EPSRC & SFI Centre for Doctoral Training in Advanced Metallic Systems

PhD in Using Historic Materials Data from Assurance Testing to Optimise Future Manufacturing Processes of High Integrity Components.

Supervisors: Dr Daniel Cogswell & Dr Eleanor Stillman
Collaborator: Element Materials Technology
Based at: The University of Sheffield
Stipend: UKRI stipend (£15,609 in 2021-22) plus £3,250 per year
Open to: Candidates with a strong degree in a STEM discipline, particularly maths, and an interest in data processing and who will be Eligible to Work in the UK on completion of the PhD.

The Centre for Doctoral Training in Advanced Metallic Systems is a partnership between industry partners and the Universities of Sheffield and Manchester and the I-Form Advanced Manufacturing Centre, Dublin. CDT students undertake a doctorate with an in-depth technical and professional skills training across a structured 4-year programme. For more information on our cohort training programme and our impact from our doctoral research projects with industry please visit www.metallicscdt.co.uk. This project is based at the University of Sheffield and is sponsored by Element Materials Technology. It is open to candidates with a strong degree in a STEM discipline, particularly maths, and an interest in data processing.

Element Materials Technology play a key role in providing independent assurance of materials performance for a range of high integrity applications across several sectors. This can only be achieved through an in depth and specific knowledge of the material behaviour and a sound technical understanding of the statistical analysis methods which underpins the assessments which keep the public safe and key infrastructure operating. This is only possible through rigorous analysis of the data from mechanical testing.

Element Materials Technology has created a strong internal digital platform for recording and reporting of test results; this presents a great opportunity to explore the ideals of the flow of data in an immersive digital twin (1) and provides a robust feedback loop to the designer and manufacturer if enacted. The existing digital data can be interrogated for trends as with any big data project but there is real benefit to industry in applying a statistical process control approach to this information, generating tools that can be used by Element Materials Technology and their customer base to monitor performance and provide preventative interventions in manufacturing prior to loss of control. Evidence of conforming to process may also preclude the need for future testing in some circumstances by defining the parameters to monitor that truly control manufacture.

Fracture toughness data often represents two key types of mechanical behaviour; low resistance trans-granular cleavage associated with catastrophic failure of structures and high resistance micro-void coalescence that describes ductile rupture (see Figure 1). Many other affects of specimen geometry, materials mechanical properties and failure modes can also effect establishing appropriate estimates of performance. Identifying when these have happened is key to providing assurance of future performance.

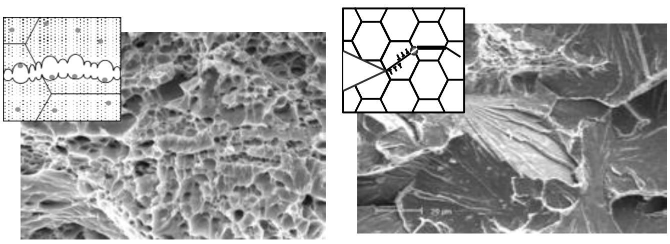

Fig 1. Scanning electron microscope images of micro-void coalescence (left) and trans-granular cleavage (right) in low alloy pressure vessel steels (2).

The Master Curve methodology has become the accepted engineering solution for processing fracture toughness data of low alloy steels in the transition region where large variability in recorded toughness values are observed (see Figure 2). Built on a Weibull lifetime analysis representation of the stochastic nature of toughness, a maximum likelihood approach estimates key parameters and establishes uncertainties. This has been adopted into international standards as the backbone of assessment methodologies (3,4). The failure

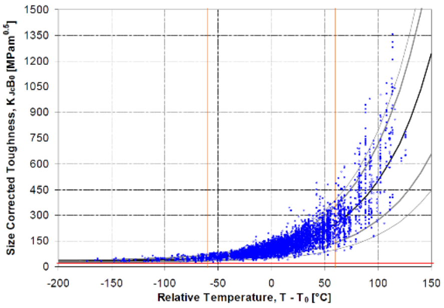

Fig 2. Statistical assessment of a very large toughness database normalised by the Master Curve reference temperature (2).

process can result in large variations even within a single material; the Master Curve provides a framework for making estimates of performance on sparse data. In doing so, it has proved very successful for energy industry applications, affording life extensions to key infrastructure.

This project will develop knowledge of assurance methodologies, metallurgy of the manufacturing processes involved and an in-depth understanding of the statistical methods that are employed to assess the data correctly. A purely data driven approach could result in over specification of the manufacturing processes, costing time, material and resources through unnecessary rejection of suitable materials. As such, the project will be run in partnership between the Department of Materials Science and Engineering and the School of Mathematics and Statistics.

Element Materials Technology are keen to support this project as a PhD or EngD. The successful applicant can be hosted at any of Element Materials Technology United Kingdom locations and it is expected that interactions with worldwide specialist laboratories are likely.

We are aware that the timing of this advert is over the examination period and that potential applicants may be focussed on completing their undergraduate studies. We welcome expressions of interest and enquiries by email (d.cogswell@sheffield.ac.uk) during this time; however, a formal application is required before the closing date to be considered.

References

1. Feasibility of an immersive digital twin: The definition of a digital twin and discussions around the benefit of immersion, High Value Manufacturing Catapult Visualisation and Virtual Reality Forum, September 2018, Available here.
2. D Cogswell, Statistical Modelling of the Transition Toughness Properties of Low Alloy Pressure Vessel Steels, EngD Thesis, The University of Birmingham, July 2010
3. ASTM E1921-20 Standard Test Method for Determination of Reference Temperature, T0, for Ferritic Steels in the Transition Range. 2020, West Conshohocken: ASTM International.
4. BS 7910:2019, Guide to methods for assessing the acceptability of flaws in metallic structures. 2019, BSI Standards Limited.