Materials Processing Institute

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ELECTRIC STEELMAKING – THE NEW PARADIGM FOR UK STEEL MANUFACTURE

Electric Arc Furnace at the Materials Processing Institute

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EXECUTIVE SUMMARY

The UK market for steel is forecasting strong and sustainable growth across a number of sectors. Despite current turmoil, the UK is well placed to exploit its natural resource of raw materials and intellectual capability, to make a transition to more electric-based steel manufacturing. The key technical barriers to electric steelmaking concern achieving product quality specifications, particularly with regard to copper and nitrogen. New technologies have recently been developed that can partly solve these problems and others are being addressed by innovation projects at the Electric Steelmaking Research Centre, part of the Materials Processing Institute at Teesside. The industry and others have made a specific request to Government to co-invest in the necessary innovation infrastructure and projects, through the Materials Catapult, a proposal from the Materials Processing Institute, TWI and IOM3. In this way the UK can lead Europe by creating the flexible, profitable and innovation-led steelmaking industry of the future.

Market Opportunity

Everything in the world is either made from steel, or with steel. As a material, steel has transformed human life, remains essential for economic growth and helps to raise the living standards of people across the world. No other materials can be made in sufficient quantity, or have the same versatility as steel. In the UK, steel production remains as vital as ever and yet the risk of the wholesale collapse of the UK steel industry has been increasing for many months. The industry is beset by the twin problems of steel from China being sold at below the cost of production and the lack of a level playing field on energy in Europe.

In the rest of UK industry, strong growth is forecast for automotive and construction, a series of large-scale national infrastructure projects in transport and energy have been announced and the aerospace industry is world-leading. These industries and projects require competitive and innovative advanced materials. A domestic steel industry is essential to provide this. Innovation in manufacturing relies on innovation in steel, sometimes with the end user, but often in the supply chain. Without the foundation of the steel industry, first the supply chain and then the large manufacturers would see a gradual erosion in their competitive position. Put simply, Britain cannot have a high value manufacturing sector without a steel industry, but the industry is not a public service, it must thrive on its own terms to be both profitable and sustainable.

The industry trade body, UK Steel, has made five asks of Government that would level the playing field in Europe, particularly with regard to energy, and to address the dumping of subsidised steel from China in the UK. However, the shake out in the UK steel industry goes far beyond these requests. As a consequence of the current trading conditions, there is a once-in-a-generation opportunity for a complete realignment of the industry, leading to new forms of ownership, new business models and new technologies.

Many of the fundamentals for the UK are already in place; manufacturing industry demands the continual development of new advanced steels, the university sector is world-leading in new steel development and the Materials Processing Institute (MPI), has a 70 year history in delivering cutting-edge process technology for the most efficient manufacture of the materials of today and the future. What is needed is a step change in the fundamental business model, enabled by a switch to different manufacturing technology and by placing innovation at the heart of the business.

Raw Materials Opportunity

Much of the discussion around existing assets, has concerned the relative merits of Blast Furnace steelmaking, as opposed to Electric Arc Furnace (EAF) steelmaking. Quite rightly the initial focus is on securing the existing asset base on a stable footing; however, some consideration must be given to how this asset base can be best developed in the medium to long term.

The dominant steel manufacturing process is the blast furnace route, where iron ore is reduced by coke. This produces liquid iron that is saturated with carbon and is processed in a second stage, the Oxygen Furnace, where the carbon is removed by supersonic injection of oxygen.

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The liquid steel resulting from this process is then further refined and alloyed to achieve the desired properties for the particular steel product being produced. A proportion of steels are also produced via the EAF route, where usually 100% steel scrap is melted using electricity. Traditionally this route was reserved for smaller scale operations and a more restricted quality range of steels.

Over time, the blast furnace steelmaking route proved to be hugely successful, with British Steel achieving a 500% increase in productivity in the four decades since the current crop of UK steelmaking facilities were commissioned. Continuous, relentless innovation has transformed these production operations, with much world-leading technology being developed here in the UK at the Materials Processing Institute. However, increasingly steel producers have struggled to recover the cost of capital, or to build in the operational flexibility needed to satisfy market demand. At the same time, the scale, quality and flexibility of EAF steelmaking has been gradually increasing. This, combined with much lower capital costs, has narrowed the differentiator available to the existing production facilities, creating precisely the conditions where an external shock can lead to a step change in the method of manufacture.

Another factor favouring EAF steelmaking is the availability of raw materials. Blast furnaces require iron ore and coal, which was advantageous when the UK had access to indigenous materials. It was the opportunity presented by the availability of these raw materials that drove the geography and development of the steel industry in the UK. As the suitability of these materials declined, the UK industry, as with most of the rest of the developed world, coalesced around large coastal sites with access to deep water ports, for ease of raw material importation.

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.

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Forty years on, the UK is once again presented with a unique raw materials opportunity. Having been the first nation to industrialise, the UK has a mature infrastructure and this leads to the generation of an estimated 10M tonnes of scrap steel annually, which is forecast to double in the coming decades. Approximately 6M to 7M tonnes of this valuable raw material are exported every year for processing and then a similar amount is imported back into the UK as steel products.

The UK has a large market for steel that is forecast to grow, access to raw material that is currently exported and the intellectual capital in the workforce, universities and at the Materials Processing Institute that are able to take advantage of this position. Switching the processing technology to EAF, at a relatively low cost, will give a step change reduction in CO_2 emissions, improve operational flexibility and meet future customer requirements for quality and service.

Technology Opportunity

The opportunity to make this technological shift represents the cusp of a paradigm shift in UK steel manufacture that could give the UK the opportunity to emerge as the most advanced and competitive steel producing nation in the world. At the Materials Processing Institute we have recognised the potential for this opportunity and we have marshalled our expertise to launch Europe's first Electric Steelmaking Research Centre (ESRC). It is not all straightforward however; there are steel quality considerations to take into account that have generally been the major limitation on electric arc furnace production. In broad terms these issues are around the presence of both copper and nitrogen in the final product.

Taking copper as the first element of concern, it can lead to cracking in the steel, is present in scrap and is difficult to remove in the metallurgical process. This means that lower copper levels are more difficult to achieve given the larger contribution of scrap in the EAF charge, as compared with the blast furnace / oxygen furnace route. Traditionally this would have been a major limitation on the technical capability of the EAF; however, scrap processing methods introduced as a result of the end of life vehicle directive are now able achieve sufficiently high levels of metal separation. Whilst not yet standard industry practice, the opportunity for a forward-thinking steel manufacturer to adopt this technology will both unlock the capability for many difficult to produce steel grades and provide a source of competitive advantages over other producers.

The second area of challenge concerns nitrogen. The electric arc furnaces necessarily result in higher levels of dissolved nitrogen in the steel, due to the difference in the process methodology, as compared with the oxygen steelmaking route and the greater opportunity for nitrogen absorption. Attempts have been made in the past to reduce air ingress into the furnace and these have been partially successful. However, it is technology currently being developed at the Electric Steelmaking Research Centre, part of the Materials Processing Institute, which could create a step change in low nitrogen steelmaking from the EAF. Drawing on a long history of EAF process developments, the Institute is developing a new approach to low nitrogen steelmaking that, once commercialised, could produce steel with nitrogen levels comparable with the oxygen furnace route.

A final area of consideration is the balance between the raw materials charged to the furnace. The opportunity for electric arc furnaces in a mature industrialised economy is centred on the availability of scrap. However, for the production of some steel qualities, it may be advantageous to utilise a mixture of blast furnace hot metal, pig iron, directly reduced iron (DRI), recovered iron units from waste, or hot briquetted iron. In the transitional period between the natural run-down of existing blast furnaces and the run-in of new electric arc furnaces, there would be particular advantages in using such a mix of raw materials. It is also the case that the long term prospects for energy and gas in some parts of the UK, particularly Teesside, give serious opportunity for investment in the production of DRI.

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Materials Catapult

It is clear that for the UK, or indeed Europe, to take full advantage of this raw materials opportunity, a significant effort will be required in research and innovation. For this reason, the Materials Processing Institute is discussing with the UK Government the creation of a new 'Materials Catapult', to enable the industry to develop and implement the technologies needed to make this leap forward. Catapult is the name given to strategic innovation infrastructure in the UK. The steel industry and the materials sector more widely are currently not supported by the existing Catapult network and this proposal has received widespread support from industry, academia and professional institutions. The Materials Catapult would utilise the existing facilities of TWI, IOM3 and the Materials Processing Institute to accelerate innovation and research commercialisation in the UK materials industries.

The steel industry, essential as it is to our economy, can only recover if the issues of steel dumping and energy prices are addressed by both Government and the EU. However, with this in place, the UK industry can be the global leader in making the step change to a new industry, based on new technology and raw materials opportunities. This will result in the flexible, profitable and advanced steelmaking capability that the UK needs, to enable growth in the advanced manufacturing sector and to continue to support the improvement in our standards of living that has been the unique contribution of steel since its inception.

Chris McDonald
Chief Executive Officer
Materials Processing Institute

Note: A concise version of this paper was published by the Institution of Chemical Engineers (IChemE), in their journal TCE, in May 2016

Materials Processing Institute

Chris McDonald is the Chief Executive Officer of the Materials Processing Institute, a not-for-profit industrial research institute, supporting the materials, processing and energy sectors. Chris led the divestment of the Institute from its then parent company, Tata Steel, 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 and is an associate faculty member at the University of Warwick.

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

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The Materials Processing Institute is an independent, open access 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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