Full Field Strain

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With new and advancing materials being developed every day, research and material testing has to adapt to keep up. Physical testing is not just a case of following a standard to collect data, but a tool used to analyze properties and optimize them. Currently, typical strain measurement requirements will be to measure axial strain at one gauge length in the centre of the specimen. In some cases transverse strain may also be measured to allow Poisson's Ratio to be determined or strain gauges will be used where traditional extensometers are difficult to use.

For materials research these current strain measurement techniques do not offer enough information about how failures occur, and so, engineers are looking for different methods. One such test technique is the use of Digital Image Correlation (DIC) in measuring full field strain over a materials surface. In addition to the strain map produced, virtual strain gauges and extensometers can be placed on the specimen post-test and replayed time and time again. This technique can be used for almost any material and any industry. Plastic, metal, composite, rubber, foam, textiles, and more have all been successfully tested using Digital Image Correlation.

DIC is a strain measurement technique that works by capturing a series of images throughout a test and analyzing them afterwards. A system includes a camera system, lighting, and a software package to control image capture and to conduct post-test analysis. Recently, integrated DIC systems (1), which use existing video extensometers, have been introduced to provide a stream-lined package tailored for the materials testing market.

Pre-test samples have a speckle pattern (2) that is added by spraying, stamping, or sticking decals to their surface. In some cases, the natural pattern of the sample will be sufficient without needing to apply any additional marking.

2 - Typical speckle pattern

The number of images captured during a test depends on time, speed, and the sample, but between 50 – 100 images are adequate. The first image – also known as the reference image – is captured when there is no strain on the sample. The image is then split into small subsets and the patterns within each subset of subsequent images are compared to the reference image and displacements are calculated. From these displacements, a strain/displacement map is produced and only one sample can be used to find axial and transverse strains and displacements, shear strain and maximum and minimum normal strains.

These maps are similar to FEA-style images (3) and this leads to one application for DIC, where there is a need to prove if an FEA simulation is correct. This is new for engineers, whom in the past would have used simple test data from extensometers or strain gauges to verify predictions from an FEA simulation. It also means that subtle changes in a material that may be missed in a simulation can be measured and identified, allowing operators to compare what they believe is happening to what actually is happening.

1 – Integrated DIC System
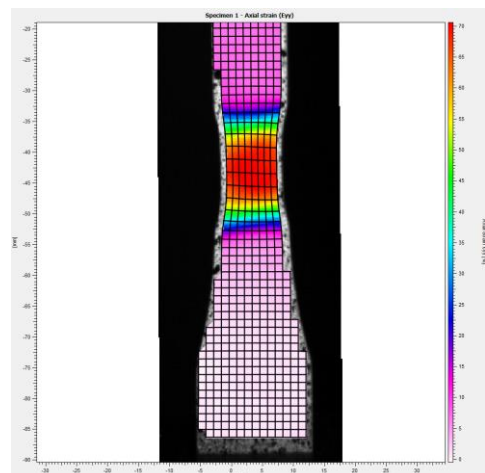
3 – Sample DIC Strain Map

DIC software also allows the inclusion of virtual extensometers and strain gauges that can be placed anywhere on the sample. This allows analysis to take place close to or around failure points and means that a position does not have to be decided before the test is conducted. It also allows existing data to be compared to new results.

Having such a visual method of seeing material failure and the scope to analyse and re-analyze data makes DIC a great tool for teaching material science and engineering graduates in universities. A good example in metals testing is where strain can be seen to create a V shape across the specimen and ultimately ending in a failure angled across the specimen (4). It would very difficult to see this strain build up without a simulation, but DIC is measuring it from real specimens.
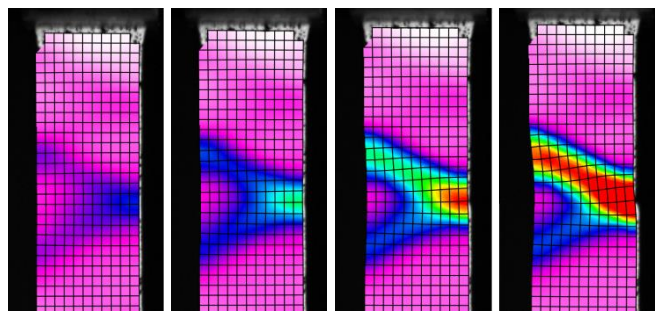
4 – DIC Strain Maps of a Metal Failing

Once the strain map had been created, virtual extensometers and strain gauges can be added at different places along the specimen to show how the strain varies when it is measured close to or away from the failure point. These results add to the theoretical teaching by giving an easy-to-understand visual representation of how failures are actually occurring.

As well as teaching, DIC can be used for specimens or samples with non-uniform strain distribution throughout the material. In these cases, single extensometers or gauges will not give much information about the deformation and strain of the sample. One example of this would be a tensile specimen containing an open hole. The hole creates stress concentration and hence produces a non-uniform strain pattern. It will be obvious to most that the strain will be greater around the hole but DIC allows the user to see how the strain forms and to measure the peak strain at the point of material failure. As shown in the images (5), axial strain builds up to the left and right of the hole and is at a minimum above and below the hole. When looking at shear strain we can see that the map created shows a varying positive to negative shear strain as we look around the hole.
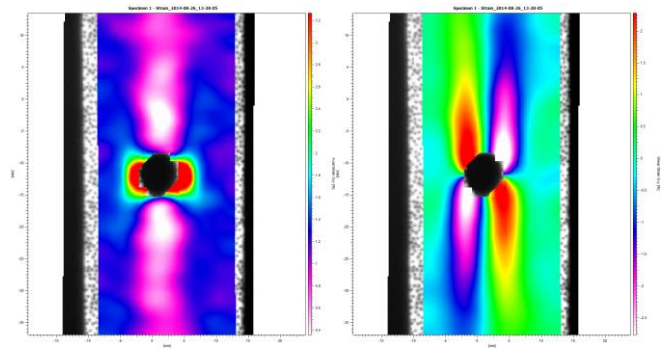
5 – Axial and Shear DIC Strain Maps for an Open Hole Specimen

DIC may not be replacing traditional extensometers or strain gauges in the short term, which are required to meet current test standards, but it is required by R & D departments and teaching establishments to understand the complexities of modern materials.