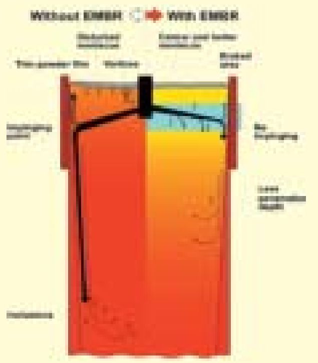
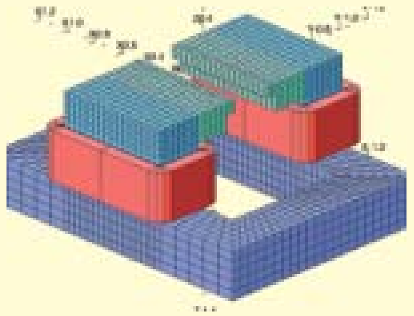
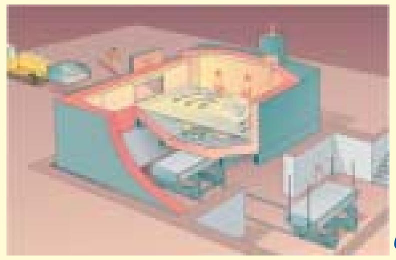
Application of OPERA to Continuous Casting of Steel





Electromagnetic brake analysed in OPERA



Furnace and AL-EMS stirrer

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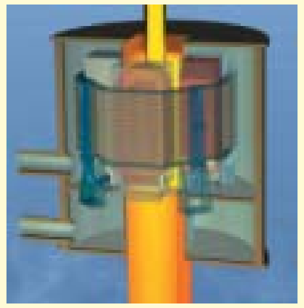
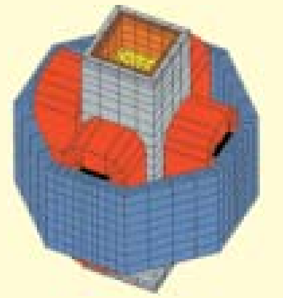
In metallurgical processing, the technology employed for stirring and mixing the melt is one of the most decisive factors when it comes to achieving higher quality and productivity. ABB has been involved with melting and casting operations since 1947, and their stirrers and brakes were developed and designed with quality and productivity in mind. The resulting benefits in terms of reproducibility and profitable production have been demonstrated over and over again. Many of their customers have reported payback times for such investments of about one year.

This paper was presented by Dr Jin Li, at the European User Group Conference 2001 on 7 September 2001, held at Chalmers Institute of Technology, Goteborg, Sweden.



ModMEMS



ModMEMS OPERA model

EM Brake Improves Performance

EMBR/FC Mould (ElectroMagnetic Brake/Flow Control Mould) are special products which have been developed by ABB for slab casters. They are best described using the figure above.

The right part of the strand indicates the steel flow with EM braking, and for comparison the left side shows the steel flow without braking. When the steel is injected from the nozzle it hits the narrow side of the strand and is divided into two flows - one flow is downwards and a second flow is directed up towards the meniscus. Without the EM braking the steel flow down the mould narrow side will induce inclusions and force mould powder deep down into the strand. Further an inclusion agglomeration zone will be formed close to the slab upper surface, especially noticeable with conventional curved casters.

In contrast, with EM braking the steel flow penetration depth is decreased and the number and size of the inclusions in the agglomeration zone is significantly reduced. The steel turbulence is reduced and the heat flow towards the solidified shell will also decrease. Further, as the steel penetration depth is decreased with braking, so the hot steel coming from the nozzle is kept high up in the strand. The result is that the steel meniscus temperature is increased.

The steel flow at the mould narrow side will form a swelling of the steel meniscus. This means that the molten layer of the mould powder will be thinner, resulting in bad lubrication and a risk of surface cracks. With EM braking this swelling is decreased and so the risk of surface defects decreased.

The fast, turbulent steel flow at the meniscus gives rise to a risk of mould powder entrapments. This is especially evident for thin slab casters. Further, biased (unsymmetrical) flow heavily increases the risk for vortices and hence mould powder entrapments. The steel flow and the turbulence is decreased with braking and the biased flow is suppressed resulting in a large reduction in mould powder entrapments. Further, the remelting of the solidified narrow side shell at the impinging point is reduced.

Stirrers

The aluminium electromagnetic stirrer AL-EMS is water-cooled and operates with a low-frequency travelling magnetic field. It can be mounted either under the bottom or at the side of the furnace. There is no physical contact between the EMS and the furnace. Stirring power and stirring direction can be controlled either manually or automatically. A bottom mounted EMS stirrer is shown in the figure.

The ModMEMS is a new type of billet mould stirrer, specially well suited for revamping projects. It is unique in many respects:

- It is cooled by existing mould water.
- No extra cooling equipment is required.
- The windings are made with copper foil which is very compact and efficient for small coils.
- For square billets it has 4 poles which decreases the air-gap in the stirrer.

These factors ensure the resulting stirrer is an extremely low power consumption, energy saving device. A standard motor converter with modified software is used as the power supply. In addition the design with individual pole modules makes it easy to adapt the stirrer to different installations.

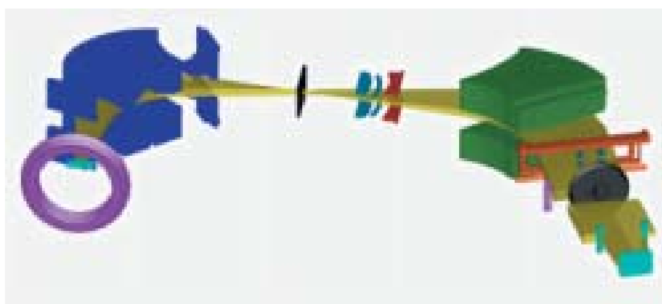
Simulation Helps Decrease Implanter Design Cycles

Varian Semiconductor Equipment Associates Inc is an industry leader in designing and manufacturing ion implantation systems - semiconductor processing equipment used in the fabrication of integrated circuits. Varian is using OPERA-3d to shorten the design cycle for new generations of ion implanters that can produce semiconductors with smaller design rules. An important requirement is shorter beam lines to reduce effects of space charge, and TOSCA combined with SCALA are used to predict the interaction of multiple magnets while simultaneously modeling the space charge of the ions, the trajectory of the ion beams, and the electrical fields within the implanter.

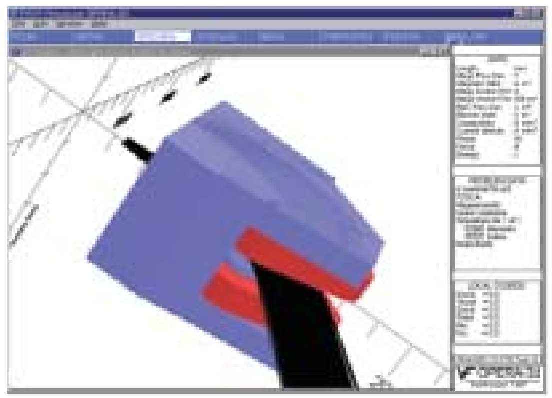
Controlled by magnetic fields

All of Varian's ion implanters work in a similar manner. Ions are pulled from a hot plasma source by means of extraction electrodes. The ions pass through an acceleration/deceleration device that changes the energy of the ion beam. The beam then passes through a number of magnetic fields that alter the beam in some way. For example, an analyzer magnet purifies the beam by filtering out unwanted species. If the source material is boron fluoride, the analyzer magnet will filter out the fluorine so that only the desired dopant, the boron ions, remains in the beam. Another magnet, called the corrector magnet, shapes the ion beam into the correct form for deposition onto the wafer. The system includes other, smaller magnets that perform functions such as measuring the ion dose.

Understanding the behavior of both electric and magnetic fields is critical to designing an ion implanter. The system includes two sources of electric fields. One is the field that is created intentionally by the extraction electrodes. The other occurs because the ions have charge, so they tend to repel each other. This space charge effect must be accounted for in the implanter design so that the beam is refocused as it passes through the implanter. Design issues related to the magnets include determining the saturation in the magnet steel, producing the correct energy range to meet the semiconductor's design specifications, and avoiding aberrations and unwanted beam distortions to prevent the inclusion of unwanted components within the ion beam. Varian's ultimate goal is to shape the beam so that it delivers a uniform, repeatable, correct dose of dopant and does this 24 hours a day.



Shows the ions paths in yellow as they pass through the VIISta 80 high current implanter. The beam exits the source at the left, passes through the 90 degree analyzer magnet where unwanted portions of the beam are filtered out, passes through a collimating slit, passes through a set of electrostatic deceleration lens, passes through the 70 degree corrector magnet, passes through a second deceleration lens, and finally strikes the wafer.



Screenshot of an OPERA simulation of the VIISta 80 corrector magnet (70 degree bend). The ion paths are diverging as they enter from the left, and are parallel to each other as they exit to the wafer.

More powerful simulation

Following an initial sketch of a new design, researchers first analyzed each individual segment using TOSCA to see the magnetic and electric fields. This step allowed them to design and optimize each individual magnet - the source, the analyzer, and the corrector as well as the other, smaller ones used in the system. Since some of the magnets were now placed close enough together to interact, the next step was to combine segment models and repeat the analysis to study the interactions. This allowed the designers to achieve their goal of reducing the length of the beam line. Rather than avoiding the issue of magnet interaction by keeping the magnets far apart, they were able to see exactly how close they could place them before they got undesirable effects.

A lower energy beam was a design goal for the new implanter because it would make it possible to deposit the dopant at smaller depths, thus supporting customers' demands for more densely packed chips. A low energy beam made space charge a serious concern however, because as ions travel more slowly in a lower energy beam, they have a greater space charge. Having a shorter beam line would help control space charge, but designers still needed to incorporate ways of neutralizing the charge into the system. They found SCALA to be very helpful in doing this because it allowed them to predict space charge and ion trajectories simultaneously with magnetic and electric fields in the region. By using the results to guide the design, designers were able to resolve the low energy beam space charge problem.

One benefit of using these analysis tools on this project is that it shortened the design process. In the past it would take many months to design and optimize the magnet for a single segment of the ion implanter. With the insight provided by electromagnetic analysis, this was done in only several days. This new ion implanter is the first in which simulation was used throughout the design process but the system was completed in less time than the company normally needs to develop a new design. The other benefit of using simulation is that it stops engineers from pursuing design ideas that look good but are really flawed. They do not go down a wrong path, and they save the time and cost of building and testing prototypes.