A stirring history

Sustained innovation sums up the history of ABB's electromagnetic products

REBEI BEL FDHILA, ULF SAND, JAN ERIK ERIKSSON, HONGLIANG YANG – **The evolution of ABB's electromagnetic products in the metals industry has been a long and impressive one, full of patents, pioneering minds, respected personalities, significant industry contributions and market leading innovations. With its foothold in the metals industry established early on, ABB has embraced opportunities along the way to engage customers in a productive collaboration that has solidified its position as a leader and innovator in the industry. This proud heritage serves as a platform for continued excellence in the metals industry and potential entry into new markets.**

The electromagnetic stirrer was invented in the early 1930s by Dr. Ludwig Dreyfus, a highly respected employee of ASEA, when he found that sufficient electrodynamic force could be developed in molten metal by means of a traveling magnetic field, and that effective stirring action could be achieved. His patent for electromagnetic stirring in electric arc furnace was granted in Sweden in 1937, which can be considered the birth of electromagnetic stirring and the foundation for all other electromagnetic stirring applications within the metals industry → 1.

First stirrer installation

The first electromagnetic stirrer in practical use was installed in Sweden in 1947 on an electric arc furnace (EAF), which at the time was used as both a melting and refining vessel. The stirrer homogenizes the melt temperature and accelerates the slag-metal reactions. Since then, several thousands of electromagnetic stirrers have been installed in various metal processing applications, such as electric arc furnace, ladle furnace, continuous casting of steel and aluminum re-melting.

World's first ladle furnace

In the 1960s, SKF and ASEA engineers developed the first ladle furnace in the world, the ASEA-SKF, to solve the problem of poor quality bearing steel production with electric arc furnace. The ASEA-SKF process, with its combination of electromagnetic stirring, vacuum treatment, electric arc heating and argon gas flushing capabilities, was the beginning of a new era of high quality steel production. The first ASEA-SKF ladle furnace went into full-scale production in 1968 in SKF Hällefors, Sweden, and about 70 ASEA-SKF furnaces were further installed between the 1960s and 1980s worldwide. Although ASEA-SKF was later replaced by more modern ladle refining processes, electromagnetic stirring in ladle (LF-EMS) remained an important tool for efficient production of both commercial and high alloyed steel [1] → 2. Today there are around 140 electromagnetic stirrers installed in various ladle refining processes.

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ElectroMagnetic BRake

Implementation of electromagnetic stirring in billet/bloom casters began in the 1970s to improve solid structures and surface quality. In the 1980s, ASEA and Kawasaki Steel applied an electromagnetic field to the conventional slab casting process to further improve slab quality. This DC magnetic field, acting on the high momentum jet flow from the submerged entry nozzle, reduced the jet speed and stabilized the fluid fluctuation in the mold → 3. The technology, later developed to be an ElectroMagnetic BRake (EMBR), found wider application in the thin slab casting process. The EMBR stabilizes meniscus fluctuations and reduces mold powder entrapments, essential for high speed casting operation and assuring thin slab quality. Today, more than half of all 70 thin slab casters in the world are equipped with an ABB EMBR.

Flow Control Mold

In the 1990s Kawasaki Steel (later JFE) and ABB developed a Flow Control Mold for conventional slab casters. The FC Mold, keeping the DC magnetic field in the lower part of the mold, adds one level DC field in the upper area of the mold to stabilize meniscus fluctuation, thus increasing flexibility in controlling flow conditions. Kawasaki Steel achieved superior results with the FC mold including

1 First patent of electromagnetic stirring in EAF by Dreyfus.

PATENT Nº 102 334 SVERIGE KLASS 21: h: 18—10

BESKRIVNING
OFFENTLIGGJORD AV KUNGL
PATENT- OCH REGISTRERINGSVERKET

BEVILJAT DEN 19 JUNI 1941
GILTIGT FRAN DEN 22 JAN. 1937
PUBLICERAT DEN 19 AUGUSTI 1941

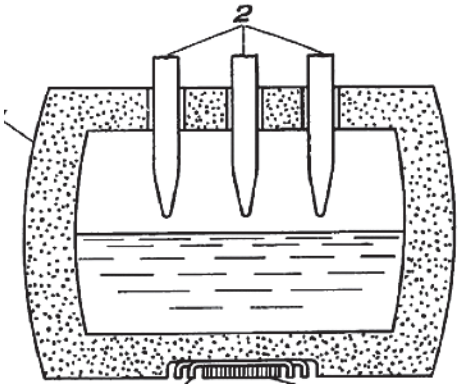
Ans. nr 281/1937. *Härtill en ritning.*

ALLMÄNNA SVENSKA ELEKTRISKA AKTIEBOLAGET, VÄSTERÅS.

Omröringsanordning vid ugnar för metallurgiska ändamål.

(Uppfinnare: L. Dreyfus.)

Det är bekant att vid s. k. virvelströmsugnar, d. v. s. ugnar vid vilka den huvudsakliga värmetillförseln till chargen sker genom i densamma inducerade elektriska virvelströmmar, vanligen av hög frekvens, åstadkomma en elektrodynamisk omröring av chargen eller badet i syfte att påskynda däri förlöpande reaktioner. I de ändamålsenligaste formerna av dylika ugnar är induktionsspolen anordnad i huvudsak kring en horisontal axel, så att nya delar av densamma upphörligt komma upp till ytan samt där utsättas för uppvärmning resp. reaktioner. Samtidigt hålles periodtalet av strömmen i omröringslindningen väsentligt lägre än lägsta kommersiella periodtal, varigenom effekten i nämnda lindning hålles låg. Någon



The FC Mold G3 is the most advanced flow control equipment available on the market for slab casters.

increased casting speed and improved slab internal and surface quality. Today, more than 70 strands are benefitting from the outstanding technology of the FC Mold for conventional slab casters.

Flow Control Mold G3

In the 2000s ABB developed the third generation FC Mold (FC Mold G3) to meet the new market demands for conventional slab casters. The FC Mold G3 adds a traveling magnetic field in the same position of the upper DC magnetic field as the FC Mold II that can function simultaneously with the AC magnetic field, which controls meniscus speed into the optimum range at almost all casting conditions ➔ 4. The FC Mold G3 is the most advanced flow control equipment available on the market for slab casters. Now in 2016 ABB will launch OptiMold Monitor, a product offering mold temperature measurement in continuous casting. Providing unparalleled process insight, this technology can be combined with the FC Mold to allow for real-time process control, taking end product quality to the next level.

Aluminum re-melting furnaces

In the 1960s, ASEA developed an electromagnetic stirrer for aluminum re-melting furnaces (AL-EMS), which showed convincing results in energy savings, yield and productivity increases. However, it only received adequate attention in the 1990s when the aluminum industry realized the necessity for energy savings and productivity increases. ABB then introduced a series of AL-EMS for the entire spectrum of furnace sizes and types ➔ 5. For typical aluminum re-melting furnaces, the AL-EMS can deliver energy saving of 10 percent and increase productivity by 25 percent. Today ABB has installed more than 200 AL-EMS around the world.

ArcSave®

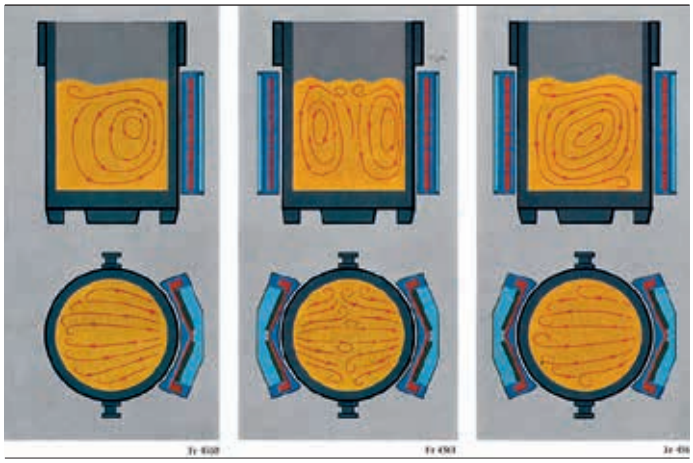
Since the 1980s, the electric arc furnace has gradually become purely a melting vessel with high power consumption and short melting time. In the early 2000s, ABB developed a new stirrer with a much stronger stirring capacity. This stirrer was later patented and commercialized as ArcSave® and was installed on a modern EAF, showing clear customer benefits in energy saving, iron yield, alloys savings and more.

Industry pioneers and continuing innovation

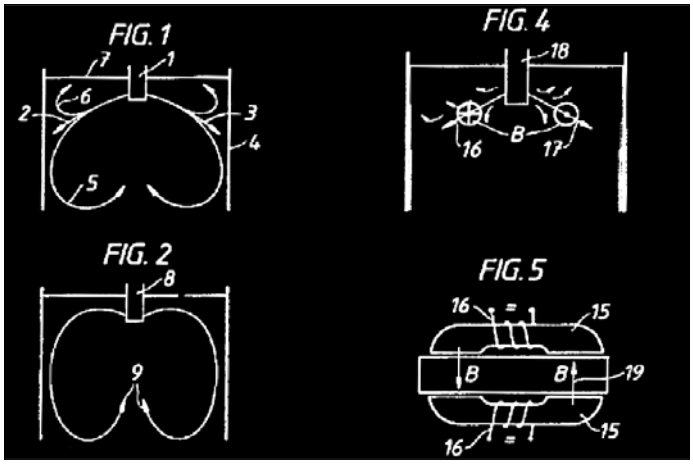
In addition to the invention of the electromagnetic arc stirrer by Dr. Dreyfus, several ABB employees have been true innovators in the industry. Just a few highlights include:

– Yngve Sundberg, employed in the 1950s–1980s, developed a complete theory covering calculation and design of electric furnaces and electromagnetic stirrers.
  He and his former ASEA colleagues hold at least six patents and his “Electric Furnaces and Inductive Stirrers” is referred to frequently in the industry even today [2].
– Sten Kollberg’s exceptional focus on issues in the customer’s casting

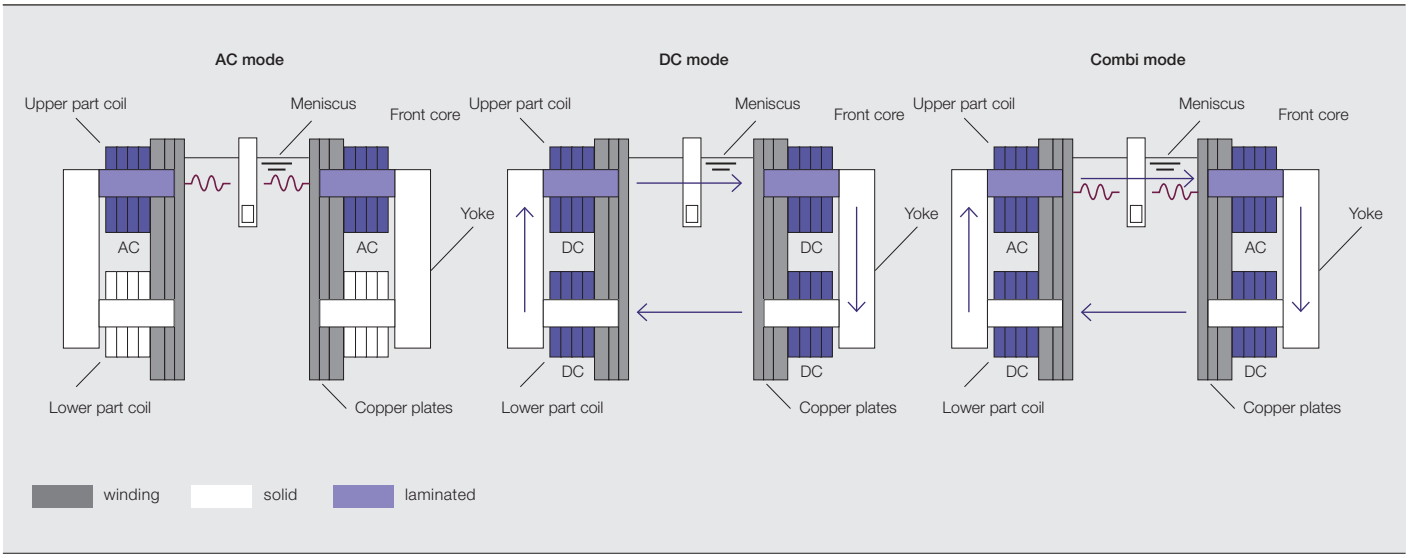
2 Different stirring pattern sketched in the early stage of ASEA-SKF process



3 First patent on EMBR in slab caster.



4 Operation modes of FC Mold G3

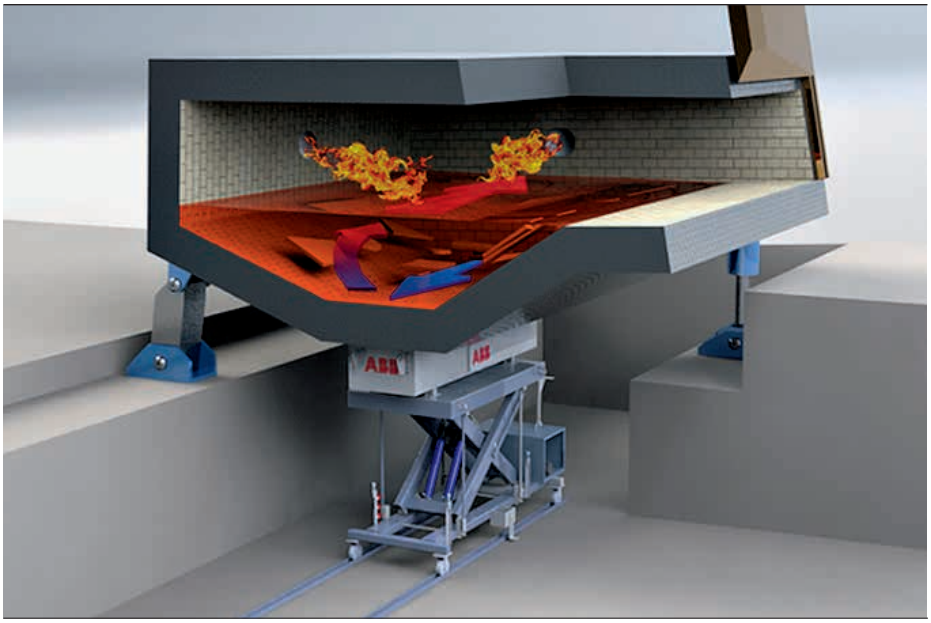


A deeper collaboration with ABB Corporate Research in the last two decades . . . has led to advanced measurements and simulation techniques . . .

process in the 1980s–1990s paved the way for the development of the EMBR and the FC Mold. He was highly respected for his people skills and ingenuity.

– Göte Tallbäck, who worked at ASEA at around the same period as Sten, introduced magnetohydrodynamics (MHD) into metallurgical processes. His paper, published 30 years ago on the numerical simulation of the EMBR process, is still being cited today. In the 2000s, he and his ASEA colleagues registered four patents for electromagnetic stirring.
– Jan-Erik Eriksson, with ABB since 1980, boasts 25 patents, together with his ABB colleagues. Jan-Erik has been instrumental in the ongoing development of the FC Mold, particularly the latest generation, and the EMBR in conjunction with Japanese industry partners.
– Rebei Bel Fdhila, who joined ABB Corporate Research in 1995, is applying his deep modeling competence together with his colleagues'

5 AL-EMS installed in the bottom of aluminum re-melting furnace



process experience to help ABB reshape its modeling, simulation and design capabilities to offer important new features in electromagnetic stirring technology and to solidify its market position.

A deeper collaboration with ABB Corporate Research in the last two decades, influenced by Rebei Bel Fdhila and Jan-Erik Eriksson, has led to advanced measurements and simulation techniques, including several types of laser based measurements and state-of-the-art Computational Fluid Dynamics. The deep fundamental knowledge of metallurgy, the continuous casting, the electromagnetic field effect and the underlying complex phenomena associated with the multiphase flows in which the liquid metal, the argon gas, and particles strongly interact, allowed the R&D ABB team to successfully improve and modernize the EMS technology with new features to enter into new markets.

Development demands and driving force

Energy efficiency, productivity and quality are fundamental to the sustainable development of the metals industry and electromagnetic stirring and braking have an important role to play moving forward. Products such as ArcSave®, the new generation of the FC Mold and the OptiMold Monitor are but a few examples of ABB's contribution and they demonstrate ABB's ability to understand and meet market demand with technological innovation. As the internet of things, services and people (IoTSP) raises expectations within the metals industry in the coming years, ABB will focus on developing products that deliver not only improved safety and reliability, cost-efficiency and quality, but that are easier to use, can measure and analyze, and that improve process performance for our customers. ABB has had the privilege of working with nearly all the leading steel manufactures around the world and is committed to remaining at the forefront of electromagnetic product innovation in the metals industry.

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[2] Sundberg, Y. (1979). *Electric furnaces and induction stirrers.* Västerås: ASEA.