CONSTEERRER™ TECHNOLOGY: GETTING THE MOST OUT OF THE ELECTRIC STEELMAKING PROCESS

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Taking into account their great history and experience in plant engineering, TENOVA and ABB have become partners creating an innovative technology to further enhance the efficiency of Consteel® furnaces. Thanks to a mutual technological effort and close collaboration, TENOVA and ABB have jointly developed CONSTEERRER™ with the aim of making liquid steel faster, in a safer manner and at lower cost. The CONSTEERRER™ technology is a new and original concept specifically designed for the Consteel® furnace. Integration of electromagnetic stirring within the EAF continuous charging process allows for control of the velocity given to the mass of the liquid steel (momentum), introducing a new parameter for more effective management of the melting process and overall performance improvement. The present study, complete with water modelling and fluid dynamic simulations, demonstrates the benefits of the CONSTEERER™ technology on the operation of the Consteel® EAF. Control is fully automated and relevant to the various EAF process steps such as scrap melting, heating and homogenization, de-carburization, deslagging and tapping. The flexibility given by the CONSTEERRER™ technology matches with any steelmaking scenario. Operation is characterized by low cost, consistent and reliable practice and high repeatability of results in the context of improved safety conditions.

KEYWORDS: SAFETY, ENERGY EFFICIENCY, ELECTROMAGNETIC STIRRING, COST REDUCTION, PERFORMANCE IMPROVEMENT, PRODUCTIVITY IMPROVEMENT, FLEXIBILITY, EAF, CONSTEEL, ARCSAVE.

INTRODUCTION

Bearing in mind the simultaneous needs of steelmakers to reduce overall production costs and increase plant productivity, Tenova and ABB have joined forces to offer an innovative technology especially designed to improve the efficiency and performance of the Consteel® EAF and electric arc furnaces operating in flat bath condition. The cooperation between Tenova, a global partner for innovative, reliable and sustainable solutions in the metals and mining industries, and ABB, world leader in design and supply of electromagnetic stirrers (EMS) within the metal industries, is long-standing and characterized by numerous successful projects carried out together to the satisfaction of our customers. Our mutual commitment to the stirrer for electric arc furnaces began in 201 with successful installation at Outokumpu Stainless AB in Avesta, Sweden (**Fig. 3**), and was strengthened in 2017 with Tenova's intention to boost performance of their continuous charging EAFs by studying a tailor-made solution to fit the particular process and operational requirements of such furnaces. The choice of ABB as partner came naturally, considering their historical leadership in electromagnetic stirring of molten metals, in the form of their in-house technological developments, know-how, trademarks, patents and patent applications. The goal of this cooperation is to make the electric steelmaking process safer, more efficient and cost-efficient by applying CONSTEERER™; a new and integrated technological stirring solution.

FLAT BATH OPERATION AND ELECTROMAGNETIC STIRRING: STATE OF THE ART SOLUTION

Sharing the long-standing principles of an industrial group and combining several areas of expertise, Tenova offers a fully integrated range of high quality products, technologies and services for the steelmaking route with the unique preheating and continuous charging technology offered by Consteel® EAF. The Consteel® EAF is a proprietary steelmaking process where the raw materials are charged continuously into an electric arc furnace and melted by immersing in the liquid steel bath present in the lower shell. The strong preheating of the charge helps reduce process energy requirements, whilst the energy coming from the electric arcs and the chemical reactions efficiently keeps the liquid steel at the right process temperature, unlike direct energy transfer to the solid charge of the conventional top-charge EAF. More than 30 years of continuous development and over 65 installations worldwide make Consteel® EAF a state-of-the-art technology for efficient steel production.

Fig. 1 – Flat bath operation of TENOVA Consteel® EAF @ Bangkok Iron and Steel Works, Bangkok, Thailand.

For over 70 years, ABB Metallurgy has been committed to the development of new electromagnetic products for improving steel quality, productivity and safety. The first electromagnetic stirrer for electrical arc furnaces (EAF-EMS) was delivered in 1947 at Uddeholms AB in Sweden and since then more than 150 EAF-EMS units have been successfully installed worldwide. Recently, the new generation of EAF-EMS (named ArcSave®) was developed by ABB to fulfill the need for greater stirring power in the EAF process for both carbon and high-alloyed steel production. Since then ABB Metallurgy have delivered four ArcSave® systems thus improving safety, increasing productivity and reducing the cost of EAF operation for their customers. The positive operating results coming from these reference plants demonstrates that ArcSave® has enhanced heat transfer and mass equilibrium in the electric arc furnace, resulting in a faster scrap melting rate, lower slag superheat during arcing, a more homogenous liquid steel bath, higher decarburization rate and higher EBT free-opening frequency [1-3]. ArcSave® has also reduced the temperature and the oxygen at tapping, which brings a higher metallic charge yield and ferroalloys saving in the ladle metallurgy treatment. Reductions in energy consumption and tap-to-tap time as well as consistent furnace operation bring increased productivity and safety.

Fig. 2 – TENOVA EAF equipped with ABB ArcSave®
@ Outokumpu Stainless AB, Avesta, Sweden.

CONSTEERRER™ TECHNOLOGY

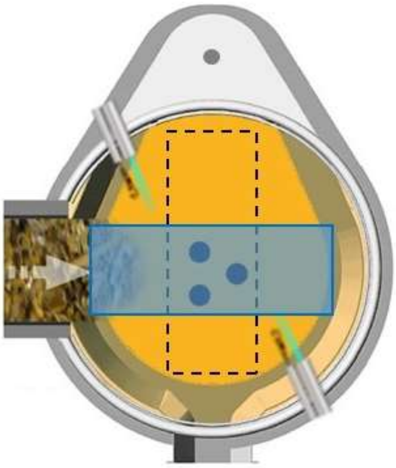

Fig. 3 – Concept of the CONSTEERRER™ technology applied to the Consteel® EAF.

The CONSTEERRER™ is specifically designed to enhance the global performance and flexibility of the Consteel® EAF. Conceived in this way, the application of electromagnetic stirring to the continuous charge furnace with flat bath operation is an innovation in the steel production scenario. The electromagnetic stirrer is applied to the traditional round-shaped EAF, a feature that keeps the machine's basic configuration simple, safe and reliable, and installed at 90 ° with respect to the door-EBT axis, it generates a stirring force directed specifically towards the scrap charging area. In this innovative configuration, the stirring force moves the liquid steel continuously with varying intensity based on the liquid steel mass to be moved. As shown by the computer fluid dynamics study (**Fig. 4**), during the continuous charging and melting phase, the flow of liquid steel at a lower temperature is moved by the stirrer from the bottom of the shell to the refractory wall. The interaction with the geometry of the furnace allows the flow to accelerate increasing its speed towards the area where the scrap falls into the furnace, which is lapped from above. The steel flow directed towards the conveyor receives energy as it passes under the working electrodes, increasing its thermal load that will subsequently be transferred to the mass of scrap entering the furnace. The CONSTEERRER™ guarantees continuous heat supply to the scrap, increasing the melting rate as well as the physical and the chemical homogenization of the bath. The advantages of controlling the homogeneity of the steel bath span the entire range of furnace performance, including reduced specific consumption and process times. The CONSTEERRER™ EAF will be faster in the melting process at the same energy consumption and will produce superior quality steel through improved control and greater repeatability of operational practices. The increase in performance can also be seen from the standpoint of flexibility, in particular regarding the investigation of alternative charge mixes. The use of surrogate materials (e.g., DRI, HBI, beach-iron) in mix with scrap, often with high carbon content, is constantly increasing. The CONSTEERRER™ EAF allows for the optimized use of these materials, increasing the high flexibility already demonstrated by the Consteel® furnace.

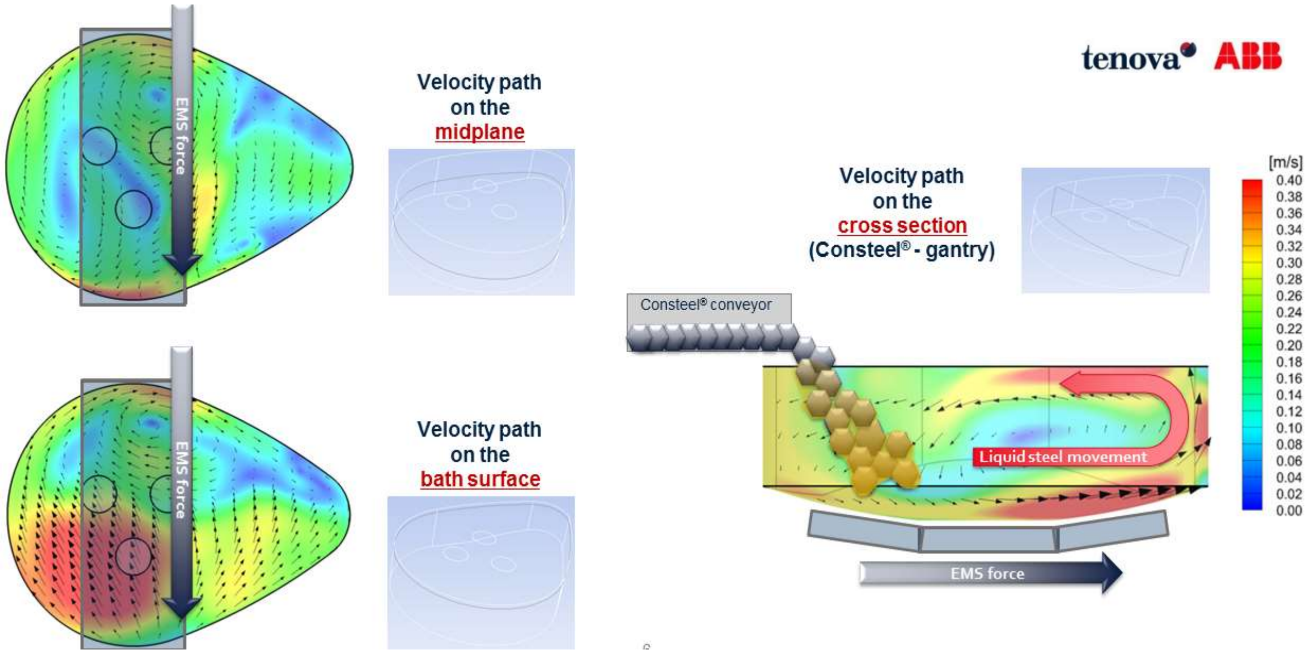

Fig. 4 – Computer-Fluid-Dynamics simulation of the CONSTEERRER™ system.

Momentum of liquid steel

A key factor that differentiates CONSTEERRER™ application from traditional top-charge EAF applications is the active control of the *momentum* of the liquid steel throughout the entire furnace power-on time. As already mentioned, the continuous-charge furnace works for the whole of its melting process in flat bath conditions. Such conditions give the opportunity to redefine the concepts and rules for controlling the velocity of the mass of liquid steel inside the furnace. Control of the *momentum* in the CONSTEERRER™ EAF is operated from the very beginning of the process, at a point when the mass of liquid is at its minimum, and it is definitely extended throughout all the phases of the heat. Momentum is relevant to the entire mass of the liquid steel inside the furnace, creating a global circulation of the whole melt, and is not limited to a restricted volume of mass as per the effect of gas stirring given by the porous plugs. Being able to fine-tune the movement of the steel phase by phase, the automated control system dynamically takes the best action in response to the specific needs of each of these phases [5].

Development and simulations

To define the basic criteria for development of the system and to confirm some assumptions made during the design phase of the project, several studies and simulations focusing on different aspects have been carried out. With the first water model – **Fig. 5** case A – the position of the stirrer was evaluated taking into consideration Consteel® EAF configuration with its characteristic flat bath melting for the whole power-on time and continuous lateral scrap charging. The results of the test demonstrate the clear effect that the stirrer layout has on the scrap melting rate (simulated with ice bricks): In the case of CONSTEERRER™ installation, the most effective action is when the stirring is directed towards the scrap falling area below the Consteel® conveyor – **Fig. 6**. The results also validate the 90° layout with respect to the furnace axis. An additional water model, developed in the frame of the RFCS partially supported project *SimulEAF*[1], allowed us to investigate the interaction and mutual action of the supersonic oxygen lances with the application of a stirring force – **Fig. 5** case B. The test shows that the stirring effect guaranteed by the EMS is higher than the punctual effect of the porous plugs and the contribution of the supersonic lances adds up in both cases. In the CONSTEERRER™ scenario the force of the EMS is predominant compared to the lances, which is certainly not true in case of the porous plugs, and lets the options for the optimum installation of the injection system guarantee good process performance without compromising the stirring effect.

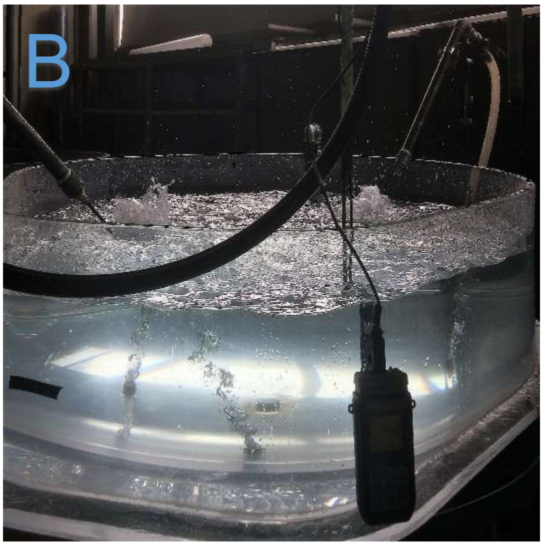

Fig. 5 – Water model simulations: A – Effect of the stirrer layout and positioning on the scrap melting rate (*ABB* laboratory); B – Interaction between stirrer technologies and oxygen injection system (*RINA Consulting* laboratory).

[1] RFSR-CT-2015-00031 - Improvement of electrical arc furnace operations with support of advanced multiphysics modeling SIMULations of the EAF process – SimulEAF. Final report to be published.

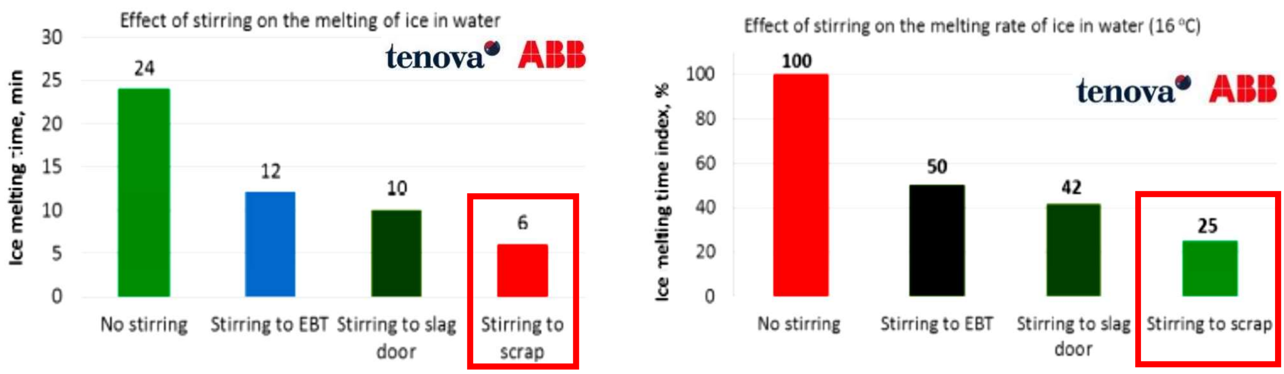

Fig. 6 – Effect of different stirring directions on the scrap melting rate, to demonstrate the effectiveness of the CONSTEERRER™ layout. Results are shown on time basis (left side graph) and percentage basis (right side graph).

Further tests and simulations are under way, with the aim of refining development of the CONSTEERRER™ EAF by way of improving the integrated process control system of the furnace, evaluating the efficiency of the system with alternative metallic charge mix and studying the effects and opportunities in relation to slag engineering.

EXPECTED RESULTS

Considering the production of low-alloyed carbon steel with a scrap-based electric arc furnace, a comparison of the operating figures for a modern Consteel® EAF with the expected operating results in cases where the furnace is a CONSTEERRER™ EAF is shown in the table here below. These expected results are based on experience from both ABB ArcSave® references [1-2] and Tenova Consteel® references [5-6].

Tab. 1 – Expected performance figures for a Consteerrer™ EAF compared to a Consteel® EAF.

	Consteel® EAF	CONSTEERRER™ EAF	*Delta*
Productivity	156 tls/hour	162 tls/hour	*+ 6 tls/hour*
Heat size	100 tls	100 tls	-
Tapping temperature	1630°C	1615°C	*- 15°C*
Carbon content at tapping	0.06%	0.06%	-
Tap-to-tap time	38.5 min	37.0 min	*- 1.5 min*
Power-on time	31.5 min	30.0 min	*- 1.5 min*
Electric energy consumption	340 kWh/tls	325 kWh/tls	*- 15 kWh/tls*
Oxygen consumption	36 Nm^3/tls	36 Nm^3/tls	-
Carbon consumption	22 kg/tls	20 kg/tls	*- 2 kg/tls*
Electrode consumption	1.05 kg/tls	0.95 kg/tls	*- 0.10 kg/tls*
Average power	64.7 MW	65.0 MW	*+ 0.3 MW*
Phosphorus content at tapping	expected P < 0.030%	expected P < 0.024%	*- 20÷25%*
Yearly production on 7.200 hours	1,123,200 tons	1,166,400 tons	*+ 43,200 tons per year*

The improvements refer to overall furnace performance. The reduction in consumption parameters are given by the increased transfer efficiency of electrical and chemical power to the molten steel. The enhanced kinetic conditions of the liquid steel bath during melting, boosted by the superior homogeneity given by the CONSTEERRER™ technology, make the most of these improvements while reducing process times. The market response was immediate: thanks to the interest steelmakers have shown in CONSTEERRER™, TENOVA and ABB have already been awarded two orders to be commissioned in the spring of 2019 – **Fig. 7** – and several offers are also in progress.

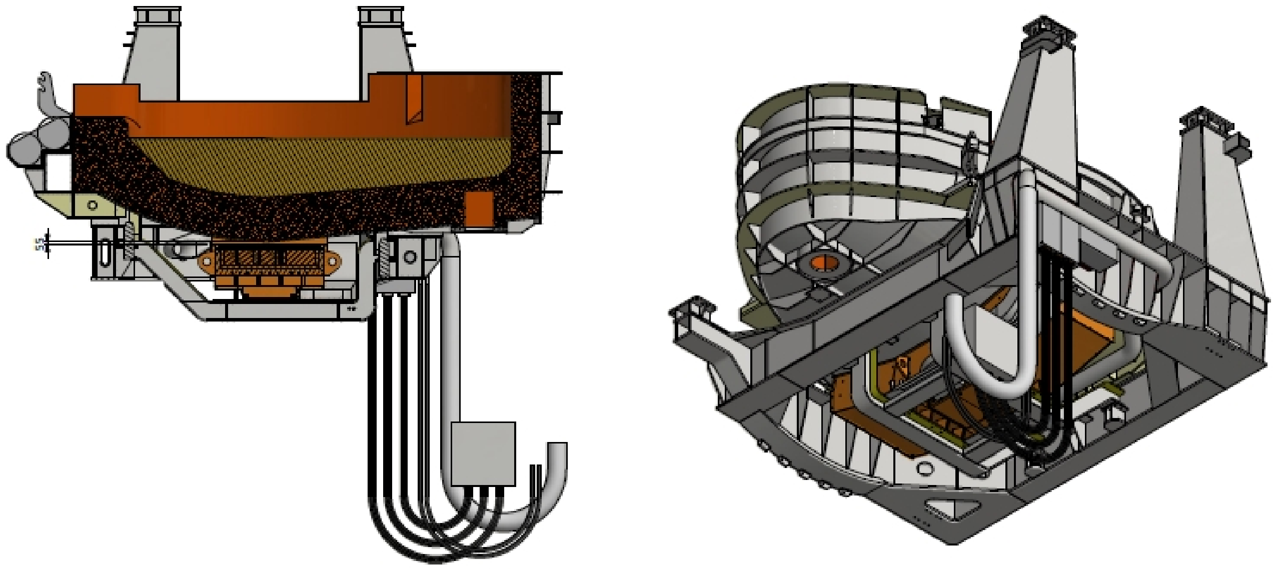

Fig. 7 – Tenova-ABB project for the installation of the first CONSTEERRER™ EAF reference.

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