EAF-EMS and the bottom skull challenge

With its impact on productivity and process efficiency, bottom skull formation in electric arc furnaces is a challenge for stainless steel producers worldwide. But it is a challenge with a proven solution, in the form of electromagnetic stirring, as Lidong Teng, Senior Metallurgist at ABB explains.

Skull formation is a common problem in electric arc furnaces (EAF) used in the production of stainless and high alloy steels. Formed from unmelted scrap and ferrochromium (FeCr), skulls create a number of issues, reducing furnace volume capacity, lowering tapping weight hit ratio and steel yield, and reducing productivity.

Given the high-productivity levels achieved at modern steel plants, even small process inefficiencies can have significant negative impacts – and ultimately hit the bottom line. Preventing the formation of skulls within EAF is therefore an important element in optimising plant performance. This can be achieved effectively by improving mass and heat transfer through the melt to eliminate cold and hot spots. The result is faster melting of the scrap and FeCr, without leaving the solid residues that form skulls.

Electromagnetic stirring (EMS) provides this through complete and precisely-controlled mixing of the whole furnace melt. It also brings additional benefits when it comes to energy consumption, process stability, and maintenance.

ArcSave is installed beneath a furnace.

Building a bright future on a proven history

ABB EAF-EMS has been around for a while now: it was first patented over 80 years ago by ABB Metallurgy. The technology now has more than 1870 references worldwide, including - 153 EAF-EMS installations. Installed under (but not in contact with) the furnace bottom shell, it produces a travelling electromagnetic field through the furnace shell and generates convection flow within the melt. This electromagnetic field penetrates the full depth and across the full diameter of the furnace, ensuring thorough mixing is achieved.

The latest iteration of ABB's EAF-EMS is ArcSave® with its strong stirring power that is designed for today's high-power furnaces, as well as adjustable, automatic control that allows stirring to be tailored to a furnace process. First installed in 2014 on an EAF for carbon steel production at Steel Dynamics' Roanoke plant, Virginia, US, it has now been applied at a number of stainless and speciality steel producers with more to come:

- Outokumpu Stainless AB, Avesta, Sweden, 2014.
- POSCO, Pohang, South Korea, 2018.
- SeAH Changwon Integrated Special Steel, Chang-Won, South Korea, 2018.
- Böhler Edelstahl, Kapfenberg, Austria, 2020.
- Nippon Yakin, Kawasaki City, Japan, 2021.

A trilogy of successes at Outokumpu Stainless

Outokumpu Stainless in Avesta, Sweden, is a leading manufacturer of stainless steel with a long history of innovation. Duplex stainless steel was invented there in 1930 and the site is now the home of Outokumpu's Global R&D functions. ArcSave was installed

Installed under (but not in contact with) the furnace bottom shell, ArcSave produces a travelling electromagnetic field through the furnace shell and generates convection flow within the melt.

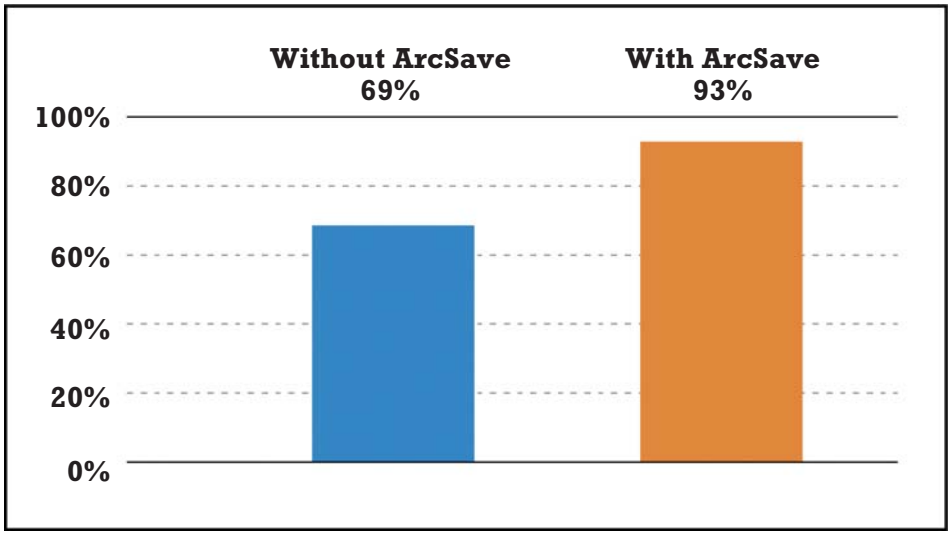
there in 2014, tasked with eliminating the formation of bottom skulls in its 90t EAF, as well as reducing power-on time and improving process conditions to the Argon Oxygen Decarburization (AOD). The EAF has a 110 MVA transformer and four-lance manipulator for O_2, N_2, FeSi and C injection, and uses a combination of electric power and three oxyfuel burners to melt the scrap for production of special steel grades with high chromium contents.
To produce these grades of steel, high amounts of FeCr alloys are added to the EAF, which was resulting in the formation of bottom skulls. The company had tried Bottom Gas Stirring (BGS) but this was unsuccessful because of the skulls and stiffness of the slag.
After the installation of ABB ArcSave, however, scrap and FeCr melting was improved, solving the company's skull problem and bringing a range of other benefits, from improved steel yield to more accurate tapping weight and controlled tapping temperature, which enabled smoother AOD operation.
Tapping temperature was reduced by 20-30°C, while tap temperature hit ratio increased from 30% to 100%.
Tap weight hit ratio was also improved from 69% to 93%. Energy consumption was also lower with the ABB ArcSave, by 3-4%, electrode consumption was reduced by 8-10%, and power-on time was reduced by 4-5%.[1]

Tackling monster skulls at SeAH

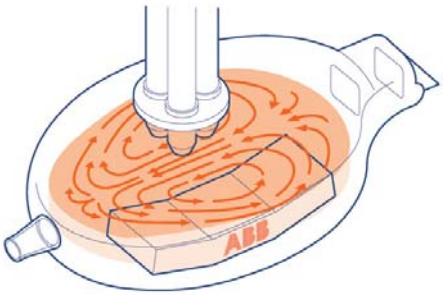
At SeAH – the only producer of stainless-steel pipes and tubes in South Korea – ABB ArcSave was installed on a 70t EAF that was struggling with significant skull build-up, which could be as much as 1000 mm thick. The SeAH EAF has a 72MVA transformer with four-lance manipulator, injecting O2, alumix and C. Three oxyfuel burners provide additional energy input to melt a 90%-scrap feedstock plus 10% of ferroalloy.
As at Outokumpu Stainless, BGS with three porous plugs had proved ineffective, leaving the company to drill out its skulls with its refractory removal machine and lift them out of the furnace by crane. To say this was a difficult and time-consuming effort is to put it mildly.
Following the installation of ABB ArcSave, bottom skull formation was reduced to less than 200mm, as a result of the homogenising impact of EMS on furnace temperature. This reduced skull thickness brought multiple operating benefits, including:

- Easier scrap bucket charging.
- Better melt bath level control.
- Improved tap weight hit ratio.
- Higher scrap and ferroalloy yield.
- Lower maintenance requirements on the furnace refractory.

Energy savings of by 3-4%, were also seen at SeAH, while power-on time fell by 4-5%. Perhaps most impressively, however, was the 70-80% reduction in the cost of scrap handling that was



Tap weight hit ratio increased by 24% with ArcSave



The electromagnetic stirring created by ArcSave provides complete and precisely-controlled mixing of the whole furnace melt.

achieved due to an improved ability to melt larger bundles of scrap and whole rejected ingots (up to 4 tons). Before the installation of ABB EAF-EMS, the SeAH EAF could only handle smaller charges to ensure full melt in one heat.[2]

Conclusion

As seen at Outokumpu Stainless and SeAH, the impact of EMS in stainless steel production is significant, not only reducing the impact of troublesome bottom skulls, but across a swath of operational parameters. Typical measures include a 5-7% increase in productivity, a 3-5% reduction in energy consumption, improved process stability and repeatability, and lower use of alloys, lime, electrodes and other process additions.
With the industry facing a number of disruptive challenges – from cost pressures to increasing competition and environmental concerns – the benefits brought by ABB ArcSave offer an important boost to those steelmakers with the willingness and foresight to adopt technology as a road to success. Accounting for a majority of ABB ArcSave installations so far, specialist and stainless steelmakers are currently leading the way in this regard.

References

1. For more on the installation of ABB ArcSave at Outokumpu Stainless, see: Teng, L., Ljungqvist, P. and Hackl, H., 'Process Improvement with EMS', Steel Times International (April 2016), pp. 59-62.
2. For more on the installation of ABB ArcSave at SeAH, see: Lee, E.-S., Kim, H.-K., Jung, E.-W., Teng, L., Kim, K.-S., Andersson, J., and Yang, H., 'Problems with and Solutions to Skull Formation in EBT Furnace for Tooling and Stainless Steel Production', AISTECH (forthcoming).