In Application

Full Field Digital Image Correlation Measurements at Very High Temperatures

School of Materials, Manchester University, UK

Introduction

Figure 1: *Hot surfaces during metal cutting*

Measuring the strain response during loading at high temperature is a key capability for determining the mechanical and thermophysical properties of materials that are to be used at elevated temperatures. Coupled with high temperature testing, there are many situations where the strain field is highly non-uniform and complex and much insight can be gained by mapping the variation in the non-uniform strain field with position. This is most interesting in examples such as friction welds or around cracks; both are common engineering topics.

Traditionally, externally applied strain gauges or extensometers are used in the types of tests discussed herein. However, such gauges have several drawbacks including; reduced reliability at highly elevated temperatures, their application affecting the integrity of the specimen, and the fact that they typically have a gauge length of tens of millimetres and give only an average value for the gauge area. DIC was identified as a useful tool to look at the local strain fields during high temperature testing because it addresses all of these issues:

- DIC can be used at elevated temperatures
- DIC does not affect the specimen surface
- DIC gives full field data identifying localisation effects

Prior to this work quantitative imaging of materials at high temperatures had been restricted to complicated setups or were limited in the maximum temperature which could be studied.

Experimental Setup

In this work the boundaries were extended and successful measurements were in excess of 1100 °C (with the possibility demonstrated to work at 1400 °C).

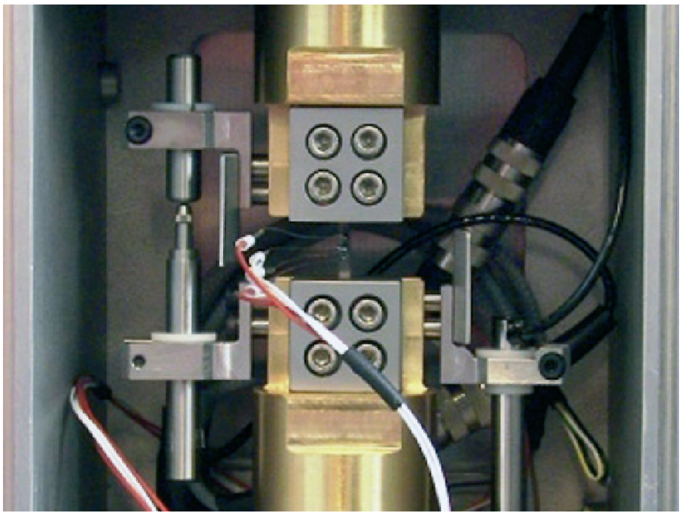

Figure 2: *High integrity capsule and LVDT from the electrothermal mechanical tester*

The in-situ DIC was performed using an electrothermal mechanical tester (ETMT). In this system, sample heating is accomplished by ohmic heating from a direct current applied across the sample. The load cell has a maximum capacity of 4 kN and incorporates an environmental chamber in order to reduce oxidation. During the test, the sample temperature was increased in 100 °C steps. At each step the sample was loaded to 200 MPa and unloaded before the temperature was ramped up again. Once a temperature of 1000 °C was attained, the sample was loaded to failure.

The test subject was a „matchstick“ sized nickel based super alloy specimens: 40 mm x 2 mm x 2 mm. The LaVision DIC system consisted of an Imager proX 4M camera, Programmable Timing Unit (PTU) and DaVis software.

LaVisionUK Ltd
2 Minton Place / Victoria Road
Bicester, Oxon / OX26 6QB / United Kingdom
E-Mail: sales@lavision.com / www.lavisionuk.com
Phone: +44-(0)-870-997-6532 / Fax: +44-(0)-870-762-6252

LaVision GmbH
Anna-Vandenhoeck-Ring 19
D-37081 Göttingen / Germany
E-Mail: info@lavision.com / www.lavision.com
Tel. +49-(0)551-9004-0 / Fax +49-(0)551-9004-100

LaVision Inc.
211 W. Michigan Ave. / Suite 100
Ypsilanti, MI 48197 / USA
E-mail: sales@lavisioninc.com / www.lavisioninc.com
Phone: (734) 485 - 0913 / Fax: (240) 465 - 4306

LaVISION

FOCUS ON IMAGING

Full Field Digital Image Correlation Measurements at Very High Temperatures

School of Materials, Manchester University, UK

Three main challenges were identified for the tests

- black body radiation by the specimen
- oxidation of the surface bringing about a change of surface pattern
- heat haze (time varying refractive index changes in the optical path)

To overcome the challenge of black body radiation from the surface a combination of blue illumination and the relevant camera filters were used. The effect of utilising the filters at 800 °C is clearly visible in the images underneath (left hand side is with filter, and right is without)

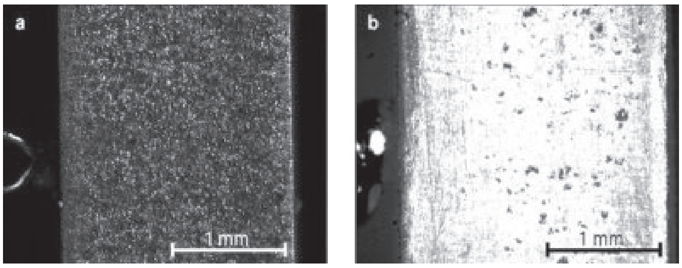

***Figure 3**: Images captured of the sample at 800 °C (a) with and (b) without the filter under blue illumination conditions*

Problems related to achieving the correct scale of surface pattern, and its adherence to the surface were avoided by simply abrading the surface using 1200 grit silicon carbide paper. Although some oxidation did occur, the sum-of-differential correlation approach allowed successful calculations. No visible effects due to heat haze were observed during the test. This may become an issue at higher temperatures but the use of a vacuum chamber would minimize the effect.

Results

The results show the average transverse and axial strain data over the specimen surface. Confidence in the approach was high because, compared to published data, the coefficient of thermal expansion and Young's modulus calculated from DIC lie within 2 per cent and 6 per cent respectively. The study presents the ability to successfully make DIC measurements at temperatures up to 1400 °C

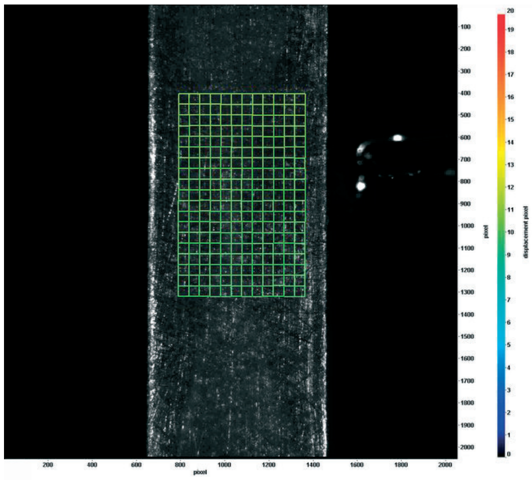

***Figure 4**: Displacement result grid overlaid on original image for one test*

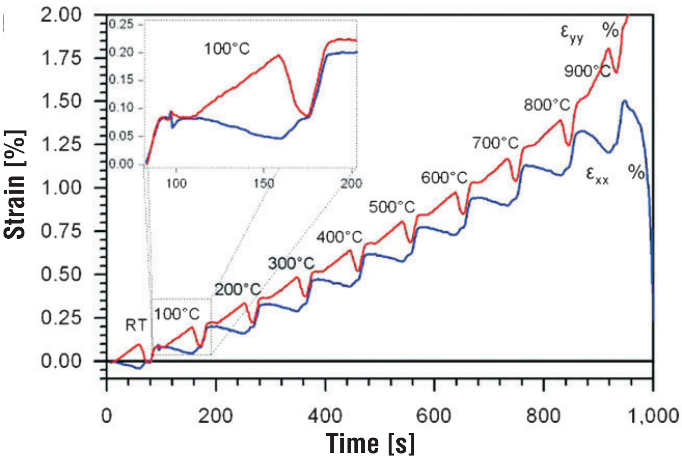

***Figure 5**: Strain evolution vs time*

LaVision offer comprehensive system configurations for high temperature testing at macro- and micro-scale. We are able to offer efficient illumination and filters to eliminate black body radiation being visible in the image, and where the natural surface pattern is insufficient, we have paints which can withstand temperatures up to 1200 °C

For further details refer to B.M.B. Grant, H.J. Stone, P.J. Withers, and M. Preuss, ‚High-Temperature Strain Field Measurement Using Digital Image Correlation', J. Strain Anal. Eng. Design, 44 (2009), 249-61.

02/14

LaVisionUK Ltd
2 Minton Place / Victoria Road
Bicester, Oxon / OX26 6QB / United Kingdom
E-Mail: sales@lavision.com / www.lavisionuk.com
Phone: +44-(0)-870-997-6532 / Fax: +44-(0)-870-762-6252

LaVision GmbH
Anna-Vandenhoeck-Ring 19
D-37081 Göttingen / Germany
E-Mail: info@lavision.com / www.lavision.com
Tel. +49-(0)551-9004-0 / Fax +49-(0)551-9004-100

LaVision Inc.
211 W. Michigan Ave. / Suite 100
Ypsilanti, MI 48197 / USA
E-mail: sales@lavisioninc.com / www.lavisioninc.com
Phone: (734) 485 - 0913 / Fax: (240) 465 - 4306