BRITISH STEEL

Rail Steel as part of a Low Carbon Transport Network

Research challenges from a steelmaker’s perspective

BUILDING STRONGER FUTURES

Introduction: Research Challenges

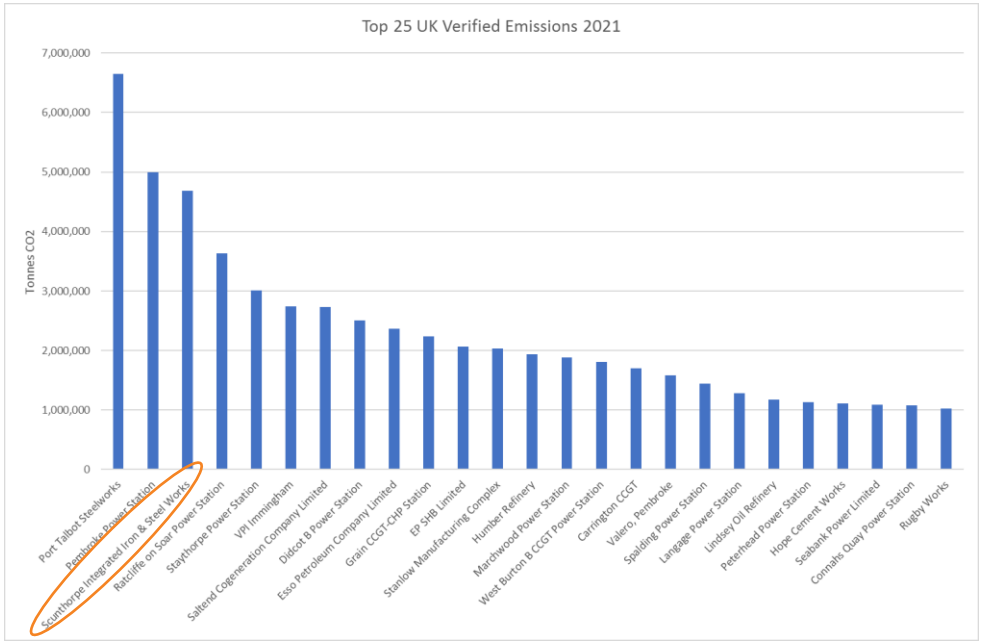
- Decarbonisation – reducing embedded and whole-life carbon of the network.
- Rail in Service – supporting customers in their use of our product.
- New Solutions – development, introduction and validation.

These all work together:

- A longer lasting rail with less maintenance requirements doesn't just sell better, it has lower whole-life carbon.
- A modal shift to rail as part of a low carbon transport network means even greater importance of reliability and dependability.
- We need to resolve these challenges both with current technologies, and by introducing the solutions of the future.

I aim to showcase some of how our current research supports these goals.

Decarbonisation



Context of our business – the Humber region represents 40% of UK industrial emissions.

We have a legal, and a moral duty to decarbonise.

We also face a commercial pressure to do so – customers are increasingly incorporating carbon metrics into their procurement requirements.

UK TARGETS

78%

UK REDUCTION IN EMISSIONS BY 2035 COMPARED TO 1990 LEVELS

NET ZERO

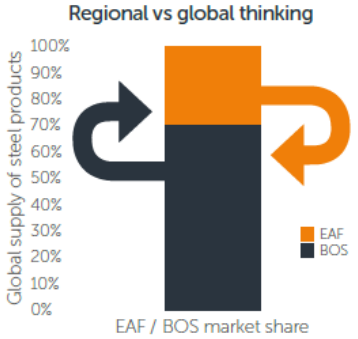
UK TO ACHIEVE NET ZERO BY 2050

EAF/Blast Furnace

British Steel plan to move to a hybrid EAF/Blast Furnace model in coming years.

This change will help our carbon footprint, but there remain significant challenges, both for British Steel and globally:

Routes to decarbonise the blast furnace route, and extend product life, are required to bridge the gap.



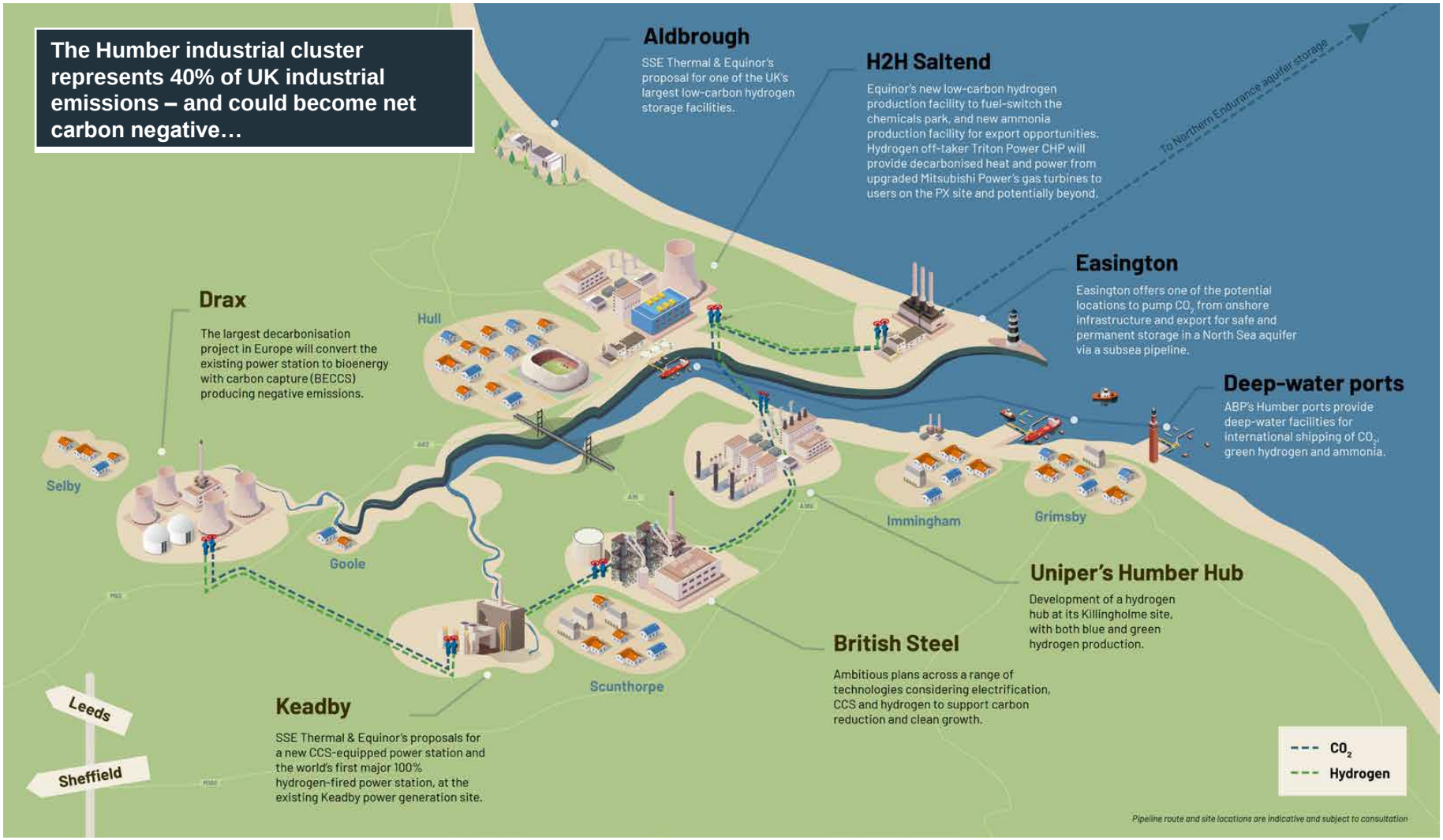
EAF is currently 29% of world steelmaking capacity – increasing this will require time and cost

Worldwide scrap supply is insufficient to support primarily EAF steelmaking

Accumulation of residuals in scrap (especially Cu) presents a challenge to EAF steelmaking routes in steels like rail with strict composition requirements – this presents a research challenge to eg SUSTAIN

Zero Carbon Humber

The Humber industrial cluster represents 40% of UK industrial emissions – and could become net carbon negative…



Rail as part of a low carbon economy

Why is rail key to a low carbon transport network?

- Rail currently circa 2% of UK surface transport emissions
- One of the greenest transport methods per passenger mile
- 76% emission reduction for rail freight compared to road
- **A modal shift to rail is an important means of decarbonising our transport network and economy**

Why is steel important?

- Steel (rails, clips, rebar in sleepers) is 58% of embedded carbon of track infrastructure
- Maintenance is 70% of whole life carbon → reduced maintenance requirements are a big deal
- **Reducing need for replacement gives significant benefits**

Life Cycle

We wish to quantify the whole-life carbon benefits of premium products with extended service life. But this is not the whole picture.

Rail exists as part of a system – what does a UK transport network look like with higher and lower modal share of rail (and hence steelmaking to make the rail)?

How does manufacturing route and scrap cycle play into this?

We are sponsoring EngD student Jacob Whittle to explore these questions.

Jacob's work is in collaboration with researchers looking into other UK foundation industries

Research by sponsored student Jacob is looking into whole life benefits of steel sleepers as well as rail

Table ENV0701
Emissions from journeys across the United Kingdom, by mode, 2021

Summary table

Transport Mode	Direct Emissions Conversion Factor	Indirect Emissions Conversion Factor[1]	Indirect Effects Factor[3]
Average Diesel Car	0.172	0.041	0.000
Average Electric Car	0.000	0.066	0.000
Average Petrol Car	0.171	0.049	0.000
Bicycle	0.000	0.000	0.000
Black Cab	0.329	0.080	0.000
Coach	0.044	0.010	0.000
Large Diesel Car	0.211	0.051	0.000
Large Electric Car	0.000	0.072	0.000
Large Petrol Car	0.278	0.079	0.000
Light rail and tram	0.046	0.012	0.000
Local Bus (not London)	0.128	0.046	0.000
Small Hybrid Car	0.104	0.028	0.000
Medium Hybrid Car	0.111	0.029	0.000
Large Hybrid Car	0.156	0.039	0.000
Average Hybrid Car	0.121	0.032	0.000
Small Plug-in Hybrid Car	0.022	0.046	0.000
Medium Plug-in Hybrid Car	0.065	0.046	0.000
Large Plug-in Hybrid Car	0.075	0.056	0.000
Average Plug-in Hybrid Car	0.069	0.052	0.000
London Bus	0.128	0.030	0.000
London Underground	0.045	0.012	0.000
Medium Diesel Car	0.169	0.040	0.000
Medium Electric Car	0.000	0.063	0.000
Medium Petrol Car	0.186	0.053	0.000
Motorbike	0.183	0.050	0.000
National Rail	0.057	0.014	0.000
Plane	0.209	0.043	0.186
Regular Taxi	0.239	0.058	0.000
Small Battery Electric Car	0.000	0.056	0.000
Small Diesel Car	0.141	0.034	0.000
Small Petrol Car	0.147	0.042	0.000
Ferry- foot passenger	0.030	0.007	0.000
Ferry- car passenger	0.208	0.047	0.000
Walking	0.000	0.000	0.000

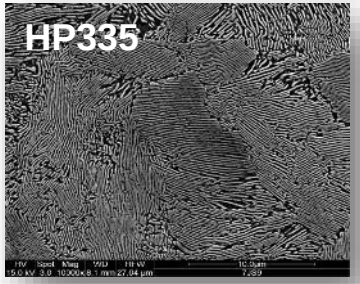
Premium Rail

Introduction of premium rail has rail life, maintenance, and associated whole-life carbon benefits.

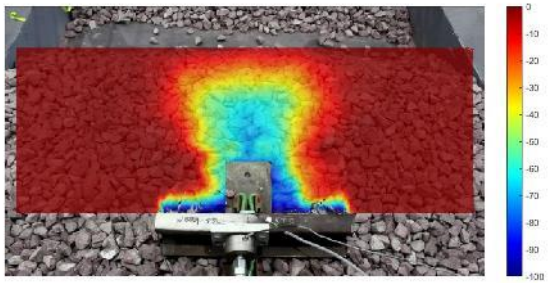
(HP335 delivers 3x better wear resistance and 2/3 reduction in grinding, resulting in 60% lower whole life costs).

Challenges:

- Models are not up to date for these harder grades.
- Demonstrating customer benefit to drive adoption of HP335.
- Troubleshooting issues arising with premium installations.
- Exploring maintenance requirements.
- Understanding mechanism of improved performance.
- The future – new grades?

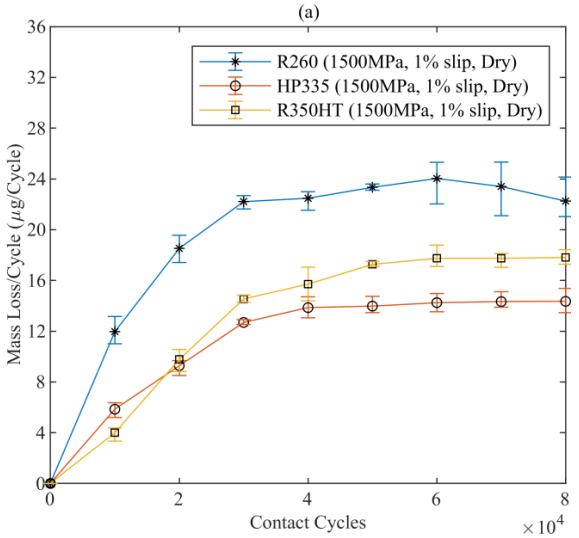


HP335 is an as-rolled premium rail steel, getting its strength from metallurgical engineering rather than heat treatment



Premium rails are not the only product requiring validation data to aid adoption: we have developed a custom test rig to show steel sleepers can provide excellent lateral resistance.

Development of new markets in heavy haul is a major objective – hence development of HP350



Twin disc data showing lower wear rate for HP335 than R350HT

Adam Wilby, Contact Mechanics 2022

Understanding Wear and RCF

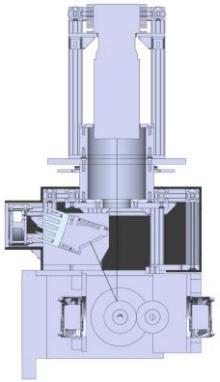
Models developed with past generation of rail steel.

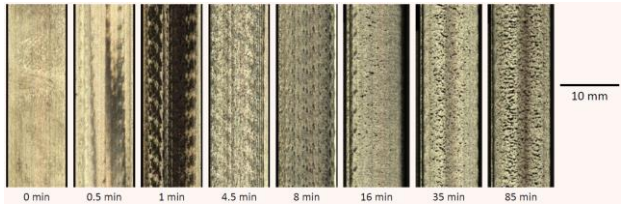
Impact of surface roughness underexplored – ties in with grinding!

Twin disc testing work (Adam Wilby) to develop updated models of surface deformation that match up with reality in premium steels.

New technologies introduced to characterize surface behaviour.

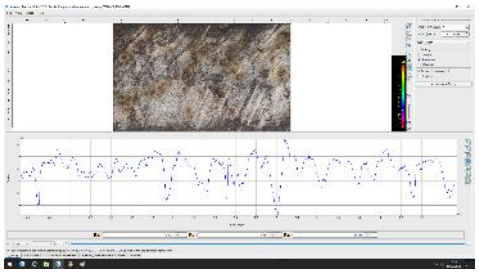
How do wear flakes form?



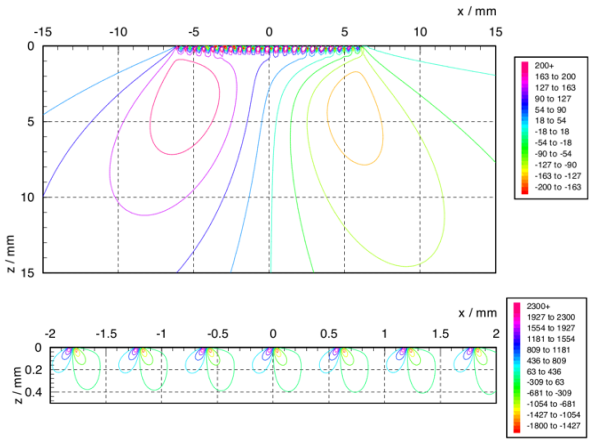


A new optical monitoring system can observe wear and RCF develop without interrupting twin disc tests.

Adam Wilby, WCRR 2022



Combining high throughput nanoindentation mapping and infinite focus microscopy to better understand near-surface behaviour.

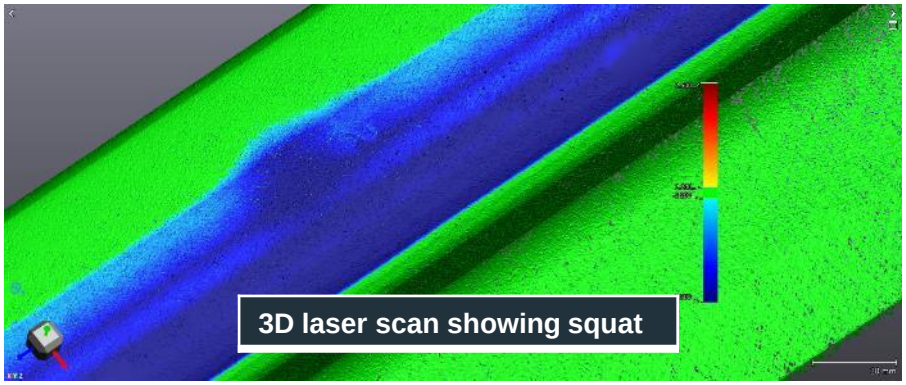


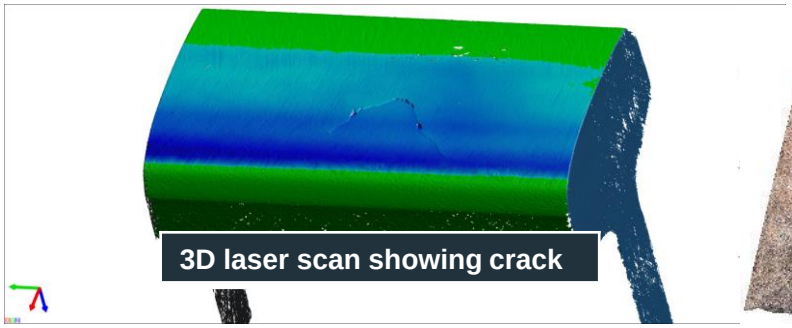
Roughness driven orthogonal shear stress near the surface of rail

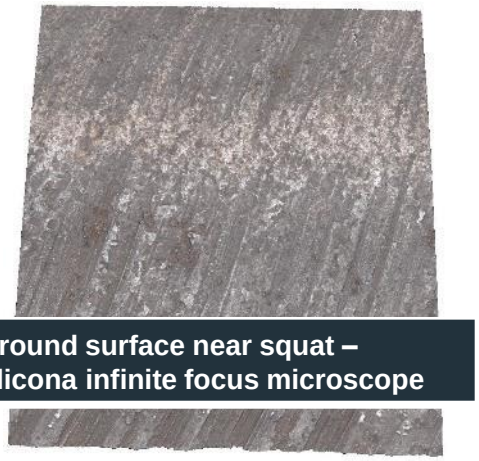
David Fletcher, Contact Mechanics 2022

Squat Characterization

We propose to use the suite of characterization equipment obtained via the UK Rail Research Innovation Network (UKRRIN) to build up a library of data on squats, enabling patterns to be identified and guiding research.

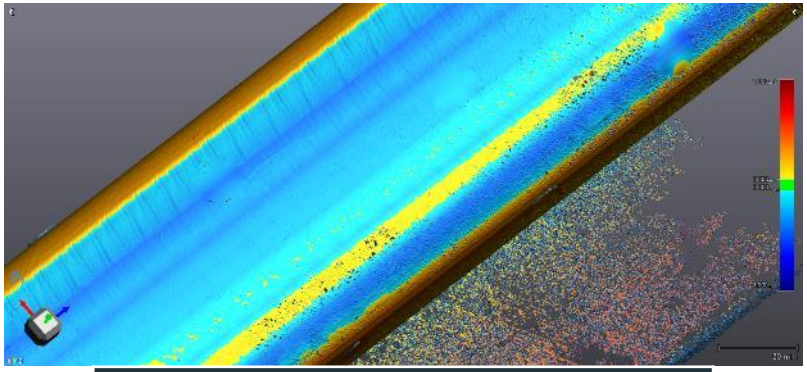




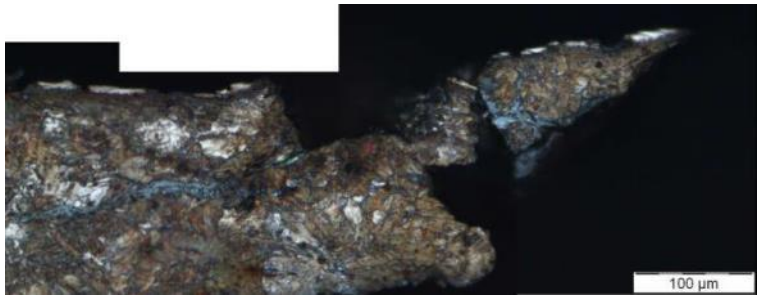


Grinding of Premium Rail

Cracks in the vicinity of grinding-induced White Etching Layer (WEL) observed in premium rail in multiple networks.



3D laser scan showing recently ground rail



Our Rail Technologies team have been investigating examples on customer networks

Our sponsored student Lucas has been visiting the Universidad Nacional de Colombia in Medellin, working on grinding research with great access to Medellin's extensive metro system

We are developing a custom test rig to help us determine a process window for grinding of premium rail grades – photo from M. Mesaritis

Towards Understanding Rail Wear – Project Proposal

Microstructural Approach

Materials: R260 and HP335

Vary heat treatment and cooling to impact prior austenite grain size

Reheated and air cooled

Reheated and force cooled

As rolled

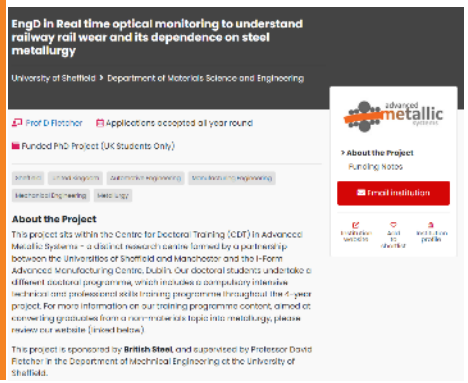
Extend to Bainitics?

Greater Understanding?

Model of wear flake generation

Prediction of wear rates

Target microstructure for reduced wear



Wear Flake Approach

Twin Disc with Optical Monitoring

Optical Data Processing

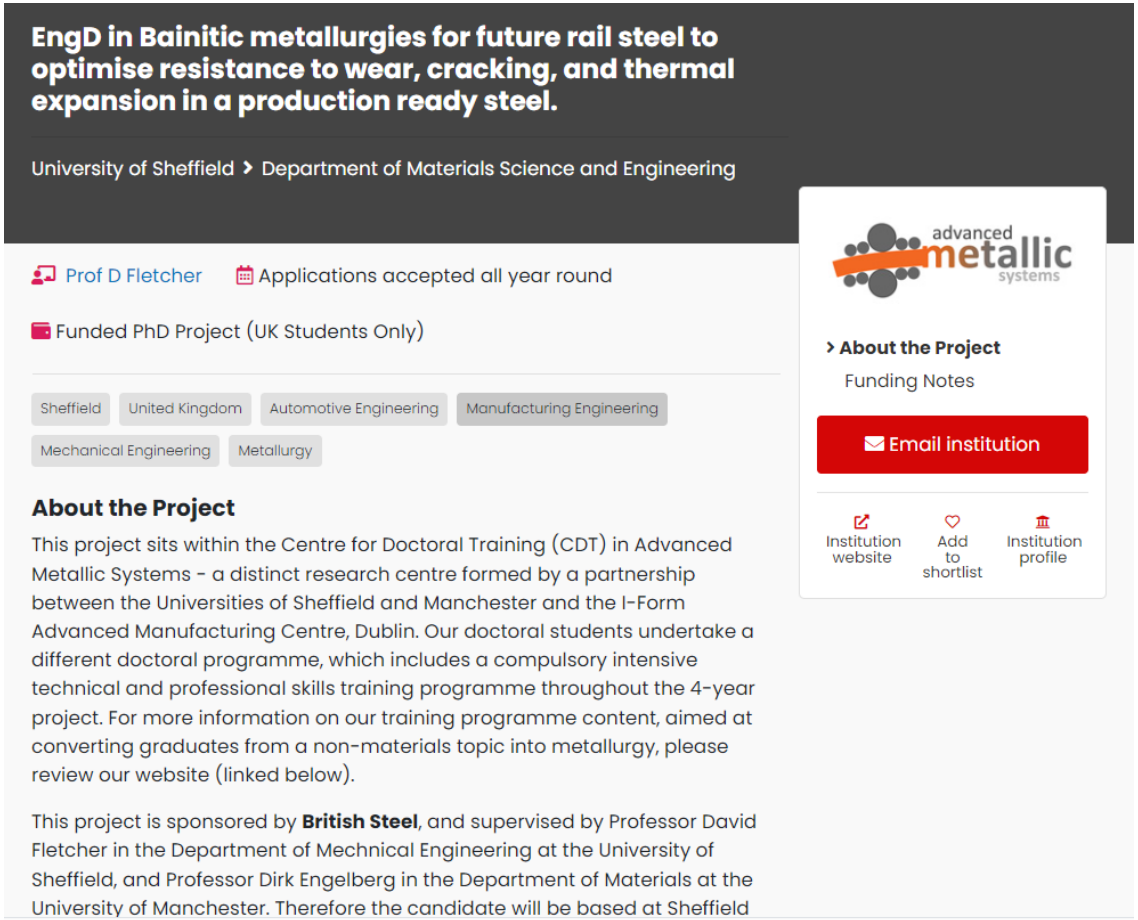
Wear Flake capture and characterization

Alicona Surface Scans

SEM/TEM of very surface looking for flake evolution

Bainitics Development – Project Proposal

- How can we optimise bainitic compositions for ease of manufacture and supply?
- How do bainitic rails generate wear and RCF?
- Can we understand and improve on this behaviour?



EngD in Bainitic metallurgies for future rail steel to optimise resistance to wear, cracking, and thermal expansion in a production ready steel.

University of Sheffield › Department of Materials Science and Engineering

Prof D Fletcher Applications accepted all year round

Funded PhD Project (UK Students Only)

Sheffield | United Kingdom | Automotive Engineering | Manufacturing Engineering | Mechanical Engineering | Metallurgy

About the Project

This project sits within the Centre for Doctoral Training (CDT) in Advanced Metallic Systems - a distinct research centre formed by a partnership between the Universities of Sheffield and Manchester and the I-Form Advanced Manufacturing Centre, Dublin. Our doctoral students undertake a different doctoral programme, which includes a compulsory intensive technical and professional skills training programme throughout the 4-year project. For more information on our training programme content, aimed at converting graduates from a non-materials topic into metallurgy, please review our website (linked below).

This project is sponsored by **British Steel**, and supervised by Professor David Fletcher in the Department of Mechnical Engineering at the University of Sheffield, and Professor Dirk Engelberg in the Department of Materials at the University of Manchester. Therefore the candidate will be based at Sheffield

advanced metallic systems

› About the Project

Funding Notes

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