummy bar or from strand tail or may be an indication that the plating is too soft for the applied clamping pressure.[1]

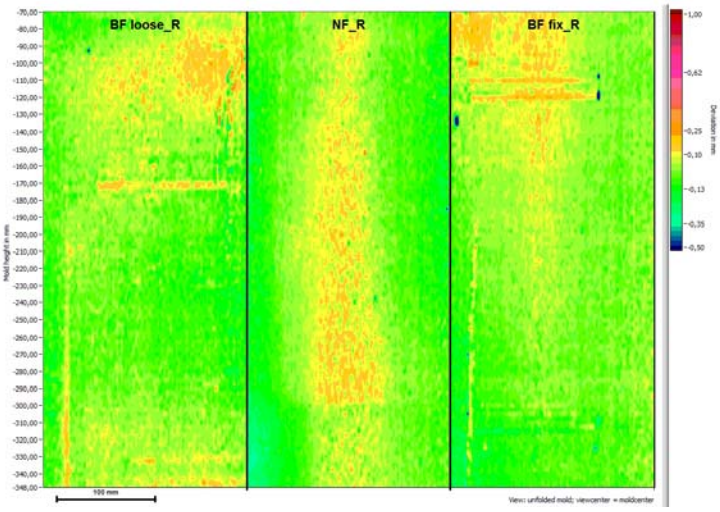

Figure 3. Mold with scratches.

Another visualization is shown in Figure 3, a so-called contour plot, where the mold surfaces (in this case the narrow face and both neighboring broad faces) are unfold. Wear from the reference plain is indicated by colors, red colors representing wear and blue colors representing regions that are too small (or typically are covered by dirt). The orange regions in the figure above indicate wear of 0.3 mm.

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Both types of scratches can be seen. The horizontal scratches are very close to the meniscus, so they can affect primary solidification.
On the narrow face (encircled in blue), it shows that wear is located more in the middle of the face than in the corner regions.

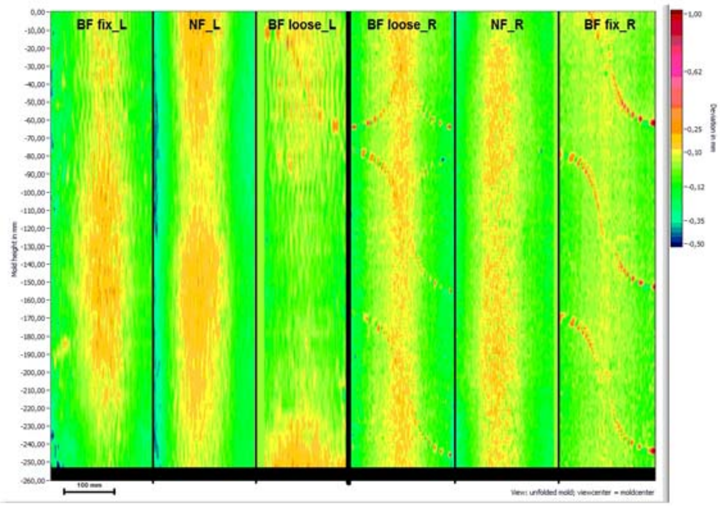

Figure 4. Scratches caused by grinding the mold plates.

Another interesting phenomenon could be observed on a mold that was returned from the maintenance shop. The operator was grinding the surface, and of course some marks of grinding could be seen, but no one expected them to be so deep.
With mold.checker^{slab,} it is now possible to also verify this phenomenon. The colors in the contour plot and also a detailed analysis of individual cross sections show that grinding leads to small spots on the copperplate that are nearly 1 mm deep.

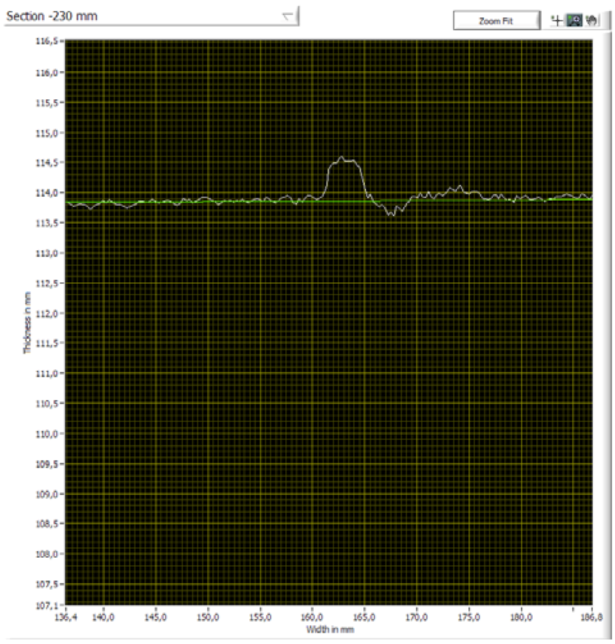

Figure 5. Detail of scratch in Figure 4.

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2.2 Checking Mold Geometry and Taper

Uneven shell growth in the corners of the narrow faces of the slab often results in subsurface cracking particularly for plate grades.(2) For that reason, narrow faces are getting a more complex shape.
This starts with changing the taper from linear to parabolic ones and results in complete 3-dimensional profiles of the narrow face where the lower part of the copper plate has chamfered edges to reduce friction, minimize copper wear and eliminate overcooling of the edges.

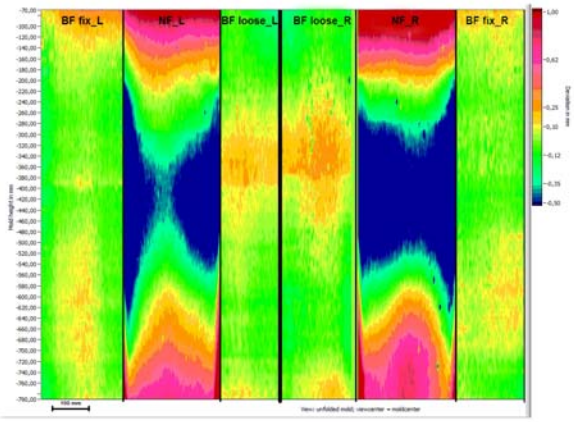

Figure 6. Contour plot of a mold with different narrow face shapes.

With 3-dimensional shape of the narrow face, a 3-dimensional measurement tool is necessary.
The contour plot in Figure 5 clearly shows the “non flat” shape of the narrow faces.
The pink spots at the edges of narrow faces in the lower part of the mold mark the chamfered edges.
Besides, red and pink regions on top of the mold are also detected. These are the parts where the parabolic taper differs much from a linear taper.
This can be seen even better in Figure 6, which shows narrow face taper.

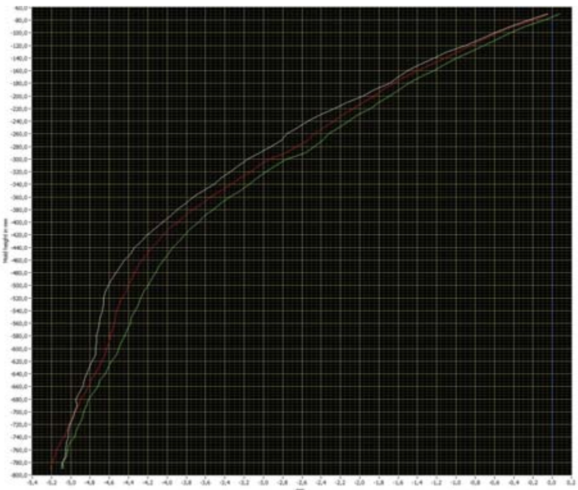

Figure 7. Taper of narrow face.

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With the mold.checker^{slab}, the taper can be checked on various vertical lines along the mold. As shown in Figure 7, taper on the narrow face is measured in the middle and at the first and last third of the face. It shows the typical decrease of taper with mold length.
Asymmetric wear on narrow faces may be caused by the "Aspect Effect", where the slab is pulled away from broad face fixed. This leads to higher wear on that side of the narrow face that is closer to the loose side and also to some higher wear on broad face fixed close to narrow faces. The reason for that effect can be uneven cooling between the broad faces.(2)
One reason for exchanging the mold can be a too small taper on broad face. The broad face taper can be decreased either by wear of mold plates or by dirt that is applied to the side surfaces of the narrow faces.
With the longitudinal plot of the mold.checkerslab (Figure 7), the operator can easily distinguish between these two phenomena.

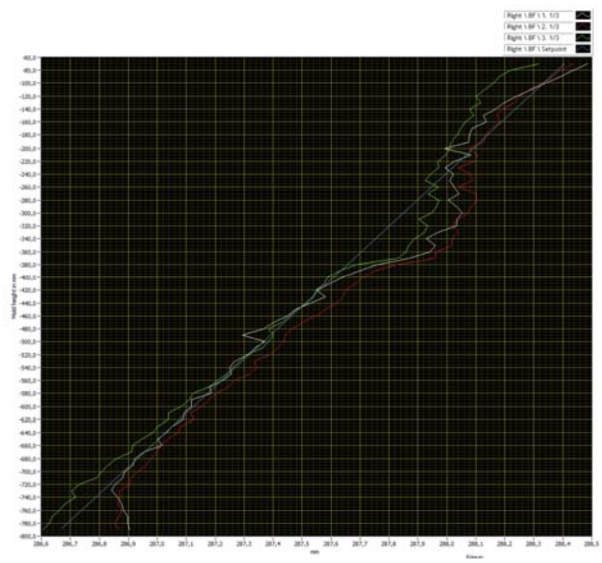

Figure 8. Mold thickness between broad faces.

The general taper is correct for most of the mold length. Only in the lowest part of the mold, taper gets lost, which is negative as the measurement gets closer to the narrow face. (The white line is closest to the narrow face.)
The set-point taper is linear, but wear increases with mold length. 400 mm from top of mold, this mold had nickel plating which has almost no wear compared to the neighboring copper. This leads to a step of about 0.4 mm.

2.3 Checking Foot Rolls

Improperly adjusted foot rolls:

- can cause cracks if they are misaligned and the steel shell is bent too much;
- can cause higher wear of copper plates by misaligned rolls or uneven wear by turned rolls.

Checking the foot rolls is therefore essential to optimize the copper plate life time.

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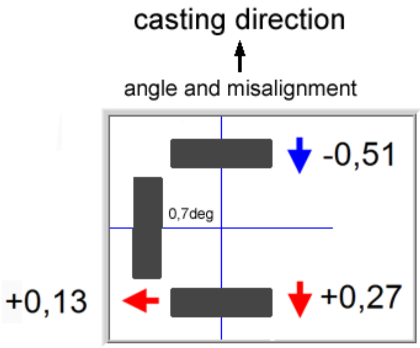

Figure 9. Foot roll measurement.

Figure 9 shows the misalignment and angle of foot rolls. Colored arrows clearly show the operator the direction in which the roll is misaligned and the angle of the narrow face foot roll.
Depending on the mold design, the mold.checker^{slab} can measure several rows of foot rolls and evaluate the angle of the narrow face foot rolls, including the displacement of narrow and broad face foot rolls from their desired position.
With an optional length, the mold.checker^{slab} slab can measure the first bender roll and therefore even detect misalignment between bender and foot rolls.

3 INCREASE OF MOLD LIFE TIME

A main goal for maintenance is to optimize the life time of the mold.
One aspect is applying a coating. The cheapest version is a step coating where only the lower part of the copper plate is coated, to full-faced tapered coating with different coating thickness from top to bottom of mold.
Different coating materials from nickel to ceramics are also available.
Nevertheless, if you want to verify the advantages of any type of coating, the mold has to be measured and wear has to be tracked against the number of heats. As wear can be located differently. only a full 3-dimensional measurement of wear guarantees an objective evaluation of wear.
Besides, when the mold coating is set, the optimum time to exchange the mold has to be found.
Conventionally, the mold is exchanged

- after a pre-defined number of casts (independent of real wear)
- if an operator detects scratches (independent of their real depth and position)
- when any problem on the mold is detected

With mold.checker^{slab},there is a tool to objectify mold wear.
With the help of the mold.checker, Acciaierie Venete S.p.A. could demonstrate the direct relation among subsurface cracks, ghost lines, out-of-squareness and wear of their billet molds.[3]
With that knowledge, they could increase the technological life of the mold (up to +40%) while meeting the product quality requirements.
For slab molds, the saving of expenses by increasing the mold life time might also be high (not to mention the improvement of quality.)

If, for example, the life time of the mold can be increased from 65,000 t to 90,000 t with repair costs of € 20,000 per mold, one can save about € 90,000 per million ton of production.

4 CONCLUSIONS

Benefits using a complete 3d-measurement of the mold:

- Scratches in the mold (e.g. caused by the movement of the narrow face) can be dangerous for the solidification of the strand. But of course, it strongly depends on where the scratches are located and how deep they are. Up to now, it was a subjective decision of the operator if he used the mold any longer or not. With this new measurement device, a simple measurement can be made that determines the position and depth of the scratch. With predefined limits, the operator is told whether to use the mold any longer or not;
- when using the device directly on casting platform, an objective status of the mold before casting is achieved: If any cast start problem or, even worse, a breakout occurs, it can clearly be identified if it was caused by any maintenance or adjustment problem in the mold. (Mold quality is documented.);
- surface cracks can be caused by improper alignment of the foot rolls or misalignment between bender and segment 1. It is not enough to measure the foot rolls in the maintenance shop because it may also happen that the position of the foot roll has changed. (e.g. screw not tightened enough.) The mold.checker^{slab} measures the mold as well as the alignment of foot rolls and can even measure down further to segment 1. For the operator, this offers the advantage that he can put the device on the mold, start the measurement and all measurements will be made automatically. This simplicity helps to avoid measurement errors;
- optimizing the life time of the mold is an evident point to gain higher yield and optimize quality. However, you need a tool where you get numbers that quantify the wear for different coatings, for example.

The mold.checker^{slab} is the only tool available making an automatic 3d-measurement of the mold and obtaining definite numbers that represent the condition of the mold.
Of course, it is still the task and knowledge of the individual steel plant to prepare fixed rules (like the decision to exchange a mold copper plate) based on the objective measurement results. Of course, these rules can be different depending on the steel quality that is casted.

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Acknowledgements

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