Research and development to enable the conversion of low quality scrap into high quality steel in the UK

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Abstract. Converting steel scrap with varying quality to high quality steel and minimising virgin materials-based steel production is an indispensable approach to a circular steel economy and a practical pathway to achieve net zero emissions for the steel industry. This article briefly introduces the research and development undertaken by the present authors to increase the scrap utilisation in the UK steel production. This includes a state-of-the-art analysis on the UK steel scrap supply and utilisation; current scrap supply chain practice and circular scrap supply chain design; fundamental understanding and technology development to improve scrap quality, remove impurities and increase residual tolerance in steel; and opportunities and challenges identified for increasing scrap utilisation in the UK steel industry.

1. UK steel scrap supply and utilisation

The quantity and quality of UK generated steel scrap and its utilisation are quantified by analysing import and export data, and domestic consumption and production reported in open sources. [1, 2] The UK steel industry produced 7.3 Mt crude steel in 2018, 78% of which was produced via the BF-BOF (blast furnace-basic oxygen furnace) process route by using imported virgin materials of premier iron ore and coking coal. The UK generated 11.3 Mt of steel scrap per year (in 2018), 8.7 Mt of which was exported, and 2.6 Mt used in the UK. The UK steel industry used 0.7 Mt internally generated scrap and 1.9 Mt purchased scrap. Out of the 2.6 Mt scrap used in the UK, 1.8 Mt was used in the EAF (electric arc furnace) steelmaking route, and 0.8 Mt in the BF-BOF route at scrap ratio of ~20%. So, the UK has sufficient scrap to support a transition to a full scrap based EAF steel production if it is necessary. However, steel scrap can be from different/unknown sources (e.g. municipal incinerator scrap, coated products), mixed with different materials (e.g. plastics, glass, bricks), and containing varying impurity elements (Cu, Sn, Zn, Pb, Sb, Co) either in the matrix or as embedded contaminants, which makes the upcycling of “low quality” steel scrap challenging. Scrap is generally sorted by the recycler before delivery to the steelmaker according to the UK scrap specifications, but the UK specifications do not have residual elements limits compared to other international standards.

2. More circular scrap supply chain

To fully understand the current status of the UK steel scrap supply practice and design a more circular scrap supply chain, we have extensively engaged with senior management from the companies in the steel and metal recycling sectors via site visits, workshops, semi-structured interviews, analysis and validation.[3] After revealing the current operating challenges, a set of strategies and enablers are proposed to increase/maximise the scrap use in the UK steel industry, including establishment/adoption of an E2E (End-to-End) supply chain integration between scrap suppliers, steelmakers and OEMS, circular supply chain, supply chain finance and digital technologies.

3. Fundamental understanding and technologies to increase scrap utilisation

Two of the factors limiting increased scrap use in steelmaking are residual elements (e.g. Cu, Sn, Zn, Pb, Sb), in particular Cu which cannot be removed viably from molten steel under current operating conditions, and other contaminants such as concrete, sand, plastics, glass. Consequently, the Cu level in recycled steel increases with the number of times that the steel is recycled if no dilution is performed in steelmaking, and the other contaminants reduce EAF steelmaking capacity, quality and cost effectiveness. The present authors have been working on improved fundamental understanding and various technology developments from scrap sorting, scrap pre-treatment (Cu removal), scrap melting, and increased tolerance in downstream processes (from casting through to annealing). The UK scrap specifications inform both metal recycler and steelmaker on scrap quality, but the industry relies on visual inspection and hand-held XRF (X-ray fluorescent) analyser for spot analysis to assure the scrap quality. The present authors are investigating the application of artificial intelligence in scrap identification, which can be used in scrap quality monitoring and improved scrap separation. Another important topic under study is how the increased residual level in steel affects the downstream processing and the product quality and how changes in processing parameters can increase the residual tolerance without compromising steel properties. A low carbon steel containing varying levels of impurity elements such as Cu, Ni and Cr has been studied in terms of chemistry, microstructure, processing parameters and steel properties.[4]

4. Opportunities and challenges for increasing scrap utilisation

Opportunities and challenges/barriers co-exist for increasing the scrap utilisation or the transition to a full scrap based EAF steel production in the UK steel industry. The main opportunities which can be explored include the UK steel demand, abundant scrap supply, through supply chain carbon emission taxation, circular supply chain and technology development and adoption. Other factors will also need serious consideration such as industrial electricity price, business rates and taxes, greenhouse gas emission costs, and geographical considerations for investment.[1] For example, improved scrap quality will be important for increased scrap recycling, the research/development and implementation of such technologies is expensive, government incentives could help to accelerate the transition.

References

[1] Hall R, Zhang W and Li Z 2021 *Domestic scrap steel recycling – economic, environmental and social opportunities* DEFRA Science and Research Project EV0490 (http://wrap.warwick.ac.uk/152270/)

[2] Spooner S, Davis C and Li Z 2020 Modelling the cumulative effect of scrap usage within a circular UK steel industry – residual element aggregation *Ironmak. Steelmak.* **47** 1100

[3] Zhang W, Chakuu S, Godsell J and Li Z 2021 *Steeling for a sustainable future: How the UK steel industry could compete through supply chains.* (https://warwick.ac.uk/fac/sci/wmg/research/scip/reports/p4024_future_viability_report_final.pdf)

[4] Duan J, Farrugia D, Davis C and Li Z 2021 Effect of impurities on the microstructure and mechanical properties of a low carbon steel *Ironmak. Steelmak.* (submitted)

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