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ELECTROMAGNETIC STIRRING IN ELECTRIC ARC FURNACE

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ABSTRACT

ElectroMagnetic stirring in Electric Arc Furnace (EAF EMS) was the first application for low frequency ElectroMagnetic Stirring in the metal industry. The technology was developed by ASEA, Västerås Sweden, 70 years ago. The first commercial application was installed 1947 in Uddeholm AB in Hagfors, Sweden. The original technology was developed to perform the secondary process steps of the EAF like assist in slag raking when changing slag, alloying and to guarantee a homogeneous melt in analyze and temperature. Assisting scrap melting of larger scrap pieces was also a valuable feature.

The need for EAF EMS was greatly reduced after that ASEA developed the ladle furnace process, which reduced the EAF to melting machine without any secondary process steps. The last new EAF EMS system, out of 134, was sold 1983.

Meanwhile the EAF technology has developed rapidly and we in ABB think that there is a place for the EAF EMS technology today. This paper will discuss the present state of the art of the ElectroMagnetic Stirring systems from ABB and how a new EAF EMS will be designed. More important the paper will present the impact on EMS on the EAF process and the potential for improvements in productivity and operating cost which can be predicted. The paper will discuss the process of melting plain carbon steel. For alloyed and stainless steel there will be additional benefits.

The modern EAF with a tap to tap time of 45 minutes, or less, is operating far from equilibrium, with a substantial energy addition from oxygen, natural gas and coal. Improvements of EAF operations from EAF EMS in the following aspects of the process will be discussed.

- Scrap melting
- Homogenization
- Steel desoxidation
- Slag reduction
- Decarburization
- Tapping

In addition to above features, the EAF EMS will provide process stability which will greatly reduce the odd occurrence which plagues the EAF process, like scrap collapsing into the melt, frozen EBT etc.

KEYWORDS
Electromagnetic Stirring, EAF, Scrap Melting, Homogenization, Steel Desoxidation, Slag Reduction, Decarburization & Tapping

1. HISTORY

The ElectroMagnetic Stirring system for Electric Arc Furnaces was the first commercial application of low frequency traveling flux for molten metal stirring from ASEA, with the first delivery in 1947. See figure 1.

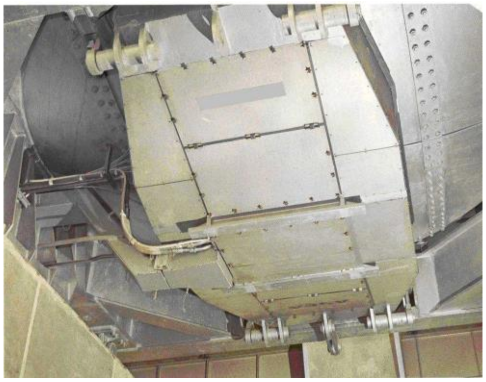

Fig. 1. Early installation of bottom mounted EAF-EMS

Since 1947, ABB has supplying various kinds of electromagnetic stirring systems for the steel and aluminum industries. More than 1,500 systems have been delivered for electric arc furnaces, ladle furnaces continuous casting machines and aluminum furnaces.

The EMS system was in the early days used for the secondary, reducing process steps of the EAF process, providing assistance for de-slagging, alloying and homogenization. The introduction of the Ladle furnace process by ASEA together with SKF in the 60-ies was the start of the demise for the 2 slag process of the EAF as well as for the EAF EMS. The last system, out of 134, was sold in 1983. EAF EMS is today still used in some furnaces for high alloyed tool steel where large quantities of alloys with high melting point are added in the EAF.

1.1 ELECTROMAGNETIC STIRRING APPLICATIONS FROM ABB

After the development of the EAF EMS, the next development was the ladle furnace EMS together with, then SKF Steel, to establish the first ladle furnace concept, the ASEA SKF process in the early 1960s. In the 70ties the development of different EMS applications for continuous casting of steel was started, which is still the larger part of the ABB EMS business. ABB have today a complete product program from stirring steel in the smallest billet caster to braking steel in the largest slab caster. See figure 2.

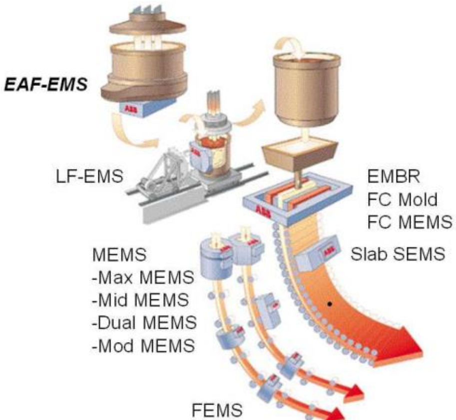

Fig. 2. Different EMS-products for molten steel applications.

In analogy to the EAF there has been a drastic development of EMS applications for melting of aluminium scrap during the last 10 years, where the benefits are metal yield, energy savings and productivity, very similar to what we foresee for the EAF process.

2. INTRODUCTION

The Electric Arc Furnace process is under continuous development, resulting in shorter Tap to Tap times. The latest technologies includes large specific furnace volume to provide one bucket charging and Con Steel, which is the surviving scrap preheating technology, as an example at the other end of the spectrum. In between there are improved operation with “traditional Electric Arc Furnaces where “step by step” improvements have drastically enhanced productivity and costs.

Examples are:

- Controlled foaming slag for utilizing longer arcs.
- Enhanced burner technology
- Improved oxygen and carbon injection technology.

Above improvements have enabled Tap to Tap times to reach 45 minutes for 2 bucket charging furnaces, and even shorter for one bucket charged furnaces.

The modern Electric Arc Furnace process use traditionally generous amounts of oxygen resulting in loss of iron yield and create process instabilities due to super saturation of oxygen in the steel.

20 years ago gas bottom stirring was widely introduced with good results reported for energy consumption, yield and productivity. Due to the problems to keep the gas stirring systems in operation, very few furnaces uses gas stirring today.

The same benefits reached by gas stirring regarding yields, energy consumption are expected with ElectroMagnetic Stirring. The added benefits during tapping will further improve the productivity. The

ElectroMagnetic Stirring system is built to withstand the harsh environment under the furnace, and will provide a very high availability of the system with out any restrictions on the maintenance schedule of the furnace.
This paper will discuss the potential benefits of reintroducing the ElectroMagnetic Stirring technology again for the Electric Arc Furnace. The paper will focus on the potential process improvements for a highly productive, typical carbon steel EAF, producing low carbon steel.

3. EAF-EMS

The main component of an EAF-EMS system is the electromagnetic stirrer coil, which is water-cooled and mounted under the furnace, see figure 1. There is no physical contact between the stirrer and the furnace. A normal refractory lining can be used, but in order to allow the magnetic field to penetrate into the ladle, a ”window” of non-magnetic stainless austenitic steel must be made just in front of the stirrer. The stirrer operates using a low frequency travelling magnetic field, penetrating through the furnace bottom with refractory lining and moving the melt in an analogous way to a linear electric motor.
The EAF-EMS system consist of one stirring coil, a frequency converter, a transformer, a cooling water station and control system, see figure 3. The stirrer can be operated from either the stirrer control system or preferable from the customer’s furnace control system.

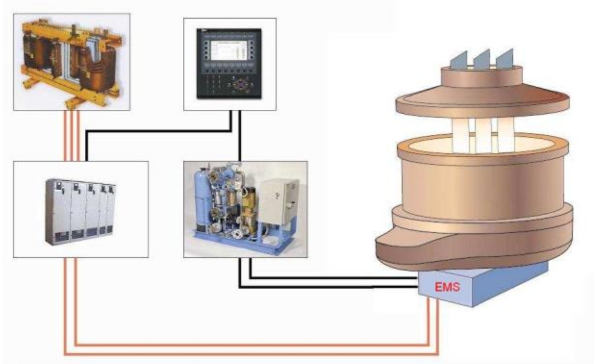

Fig 3. EAF-EMS stirring system: Transformer, frequency converter, water station, control system and stirrer coil.

3.1 PROCESS BENEFITS FOR A TYPICAL ELECTRIC ARC FURNACE PRODUCING CARBON STEEL

By stirring the metal bath during the melt cycle, see figure 4, several process improvements are obtained. In the following section the six prime benefits of EAF-EMS are discussed:

- Scrap melting
- Homogenization
- Decarburization
- Steel desoxidation
- Slag reduction
- Tapping

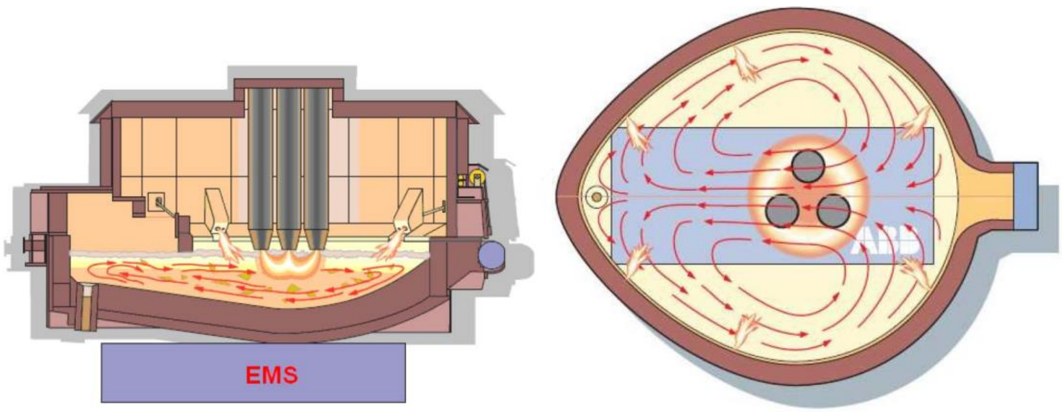

Fig 4. Liquid metal motion formed by EAF-EMS in an EBT-furnace.

3.1.1 SCRAP MELTING

There are several positive effects from EMS during the scrap melting phase. The most important is that the assistance from EMS will introduce convectional melting during the later phase of the melt cycle. This will enhance the melting of larger scrap pieces, bundles and make scrap stratification less important. The movement of the melt can decrease the incidents of scrap cave-ins resulting in violent carbon boil-outs due to chilling of the melt.

3.1.2 HOMOGENIZATION

By introducing a high level of bulk mass flow, as mentioned above, the melt homogenization in terms of both temperature and composition is assured, see figure 5. This improves the reliability, of both temperature measurements and chemical analysis, at an earlier stage compared to no stirring. The melt homogenization further improves the possibility for process optimizing.

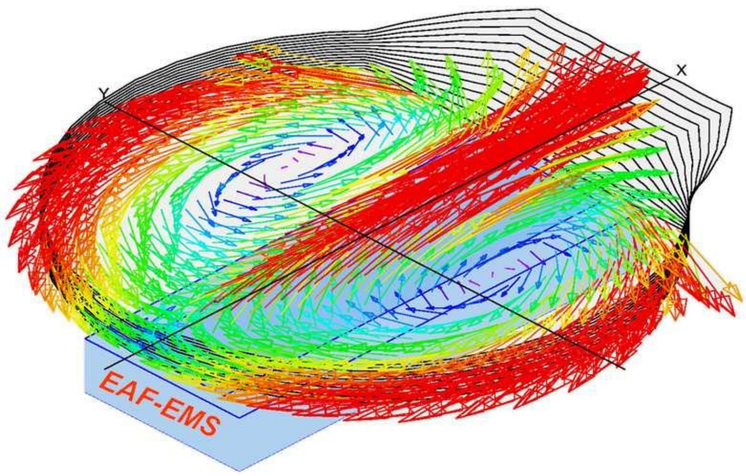

Fig. 5. CFD-calculation of velocity vectors near bottom on an EBT-furnace.

3.1.3 BURNER/OXYGEN/DECARBURIZATION

ElectroMagnetic Stirring will enhance the performance from oxygen lancing by providing fresh carbon-rich steel under the oxygen injectors/lances, thus limiting the over-oxidizing of Fe, by that improving the oxygen yield. This, together with a later complete steel bath desoxidation will enhance and promote a reliable process for tapping at low carbon content with reliability, i.e. below 0.04 % C.

3.1.4 STEEL DESOXIDATION

Strong stirring during the later part of the cycle will provide complete desoxidation of the over saturated steel bath, using carbon as the desoxidation agent. Due to nature of ElectroMagnetic Stirring, providing a very good mixing of the steel bath, the oxygen level at tapping will be close to equilibrium. This will, in addition to secure tapping at lower carbon levels, also save substantial costs from reduced alloys (Si, Al), used to desoxidize the steel in the ladle.

3.1.5 SLAG REDUCTION

Vigorous stirring before tapping will promote reduction of FeO and MnO from the slag by exposing new slag surface to the steel bath improving the mass transfer. The level of slag reduction will be dependant from available time.

3.1.6 TAPPING HYGIENE

There are several factors for improvements for the tapping process of the EAF. Firstly, the EMS will provide tapping stability by melting all scrap in the EBT area. This will secure and stabilize a high opening ratio and provide the opportunity to lower the tap temperature, if a high tap temperature has been govern by tapping problems. Lower tap temperature will improve tap hole refractory life, and further lower the oxygen content at tap. It will also reduce the tap to tap time, energy and general refractory life.

Controlled stirring at tap will also have the potential to disturb and reduce the vortex creation during tapping, which will reduce or even eliminate the slag carry over for an EBT furnace.

4. DISCUSSION AND CONCLUSION

Reintroduction of the Electric Arc Furnace ElectroMagnetic Stirring system is discussed. The very sturdy and reliable ABB EAF EMS system will be able to provide strong stirring during the crucial parts of the heat cycle, which will give the following benefits for a typical high productive carbon steel producing EAF.

- Promote scrap melting by introducing melting by convection.
- Assuring total melt homogenization.
- Improve burners and oxygen injectors by supplying carbon rich steel under the lances/injectors, lowering the level of over oxidation.
- Desoxidizing the steel with carbon from the melt, before tapping. This will further guarantee tapping at lower carbon levels with high reliability
- Reducing FeO and MnO from the slag with the steel.

EAF EMS will drastically improve the tapping process by melting all scrap in the EBT, and disturb the vortex. The hot EBT will allow a lower tap temperature, if permitted by logistics, which together with less slag carry over will improve the iron yield as well as productivity and the general refractory consumption.

Above advantages will make a drastic impact on the EAF performance and energy savings can be expected by at least 5%. Productivity improvements will come from 2 different ways. First productivity will improve from the lower electric energy consumption. Secondly and most important is the reduction of disturbances, the EAF EMS will provide. With disturbances, I recognize: scrap cave-ins, carbon boil-outs, tapping disturbances, tapping too high carbon.

The final conclusion is that the EAF EMS will stabilize the EAF process.