ESRF	**Experiment title:** ***Residual stress distribution due to fatigue crack growth at cold expanded holes.***	**Experiment number**: ME619
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Names and affiliations of applicants (* indicates experimentalists):

B. Nadri[a], J.Tan[a], J. Santisteban[a], M. T. Hutchings[a], L. Edwards[a], M. E. Fitzpatrick[a] & A. Lodini[b]

[a] The Open University, Material Engineering Department, Walton Hall, MK7 6AA Milton Keynes, United Kingdom.

[b] LACM, Université de Reims Champagne-Ardenne, UFR Sciences, Moulin de la House BP 1039, 51687 Reims cedex2. France

Report:

Improving and extending the life of aircraft structures becomes a very importance aim for aerospace industry. The use of cold expansion process to introduce a compressive residual stress field in the material surrounding the hole can improve the fatigue life of aerospace components by retarding the growth of fatigue cracks (Reid 1986; D.Stefanescu 2003). This process has been used on aging aircraft as well as the new production aircraft. The technique of cold expansion involves placing a longitudinally split-sleeve through the hole with the nosecap held firmly against the workpiece and then pulling an oversize tarped mandrel through the assembly with the puller unit. As the mandrel passes through the hole, the material surround the hole yields by a combination of radial and hoop stresses. On the removal of the mandrel, the yielded zone around the hole unloads and may have reverse yielding under the influence of the surrounding elastically deformed material which introduces a residual compressive hoop stress around the hole.

Experimental work and results

In order to see how the crack growth affects the residual strain distribution around cold expanded fastener holes six specimens of 300 x 40 x 6.35mm from 2024-T351 aluminum alloy containing 6.25mm double cold expanded holes, with varying crack length have been prepared. Cracks have been grown using an Instron 100kN Servo hydraulic test machine. The table below shows the details of all cracks length for both faces, first out and second out with respect to the entry and exit of the mandrel.Five lines separated by 1mm through the thickness in both direction hoop and radial have been measured. The parameters used in this experiment were: λ=0.309 A^0, 2θ=14.572, (hkl)=(311), E=40KeV. The gauge volume of $0.5x0.5x0.5mm^3$ was used for the hoop direction and $4x0.5x0.5mm^3$ for the radial direction.

Second out	crack	dce1	dce2	dce3	dce4	dce5	dce6
	Principal	0.58mm	0.9mm	1.45mm	2.23mm	3.5mm	4.6mm
	Secondary						1.8mm
First out	Principal	0.48mm	0.53mm	0.8mm	1.01mm	1.18mm	1.2mm
	Secondary						0.65mm

Crack length emanating from double cold expanded holes

Four specimens were taken for further study. After double cold expanding 6 mm fastener holes on the centre of each specimen, three different crack lengths within the zone of plasticity and one crack length that exceeds this zone were grown using a Instron fatigue testing machine. The residual stress was measured along three lines through the thickness and across the crack face using synchrotron radiation at ESRF and neutron diffraction at ISIS. (Mid-thickness, + 2mm and -2mm away from the mid-thickness).

The results of the hoop stress measurements reveal that the magnitude and the shape of compressive residual stresses surrounding the hole for the first three of these specimens stays approximately the same on the side corresponding to the first mandrel exit face, slightly change in the middle of specimens and show significant relaxation on the second side corresponding to the second mandrel exit face. This is because the compressive residual stress zones created by the double cold expansion process are wider on the first mandrel exit face compared to the second one.

For the fourth specimen where the crack length exceeds the zone of plasticity, the hoop stresses were significantly relaxed throughout the thickness..

These results show that the relaxation of the residual stress field with crcak growth is far more subtle that originally thought. Further work is progressing comparing the growth of paired cracks on either side of the hole(more complex but closer to cracks actually seen in aircraft structures) with the single edge cracks studied here (Stefanescu 2004 a 2004)

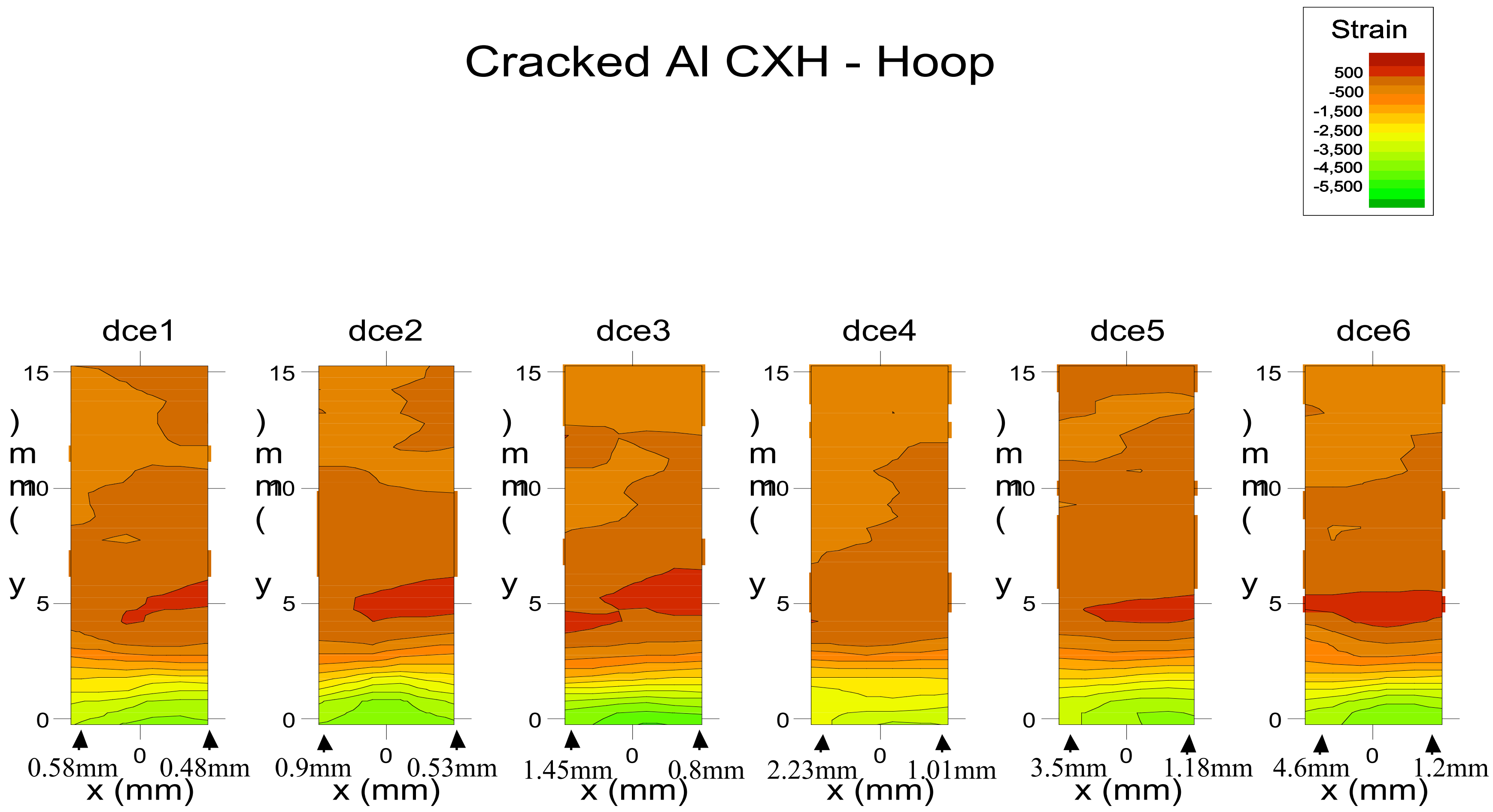
The strain mapping results obtained for hoop and radial directions are given respectively below:

References:

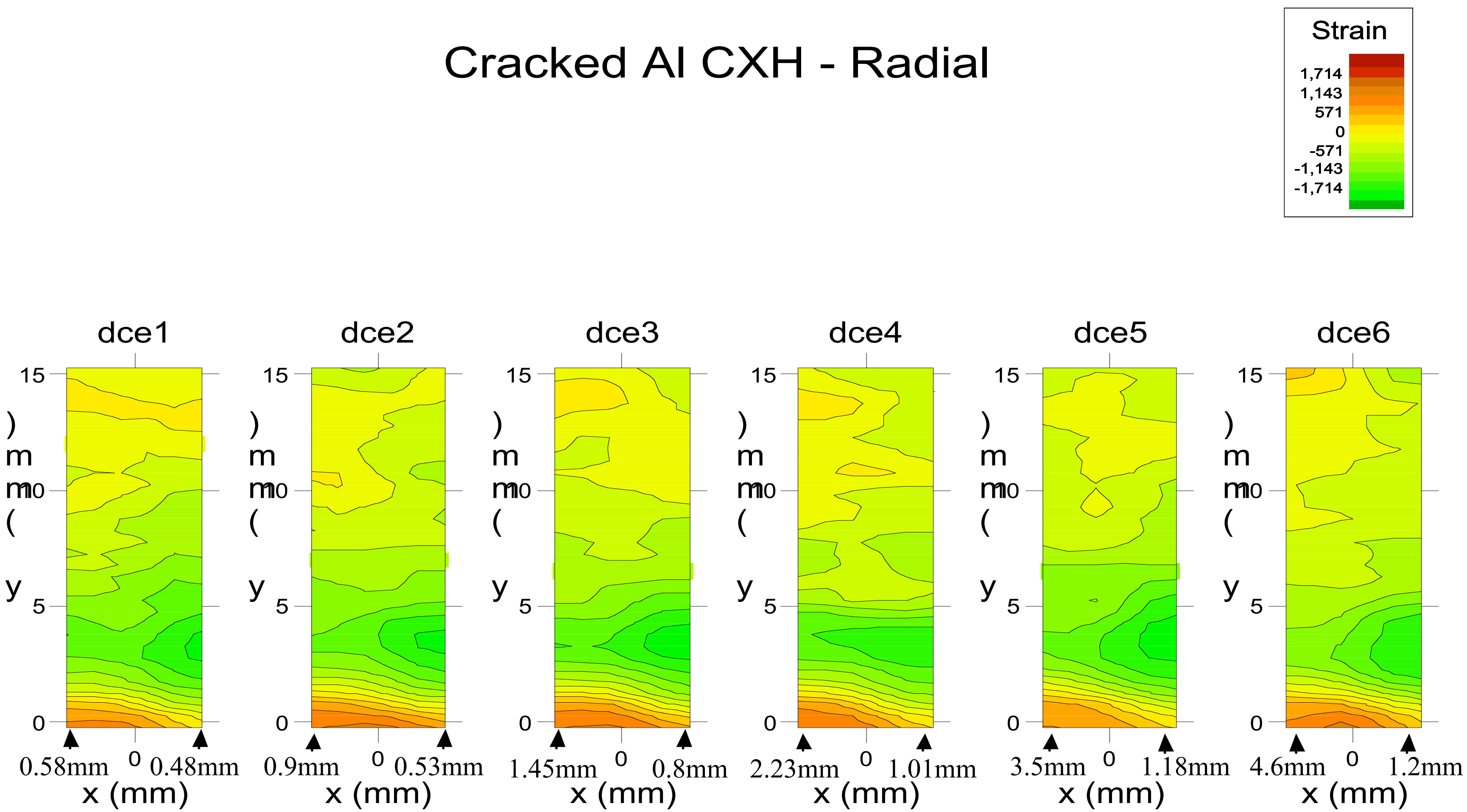
Reid, L. (1986). *Enhanced repair durability with cold expansion techniques*. 41st international SAMPE, Symposium, Fatigue technology. Inc,.

Stefanescu, D., Edwards, L., and Fitzpatrick, M.E. (2003) *International Journal of Fatigue.* 25, pp. 569-576,

Stefanescu, D., A. Steuwer , A., Owen, R.A., Nadri, N., Edwards, L., Fitzpatrick M.E. and P J Withers, P.J. J. (2004) Strain measurement around cracked cold expanded fastener holes using the synchrotron X-ray diffraction technique" In Press 2004. *Journal of Strain Analysis for Engineering Design*



Hoop strain distribution along different crack length emanated from 4% cold expanded hole in 2024-T351 aluminum alloy.



Radial strain distribution along different crack length emanated from 4% cold expanded hole in 2024-T351 aluminum alloy.