How are we designing steel processes and grades for the future?
Customer requirements for new products using cost effective, low energy processes are key challenges facing the steel industry. At the Advanced Steel Research Centre (ASRC) we focus on research to develop new and improved steels and understand new processing technologies. Our researchers work on physical-chemical topics relating to iron and steel manufacturing and usage, tackling both fundamental and applied research from steelmaking, through to production and service.

We’re investigating the opportunities in new iron making technologies, new casting processes, increased use of recycled steel, in-line microstructural engineering, late stage differentiation of products and through process modelling. Alongside these, we also address product performance, optimisation and customer requirements.

How are we addressing the challenges?

Our work combines fundamental studies of scientific issues with applied problem solving; undertaking collaborative R&D with industry. We are also educating and developing our research students to meet the global need for highly trained engineers who understand issues of policy and the environment.

Our Advanced Steel Research Centre houses cutting edge facilities, with a focus for in-situ examination, to:

- Manufacture new steel chemistries
- Assess processing stages from liquid metal - slag - gas interactions, to thermomechanical processing to coatings
- Generate key thermal-physical-chemical-mechanical data for models
- Characterise microstructures at all scales

The ASRC has been made possible by the Engineering and Physical Sciences Research Council (EPSRC) and the Government’s Local Growth Fund through Coventry and Warwickshire LEP.
Liquid metal processing

A major research interest for us is to create the fundamental knowledge needed to realise transformative changes for extraction, refining and casting of liquid metals and to address the future global mega trends in raw materials, energy, CO₂ regulation and oversupply in steel manufacturing.

The fundamental knowledge required for liquid metal processing is focused on the mechanisms and rates at which reactions and transformations in multi-phase systems occur at extreme temperatures. The next step is solidification control during casting where the role of cooling rate, fluid flow, bulk and local composition and liquid-mould interactions all need to be taken into account so that grade and process optimisation can be considered.

In-situ observations

The confocal laser scanning microscope (CLSM) allows us to directly observe liquid steel under controlled thermal and environmental conditions to study the reactions between the liquid metal and inclusions, the solidification structure and dendritic growth rates and local solidification temperature ranges.

Our work is leading to the development of new mould powders for casting difficult to produce alloy grades, new steel chemistries for as-solidified grain size control and quantification of transient phenomena in metallurgical processes, for example, Basic Oxygen Furnace (BOF) steelmaking and secondary refining. The in-situ CLSM observations have been coupled with 3D image re-construction of post solidification samples using X-ray computed tomography (XCT) scanning.

Casting trials

We have the capability to produce bespoke steel compositions using our Vacuum Induction Melting (VIM) or TopCast facilities and then to cast into instrumented moulds, including wedge moulds for varying cooling rate trials. We have a Gleeble HDS-V40 system that provides the ability to melt, solidify and directly deform (without cooling to room temperature) samples, allowing replication of commercial processing routes such as Thin Slab Direct Roll (TSDR) and Belt Casting technologies.

Modelling

We are working on multi-scale modelling approaches, being able to consider fluid flow in the continuous caster and re-distribution of solute between dendrites, which gives compositional segregation resulting in local solute rich areas that can give rise to coarse particle formation. We use a range of modelling techniques from phase field, to thermodynamic and kinetic approaches. Optimisation of process parameters and steel composition is being considered to produce the desired high quality microstructures.
New steel development and through process analysis

Customers continue to demand new and improved processing and steel grades to allow lightweighting of components or improved performance. We are working on:

Development of low density and electrical steels
- Solidification behaviour to understand grain size development; for example in low density steels some grades suffer from large grain sizes that limit performance
- Compositional optimisation to provide maximum strengthening from interphase precipitation
- Coating performance to ensure that new grades can be coated to give required final product performance

Increased use of scrap
Consideration of increased usage of scrap (including high residual obsolete scrap) in the BOF process and scrap-based EAF process, and the consequences for both the final steel grade and process route. This is carried out by using a through process approach from scrap separation, through refining and casting to thermal processing.

Development of new steel grades and process routes
For example we are working on steel compositions for powder production for future net-shape production processes, and understanding the microstructural development and flow stress characteristics in conventional and new generation automotive transmission unit steels to allow optimisation of forging processes.

Rapid through process suite
Development of a rapid through process suite of equipment to assess new compositions using small scale samples.
- Powder feed 3D ingot printer to generate samples
- Drop furnace for casting optimisation
- High throughput rolling mill
- Bespoke surface/bulk deformation rig to consider surface state development (and oxide removal) during hot processing
- Plasma vapour deposition (PVD) to enable rapid assessment of current coatings on new alloys and co-development of new compatible coatings
- Electro-thermal-mechanical testing (ETMT) for rapid assessment of coating quality under load and new alloy thermomechanical properties for forming and welding

Modelling development
Through process (casting, rolling and cooling) modelling development to allow process and composition optimisation.
Electromagnetic sensors for microstructural characterisation

Electromagnetic (EM) sensors are sensitive to changes in microstructure and offer the potential for characterising steel microstructural parameters in products and during processing. The ability to non-destructively characterise steel microstructure in-situ during processing presents opportunities to provide feedback during production and, in the future, to optimise microstructure and mechanical properties through dynamic process control.

Assessment of products includes power generation components’ condition and microstructural changes in service, strength predictions from microstructure in automotive dual phase steels and pearlite lamellae spacing in wire steels. We are working to understand the links between EM sensor signals and microstructure including:

**Magnetic domain imaging**
Dynamic imaging of magnetic domains and domain wall movement related to microstructural features under different magnetic fields to develop an understanding of the fundamental relationship between the EM sensor signal and microstructure. This is achieved by the Bitter method and Lorentz microscopy.

**Magnetic property modelling**
We have developed detailed 3D microstructure - magnetic flux FE models to predict the magnetic parameter behaviour for different steels and can link these to sensor output models to predict the sensor signals. We model the BH curves taking into account microstructural features, for example grain size and precipitate distributions. Laboratory and commercial sensor systems are also modelled.

**Magnetic measurements**
Working with in-house equipment we measure the magnetic behaviour of steel microstructures using BH curves and low field permeability (including the effect of temperature and stress).

**Demonstration systems**
We support the development of commercial and deployable sensors through the use of proto-type and demonstration systems to link signals to the material features of interest. For example, a furnace-roller table with embedded commercial sensor for real-time microstructural engineering capability development.
Characterisation and testing

A key feature of our work is problem solving, and using our research capability and dedicated microscopy and characterisation facilities to solve issues directly affecting industry.

Electric Power Research Institute
We have been working with the Electric Power Research Institute (EPRI) to develop state of the art characterisation guidelines for auto-mapping of inclusions and strengthening particles in power generation steels for size, morphology, composition and distribution.

Metrology
We collaborate with WMG’s metrology group using X-ray computed tomography (XCT) on industrial, pilot and lab scale samples; for example to interrogate metal-slag surface areas to understand phenomena such as phosphorus removal; working with Tata Steel. A new addition to our XCT capability is the introduction of a high-throughput detector panel as well as the nation’s first lab based 720kV X-ray source, which allows faster scan acquisition and investigation of much larger samples.

Silson Ltd
We have been working with a local SME, Silson Ltd, to develop a methodology to produce bespoke grids and gratings at the micron and sub-micron scale using focused ion beam milling (FIB) in the scanning electron microscope (SEM).

Automotive industry
We have used in-situ material characterisation and correlative microscopy in combination with lab scale rolling and coiling trials to propose novel thermomechanical processing and subsequent accelerated cooling to maximise strength and formability in sheet steel. This has been implemented in the production of high strength formable automotive chassis components giving light weighting and cost savings.
How are we transferring our knowledge to industry?

Transmission supply chain excellence for next generation dual clutch technologies (TRANSCEND)
TRANSCEND is a multi-partner, industry-led project to develop new transmission units combining innovative mechanical design and advanced manufacturing techniques.

We are supporting the manufacturing process by providing input data on the steels being considered in terms of their quality and high temperature mechanical properties. Assessment of processing windows to allow optimum manufacturing schedules is essential in achieving the required product properties.

Real-time in-line microstructural engineering (RIME)
RIME is an EPSRC funded and industry supported project with the University of Manchester (UoM), and follows on from previous EPSRC and EU projects developing EM sensors. The main industry project partners are Primetals Technology Limited (PTL) and Tata Steel Europe, with additional support from British Steel and Tenaris.

Novel EM sensors have been developed to measure phase transformation during hot strip steel production (UoM), leading to the production of a commercial system (PTL). Further ongoing research is modelling the complex relationship between EM signal and microstructure and how the signals can be used as feedback to control microstructural development.

EPSRC Manufacturing Fellowship
Dr Zushu Li joined us from Tata Steel, where he was a principal scientist, under the prestigious EPSRC Manufacturing Fellowship scheme. Dr Li is bringing his industrial experience and awareness of the challenges facing the steel industry into the academic world where he is focused on uncovering the fundamental mechanisms involved in low carbon, low energy alternative ironmaking (e.g. Hisarna Technology).

Dr Li is responsible for the experimental facilities that allow in-depth study of the interactions between liquid iron, different reactive gases and slag materials. He works closely with his former colleagues in Tata Steel and is also developing new collaborations with companies in the UK and China.
How can you work with us?

We have extensive experience working with different companies, from SMEs to OEMs including multinational steel producers. We engage in short term problem solving and doctoral student research projects through to large scale international collaborative projects working on fundamental science, applied problems and product development. Working with us you will gain access to state-of-the-art facilities and a team of dedicated expert researchers.

**Commission bespoke research**
Define a research project or challenge tailored to your organisation, paying the full project costs to ensure you own the IP generated.

**Collaborate on single or multi-partner projects**
Collaborate with us, and other partners, on bids into public funding sources such as EPSRC, Innovate UK, Advanced Propulsion Centre and others. Rights to the commercial exploitation of IP generated are agreed at the outset of the project and usually result in free licences to industrial partners.

**Sponsor a doctoral research project**
Put forward a project to be carried out by a doctoral researcher under a PhD or EngD arrangement. Research is carried out over four years and PhD students carry out their work primarily at WMG although they can undertake secondments within your company, whilst EngD candidates typically divide their time between WMG and your organisation, working on a series of industrial challenges that you have identified. In many cases, the researchers go on to be valued employees in the sponsoring company.

**As an SME, join our support network**
If you need help with a manufacturing problem associated with materials issues contact the WMG SME team (wmgsme@warwick.ac.uk) and receive assistance with finding a solution to the problem, including access to the ASRC equipment and expertise.

Getting in touch

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