

<b>Project title:</b>	Micro-Contour Residual Stress Measurement Technology
<b>Discipline</b>	Mechanical Engineering, Materials Engineering, Physics
<b>Key words:</b>	Residual stress, Contour method, Grain scale stresses
<b>Supervisory team:</b>	Foroogh Hosseinzadeh, Richard Moat, John Bouchard (Technical Advisor)
<b>URL for lead supervisor's OU profile</b>	<a href="http://stem.open.ac.uk/people/fht7">http://stem.open.ac.uk/people/fht7</a>

**Project Highlights:**

- Advancing the contour method of residual stress measurement to micro-scale,
- Measuring reliable residual stresses in thin structures,
- Fitting closely with the planned research agenda for the proposed International Stress Engineering Centre (I-SEC) to be built at the ISIS Facility.

**Overview:**

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 stress can be measured when the technique is combined with other

residual stress measurement methods or multiple cuts are performed.

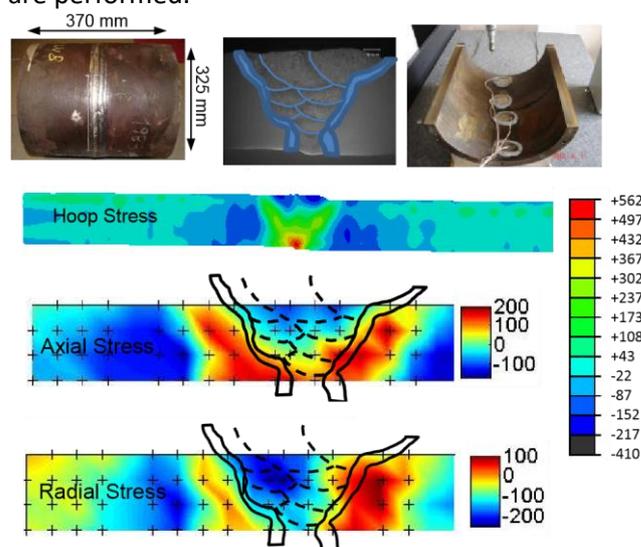


Figure 1 Application of the contour method to measure multiple components of the stress tensor using multiple methods [2]. Stress units are in MPa.

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 microdisplacements 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).

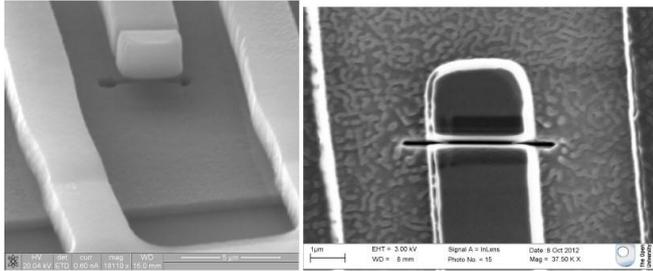


Figure 2 A single line pass made through 2 µm thick silicon.

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. Prime, M.B., DeWald, A.T, *The Contour Method* Chapter in *Practical Residual Stress Measurement Methods*, ed, Schajer, G., 2013.
2. Hosseinzadeh, 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. Hosseinzadeh, 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 Engineering, Mechanical Engineering or physics and enthusiasm for laboratory experimental work and have experience of programming in Matlab, Python or similar platform.

Please contact Dr Foroogh Hosseinzadeh ([foroogh.hosseinzadeh@open.ac.uk](mailto: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
- [Open University application form](#)

- Applicants will need to demonstrate good competence in the English language. To be eligible for a full award, a student must have no restrictions on how long they can stay in the UK and have been ordinarily resident in the UK for at least 3 years prior to the start of the studentship.

Applications should be sent to [STEM-EI-PhD@open.ac.uk](mailto:STEM-EI-PhD@open.ac.uk) by 24.04.20.