Scientific Knowledge Group

Research Article

Journal of Material Sciences & Energy Advances

Roturbo Multimode Electromagnetic Stirrer (Mode-Ems) Processing Modeling by Multiphysics

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Abstract
Roturbo, multi-mode meniscus electromagnetic stirring (MODE-EMS) in tundish and flow controlling system is the advanced product. The unique magnetic turbo-circuit design and control technology, the product can automatically realize many stirring modes: single/turbo rotation mode, acceleration mode, deceleration mode, two-zone turbo mode, double-helix acceleration mode and so on. By using the metallurgical data packet, the required stirring position, modes and parameters can be switched according to the steel grades, the strand section and the quality requirements. So, electromagnetic stirrer for meniscus is installed on the mold the continuous caster. The strong Multiphysics coupling is studied with heat transfer or Navier-Stokes interface for induction heating or fluid flow control. In the case if the of laminar flow steel depth δ (penetration depth of the electromagnetic field inside the material) is very small compared to the characteristic dimension (e). A surface Impedance is set up and we do not need to resolve in detail the interior volume. Regarding, a thin conductive layer (e < δ), the layer is described only by a surface with a two-way boundary condition. The electromagnetic action zone covers the meniscus. Mainly used to improve surface and subsurface quality of the bloom / slab. It is one of the key metallurgical equipment's for continuous casting of special steel with high surface quality requirements, such as EV-cars and household appliances [1]. Roturbo MODE-Electromagnetic (MODE-EMS) processes are good candidates for energy saving and CO reduction demands. In metallurgy industry, it leads to productivity improvement, maintenance reduction and safety integration.

Keywords: Heat Transfer, Metallurgy, Contact Resistances, Solid Mechanics, Thermal Dilatation.

Received: January 20, 2026;
Accepted: January 28, 2026;
Published: Febuary 04, 2026

Introduction

Numerical modelling is a very useful tool to increase the control of foundry processes and to predict the metallurgical and mechanical properties of molten metal ingots. In Sidex , various melting processes are used. Example, the plant produce large forging and castings products in carbon steel or stainless steel which are required to manufacture the primary components of a nuclear power plant. At Sidex plant, the vacuum arc remelting process is used to produce superalloys ingots with a high level of quality in terms of chemical composition and solidification structures. Finally, the vacuum induction melting is used in several laboratories to produce and study alloys and melting processes. The objective of this work is to develop a model able to describe crucible filling through a simplified approach and to study in details continuous-casting / ingot-crucible interactions, to predict their influence on the performant metallurgy results. Different physical phenomena are of primary importance, such as the cooling mode and the contact conditions between the ingot and the crucible.

State of the Art Technologies

Mold Electromagnetic Stirrer (m-ems)

Actual main technologies have developed an in-mold electromagnetic stirrer, (M- EMS), consisting of four-part stirrers, two on each wide side of the mold, placed high in the mold.] Two-part stirrers are electrically connected cross-wise to two frequency converters in

Citation: Paul OLARU (2026) Roturbo Multimode Electromagnetic Stirrer (Mode-Ems) Processing Modeling by Multiphysics. J Mat Sci Ener Adva 1: 1-5.

order to facilitate different Lorentz force combinations along the meniscus level. The M-EMS creates a circulating meniscus flow (Figure 1), resulting in less nonmetallic inclusions entrapped in the initial solidified shell and an improved shell growth homogeneity and thus a decreased number of longitudinal cracks. The M-EMS is installed at most SIDEX slab casters and in some cases also in combination with an electromagnetic brake (E-MBR) field at the bottom of the mold.

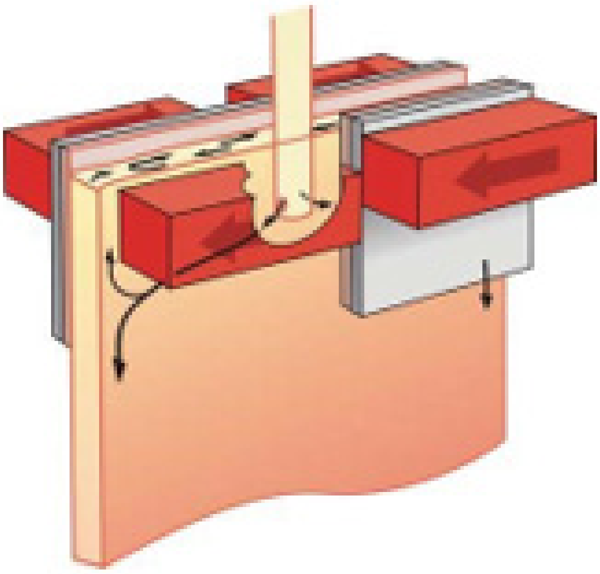

Figure 1: M-EMS circulated meniscus flow

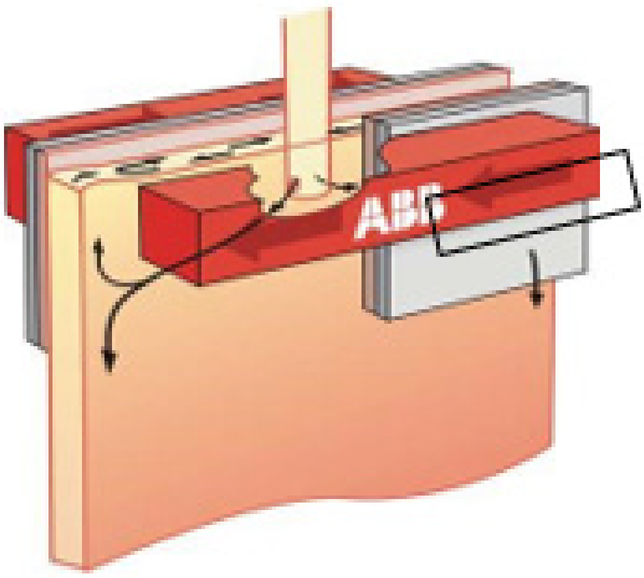

Figure 2: FC M-EMS mold electromagnetic stirrer

The Flow Casting Mold Electromagnetic Stirrer (FC MEMS) consists of two (2) part stirrers, one on each wide side of the slab, placed high in the mold and controlled from one common frequency converter, (Figure 2) [2]. A longer pole pitch of the coil makes it possible to achieve a stronger magnetic flux distribution in the mold and to maintain normal iron thickness, and with the benefit of reasonably low power consumption. The FC MEMS creates a circulating meniscus flow (Figure 2), resulting in less non-metallic inclusions entrapped in the initial solidified shell and an improved shell growth homogeneity and thus a decreased number of longitudinal cracks. The FC MEMS is intended for low to medium speed casters and is also recommended for crack sensitive grades, i.e. peritectic steel grades, and for wider strands.

Roturbo Multi-Mode Meniscus Electromagnetic Stirring (MODE-EMS)

The ROTURBO MODE-EMS consists of four (4) stirrers, located in the middle of the mold, two on each wide side of the slab mold, (Figure 3) [3]. The stirrers on the right and on the left respectively are series connected and each fed by one frequency converter. The stirrers are normally operated in two different modes. MODEmode (stabilizing) is used for high-speed casting when the meniscus velocity is too high [4,5]. The force of the stirrers is then directed towards the submerged entry nozzle (SEN) and counteracts the metal jets, reducing the velocity of these jets and thereby also the meniscus velocity. Electromagnetic low-alloy EMLA-mode (accelerating) is used for low-speed casting when the inertia in the jets from the SEN is not sufficient to reach the minimum meniscus metal flow velocity required [5]. The force of the stirrers is then directed towards the narrow faces, accelerating the steel in the center of the mold and increasing the meniscus flow velocity. Electromagnetic Brake-Mode Stirring (E-MRS) is a third mode that is intended to rotate the steel in the middle of the mold. However, it is not clear from the literature what the effect is and whether new mold powder inclusions appear with this low position in the mold nor when it is intended to be used [3].

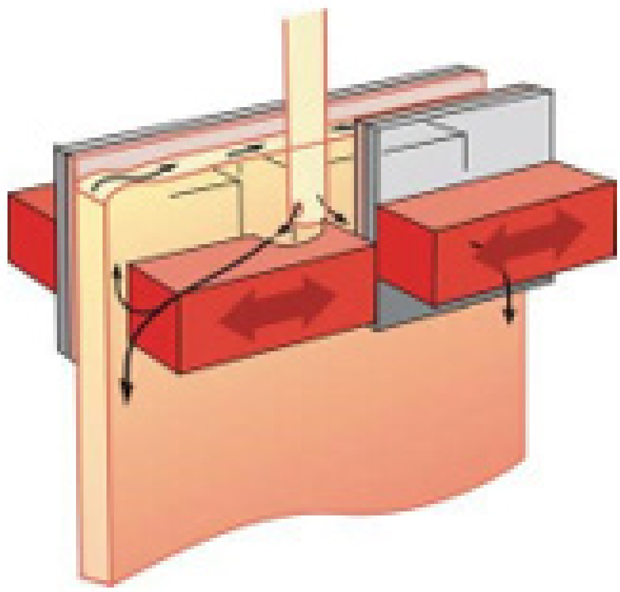

Figure 3: ROTURBO with MODE-EMS

Flow Casting Mold- (FC MOLD)

The FC Mold uses two static magnetic fields, (Figure 4), an upper field at the slab meniscus level to control the meniscus metal flow velocity and a second independently controlled lower field at the bottom of the mold to minimize the penetration depth of the steel jets from the SEN [4,6]. Simultaneous and independent control of the meniscus flow speed and the penetration can only be achieved by the FC Mold. The FC Mold is a tool for medium to high-speed casting. The metal jets from the SEN are braked by the DC magnetic field and when reaching the narrow sides one flow path will turn up towards the meniscus and the upper field can then control this flow velocity. The second flow path will turn downwards and the lower field will minimize the penetration down into the slab. The FC Mold can also be used to increase the metal flow velocity at meniscus, should this velocity be lower than optimal. This is the most common electromagnetic device with totally 30 strands equipped or sold up to today.

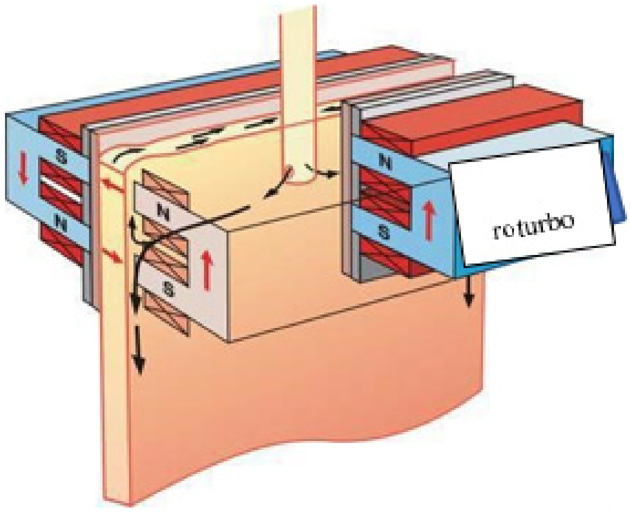

Figure 4: ROTURBO with MODE-EMS in FC Mold technology

Metallurgical Results

The penetrating flow velocity of the steel jets from the SEN should be kept as small as possible in order to minimize inclusions being brought deep down into the strand (Figure 6). This penetrating flow increases with increasing casting speed. The meniscus flow velocity, on the other hand, should be kept in a certain range (Figure 5). It should be kept stable and not vayrying, neither in absolute velocity over time nor the swaying from the left- to the right-hand side of the SEN, i.e. biased flow. It should be kept stable and not varying, neither in absolute velocity over time nor the swaying from the left- to the right-hand side of the SEN, i.e. biased flow. The flow from the SEN can ideally be characterized as single or double roll or, via a stirrer, a rotational stirring pattern at the meniscus. However, what is important is to secure a stable flow pattern for an efficient washing of non-metallic inclusions to prevent them from being entrapped in the solidified shell. The ideal flow control device should therefore keep the meniscus flow velocity at a constant level for various casting conditions and promote a temperature increase at the meniscus area. The literature usually specifies this velocity to be around 0.2-0.4 m/s[7-11].

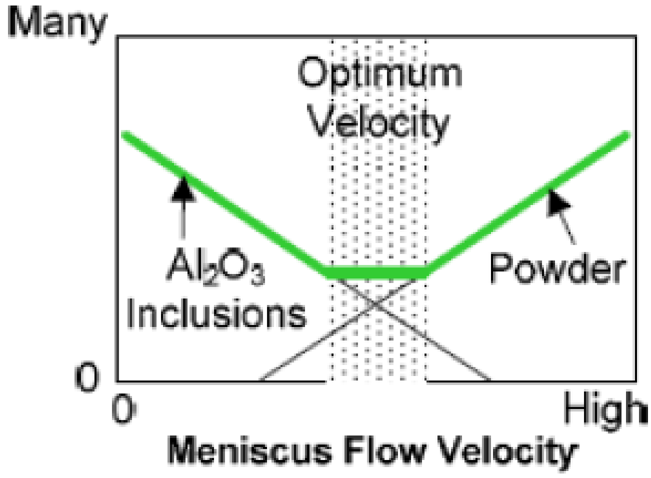

Figure 5: Meniscus flow velocity

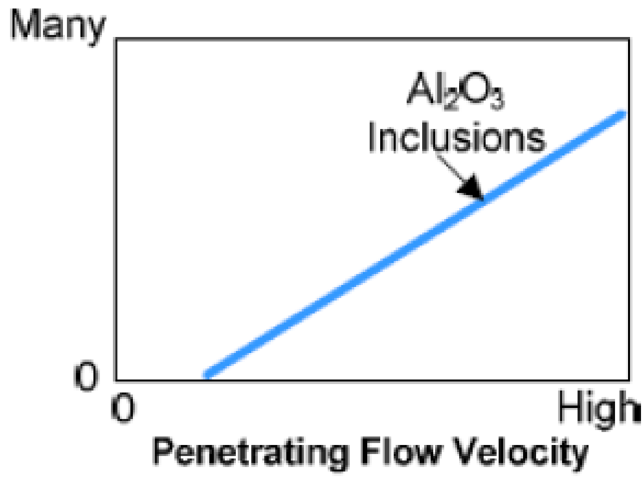

Figure 6: Penetration flow velocity

The meniscus level fluctuations have therefore been measured as a function of time with and without the FC Mold (Figure 7). The result is a very stable meniscus profile when using FC Mold.

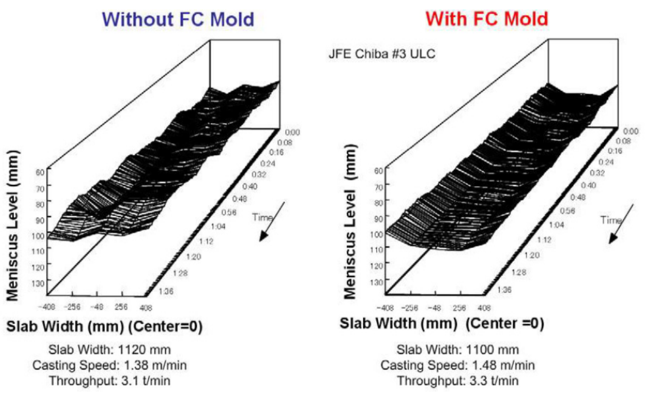

Figure 7: Meniscus shape measured by thermocouples in the Cu plates more stable with FC Mold

Modeling By Multiphysics

The Figure 8 shows a time averaged computer simulation result of 180 sec. of meniscus metal flow in a slab caster of strand size 200x1500 mm with a casting speed of 2.2 m/min, an Argon flow rate of 10 L/min and a SEN angle of (-15°). The flow pattern without an electromagnetic device gives a high meniscus velocity reaching peaks of 0.55 m/s and an unstable meniscus wave with a substantial amplitude. The FC Mold slows down the flow to an optimum meniscus speed, which stabilizes the meniscus and prevents mold powder entrapments.

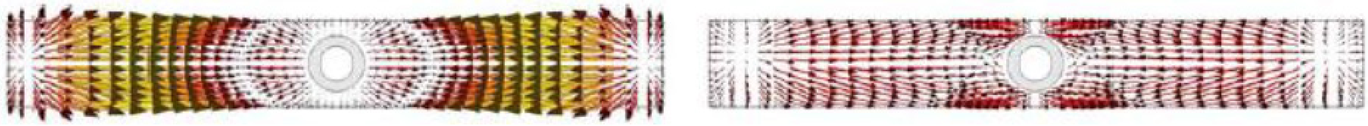

Figure 8: Meniscus metal flow velocities, no electromagnetic device (left), FC Mold controlling the meniscus flow (right).

The Figure 9 displays the time averaged meniscus metal flow velocities in a slab caster of strand size 210x1500 mm with a casting speed of 1.2 m/min, an Argon flow rate of 7 L/min and a SEN angle of (0°).

Without an electromagnetic actuator, the meniscus flow is weak.

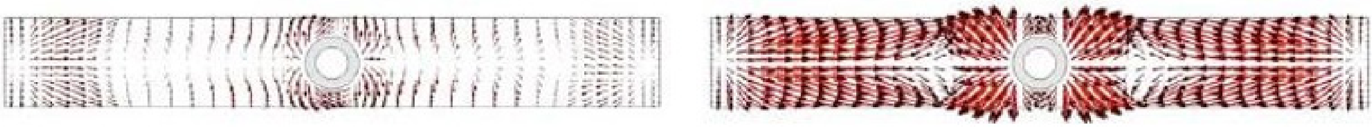

Figure 9: Meniscus metal flow velocities, no electromagnetic device (left), FC Mold accelerating the meniscus flow (right).

Meniscus Flow Casting Activity

The meniscus flow at low casting speed is often too weak for a sufficient homogenization of the melt temperature distribution in the critical initial shell growth regions. The risk of entrapment of inclusions causing subsurface defects is also imminent with a low meniscus metal flow speed. The Figure 10 displays the calculated increase of the meniscus flow speed with a 1500 mm long FC M-EMS compared to casting without an electromagnetic actuator. The slab caster strand format is 250x2000 mm with a casting speed of 0.7 m/min, an Argon flow of 6.1 L/min and a SEN angle of (-15°).

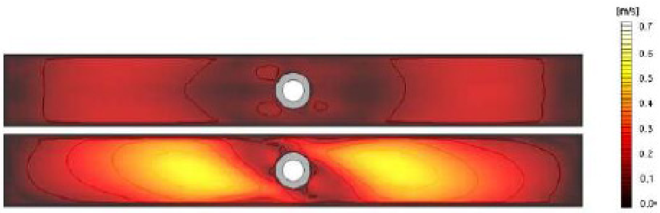

Figure 10: Meniscus metal speeds, no electromagnetic device (top), FC M-EMS increasing meniscus velocity (bottom).

The Figure 11 presents the resulting time averaged meniscus flow speeds for a 1500 mm long stirrer applied with center line 0, 100, 200, 300 and 400 mm below meniscus. The strand format is 250x2000 mm, with casting speed 0.7 m/min, Argon flow rate 6.1 L/min and SEN angle (-15°).

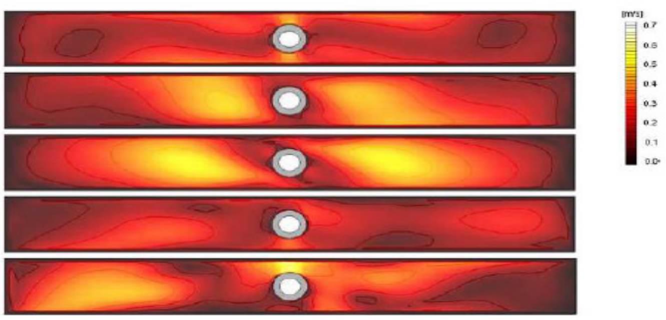

Figure 11: Meniscus metal flow speeds for a stirrer applied with center line 0, 100, 200, 300 and 400 mm below meniscus

Conclusion

- The results exhibit an increase in meniscus flow speeds with an FC MEMS. In areas close to the SEN, the FC MEMS prevents flow stagnation.
- The flow speed distribution at the same casting conditions is quantified the simulated tangential flow speed 10 mm inside one of the wide sides of the strand at the meniscus.
- These results indicate that the FC MEMS doubles the meniscus flow speed at the solidification front, thus ensuring temperature homogenization and preventing nonmetallic inclusions from being entrapped in the solidifying shell. In areas close to the SEN, the FC MEMS prevents flow stagnation with the FC mold, meniscus flow velocity and down flow can both be optimized for medium to higher casting speeds.
- The FC Mold is also applicable for medium casting speeds, as the steel jets from the SEN are reflected upwards by the lower field, thus increasing the metal flow velocity at the meniscus.
- Regarding really low casting speeds, the momentum of the steel coming out from the SEN is not sufficient to give a suitable acceleration at the meniscus, thus a mold stirrer is more suitable.

References

1. Herbertson J (1991) Modelling of Metal Delivery to Continuous Casting Mould. Steelmaking Conf, Proc 74: 171-185.
2. Hackl H (2007) Electromagnetics give Superior Slab Quality. METEC In SteelCon 736-743.
3. Kunstreich S (2005) Multi-mode EMS in Thick Slab Caster Moulds and Effect on Coil Quality and Machine Performance. ECCC 482-489.
4. Suzuki M (2005) Recent Research and Technologies on

Inclusion Removal in Ultra Low Carbon Steel. ECCC 508-515.

5. Sang-Min L (2003) Electromagnetic Stirring in the Mould at the newly Rebuilt. POSCO Pohang No. 3 - 3 Machine, ISSTech 2003 Conference Proceedings 505-518.
6. Lehman A (1994) Fluid Flow Control in Continuous Casting using Various Configurations of Static Magnetic Fields. International Symposium on EPM, 1994, Nagoya, ISIJ 372-377.
7. Abbel G (1996) Argon bubbles in slabs. ISIJ Int 36: S219-S222.
8. Widlund O (2000) Modeling of anisotropic turbulent transport in simulations of liquid metal flows in magnetic fields. 3rd Int. Symposium on Electromagnetic Processing of Materials, EPM2000, Nagoya, Japan 97-102.
9. Domgin JF (2005) Effect of Process Parameters Variations on CC Mould Hydrodynamics and Inclusions Behavior. ECCC 490-499.
10. Kittaka S (2005) Nippon Steel in-Mold Electro-Magnetic Stirrer for Improving Slab Casting. ECCC 476-481.
11. YOKOTA K (2004) Electromagnetic Coil Designed by Magneto-Hydro-Dynamic-Simulation. Nippon Steel Technical Report 89: 564.