Using **Digital Image Correlation** to Measure Full Field Strain

With new and advanced materials being developed continually, both research efforts and materials testing must adapt to keep up. Physical testing is not simply a matter of following a standard to collect data, but is a tool to analyze and optimize properties. Traditional strain measurement requirements involve characterizing axial strain at one gauge length in the center of the specimen. In some cases, transverse strain is also measured to determine Poisson's ratio, and strain gauges are used where it is difficult to use traditional extensometers.

However, existing strain measurement techniques do not offer enough information about how failures occur, so alternative methods are required. One technique involves using digital image correlation (DIC) to measure full field strain over the entire material surface. In addition to the strain map produced, virtual strain gauges and extensometers can be placed on the specimen after the test and replayed multiple times. Further, the technique can be used for almost any material; polymers, metals, composites, rubbers, foams, textiles, and other materials have been tested using DIC.

How digital image correlation works

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

Pre-test samples are usually treated with a speckle pattern (Fig. 2) added by spraying, stamping, or sticking decals to their surfaces. In some cases, the sample's natural surface pattern is sufficient without the need to apply any additional marking. The number of images captured during a test depends on time, speed, and the sample itself, but 50 to 100 images are usually adequate. The first image—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 which a strain/displacement map is produced. Only one sample is required to determine axial and transverse strains and displacements, shear strain, and maximum and minimum normal strains.

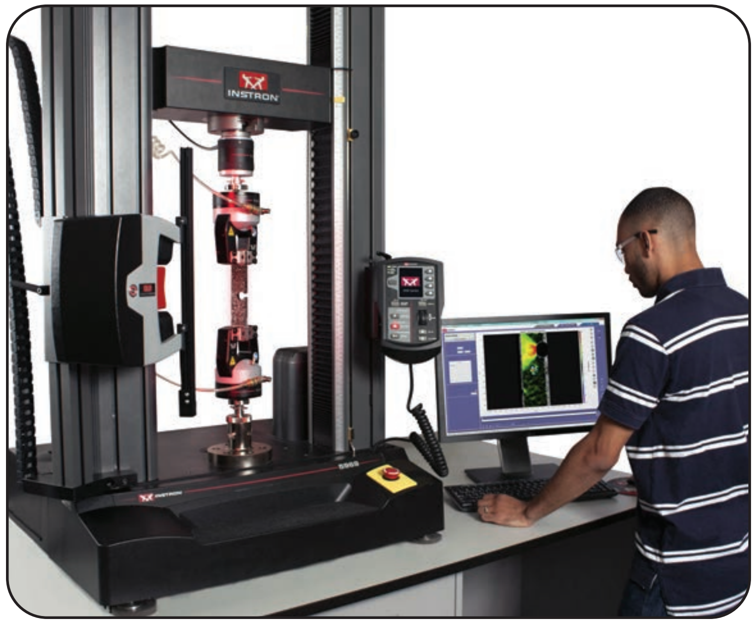

Fig. 1 — *Integrated digital image correlation (DIC) system.*

Fig. 2 — *Typical speckle pattern applied to a test sample.*

These maps are similar to FEA-type images (Fig. 3), which leads to a very useful application for DIC—proving whether or not an FEA simulation is correct. In the past, engineers used simple test data from extensometers and strain gauges to verify predictions from an FEA simulation. With the new technique, subtle changes in a material that might be missed in a simulation can now be physically measured and identified, allowing operators to compare what they believe is happening to what is actually happening.

DIC software also allows the inclusion of virtual extensometers and strain gauges that can be placed anywhere on the sample. This enables analyzing the sample near failure points, so a position does not have to be selected before conducting the test. It also enables comparing existing data with new results.

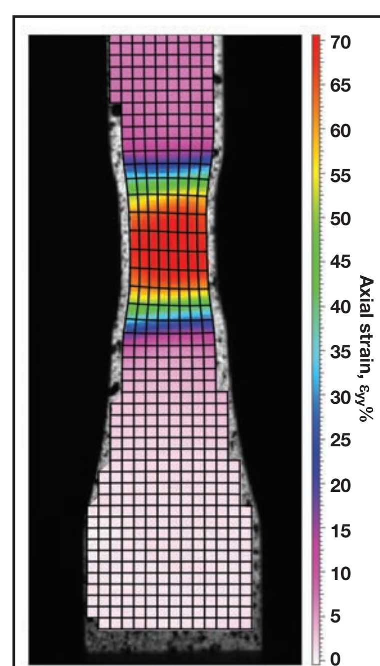

Fig. 3 — *Sample DIC strain map.*

DIC as a teaching tool and more

Having this type of visual method to observe material failure in action, as well as

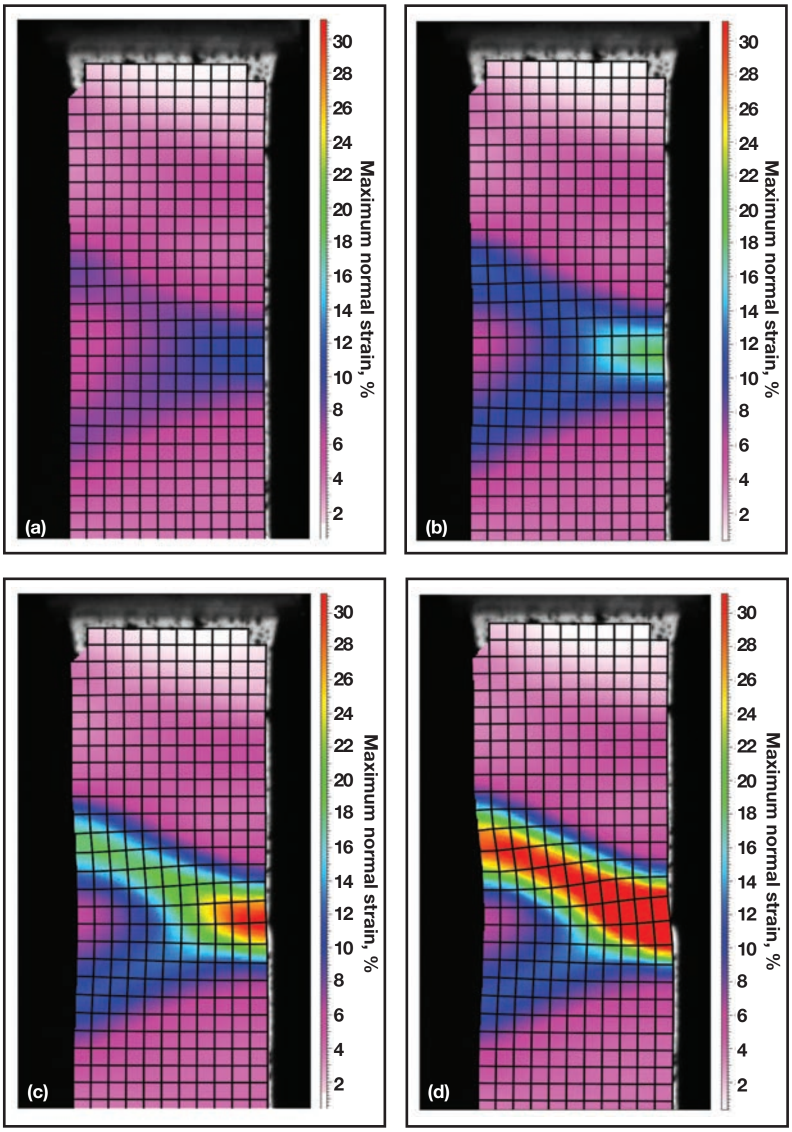

Fig. 4 — *DIC strain maps of a metal proceeding to failure.*

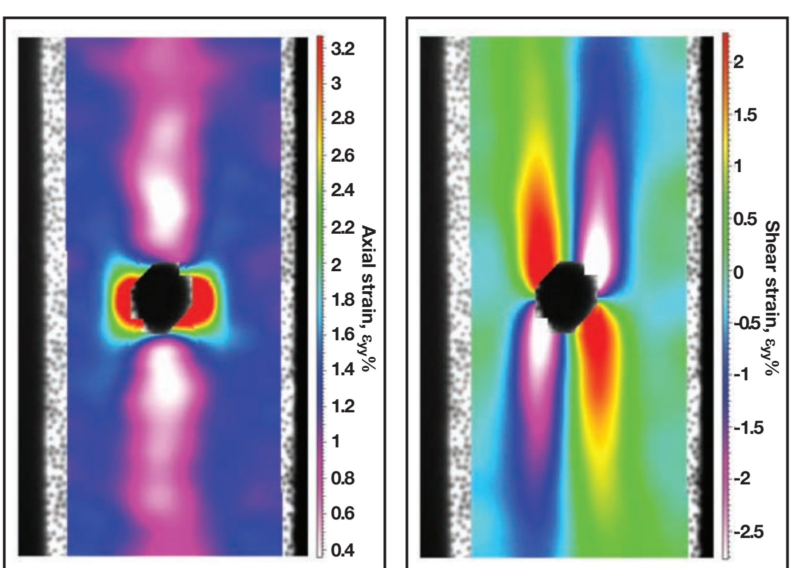

Fig. 5 — *Axial (left) and shear (right) DIC strain maps for a through-hole specimen.*

the capacity to analyze and reanalyze data, makes DIC a great teaching tool for materials science and engineering courses at the university level. A good example in metals testing is where strain can be seen as creating a "V" shape across the specimen, ultimately ending in a failure angled across the sample, as shown in Fig. 4. It is very difficult to see this strain buildup without a simulation, but DIC is measuring it from real specimens.

Once a strain map has been created, virtual extensometers and strain gauges can be added at different locations along the specimen to show how strain varies when it is measured either close to or away from the failure point. These results add to the teaching value by offering an easy-to-understand visual representation of how failures actually occur.

In addition to teaching, DIC can be used for test specimens and samples with nonuniform strain distribution throughout the material. In these cases, single extensometers and gauges do not provide much information about the test piece deformation and strain. For example, consider a tensile specimen containing a through-hole. The hole creates stress concentration, and therefore, produces a nonuniform strain pattern. While it might seem obvious that the strain is greater around the hole, DIC shows how strain forms and also allows measuring peak strain at the point of material failure. As shown in Fig. 5, axial strain builds to the left and right of the hole, and is at a minimum above and below the hole. With respect to shear strain, the map shows a varying positive-to-negative strain path around the hole.

DIC is unlikely to replace traditional extensometers or strain gauges in the short term, as these tools are required to meet current test standards. However, it is also a requirement of research departments and teaching universities to understand the complexities of modern materials. Digital image correlation is another tool to help accomplish this goal. ❍

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