Full Field Strain Measurement

On a Test Specimen

Using

Digital Image Correlation.

Comparison of Test Data With Photo Elasticity

And Strain Gage Measurements.

VIC-3D Digital Image Correlation System
The method of 3-D DIGITAL IMAGE CORRELATION - DIC is based on principles similar to human depth perception: (Photogrammetry) by viewing the same object or process from two different viewpoints, the precise shape of the object in three-dimensional space can be resolved. Position resolution in three-dimensions is accomplished by referencing a system-wide coordinate system that is established through a calibration process. The calibration process, conducted prior to the start of each test, establishes the intrinsic camera parameters (focal distance, lens distortion factor, and sensor aspect ratio) and geometric parameters (camera positions relative to each other and to the imaged object), that control the transformation between the system-wide coordinates and the coordinates on each camera’s image plane.

The idea behind the method is to infer the displacement of the material under test by tracking the deformation of a random speckle pattern applied to the component's surface in digital images acquired during the loading.

Mathematically, this is accomplished by finding the region in a deformed image that maximizes the normalized cross-correlation score with regard to a small subset of the image taken while no load was applied. By repeating this process for a large number of subsets, full-field deformation data can be obtained.

The DIC method does not require the use of lasers and the specimen can be illuminated by means of a white-light source. However, the specimen surface must have a fairly uniform random pattern, which can either be naturally occurring or applied to the specimen before the test. Among the many methods for pattern application are self-adhesive, pre-printed patterns, stamps and application of paint speckles with air-brushes, spray cans or brushes.

Images of the Test Component in un deformed and Deformed State are captured using 2 CCD Cameras.

The CCD Cameras are placed in such a way that the distance between the cameras and the test component are equal in distance. (In a Equilateral Triangle). The two cameras are mounted on a rigid bar to avoid relative motion of the cameras.
A speckle pattern is applied on the Test Component as shown.

A series of images are captured while the specimen surface is deformed (in-plane, out of plane, rotation, elongation and compression) due to loading. In each captured image, a specific pattern matching algorithm determines the shift, rotation and distortion of each point with respect to the reference image.

DIC measures displacement by tracking the gray value pattern in small neighborhoods called subsets (indicated in red in the figure) during movement, see the image below

A subset is defined as a group of pixels, usually between 20×20 and 30×30 pixels. As the surface deformation is measured point wise, displacement of individual surface points and subsequently surface strains can be evaluated.
Results Obtained from 2D Digital Image Correlation

Displacement: - u and v.

Strains: - $\varepsilon_{xx}$, $\varepsilon_{yy}$, $\varepsilon_{xy}$, $\varepsilon_1$, $\varepsilon_2$ Von Mises, Tresca and Directions of Principal Strains
Two Firewire Camera interfaced to the Fire Wire Ports of the PC.

3D, DIC SYSTEM.

Results Obtained from 3D Digital Image Correlation

Displacement: \( u, v \) and \( w \).

Strains: \( \varepsilon_{xx}, \varepsilon_{yy}, \varepsilon_{xy}, \varepsilon_1, \varepsilon_2 \), Von Mises, Tresca

and Directions of Principal Strains
The Test Specimen is a Typical Photo elastic Model and is made out of Acrylic Sheet of 0.5 mm thick.

A speckle Pattern is Applied on the Test Specimen on the front side.

A strain Gage (350 Ohms, Quarter Bridge) is bonded at the centre of the back side of the specimen.

The Specimen is mounted on a test Rig (Designed By Pyrodynamics)

The Strain Gage output is connected to SCAD 500 – Strain Measurement System.

The strain data is viewed on the Front Panel LCD of SCAD 500 and also on the Host PC via RS 232 Interface.

The Test Rig has a Thumb wheel and rotation of the wheel in clockwise direction introduces tensile strain and anticlockwise rotation introduces compressive strain.

The images are captured using 5 Mega Pixel Digital Camera.

Loading Pattern:-

The Test Specimen is mounted in the Test Rig.

A Tensile Load is applied by rotating the Thumb Wheel till the SCAD 500 shows a strain value of 2000 $\mu$ε. At this stage a image is captured. Subsequently images are captured in increments of 2000 $\mu$ε upto failure of the test specimen.

**THE DIC MEASUREMENTS COMPARED EXTREMELY WELL WITH THE PHOTO ELASTIC FRINGE PATTERN AND STRAIN GAGE MEASUREMENTS. DIC RESULTS ALSO SHOWED EXCELLENT LINEARITY.**
PHOTOELASTIC FRINGE PATTERN

The Pattern has a Fringe Order of 4 at the Left Side Edge & has the highest strain.

The Lowest Strain is at the Right Side Edge Fringe order 0.

DIGITAL IMAGE CORRELATION PATTERN.

Load Step 3 (6000 µε)

CLICK HERE TO OPEN VIDEO OF STRAIN - Y

Values:
- 23817 µε
- 21314 µε
- 20243 µε
- 17875 µε
- 9284 µε
- 1384 µε
- 770 µε
DIC MEASUREMENTS
COMPARISON WITH STRAIN GAGE MEASUREMENTS

**STRAIN - Y DIRECTION**

<table>
<thead>
<tr>
<th>MICROSTRAIN</th>
</tr>
</thead>
<tbody>
<tr>
<td>37500</td>
</tr>
<tr>
<td>35000</td>
</tr>
<tr>
<td>30000</td>
</tr>
<tr>
<td>25000</td>
</tr>
<tr>
<td>20000</td>
</tr>
<tr>
<td>15000</td>
</tr>
<tr>
<td>10000</td>
</tr>
<tr>
<td>5000</td>
</tr>
<tr>
<td>0</td>
</tr>
</tbody>
</table>

**LOAD STEP**

- STRAIN GAGE
- DIC

**PROFILE OF STRAIN Y**

- LOAD STEP 1
- LOAD STEP 2
- LOAD STEP 3
- LOAD STEP 4
- LOAD STEP 5
- LOAD STEP 6
- LOAD STEP 7
- LOAD STEP 8
- LOAD STEP 9
- LOAD STEP 10
- LOAD STEP 11
- LOAD STEP 12
- LOAD STEP 13
- LOAD STEP 14

**X CO ORDINATES - MM**

- 85
- 95
- 105
PHOTOELASTIC FRINGE PATTERN

Strain Pattern obtained from Digital Image Correlation

STRAIN Y – (Unit Strain)
PHOTOELASTIC FRINGE PATTERN

Strain Pattern obtained From Digital Image Correlation
A speckle pattern was screen printed on the Test Specimen

A Compressive load was applied and the tensile specimen was subjected to bending.

Out of Plane Displacement - $w$

Strain X
A Speckle Pattern was applied on a Test Specimen 100 x 100 mm.

A displacement was provided by a micrometer in the V(Y) direction.

Each rotation of the micrometer provides 500 microns of displacement.

The displacements field showed very little gradients.

The mean of the DIC plot was taken for comparison with the micrometer readings.

Displacement of the micrometer and DIC measurements matched perfectly.
FULL FIELD STRAIN MEASUREMENT ON A CARBON STEEL TENSILE SPECIMEN

Tensile Specimen With the Speckle Pattern Mounted in a UTM.

Plot of Y Displacement from DIC Vs UTM Displacement

Strain – Y
69740 µε

Strain – X
25393 µε
FULL FIELD STRAIN MEASUREMENT ON A CARBON STEEL TENSILE SPECIMEN

PLOT OF STRAIN GAGE VS DIC

DIC MEASUREMENT - MICROSTRAIN

STRAIN GAGE MEASUREMENTS - MICROSTRAIN

Stress (MPa) vs DIC (% Strain)

DIC (% Strain) vs Position (mm)
TENSILE TEST CARBON STEEL
LUDAR BANDS OBSERVED

DYNAMICS
A Speckle Pattern is applied on a SMA Wire of 370 micron diameter.

The wire is black in color and only white dots are applied using a Air Brush with 0.2mm nozzle.

A PGR 5 MP Camera with a 180mm Tamron Lens is used for capturing images every 250 milliseconds.
Correlated Solutions VIC 2D / VIC 3D Offers the following Advantages:-

- Provides Full Field Displacement and Strain Fields.

- Non Contact.

- Easy Set Up. Applying Speckle pattern is simple and hardly takes any time.

- Can measure strains in a area or along a profile.

- Mechanical material properties up to fracture

- True strain information

- On almost any contour and any material

- High speed measurement possible
List of End Users of VIC-3D/2D Systems In India.

- National Aerospace Laboratories – Bengaluru.
- MRF Limited – Chennai.
- Indian Institute of Technology – Chennai – Department of Aerospace Engineering.
- General Motors Technical Centre – Bengaluru.
- Indian Institute of Technology – New Delhi – Department of Applied Mechanics.
- GEITC – John Welch Technology Centre – Bengaluru.
- Central Glass and Ceramic Research Institute – Kolkatta.
- Indian Institute of Technology – Chennai – Department of Engineering Design.
- Indian Institute of Technology – Hyderabad – Department of Civil Engineering.
- Vikram Sarabhai Space Centre – Thiruvananthapuram.
- Central Glass and Ceramic Research Institute – Kolkatta.
- Indian Institute of Science – Bengaluru – Department of Aerospace Engineering.
- Indian Institute of Technology – Hyderabad – Department of Mechanical Engineering.
- GEITC – John Welch Technology Centre – Bengaluru.
- Indian Institute of Technology – Kharagpur - Department of Mechanical Engineering.
- Indian Institute of Technology – Chennai – Department of Applied Mechanics.
- Indian Institute of Science – Bengaluru – Department of Materials Engineering.
- Indian Institute of Technology – Kharagpur – Tribology Laboratory.
- Indian Institute of Technology – Kanpur – Department of Mechanical Engineering.
- Indira Gandhi Centre For Atomic Research – Kalpakkam.
For More Detailed Information or Demonstration Please contact us at

PYRODYNAMICS
No 632, 22nd Main Road
4th “ T “Block, Jayanagar
Bangalore – 560041

Ph: 080-22454993
Fax: 91-80-2 66 55 333

E-Mail:- pyrodynamics@bsnl.in

Thank You