E&I Research Studentship project proposal 2019

Project title: A Novel Hybrid Method for Reliable Surface Residual Stress Measurement

Supervisory team:
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Project Highlights:

- Developing a novel hybrid residual stress measurement method,
- Measuring reliable surface to near surface residual stresses,
- Fitting into the International Stress Engineering (ISEC) Programme, unlocking further funding opportunities from end users (Airbus, Rolls-Royce, etc) and increased income for StressMap.

Project Description:

All manufacturing processes introduce internal stresses (residual stresses) into fabricated components. For safety-critical applications, it is paramount to "design against failure" and this often requires accurate knowledge about the distribution and magnitude of residual stresses locked into structures. There are various techniques available for residual stress measurements; however, characterising surface or sub-surface residual stresses reliably is notoriously difficult.

The Contour Method [1-3] is a recently invented technique for measuring and mapping residual stresses in a component. The method involves making a straight cut in the sample of interest along a plane where knowledge of residual stresses is required. The created cut surfaces locally deform owing to the relaxation of residual stresses present before the cut. These deformations are measured and then applied as a boundary condition in a finite element model to determine the out-of-plane residual stress distribution at the cut surface. The contour method is unique in that it can provide a 2D map of residual stress over the plane of interest using a single cut, it is not sensitive to microstructural variations and is not limited by the thickness of the component (see Fig. 1).

However, the contour method cannot measure residual stresses near to surface with high accuracy. The main reason is that it is practically impossible to accurately measure the surface deformations near to the edges. As such the measured surface deformations near to the edges are often discarded and the surface deformation data are extrapolated to the edges of the component being measured. The back calculated stresses in the extrapolated region are often not reported.

This project explores development of a novel hybrid method combining the contour method with x-ray diffraction technique to provide 2D map of residual stress with high accuracy near the surface edges. The surface stresses are measured using x-ray diffraction along a line profile on the top and back faces of the test component aligned with the location of a contour method measurement.

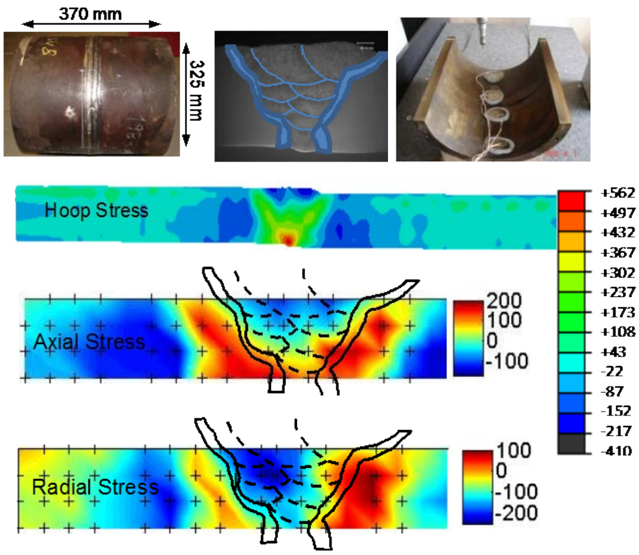

Fig. 1 Application of the contour method to measure multiple components of the stress tensor using mutiple methods [2]. Stress units are in MPa.

Then the conventional contour method is implemented and the data analysis and finite element (FE) modelling to back calculate the stresses are made in a conventional way. An iterative FE modelling is proposed to correct the contour surface stresses based on the measured x-ray diffraction stresses. The iterative FE modelling is converged once the corrected contour surface stresses approach x-ray surface stresses.

Methodology:

Numerical modelling will be employed to underpin the project. Extensive finite element simulations will be conducted to a) design benchmark test specimens with reproducible and well-defined residual stresses, b) predict residual stresses in benchmark test specimens and c) to examine the viability of the proposed correction approach.

The results of the finite element simulations will be utilised to develop a new data analysis approach. The developed data analysis approach will be examined by simulating the Contour Method measurement. This will be followed by conducting experiments on benchmark test specimens. The proposed approach will be implemented experimentally on benchmark test specimens and will be validated by various established residual stress measurement techniques such as the neutron diffraction, hole drilling and slitting methods.

Publication and Impact

The PhD project will lead to the creation of new knowledge that can be published in relevant journals such as Experimental Mechanics. The work will have high impact across different industrial sectors. Moreover the new hybrid measurement technique developed will open up new measurement opportunities for StressMap.

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 Mechianics, 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 or Mechanical Engineering and enthusiasm for laboratory experimental work and competent Finite Element Analysis (FEA) skills. The student will join a well-established team researching residual stress in engineering structures and working within the world leading Contour Measurement Facility at the Open University. Please contact Dr Foroogh Hosseinzadeh for further information (foroogh.hosseinzadeh@open.ac.uk).

Applications should include:

- 1000 word cover letter outlining how they are equipped in their educational background and expertise to conduct the research project,
- a CV including contact details of two 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 (Note: This is an Advertised studentship and you do not need to submit a proposal).
- IELTs English Language test scores on application. An average of 6.5 and no less than 6 in anyone of the four components. Applicant should have these results when applying.

Applications should be sent to **STEM-EI-Research@open.ac.uk** by 28 February 2019