Engineering and Innovation Research Studentship 2022/2023

Project title:	Micro-Contour Residual Stress Measurement Technology
Discipline	Mechanical Engineering, Materials Engineering, Physics
Key words:	Residual stress, Contour method, Grain scale stresses
Supervisory team:	Foroogh Hosseinzadeh, Ho Kyeom Kim
URL for lead supervisor's OU profile	http://stem.open.ac.uk/people/fht7

Project Highlights:

- Advancing the contour method of residual stress measurement to micro-scale,
- Measuring reliable residual stresses in thin structures,
- Project outputs will be influential in improving structural integrity assessment method of safety critical components.

Manufacturing processes often introduce locked-in stresses, namely residual stresses, in the fabricated parts. These stresses can cause distortion and cracking, influence function, and potentially reduce a product's lifetime through premature failure; all of which will result in lower productivity.

The Contour Method of residual stress measurement [1-3] was invented around 2000 is increasingly being applied to map internal stresses locked within engineered products and structure. The method involves cutting the sample of interest into two parts using a planar cut. The cut surfaces locally deform owing to the relaxation of residual stresses present before the cut. The out of plane deformation (the contour) is measured and applied as a boundary condition in a finite element elastic stress analysis of the cut sample. This determines the residual stress acting normal to the cut plane in the original component. The contour method is unique in that it can provide a 2D map of residual stress over the section of interest and is not sensitive to microstructural variations.

Multiple components of residual sress can be measured when the technique is combined with other residual stress measurement methods or multiple cuts are performed.

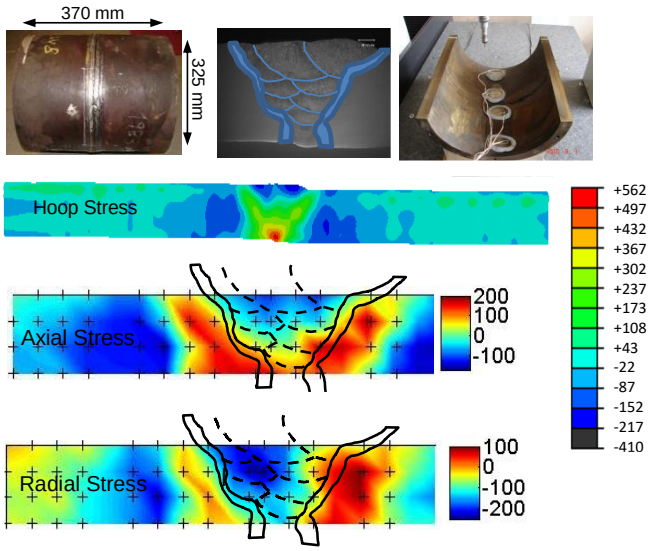

Figure 1 Application of the contour method to measure multiple components of the stress tensor using mutiple methods [2]. Stress units are in MPa.

The contour method has been mostly applied to structures having dimensions in the range 5 mm to 500 mm. This PhD project will address the research question: "can the contour method can be downsized by an order of magnitude?" Potential new applications for micro-contour technology include components formed from thin sheet, wire strands, grain scale stresses and thin films (such as the deposited layers in microelectronic and micro-electro-mechanical systems, MEMS).

Methodology:

The challenges to be resolved in this project are the development of a suitable technique for making the cuts at the micro-scale, the measurement of micro-displacements of the surfaces of cut material, the characterisation of surface elastic properties, the analysis of the data (e.g. the treatment of noise), and validation. Various options for cutting will be evaluated including micro-EDM (using the OU's

specialist machine with 20 micron dia wire) and modified focused ion beam (FIB) milling (a challenge for this technique is control the ion beam in such a way that the distortion of the cut surface is preserved and not etched to flatness by the beam).

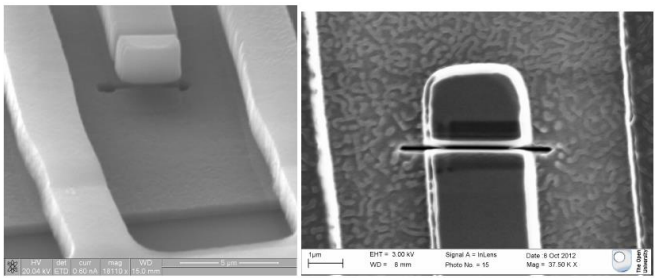

Figure 2 A single line pass made through 2 µm thick silicon.

The suitability of atomic force microscopy (AFM) and laser interferometric methods for measuring surface deformations will be examined. For measuring grain scale stresses it would be necessary to characterise the local elastic modulus, for example by high speed AFM, nanoindentation, acoustic means, or models informed by EBSD.

Further reading:

1. P rime, M.B., DeWald, A.T, *The Contour Method* Chapter in Practical Residual Stress Measurement Methods, ed, Schajer, G., 2013.
2. H osseinzadeh, F., et al., *Mapping Multiple Components of the Residual Stress Tensor in a Large P91 Pipe Girth Weld using a Single Contour Cut*, International Journal of Experimental Mechanics, 2013, 53(2), p.171-181.
3. H osseinzadeh, F. et al., *Steps Towards Good Practice Guidelines for the Contour Method of Residual Stress Measurement*, The Journal of Engineering, 2014.

Further details:

Students should have a strong background in Solid Mechanics, Materials Engineeeing, Mechanical Engineering or physics and enthusiasm for laboratory experimental work and and have experience of programming in Matlab, Python or similar platform.

Please contact Dr Forooh Hosseinzadeh (foroogh.hosseinzadeh@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**