Engineering and Innovation Research Studentship 2022/2023

Project title:	**A new approach for near surface residual stress measurement using Digital Image Correlation (DIC)**
Discipline	Mechanical/material engineering
Key words:	Residual stress, Digital Image correlation, Mechanical strain relaxation technique, Finite element Analysis
Supervisory team:	Ho Kyeom Kim, Foroogh Hosseinzadeh
URL for lead supervisor's OU profile	https://www.open.ac.uk/people/hkk43

Project Highlights:

- Developing a new technology for 2D mapping of surface residual stresses.
- Project outputs will be influential in improving structural integrity assessment method of safety critical components.
- Opportunity to use international diffraction facilities in the UK, France and Germany.

Overview:

Residual stresses are often developed in engineering structures from various manufacturing processes. They can cause distortion, cracking and will interact with service loading and can lead to premature failure. Surface residual stresses play a key role in the performance of engineering structures in the presence of life limiting degradation mechanisms such as fatigue, corrosion-fatigue and stress corrosion cracking. Reliable knowledge of the state of residual stress is of paramount importance from the design stage through to structural integrity assessment of assets operating in service.

A wide variety of techniques are available for residual stress measurement An overview and detailed use of residual stress measurement technique are provided in [1]. The techniques often used for surface residual stress characterisation include x-ray diffraction and incremental centre hole drilling. X-ray diffraction measurements are error prone due to microstructure and grain size of the material and surface topography. The incremental centre hole drilling is based on the assumption that the stresses are uniform over the planes in which residual stresses are measured. This would lead in high levels of uncertainty for measurements made in a rapidly changing stress field.

Many of the techniques commonly used for bulk residual stress measurements are not suitable for characterising surface or near surface residual stresses; for example the contour method, neutron diffraction and deep hole drilling techniques. The contour method however is a very powerful residual stress measurement technique in that it can provide a 2D map of residual stress over the plane of interest, is not sensitive to microstructural variation and can be applied to components of complex geometry.

This project will address the research question: Can the contour method use Digital Image Correlation for reliable near surface residual stress characterisation? Potential applications will be vast including measuring near surface residual stresses for offshore, oil and gas and nuclear industry.

Methodology:

In phase 1 of the Project the technique will be developed for the measurement of stress in thin components in plane stress condition. The in-plane relaxed displacements will be measured using Digital Image Correlation (DIC). DIC is a full-field deformation measurement technqiue allowing to record large in-plane deformation data. It is also a non-contact technique which has the advantage of not being affected by the surface topography of the sample.

The measured displacement is then applied to the FE model of the cut parts as boundary condition to reconstruct the initial residual stress. With the benefit of using FE analysis, it can reconstruct a rapidly varying non-uniform residual stress and can be applied to components with complex geometry. Another advantage of this technique is that due to the full-field displacement measurement using DIC three components of the stress tensor can be measured.

The major challenge to be investigated is pattern preservation during the cut. The accuracy of the DIC depends upon suitable surface preparation. Preserving the surface during the cutting is critically important to enable the cross-correlation of the surface image. Figure 1 shows an example of a failed surface pattern that leads to inaccurate residual stress field reconstruction.

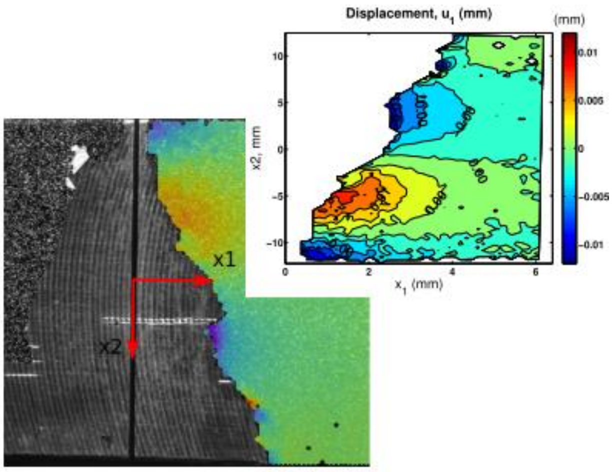

Figure 1: An example of a failed surface pattern due to pattern damage during the cut and its u_1 displacement field [3].

The second phase of the project will look into combining the conventional contour method with the proposed technique to measure bulk as well as reliable near surface residual stresses for large structures.

The proposed technique will be implemented on well defined and reproduceable benchmark test specimens and validated against slitting and synchrotron diffraction measurements.

References & Further reading:

[1] G. S. 13Schajer and Ed., *Practical residual stress measurement methods*. John Wiley & Sons, 2013.

[2] H. K. Kim, "Assessment and Experimental Validation of a Mechanical Strain Relaxation Technique for Measuring Highly Non-uniform In-plane Residual Stress", Ph. D. thesis, University of Bristol, Bristol, UK, 2016.

Further details:

Students should have a strong background in Solid Mechanics, Materials or Mechanical Engineering or physics and enthusiasm for laboratory experimental work and have experience of programming in Matlab, Python or similar platform. Experience in Finite element analysis is also desirable. Student will be working within the materials group in STEM faculty where research performed by experienced group of researchers and fellow PhD students on residual stress technologies with the strong collaboration between industries and academics. Please contact Dr. Ho Kyeom Kim (ho.kim@open.ac.uk) for further information.

Applications should include:

- A 1000 word cover letter outlining why the project is of interest to you and how your skills match those required
- an academic CV containing contact details of three academic references
- an Open University application form, downloadable from: http://www.open.ac.uk/postgraduate/research-degrees/how-to-apply/mphil-and-phd-application-process
- IELTS test scores where English is an additional language

Applications should be sent to **STEM-EI-PhD@open.ac.uk by 04.03.22**