Materials Processing Institute

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ELECTRIC ARC FURNACE INNOVATION - ADDRESSING THE TECHNOLOGY CHALLENGES

Electric Arc Furnace at the Materials Processing Institute

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EXECUTIVE SUMMARY

The global steel industry is seeking innovative new solutions to the challenge of CO_2 emissions and opportunities for investment in sustainable businesses and operating models. In this environment, the electric arc furnace (EAF) presents an opportunity for those regions where there is a sufficient supply of secondary, or other suitable raw materials. Switching an increasing proportion of global steel production to the EAF could give significant benefits, but it is hindered by the challenge of energy availability and product quality. This challenge has been identified by a number of leading steel companies in nations including the United Kingdom, Germany, Sweden and Austria, and in all cases, innovation is seen as the key to unlocking this potential.

In the UK, the Materials Processing Institute is utilising its unique pilot scale EAF facilities to directly tackle the problem of residuals and nitrogen in steel, an area where it has recently filed a patent. Responding to these challenges will take time, but in doing so, the steel industry will be well positioned to benefit from structurally lower capital costs and increased operational flexibility. In the current wider industrial drive for increased automation, as part of Industry 4.0, this technology shift can be seen as positioning the steel industry to be highly automated, with environmental sustainability at its core, investing for the long term in the training and skills of its people and led by a strategy centred on innovation.

THE GREAT EAF OPPORTUNITY

Around the world, steelmakers are seeking a response to the global challenge to reduce CO_2 emissions and have a more sustainable business model, both in terms of environmental impact and financial return. In Europe, in particular, this is exacerbated by the need to import raw materials, whilst the continent, as a whole, exports much of its scrap. Another challenge is the looming scale of reinvestment that will be required to equip the existing round of integrated steel mills for the environmental, automation and product quality challenges of the coming decades.

It is in this background, where steelmakers would benefit from a low capital cost, flexible, specialist steel operation, utilising home sourced raw materials and emitting intrinsically less CO_2, that the great opportunity for the electric arc furnace has arrived.

Pilot Scale Electric Arc Furnace at the Materials Processing Institute

This is not to say that the end is imminent for existing blast furnace operations. The blast furnace has proven its ability to be one of the most efficient industrial processes ever devised. Existing blast furnace producers, will continue to invest in developing and maintaining these vital assets and indeed, new blast furnaces will be built, particularly in regions where there is little availability of suitable EAF charge materials. However, the essential chemical reliance of the blast furnace on carbon as a reductant, combined with the relatively high cost of capital, means that a gradual rebalancing over time to EAF production now seems inevitable.

For the EAF to realise this potential, significant effort is required in innovation to overcome both quality and economic challenges. Some of these challenges were outlined in a previous paper[1], but a more systematic approach is required to address these and this is being co-ordinated by the Materials Processing Institute as indicated in Table 1. The Institute is open to working with steel companies and supply chain partners from around the world on this range of challenges.

ELECTRIC ARC FURNACE INNOVATION - ADDRESSING THE TECHNOLOGY CHALLENGES

LOW CARBON STEELMAKING

It is clearly the case that the potential for greater exploitation of electric arc steelmaking is greatest in those parts of the world where there is an abundant supply of scrap, but electricity and a robust electrical infrastructure are also essential.

One of the most significant advantages of the electric steelmaking route is the potential for significant reductions in carbon emissions.

To realise this requires a primary electricity source that is not only carbon neutral, but is sufficiently robust to enable matching of the demand surges associated with EAF production, to the sometimes intermittent generation capacity associated with renewable energy.

To overcome this problem researchers at the Zero Carbon and Hydrogen Hub, part of the Materials Processing Institute in the UK, have developed a concept for energy storage, regeneration and distribution, based on a hydrogen system and DC/AC smart grids.

Currently in the design phase, a technology demonstrator is planned, utilising the Institute's 7T pilot scale EAF and off-grid capability as a complete demonstration site. A similar approach is taking place in Sweden, where significant Government funding has also been announced[2]. Further initiatives are also taking place in Austria[3].

Typical sources of Zero Carbon Energy Generation

TABLE 1 - KEY INNOVATION CHALLENGES FOR LOW CARBON EAF STEELMAKING

CHALLENGE	INNOVATION AREAS	STATUS AT MATERIALS PROCESSING INSTITUTE
Energy	• Production • Storage • Distribution	Development of Zero Carbon & Hydrogen Hub technology demonstrator.
Raw Materials	• Scrap quality • Alternative ferrous materials	Development of techno-economic models to evaluate new process configurations and material evaluation at Electric Steelmaking Research Centre, using pilot EAF facility.
Product Quality	• Processing of steel melt to remove residual elements • Low nitrogen steelmaking • Direct casting	New technology concepts for low nitrogen steelmaking, support for fundamental research on residual removal. Investigations into benefits of direct casting, e.g. pilot twin roll caster facility.

RAW MATERIALS

With progress being made on low carbon energy, raw materials are the next consideration and link directly to product quality.

There can be a general perception that production of steels via the EAF route necessarily results in intrinsically lower quality product, with residual levels the primary concern, but this need not be the case. In the UK, the British Metals Recycling Association (BMRA), has published information[4] to show that it is technologically feasible to separate ferrous and non-ferrous materials in scrap to such an extent that most trace elements can be eliminated. The EAF can also accept alternative raw materials, such as Directly Reduced Iron (DRI), Hot Briquetted Iron (HBI), or other novel ferrous raw materials currently under development, in partnership with the Electric Steelmaking Research Centre, at the Materials Processing Institute.

By utilising such raw materials technologies and alternative raw materials, the non-ferrous element in the melt can be reduced to acceptable levels.

STEEL PROCESSING

Where it is either not feasible, or not economic to remove residuals prior to melting, efforts must be made to improve the steel quality during EAF processing. There are two challenges here in both copper and nitrogen. Much can be done to remove copper prior to melting, but efforts are now also being made to address the issue of copper during processing.

Nitrogen presents a particular challenge in that low levels are critical for many steel strip applications, but the 'open' nature of the EAF results in higher levels of dissolved nitrogen than that found by the oxygen steelmaking route.

This challenge is receiving attention from the Materials Processing Institute, where a patent application has been submitted[5] for a new technology, capable of being retrofitted to existing EAFs, that would enable low nitrogen steels to be produced via this process for the first time. This technology could immediately transform the production of high quality strip steels.

ADVANCED CASTING TECHNOLOGIES

The implementation of such processing technology will of course be dependent to some extent on local economics, but there is another option that presents itself to the steelmaker and one with much further reaching advantages. The EAF lends itself extremely well to working in combination with advanced near net shape casting technology, such as twin roll strip casting. This has an immediate quality advantage in that the rapid solidification prevents the development of metallurgical defects associated with, for instance, copper contamination. Twin roll casting also has clear financial benefits, both in terms of capital expenditure, low labour costs and high productivity.

In addition to the pilot EAF and alloying facilities, the Materials Processing Institute uniquely possesses a pilot twin roll casting plant, that has been used for the development of this processing route and associated steel products, with the potential for new investigations on more advanced steel grades.

Pilot Scale Twin Roll Caster at the Materials Processing Institute

THE 4th INDUSTRIAL REVOLUTION

Resolving these technology challenges will help steelmakers to transition over time from their existing blast furnace operations. The long lead time to develop many of these technologies requires early investment in innovation, long before the transition becomes imminent.

However, the potential for more widespread adoption of electric arc steelmaking presents a far reaching opportunity for the global steel industry to adopt new, more flexible business models, with lower capital expenditure and scope for greater product specialisation and productivity improvement through automation.

The product quality challenge of metallic residuals can be overcome by utilising the latest scrap processing technology, considering alternative charge materials and utilising rapid solidification processes for sheet steels, such as twin roll casting. Nitrogen as a residual level remains problematic, but innovations under development at the Materials Processing Institute, suggest that even this last quality challenge can be overcome.

It is apparent though, that to successfully exploit this process route, with its potential technical and financial advantages, requires more than investment in EAFs. To be fully successful requires significant investment in innovation, a more flexible business model than that traditionally associated with the integrated works, greater product specialisation and investment in the latest, most innovative casting technologies.

The future vision for the steel industry is to be highly automated, with environmental sustainability at its core, investing for the long term in the training and skills of its people and led by a strategy centred on innovation.

This is the vision for the steel industry on which leading global steel companies are working with the Materials Processing Institute.

Chris McDonald
Chief Executive Officer
Materials Processing Institute

Note: A concise version of this paper was published in Iron & Steel Today, May 2017

THE ELECTRIC STEELMAKING RESEARCH CENTRE

The Electric Steelmaking Research Centre at the Materials Processing Institute carries out all aspects of electric steelmaking and metals processing research from fundamental theory to practical implementation on an industrial scale.

The Centre features state-of-the-art pilot steelmaking facilities for rapid steel product prototyping and upscaling of novel steel processes.

The Centre combines the expertise of world-leading scientists, metallurgists and engineers. It has been at the forefront of innovations and process developments in electric arc steelmaking for over 50 years and is renowned globally for this expertise. The Centre works with steel companies worldwide to support the development and implementation of new processes and technologies in electric steelmaking.

[1] 'Electric Steelmaking – The New Paradigm for UK Steel Manufacture' : Materials Processing Institute,

http://www.mpiuk.com/downloads/industry-papers/MPI-Paper-02-Electric-Steelmaking-The-New-Paradigm-for-UK-Steel-Manufacture.pdf May 2016

[2] 'Funding for Green Steel production': Steel Times International, **42**(2), March 2017, p5

[3] 'Voestalpine, Siemens and VERBUND are Building a Pilot Facility for Green Hydrogen at the Linz Location':

http://www.voestalpine.com/group/en/media/press-releases/2017-02-07-voestalpine-siemens-and-verbund-are-building-a-pilot-facility-for-green-hydrogen-at-the-linz-location / February 2017

[4] 'Known Unknowns': Fell, R, Materials World, **25**(4), April 2017, pp40-41

[5] 'Nitrogen Removal': GB Patent Application, 16 14 938.7, September 2016

Materials Processing Institute

Chris McDonald is the Chief Executive Officer of the Materials Processing Institute, a not-for-profit industrial research institute, which has been supporting the materials, processing and energy sectors for over 70 years. Chris led the divestment of the Institute from its then parent company, Tata Steel, returning the organisation to independent ownership in 2014.

Chris's background is in industrial research and manufacturing, where he has worked internationally. A graduate of Cambridge University, Chris is a Fellow the Institute of Chemical Engineers and of the Institute of Materials, Minerals and Mining. He sits on industrial advisory boards at a number of universities, including Oxford and Sheffield.

Chris has an interest in innovation management and industry dynamics. He provides expert opinion and support to companies, institutes and government organisations on innovation strategy & management to support growth and inward investment. He is the Innovation Lead for the UK Metals Council, a member of the GreenSteel Council and is a member of both the CBI Regional Council and Shadow Monetary Policy Committee for the North East.

Chris is often called to commentate in the media on innovation leadership and the steel industry.

A member of the CBI Regional Council and the Innovation Lead for the UK Metals Council

Chris McDonald
Chief Executive Officer
Materials Processing Institute

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The Materials Processing Institute is an independent, and not-for-profit technology and innovation centre working with industry, government and academia worldwide. Support ranges from small scale, site based investigations, through to long term collaborative research programmes.

The Materials Processing Institute has expertise in materials, materials processing and energy, specialising in challenging processes, particularly those involving high specification materials, high temperatures and difficult operating conditions.

The Institute has over 70 years' experience as a leading UK technology provider. Extensive materials processing knowledge is supported by state-of-the-art facilities with a broad range of equipment, from laboratories through to demonstration, scale-up and production plant.

Scientists and engineers work with industry and apply their expertise to develop and implement robust solutions to research and development and improvements for products and processes.

Expertise is spread across a wide range of disciplines, including:

> Materials Characterisation, Research and Development

> Simulation and Design

> Monitoring, Measurement and Control in Hostile Environments

> Process Development and Upscaling

> Specialist Melting and Steel / Alloy Production

> Engineering / Asset Management

> Materials Handling

> Minerals and Ores

Research and project management teams deliver support across a wide range of industrial and manufacturing sectors including:

> Metals and Metals Manufacture

> Chemicals and Process

> Nuclear

> Oil & Gas

> Energy

> Aerospace and Defence

> Mining and Quarrying

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