Electromagnetic stirring and EAFs

The importance of electric arc furnaces (EAF) in global steel production has been continuously increasing in recent years – and seems likely to continue to do so. But in common with all steelmaking, EAF will have to become smarter to succeed in a challenging environment. **Lidong Teng***, explains why electromagnetic stirring is one key to surviving and thriving in today's market

Electric Arc Furnace in operation

ELECTRIC arc furnaces (EAFs) have played an increasingly important role in global steel production in recent years. EAF steel production was only about 405Mt in 2015, but increased by 28% to 517Mt in 2019, according to the World Steel Association (worldsteel).[1]

The longer-term future of the EAF also appears bright, thanks to the sustainability advantages it holds over blast furnace production, particularly if low-carbon forms of electricity continue to become more widely available. An increase in the availability of scrap steel, which worldsteel expects to hit 1 billion tonnes by 2030,[2] will play another key role in supporting growth in EAF production. The recycling of steel is an easy win for the circular economy, with important results in terms of reducing the carbon footprint and the need for newly-mined raw materials.

With the disruption caused by COVID-19, however, the figures for this year look more challenging. For the steel industry as a whole, worldsteel anticipates a 6.4% reduction in demand, followed by a 3.8% fall next year.[3] We will have to wait and see how this effects EAF production levels, but market conditions seem set to be much more challenging, at least in the short term, adding to the existing competitive and environmental pressures under which the industry was already operating.

With market conditions looking tougher after Covid-19, it is those steelmakers that are best able to embrace the advantages offered by new technology – through innovative cost cutting and a steady focus on performance – that will be best placed to ride the storm through to calmer seas.

Stirring the melt in an EAF has long been known to bring a range of benefits: from increased productivity to lower costs and enhanced control of process conditions downstream of the furnace, as well as a reduced carbon footprint. In uncertain times, these benefits could prove vital in enabling a steelmaker to survive and thrive. At the forefront of stirring technology is electromagnetic stirring (EMS).

A proven solution

EMS is not a new technology: it was first patented about 80 years ago and there are now more than 1,870 references worldwide, across various applications, including 158 on EAF. On an EAF, the EMS

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ABB ArcSave technology

hardware is installed under the furnace bottom – but not in contact with it – and generates a travelling electromagnetic field that penetrates into the furnace and generates a magnetic force within the melt that produces the stirring effect. This results in improved mass and heat transfer through the melt.

The contactless installation avoids the inherent risk of breakthrough that comes with the use of the gas plugs used for bottom gas stirring (BGS). It also means maintenance requirements are negligible; the EMS stirrer coil itself is maintenance free, while the auxiliary equipment requires only minor maintenance, for example, to clean strainers on the heat exchanger every couple of years. EAF-EMS has also proven particularly long-lived with the oldest operating for 54 years and counting. This contrasts with bottom gas stirring (BGS), which requires regular maintenance and replacement of the porous plugs.

As a result, EAF-EMS has been shown to offer much lower operating costs, in the range of 20% to 40%, than BGS, while creating a global stirring effect, without dead zones or cold spots, and much higher stirring power. Its latest iteration, ABB ArcSave®, is able to generate average melt flow velocity of 0.2-0.4m/sec in today's high-power EAF. It also offers adjustable and automatic control that means stirring can be tailored to specific operating parameters.

As a result, payback time for EAF-EMS is relatively short with return on investment for ABB's technology standing at 12-18 months, depending on annual production and EAF volume (larger furnaces generally experience quicker ROI).[4]

A track record of results

Currently, nine steelmakers have installed or will install ArcSave, the latest EAF-EMS technology, representing all furnace types – carbon steel, stainless/specialist and Consteerer™ including:

- Steel Dynamics Inc., Roanoke, USA, 2014, on a 90 tonne EAF for carbon steel production.
- Outokumpu Stainless AB, Avesta, Sweden, 2014, on a 90 tonne EAF for stainless steel production.
- POSCO, Pohang, South Korea, 2018, on a 95 tonne EAF for stainless steel production.
- SeAH Changwon Integrated Special Steel, Chang-Won, South Korea, 2018, on a 70 tonne EAF for stainless steel and tooling steel production.
- Yongfeng Steel, Shandong, China, 2019, on two 160 tonne Consteel™ furnaces for carbon steel production.
- Böhler Edelstahl, Kapfenberg, Austria,


Outokumpu Stainless Steel plant at Avesta, Sweden

2020, on a 50 tonne EAF for special steel production.

- Nippon Yakin, Kawasaki City, Japan, 2021, on a 70 tonne EAF for special steel production.

Improving furnace productivity

EAF-EMS has a measurable impact on furnace productivity. At Steel Dynamics, for example, productivity increased by 6%; at Outokumpu Stainless by 6-8%; and at SeAH, the increase was 5-7%. There is also an increase in yield, typically by about 1%.

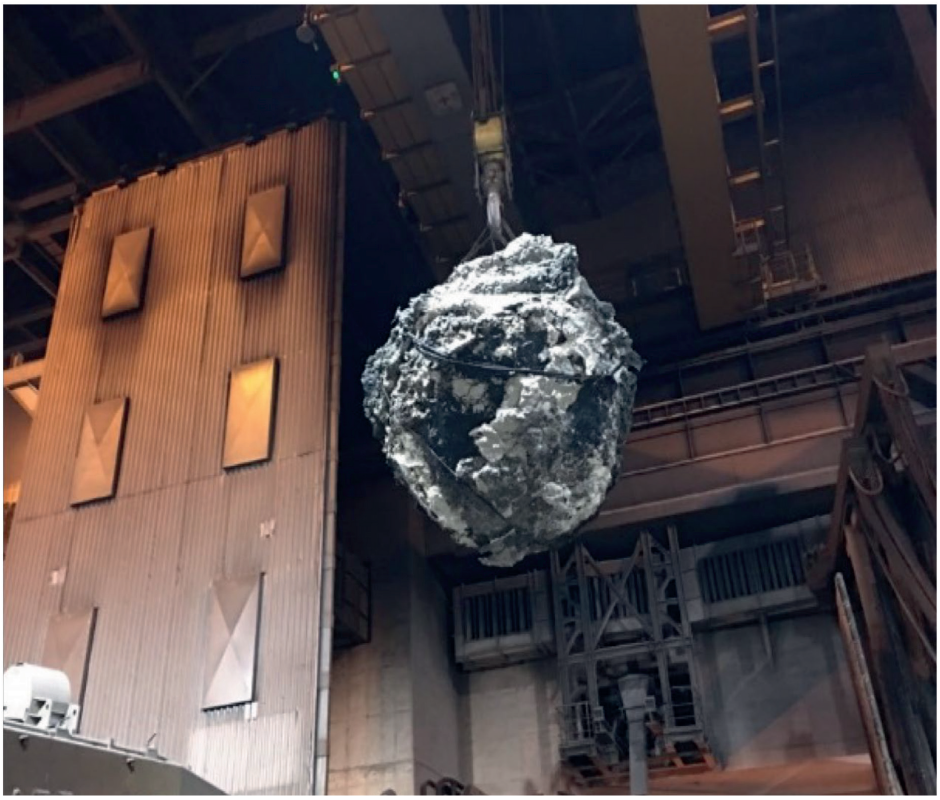
This productivity gain comes from the improved heat and mass transfer through the melt, which results in faster melt times and more homogenous melt conditions. Power-on time is, therefore, lower with EAF-EMS, while larger scrap bundles can be used to charge the furnace without compromising performance. At SeAH, for example, scrap handling costs were reduced by 70-80% as a result of its improved ability to melt larger scrap and whole rejected ingots (up to 4 tonnes).

Better melt conditions also help avoid the formation of bottom skulls, a particular challenge for stainless and special steel producers that reduces the capacity of the furnace. At both Outokumpu Stainless and SeAH, a reduction in bottom skull formation was a primary motivation for installing EAF-EMS, as previous attempts with BGS has failed to tackle the problem. At SeAH, bottom skull build-up could be as much as 1000 mm thick and require drilling out with the refractory removal machine. This was a significant effort in terms of the time taken to remove the bottom skull, during which the furnace was not operating, as well as the costs involved. Following EAF-EMS installation, bottom skull formation at SeAH was reduced to less than 200mm.

The stirring force generated by EAF-EMS can also help to double the decarburization rate, which is particularly relevant when charging the EAF with hot metal or pig iron, as well as in EAFs where decarburization is a current bottleneck.

Keeping control of costs

Steelmakers with EAF-EMS are able to maintain greater control of costs. Critically, energy costs are reduced, as power-on time is shorter and complete melting is achieved more efficiently. Energy consumption fell by 5% at Steel Dynamics, and by 3-4% at both Outokumpu Stainless and SeAH. These energy savings are inclusive of the energy used by the stirrer, which is roughly 2-3kWh per tonne of liquid steel.



Skulls being lifted from the EAF with a crane[5]

Savings are also seen in the consumption of refractory materials. Better mixing of the melt not only means no cold spots in the melt, but also reduced surface superheat during the power-on period – which results in less refractory wear in the slag-line area. Meanwhile, as long as the melt velocity is well controlled, there is no increase in refractory wear in other parts of the furnace, for example on the furnace bottom.

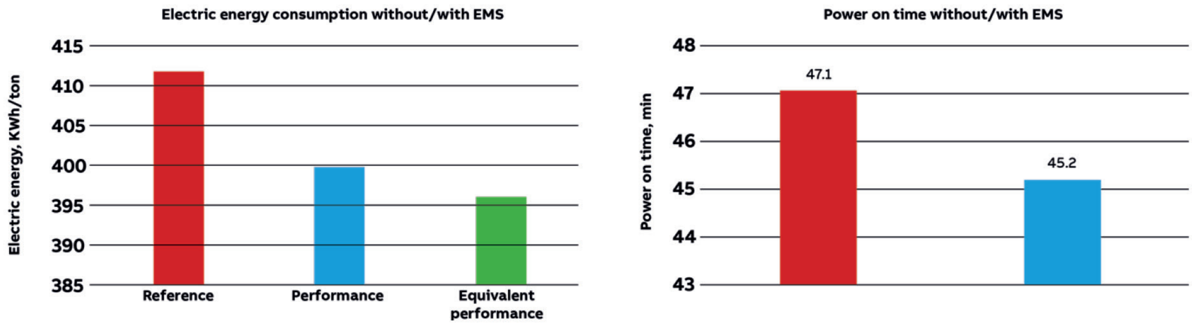
At Steel Dynamics there was a 20% decrease in furnace repair material consumption after the installation of EAF-EMS, while at SeAH, there was a 40-50% fall in hot gunning materials consumption and a 6-10% fall in wall refractory consumption.

The faster scrap melting – particularly of larger scrap bundles – that is achieved by EAF-EMS also helps to limit scrap stratification effects and cave-ins, reducing electrode current swings by 50-60% and stabilizing the arc. This results in higher arc power input and lowers electrode consumption, which fell by 3% at Steel Dynamics, 8-10% at Outokumpu Stainless, and 3-4% at SeaH.

Improving conditions downstream of the EAF

A final area in which EAF-EMS has an impact are conditions downstream of the furnace. At Outokumpu Stainless, for example, tap temperature hit ratio improved from 30% to 100%, tap weight hit ratio went from 69% to 93%, and tapping temperature fell by 20-30°C. All of which helped to improve conditions to the Argon Oxygen Decarburization (AOD) process. A similar tapping temperature reduction was seen at SeAH, while tapped liquid steel per heat rose by 3-5 tonnes. Tapping temperature fell at Steel Dynamics by 13°C.

There is also a reduction in carryover slag in the tapping ladle with EAF-EMS. High carryover slag is caused by vortex formation in the EBT area and leads to higher ferroalloy consumption in the ladle furnace. Due to the global stirring effect of EAF-EMS, the vortex is moved away from the surface, so that it no longer forms or sucks slag into the melt. There is no similar effect when using BGS. As a result, measurements at Steel Dynamics showed a 40-50% reduction in carryover slag in the ladle after tapping, resulting in a cost saving in ferrosilicon and calcium carbide consumption in the ladle furnace.



Effect of ArcSave® on electric energy consumption (left) and power on time (right) reduction

SeAH Changwon Integrated Special Steel, Chang-Won, South Korea

Conclusion

EAF-EMS brings important benefits to the process of electric steelmaking – benefits that are particularly relevant in current market conditions and given the challenges that now face the industry. In addition, EAF-EMS helps steelmakers tackle the challenge of sustainability. Lower energy consumption results in lower carbon dioxide emissions, while lower consumption of refractory materials, electrodes and additives helps to reduce the impact of steelmaking on the environment.

Steelmaking is going to have to become increasingly smart if it is to ride out the current storms to a sustainable future. EAF-EMS is one way of making that change to a smarter future – not just in the furnace but through the downstream process steps.

References

1. Steel production figures taken from World Steel in Figures, 2016 to 2020, published by the World Steel Association.

2. Çiftçi, B.B., 'Blog: The Future of Global Scrap Availability', worldsteel.com (2 May 2018). Accessed (27 July 2020): https://www.worldsteel.org/media-centre/blog/2018/future-of-global-scrap-availability.html

3. 'worldsteel Short Range Outlook June 2020', worldsteel.com (4 June 2020). Accessed (27 July 2020): https://www.worldsteel.org/media-centre/press-releases/2020/worldsteel-short-range-outlook-june-2020.html

4. ROI calculations include the cost of the stirrer, auxiliary equipment, and any necessary furnace modifications (EAF-EMS requires a stainless- steel bottom furnace shell or window to operate), but do not include potential productivity gains experienced as a result of EAF-EMS installation, which may reduce payback time. ■

Typical benefits of ArcSave® electromagnetic stirring