Materials Processing Institute

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# BLAST FURNACE 2030 - A VISION FOR SUSTAINABLE IRON PRODUCTION

Pilot Carbonising Facility
Materials Processing Institute

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## EXECUTIVE SUMMARY

Following on from the previous instalment in this series, which looked at innovation in electric arc furnaces, this paper is concerned with the future transformation of heavy steel processing. Presenting a forward thinking vision, the continued role of the blast furnace in primary steel production is considered, with a demonstration of how this process route can be developed, to meet challenges associated with investment, decarbonisation and changing raw materials in the future.

**The vision for the future blast furnace is one that is both financially and environmentally sustainable with:**

- *Return On Capital Employed (ROCE) that is competitive throughout the economic cycle*
- *$CO_2$ emissions at less than 10% of current European average levels*

This transformation can be achieved by a focus on new technology and innovation, such as developments currently being pioneered at the Materials Processing Institute. This paper gives those steel companies with the ambition to take the blast furnace forward, a clear direction for future research.

**Priority areas for research activity and areas in which the Materials Processing Institute is already moving ahead, include:**

1. Process integration of carbon capture with potential utilisation.
2. Alternative reductants, including biomass and hydrogen enrichment.
3. New ferrous materials to reduce capital costs, operating costs and $CO_2$ emissions.
4. Cross-cutting innovation, such as heat recovery, by-product reduction and carbon cycle analysis.

Achieving this ambitious and innovative strategy will transform existing blast furnace operations into 2030 and beyond.

## OPPORTUNITIES FOR TRANSFORMING BLAST FURNACE OPERATIONS

In a previous paper[1] the challenge of decarbonisation for the global steel industry was considered with reference to the technology needs for electric arc furnace production. In that paper, the continued role of the blast furnace, both in existing furnace operation and new investments, was highlighted, but at that time the detail of how this could be achieved was not described. Recognising the ongoing and important role of the blast furnace in future steel production, this paper sets out a vision for the future blast furnace that is both financially and environmentally sustainable. Analysis of the key technology challenges enables steel producers to plan the direction of future research.

JSW Blast Furnace No.4, Vijayanagar Works, India
Courtesy of Primetals Technologies Limited

For existing blast furnace operators, particularly in Europe, looming financial requirements associated with the refurbishment and eventual replacement of not only blast furnaces, but the entire ironworks infrastructure, from port, through raw materials, sinter plants, coke ovens and by-products plants, presents a significant business challenge. There is a danger that faced with such an investment requirement, some operators will choose to exit the market altogether. However, an alternative approach is to view this need for investment as the very requirement which presents a once in a generational opportunity to radically rethink the infrastructure around the blast furnace, and so prepare this ultimate in industrial processes for the new generation of 2030 and beyond.

Critically, amongst the challenges facing the blast furnace is decarbonisation. Significant steps have been made by the steel industry to increase the thermal efficiency of blast furnace operation, but ultimately there is a hard limit in decarbonisation, associated with the need for carbon as a chemical reductant.

Data from the Global CCS Institute[2] shows that $CO_2$ emissions in Europe are some of the lowest in the world at 1.3t$CO_2$/t steel. However, to meet a target of 0.2t$CO_2$/t steel, more radical solutions are required.

**The key challenges facing future blast furnace operation are therefore:**

1. Reducing CapEx and OpEx significantly to generate a sustainable ROCE throughout the economic cycle.

2. Reducing effective $CO_2$ emissions to a point even below that determined from chemical thermodynamics of the conventional coke based process.

To address this point a number of technology opportunities have been identified and are summarised in the table below.

KEY INNOVATION OPPORTUNITIES FOR THE FUTURE BLAST FURNACE

| INNOVATION AREAS | OPPORTUNITY | REQUIRED RESEARCH AND INNOVATION FOCUS |
|---|---|---|
| Carbon Capture | 60% reduction in $CO_2$ | Process integration aspects of carbon capture to enable retrofitting to existing furnaces, without a detriment to process performance, particularly associated with capture and utilisation. |
| Coke Substitution | 30% reduction in $CO_2$ | Use of biomass and sustainable carbon alternatives to coal. |
| Hydrogen Reduction | Reduction of carbon requirement below current thermodynamic limit. | Hydrogen enrichment of coke oven gas. Aligned to the Zero Carbon & Hydrogen Hub at the Materials Processing Institute. |
| New Ferrous Materials | Reduction in investment capital, working capital and operating costs. | Development of innovative new ferrous materials being researched by partners with the Materials Processing Institute. |

## CARBON CAPTURE

To achieve a step change reduction in $CO_2$ emissions from steel, it is often mistakenly presumed that attention must be focused on the transition from conventional blast furnace production to technologies such as the electric arc furnace. Significant reductions can in fact be achieved, but any solution for decarbonisation of the blast furnace route requires some element of carbon capture. This has been recognised in the European Commission Low Carbon Roadmap[3] and the UK Industrial Decarbonisation and Energy Efficiency Roadmap[4].

Most carbon capture schemes are generally associated with storage, but utilisation can also be considered. For example, the German Government is investing €50 million in carbon capture and utilisation for the steel sector, with the creation of a centre to investigate the use of steel processes gases as a chemicals feedstock.

One promising variation on carbon capture is top gas recycling. This process involves the use of 100% oxygen in the blast, the scrubbing of $CO_2$ and recycling of these into tuyeres and bosh. This process offers the potential for a greater then 50% saving in $CO_2$ emissions, though there is general consensus in the industry that reductions greater than 80% are not possible.

This connection between carbon capture and utilisation highlights an important area of research that is currently of interest to the Materials Processing Institute and that is around process integration. Compared with aspects such as collection, transport and storage, the area of process integration by retrofitting of an existing blast furnace with a carbon capture system, has received little consideration.

It is to be expected that for the majority of ironworks sites, carbon capture will be commissioned alongside blast furnaces that have operated for many decades. There is the potential for a significant level of process interference associated with aspects such as gas quality, pressure, operational protocols and the relative optimisation of both the blast furnace and carbon utilisation plants. Retrofitting and subsequent operation must be achieved without compromising either operational efficiency, or product quality, of the existing ironworks assets.

In this area of process integration the Materials Processing Institute has advanced process simulation and modelling techniques which can be deployed to optimise the combination of an integrated blast furnace and carbon capture system. In this respect a combination of thermo-fluid modelling, with process kinetics and through process economic modelling, aligned to an understanding of the key ironworks process parameters, will be required. Given such a focus, the application of carbon capture to existing ironworks operations could be realised.

## COKE SUBSTITUTION

Increasing the use of biomass in the blast furnace provides an opportunity to introduce essential carbon into the process, but in an environmentally sustainable way. It has recently been reported[6] that the Swedish steel producer SSAB has launched a £1.25M innovation project in exactly this area, with a target of reducing $CO_2$ emissions from the process by as much as 30%.

It is inevitable in that when considering such technologies a number of cross-cutting themes around economics and overall $CO_2$ emissions need to be considered. For instance, the use of $CO_2$ and process gases as chemical feedstocks may require additional purchase of fuels for the reheating furnaces, which will impact on integrated works costs, steel quality and total $CO_2$ emissions. Any solution to be taken further for consideration must have the potential to achieve a multi-component optimisation of these individual aspects.

## HYDROGEN REDUCTION

The fundamental environmental challenge for the blast furnace is the use of carbon as a chemical reductant. This presents a hard thermodynamic limit, below which further carbon reduction is not possible without a significant process change. One such process change is a partial switch from carbon to hydrogen as the reductant. Such technologies are being investigated as part of the Course-50 initiative in Japan[7], where a greater proportion of reduction with reformed and hydrogen enriched coke oven gas is proposed.

Hydrogen is already used in direct reduced iron (DRI) processes and so there is a basic understanding of the mechanisms and chemical thermodynamics, but there is an opportunity for further process research and innovation around the extent to which the balance between hydrogen reduction and carbon reduction can be shifted within the furnace. Such R&D activity would encompass not only process aspects, but also process engineering and plant performance.

This area of innovation links directly to the wider cross-cutting aspects associated with the hydrogen economy and as such fits with the Zero Carbon and Hydrogen Hub demonstration facility being developed at the Materials Processing Institute. This facility aims to link zero carbon electricity to energy intensive users, through the development of technologies that facilitate the use of hydrogen as an energy storage medium, fuel and chemical agent.

## NEW FERROUS MATERIALS

Continuing the theme of carbon reduction, more could be done to reduce the environmental impact of the blast furnace, particularly when a holistic approach, including raw materials, by-products and application is taken into account. This approach has the added advantage of reducing the requirement for replacement of embedded capital assets, thereby addressing both of the key sustainability concerns for ironworks operations.

Recent trends in blast furnace innovation have seen a concentration of activity around the ferrous feedstock. This is a result, at least in part, of the gradual depletion of prime sinter raw material and a need to utilise ores of variable quantity and quality. By emphasising and accelerating this trend in innovation and technology, a gradual reduction in sinter dependence becomes not only achievable, but desirable.

The long-established capability at the Institute for the development of ferrous materials at the pilot scale means it is continuously at the forefront of developments. Using propriety cutting-edge technology in partnership with clients, alternative raw materials are being developed that will address both the environmental and financial issues associated with existing ironworks facilities.

## FERROUS MATERIALS RESEARCH

The Materials Processing Institute has a range of expertise and equipment to support the development and testing of ferrous materials. Raw materials research is undertaken to develop pre-treatment and agglomeration technologies and optimise the blast furnace ferrous burden strategy. This includes reduction in environmental impact and generating significant financial benefits.

Advice can also be given on ore mine optimisation and exploitation strategies, including the through process value in use of raw materials for specific ironworks configurations.

Specialist technology and equipment includes:

- *Raw materials preparation through briquetting and pelletising.*
- *Sinter plant optimisation with pilot sinter box, flow factor, shatter and compression testing.*
- *Quality assessment including XRF, TGA and EDXA, all performed to international, ISO standards.*


1 'Electric Arc Furnace Innovation – Addressing the Technology Challenges': Materials Processing Institute,
**http://www.mpiuk.com/downloads/industry-papers/MPI-Paper-03-EAF-Innovation-Addressing-the-Technology-Challenges.pdf** June 2017

2 'Global CCS Institute'
**https://www.globalccsinstitute.com/insights/authors/dennisvanpuyvelde/2013/08/23/ccs-iron-and-steel-production**

3 'European Commission Low Carbon Roadmap'
**https://ec.europa.eu/clima/policies/strategies/2050_en**

4 'Industrial Decarbonisation and Energy Efficiency Roadmap'
**https://www.gov.uk/government/publications/industrial-decarbonisation-and-energy-efficiency-roadmaps-to-2050**

5 **https://www.thyssenkrupp.com/en/carbon2chem/**

6 'Wood Chips May Reduce BF Carbon Dioxide Emissions': Steel Times International,
**http://www.steeltimesint.com/index.php/news/view/woodchips-may-reduce-bf-carbon-dioxide-emissions** August 2017

7 'Course 50': The Japan Iron and Steel Federation,
**http://www.jisf.or.jp/course50/index_en.html**

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## INNOVATION STRATEGY – BLAST FURNACE 2030

Based on this analysis of the challenges and opportunities, an innovation strategy is proposed to equip the blast furnace for operations into 2030 and beyond. The key pillars of this innovation strategy are:

1. **Carbon Capture and Utilisation:** Consideration of $CO_2$ as a value feedstock for other processes, e.g. chemicals, alongside other steel industry process gases, such as hydrogen from coke oven gas, blast furnace gas, etc.

2. **Alternative Reductants:** To consider opportunities to reduce large scale $CO_2$ emissions in ironmaking by use of alternative reductants to coke and coal, including biomass and hydrogen enrichment.

3. **New Ferrous Materials:** By development of alternative agglomeration processes, to reduce the capital and operating costs associated with sintering, reduction in $CO_2$ emissions and use of more readily available and economical raw materials.

4. **Cross-cutting Innovation:** Economic and value-in-use study of technology solutions to prioritise against technology risk and economic feasibility, including a through carbon life cycle analysis. Investigation into alternative strategies for the prevention of waste heat and recovery of low grade heat. Raw materials optimisation through by-product reduction.

The Materials Processing Institute is actively seeking to implement this strategy and is open to working with ambitious steel companies from around the world, on a collaborative, or confidential basis, to create the sustainable blast furnace of the future.

Chris McDonald
Chief Executive Officer
Materials Processing Institute

Materials Processing Institute

## Materials Processing Institute

### 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 through partnership 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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