The Strategic University Steel Technology and Innovation Network Presents

Task 7: Disruptive processes -

7.1: Direct reduction iron (DRI) and
7.2: Near net shape casting / reduced rolling

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7.2: Professor Claire Davis / Dr Carl Slater - WMG

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Engineering and Physical Sciences Research Council

WMG THE UNIVERSITY OF WARWICK

Names and Organisations

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- Professor Claire Davis
- Dr Carl Slater

All members are from the Advanced Steel Research Centre, WMG, University of Warwick

Introduction to Project

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To inform future capital investment decisions for new technologies for the UK steel industry, fundamental knowledge about new processes is required so that all adoption implications can be considered.

“Direct reduction of iron ore using renewable energy-generated (clean) hydrogen” and “near net shape casting with reduced rolling” have been identified as potential future technologies not covered in on-going research projects

Two PhD projects in these areas have been proposed.

Introduction to Project:
Direct reduction of iron ore using clean hydrogen

- Decarburisation – a globally recognised technology trend having far-reaching implications for the steel industry and its supply chain.
- Rapid deployment of renewable energy technologies and their promising applications in steel manufacturing attracted great attention globally, such as clean H_2 generation and H_2-based DRI production.
- DRI production by using renewable energy-generated hydrogen – an ultra-low/even zero CO_2 emissions alternative ironmaking technology.
- Significantly increasing scrap usage in UK steel production while the residual elements in scrap are accumulated, requiring dilution.
- Scrap dilution/replacement in BOF steelmaking; an ideal dilution additive for (high residual) steel scrap in the EAF route (DRI + scrap-based EAF) to produce high quality steels .

Aims and Impact:
Direct reduction of iron ore using clean hydrogen

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Aims

- Understanding of the state-of-the-art with regards to hydrogen applications in steel industry

- Creation of fundamental knowledge on the production of direct reduced iron (DRI) by using renewable energy-generated hydrogen, in particular reducing mechanisms and effects of impurities in the iron ore, via *in-situ* observation, and in-line gas monitoring on bespoke gas furnace operating under flammable gases, and ex-situ characterisation.

Impact

- Recommendations on the application of hydrogen in UK steel industry

- Contribution to the creation of an ultimately low carbon ironmaking process by using renewable energy-generated hydrogen

- Contribution to achieving net zero emissions UK steel industry by 2050.

Introduction to Project:
Net shape casting

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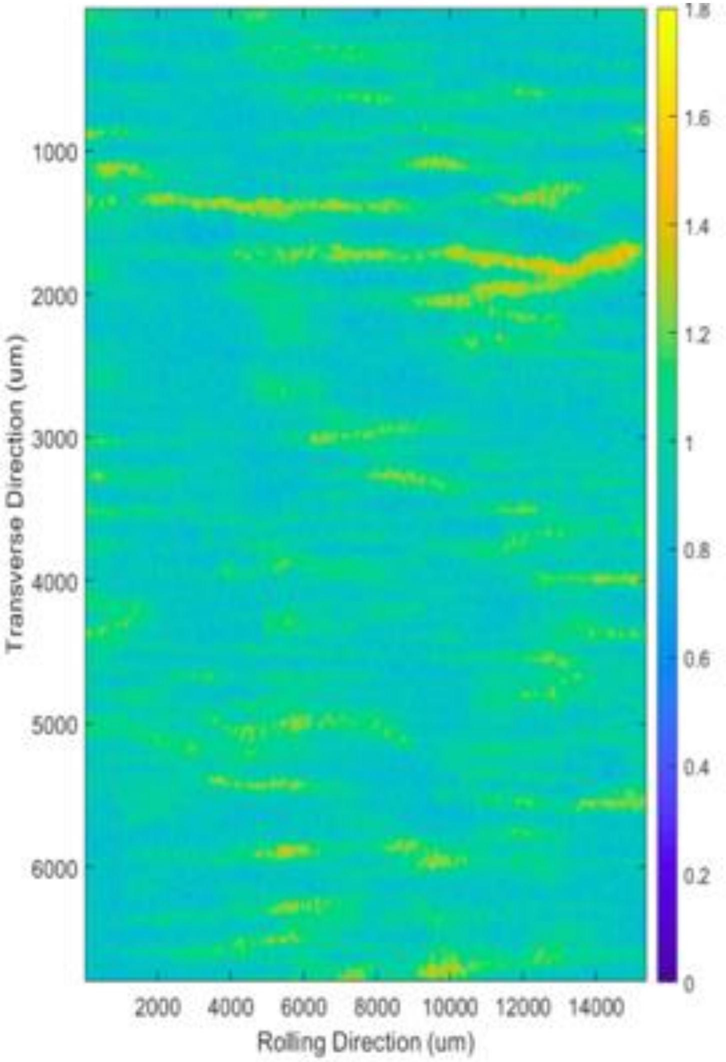
- Near net shape casting produces material that needs minimal hot deformation to achieve the required product thickness; using significantly less energy compared to traditional continuous casting to large sections with subsequent hot rolling; e.g. energy use could be reduced by >3 GJ/T steel produced for belt casting of strip steels.
- The removal/reduction of reheating & thermo-mechanical deformation, whilst saving energy, mean that desirable microstructural modifications of recrystallisation & phase transformations can be excluded. Thus, it is important that quantitative composition, process parameters and microstructure relationships are established for these new processing routes.

Aims and Impact:
Net shape casting

- Aims
- Modeling and experimental validation for the impact that variations in cooling rate and deformation levels (as well as temperature and strain gradients) have on microstructure development. To include consideration of inhomogeneity in microstructure and composition over a range in solidification rates.
- Case studies for high microalloy steels, to determine the compositional limits for retaining elements in solution during solidification for subsequent nano-precipitation, and high substitutional alloy steels, where segregation affects local solid solution strengthening and hence local strains on deformation.

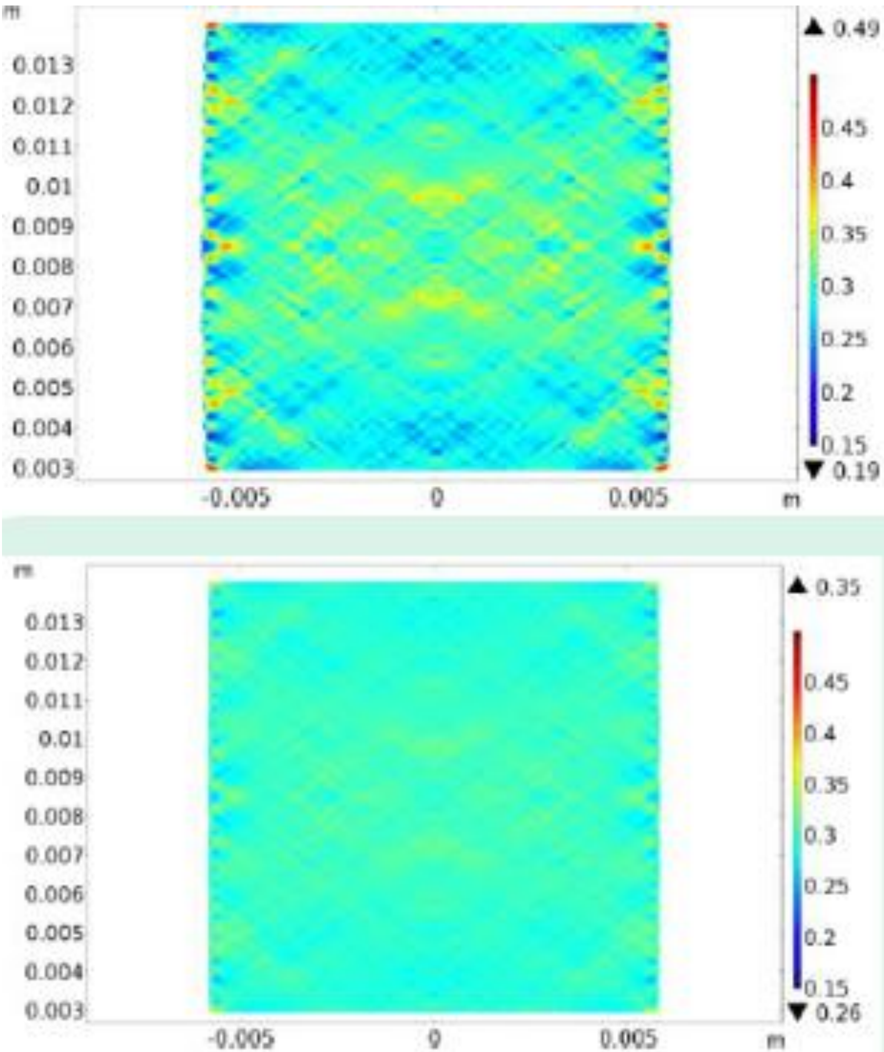
- Impact
- Improved steel grade production often relies on narrow process operating windows and tight alloy composition control therefore achieving consistent high quality is challenging. Understanding property inhomogeneity due to spatially varying composition and strain / temperature is important for optimisation of alloy design and/or process windows to achieve required properties.
- Fundamental research on the effect of cooling rate on inhomogeneity, and subsequent consequences during processing, will provide insight into microstructural sensitivities for new processing technologies and conventional casting techniques.

Background for research significance



Micro-XRF image of an ingot cast and rolled to 90 mm bar stock 20MnCr5 grade steel showing Mn segregation. The spatial distribution (bands) of Mn is linked to interdendritic segregation during casting (and subsequent rolling deformation for the example shown) with the magnitude and spacing being affected by the cooling rate during (secondary dendrite arm spacing) and subsequent (back diffusion) to solidification.

Background for research significance



Predicted strain distributions on uniaxial compression for a segregated composition sample (top) and a homogenised sample (bottom) showing the strain inhomogeneity that can arise due to the variation in local strength (from solid solution strengthening) due to compositional (Mn) inhomogeneity.

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