Vic-2D v6

Testing Guide

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SOLUTIONS

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SAFETY AND RISK MANAGEMENT

SAFETY

- Some mechanical assemblies contain pinch points - use proper care and tools when assembling to avoid injury.
- Incandescent lights can get very hot. Use caution when moving or working around these lights, and beware of excessive heating of the specimen, cameras, lenses, or other surfaces. Leave lights off when possible.
- When mounting cameras it may be possible to create an unstable or unbalanced situation. Be careful not to cantilever cameras excessively, especially heavier or high-speed cameras.
- Personnel should be in a safe location whenever a dangerous or destructive test is being performed. Various solutions are available for extending cabling/controls to allow the system to be operated in a safe, remote location – please contact Correlated Solutions for more details.
- Various paints, chemicals, and solvents may be used in preparing specimens for testing. Always observe label precautions.
- If any cables become frayed or damaged, replace immediately to avoid risk of shock.
- Do not attempt to repair or disassemble the computer or any electronic parts. Risk of shock or damage may result.
- When using a cart system, be certain to lock the wheels whenever the system is not being moved.

RISK MANAGEMENT

- Always fully support cameras when moving, assembling, or adjusting, until all fasteners are completely tight. For larger high-speed cameras, two people may be required. Cameras can suffer severe damage if dropped.
- Always support lenses when installing or removing. In addition, for certain lenses, during focusing operation, the front must be supported to prevent drops.
- While most power and data connections are keyed, it may be possible to incorrectly plug in or force a USB, 1394a, or 1394b connection. Always check orientation and compatibility before making any connection.
- For any test where excessive heat, shock, or flying debris may be present, take steps to protect the cameras and equipment. Various shielding solutions are available – please contact Correlated Solutions for more details.

INTRODUCTION

Completing a test with Vic-2D is fairly straightforward but a few pointers can help to get the best results in the shortest period of time. This document explains the basics of a test from start to finish. The steps covered will be:

- Preparing the specimen
- Setting up the camera
- Running the test
- Image analysis
- Viewing and reducing data

PREPARING THE SPECIMEN

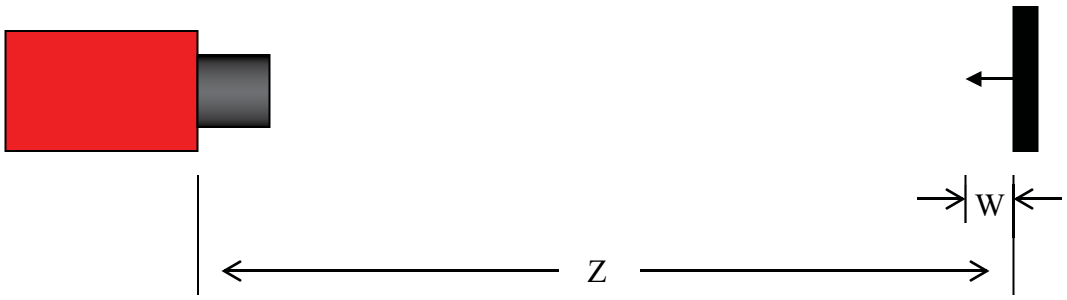
Begin by preparing the region of interest on your specimen with a speckle pattern. For more information on techniques and guidelines, please see the attached application note AN525, Speckle Pattern Fundamentals.

For this test we'll be using a small tensile specimen made of white natural rubber. Because the specimen is white, no base coat is needed; black elastomeric paint is used to create a speckle pattern on the surface.

SETTING UP THE CAMERA

Accurate 2D image correlation depends on the specimen being planar and parallel to the camera sensor; because of this, careful alignment is key to highly accurate results.

The first step will be lens selection. In 2D correlation, errors can be introduced when the specimen is misaligned or moves out of plane; these errors are proportional to w/Z, where w is the out-of-plane motion, and Z is the distance from the camera to the specimen.

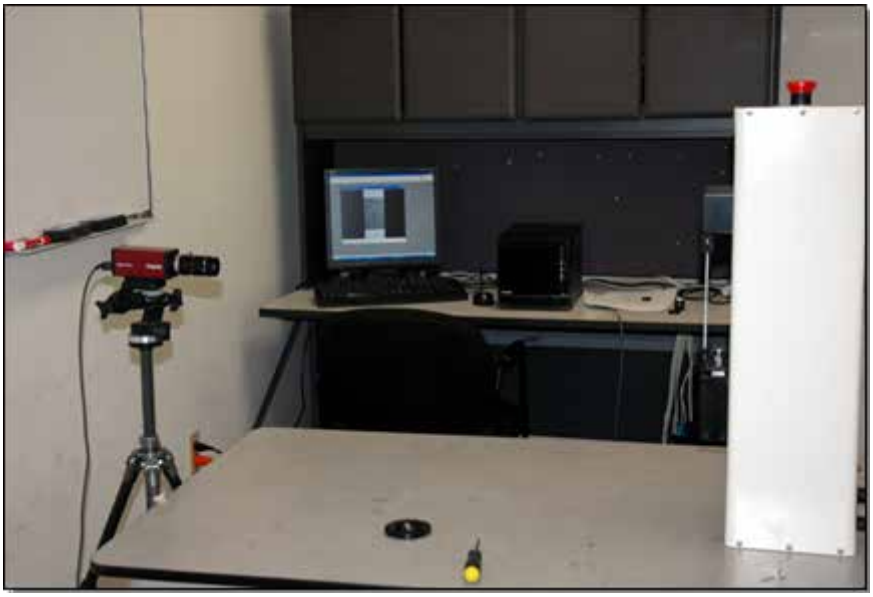


We will minimize the error by reducing w and increasing Z. The out-of-plane motion can be reducing through testing configuration and procedure. The Z distance can be increased by selecting a long focal length (e.g., telephoto) lens. In general, select the longest available lens that will allow you place the camera with a line of sight to the specimen and still image the entire area of interest.

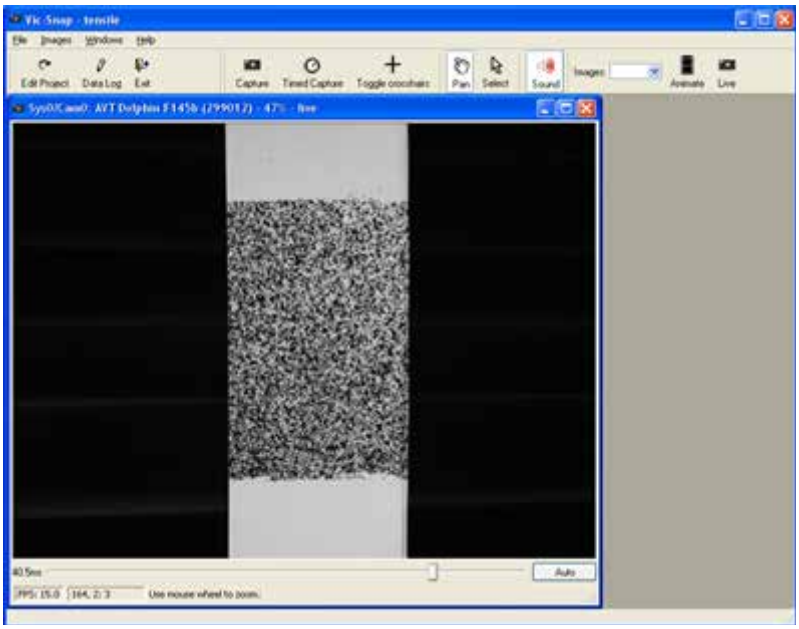
Once a lens has been selected, the camera should be placed to image the entire area of interest. Be sure to leave a buffer for any expected motion or expansion of the test specimen. In our tensile test, the specimen will be pulled symmetrically, so we leave space both above and below.

Once a distance has been established, carefully place the camera at the same height and lateral position as the specimen. This can be accomplished by carefully sighting along the camera, or more accurately by using a ruler and/or a level to check the height and alignment.

Here, a camera has been set up with a 75mm lens imaging a small tabletop test frame:



After placing the camera, Vic-Snap is started so that we can preview the image. The height and tilt adjustments on the tripod are used to align the center of the specimen in the center of our view.



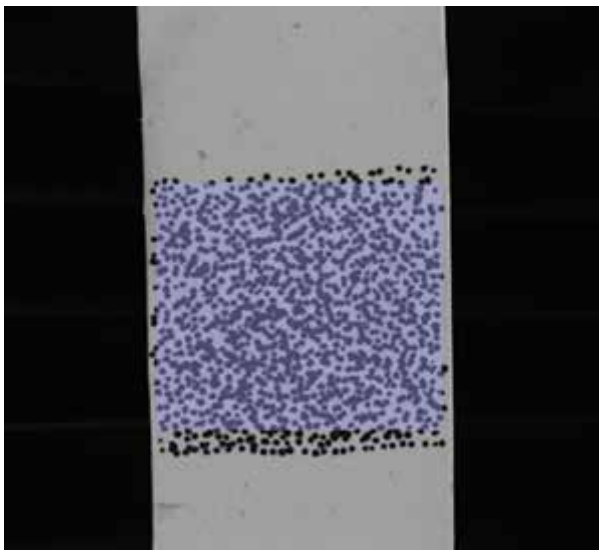
When the camera is at the same height and lateral position as the specimen, and the specimen is centered in view, it follows that the optical axis is correctly normal to the specimen.

Note the room above and below the region of interest to allow for high tensile strains without losing parts of our area of interest. In some cases (very high strains) the specimen will only take up a small part of the field, initially.

When the camera has been positioned, the next step will be to set focus. Use the focus control on your lenses to achieve a sharp focus on the entire specimen. Usually, it will be necessary to zoom in on the image to check fine focus; slight defocus will not be visible with the image zoomed out to fit on screen.

Zoom in by placing the mouse cursor over the image in Vic-Snap and rolling the mouse wheel. While zoomed in, look closely at both the far and near edge of the specimen to ensure that the entire surface is in focus, before proceeding. To pan around a zoomed image, hold Shift (the cursor will change to a hand icon) and click and drag the image.

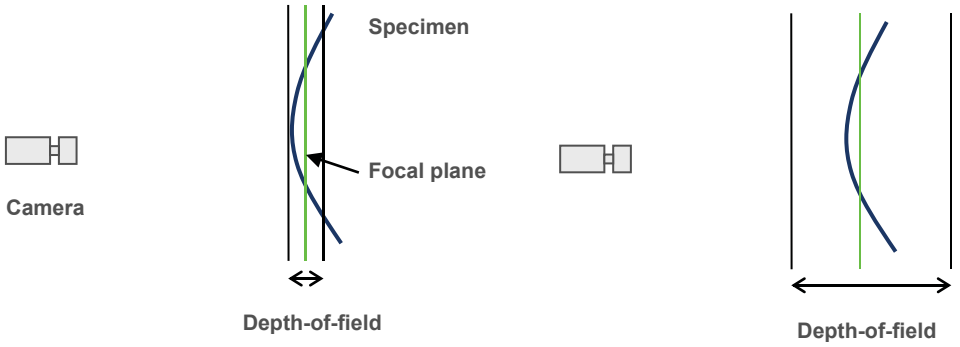
You may also use the focus bar in Vic-Snap as a qualitative focus measure. Click and drag in the image to select the area of interest:



Then, right-click and select Show Analysis. A histogram and a focus bar will appear below the image.

Adjust the focus in one direction until the focus bar starts dropping; go back in the other direction until the bar passes its peak and drops again; finally, return to the peak. Right-click and select Show Analysis again to hide.

A tip: if you open the aperture of your lens all the way (lowest F-number), it will cause the depth of field to become very small. This will exaggerate any out-of-focus areas, so it can be helpful to set your focus this way, then return the aperture to the appropriate setting for the test. (You will need to temporarily reduce the exposure time to compensate – see following section.)



Focusing with large aperture – small DOF

After closing aperture – focal plane is well centered

APERTURE AND EXPOSURE TIME

As you make the image sharp through the focus adjustment, it will also be necessary to adjust the brightness of the image. There are two controls available for this: the aperture/iris setting on the lens, and the exposure time setting of the camera.

- **Aperture:** opening the aperture allows more light to fall on the sensor. The aperture setting is also called the f-number; f-numbers are usually indicated on the lens's aperture ring and typically go from an open setting of 1.4 or 2.8 to a closed setting of 22 or 32. Using a bigger aperture (lower f-number) will make the image brighter. However, it will also decrease the depth of field – the range over which the focus is sharp. For typical Vic-2D applications, the specimen will be very nearly flat, so that there is no practical need for a significant depth of field.

- **Exposure time:** this is the amount of time the camera sensor gathers light before reading out a new image. Longer exposure times make the image brighter but can also create blur if significant motion happens during the exposure times. Maximum acceptable exposure time will depend on the test speed; for a typical quasi-static test, exposure times of up to 50-100ms will be acceptable. A specific determination can be made by calculating the linear speed of the fastest-moving part of the specimen. In pixel terms, this speed should be no more than 0.01 pixels over the exposure time.

The image should be as bright as possible without showing any saturation (displayed as red in the image window). Some materials (i.e., HDPE) will get lighter in color as they strain – for these materials the image should be made a bit dimmer to compensate for the brightness increase.

Controls for focus and aperture differ by lens; two common C-mount styles are shown below.

This lens has a focus and aperture ring, each with locking knob. The aperture ring is normally closest to the camera. Loosen the locking knob (if present); make any adjustments; and tighten the lock before calibrating.

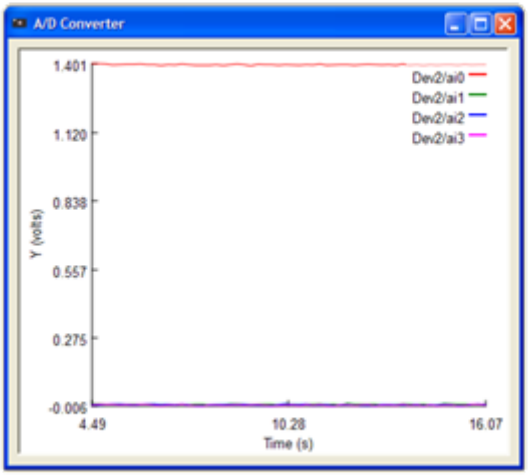
This lens has an aperture ring with a locking knob. To focus, loosen the collar (for this particular lens, a 2mm hex driver is used), and rotate the entire body of the lens. Loosen the lens body (counterclockwise) to focus closer; tighten (clockwise) to focus farther. Tighten the collar when complete.

Caution – the lens body is not captive and will fall if screwed all the way out.

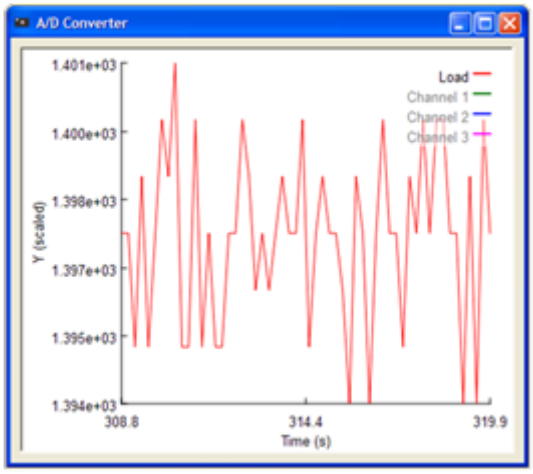
Once the camera has been positioned, carefully lock down any tripod adjustments and lens settings. If necessary, tie down any loose cables, and make sure cables are routed so you can access relevant equipment without interference.

ANALOG DATA

For systems equipped with data acquisition hardware, several channels of analog data may be acquired along with the image data. To view the analog data, click the **Analog Data** button in the toolbar. (If this button is not present, analog acquisition is not installed. If it is present but grayed out, the acquisition is installed but not active.) A dialog will appear showing the voltage for each channel present in the device (typically, 4 or 8 channels).



You can double-click on a channel heading to remove it from the display (double-click again to return it). You can also scale and rename these channels; right-click and select **Edit channels**. You can enter a title, range, and multiplication factor for each channel. Selecting the appropriate range will give higher accuracy. To view scaled data, right-click and select S**how scaled**.



This data is saved in the CSV log file associated with the project. This file will have the same name as the project prefix and for each image set, contains the image count, the filenames, the exact times, the unscaled analog data, and the scaled analog data.

RUNNING THE TEST

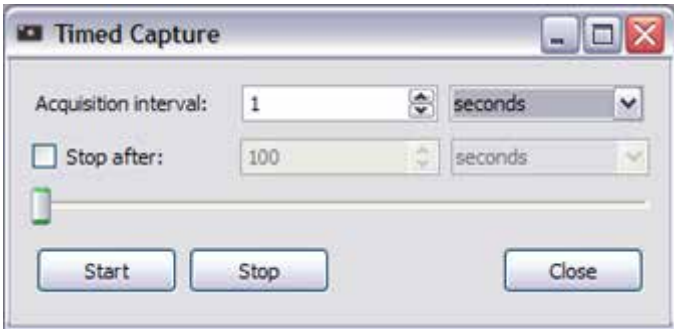
Before beginning, connect desired analog voltage outputs (load, etc) to inputs on your acquisition system and confirm that the correct signals are being acquired. Also, check that enough drive space will be available to acquire as many images as desired.

Typically, images will be acquired either manually, or at set intervals. For a simple before/after test, simply acquire one image

of the specimen in its reference state, and another in the deformed test. In Vic-Snap, images may be acquired by clicking the Capture button or simply pressing the space bar.

For a typical continuous test – i.e., a pull test of a dogbone specimen – many images can be acquired. In most cases, it's best to acquire a smooth sequence of many images rather than just a few. This is because when motions from one image to the next are small, the analysis will work automatically with no user intervention; when motions are large, initial guess input may be required.

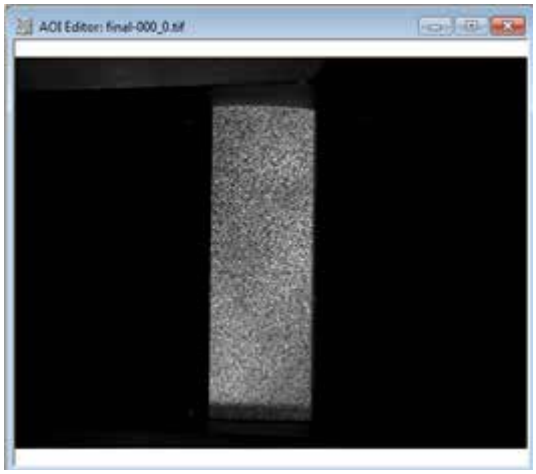
For timed acquisition, it's best to begin the acquisition, and then begin the test – excess images can always be discarded. Be sure to monitor the image during the test – some materials can become brighter or darker, requiring a change in exposure time. To use timed capture, select Images… Timed Capture, or use the toolbar button.



Select an interval and, if desired, a total time; and click Start to begin. Images will be saved at the specified interval.

ANALYZING IMAGES

To begin, start Vic-2D. Click the **Speckle images** toolbar button (or select Project… Speckle images, from the menu bar) and navigate to the folder where your test images are stored. Select your test images and click **Open**. The first image will appear in a window.



This image is the Reference image; it will be the reference state and all strains and displacements will be relative to this image. By default, the first image in the sequence is the reference; if you would like to select a different image, right-click on the image in the image list at the left, and click **Set reference image**.

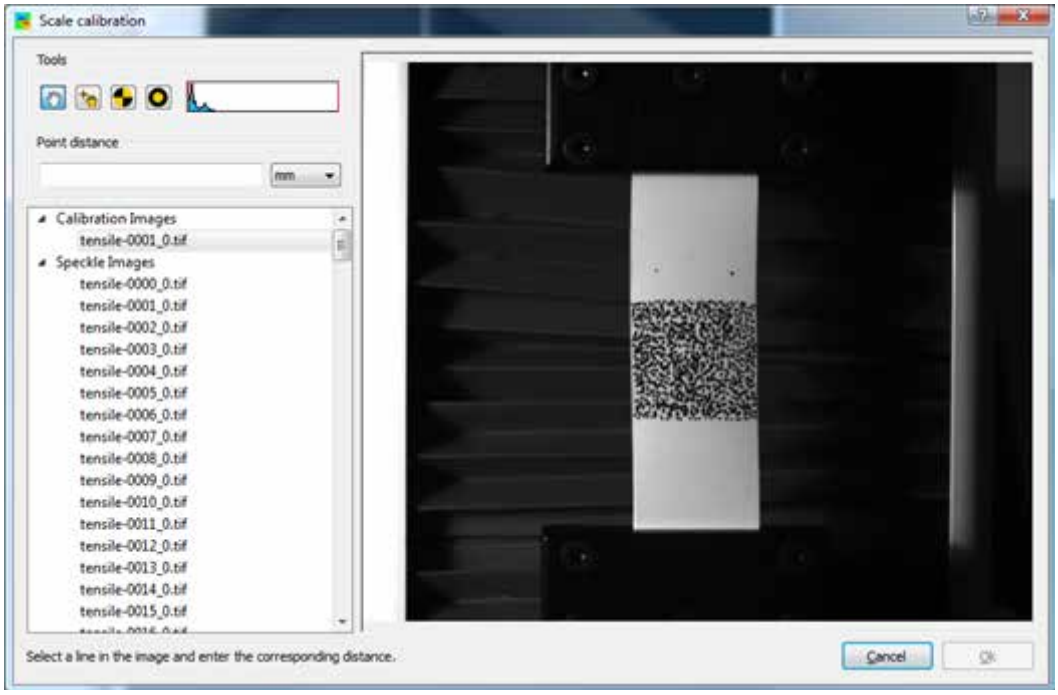
Next, select your area of interest (AOI), using the rectangle or polygon tool in the AOI toolbar. Click once in the reference image to define the first point; click again to define subsequent points. For the polygon, double-click to complete drawing. Here, we use the rectangle tool:

Select a subset and step size for your AOI, using the spin boxes in the AOI tools. The subset size controls the size of the DIC analysis window and is displayed in the size of the yellow seed point box; this should be at least as big as your smallest speckle. The default works well most tests. The step size controls the density of analyzed data; a step size of 5 will analyze every 5th point in each direction. A higher step size gives faster results but coarser data. A smaller step size will return more points but will take longer.

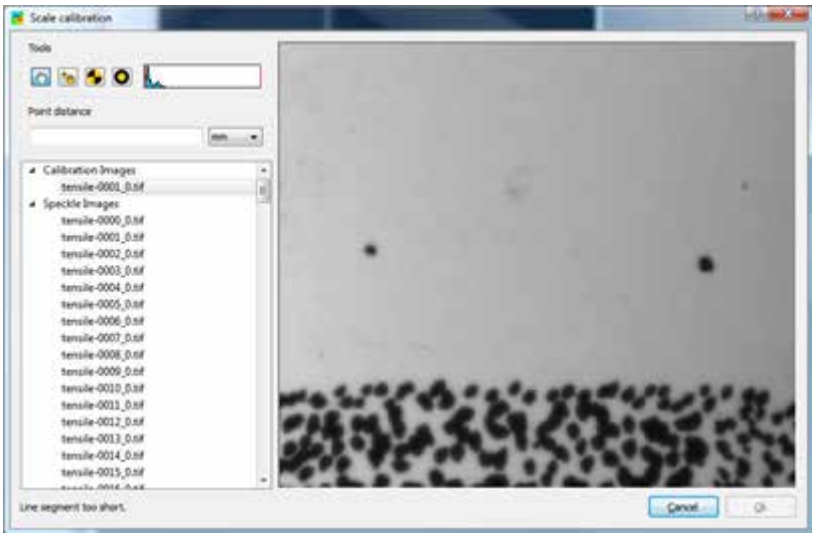
CALIBRATING FOR SCALE

Before running the analysis, you can calibrate for scale in order to generate results in physical unitsIf you do not calibrate for scale, all results will be in pixels. As a dimensionless variable, strain will be unaffected.

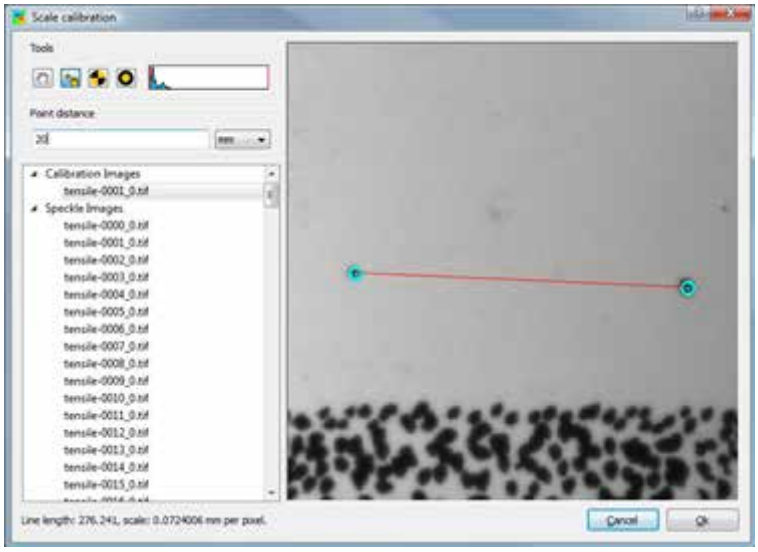
To calibrate for scale, you must have an image which contains a known distance, either marked on the specimen, or on a ruler or target that is in the same plane as the specimen. Select **Project… Calibration images**, and add this image. Then, select **Calibration… Calibrate scale**. The image we have used here is the specimen image, with two dots marked exactly 20mm apart.



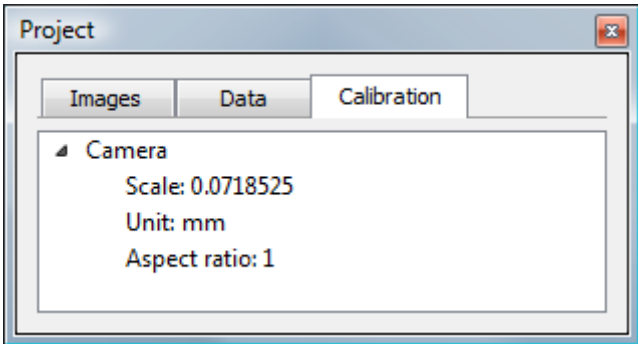
We zoom in on the image so that we can pick the points more exactly:



Then, we pick the **Manually select** tool, click on the first point, and drag to the second point. A line appears. We then enter 20 mm in the Point distance box, and click **Ok**.

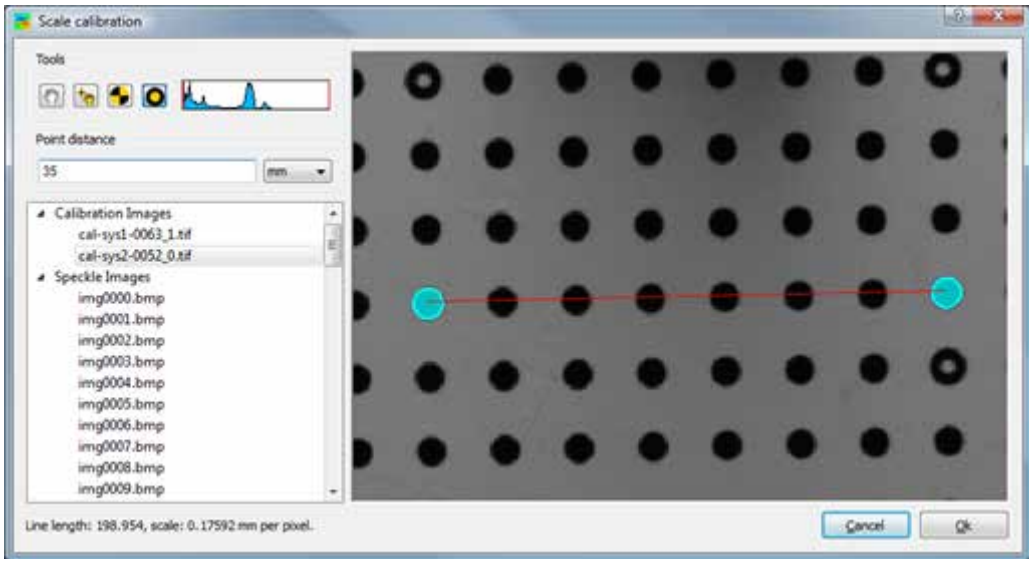


The system is now calibrated, and a scale appears in the **Calibration** tab:



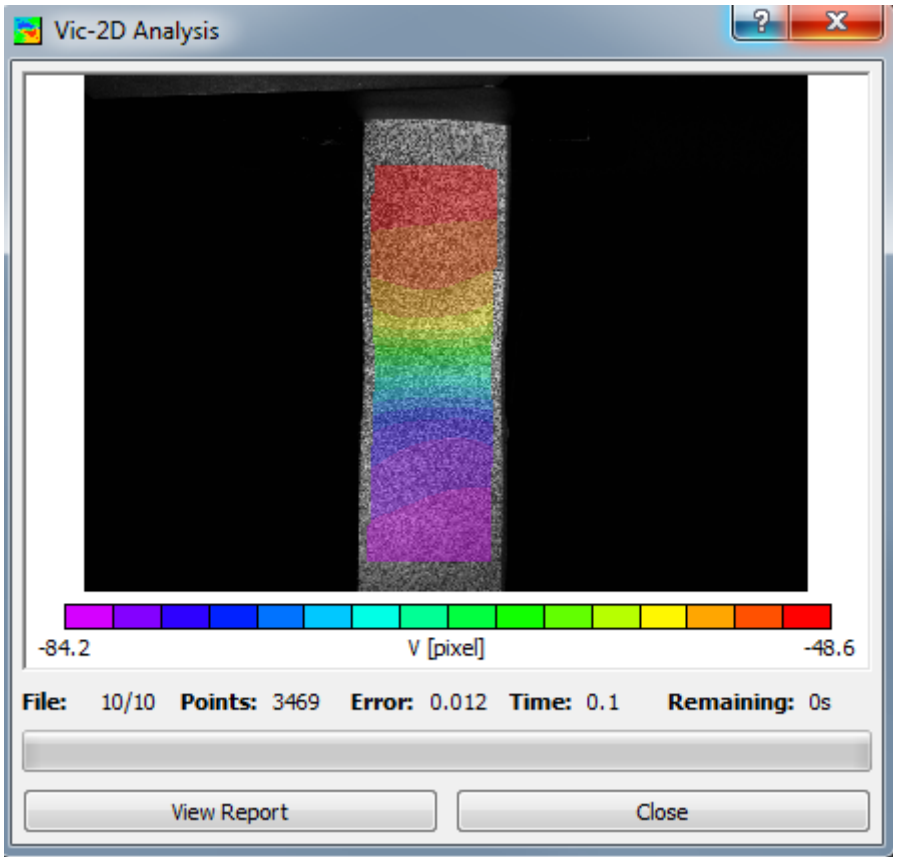
Data analyzed after this point will contain metric dimensions in addition to the pixel units.

If you have a suitable ellipse target – such as a 3D calibration grid – you can get a more accurate extraction by using the **Snap to circle** tool. This allows subpixel accuracy. To use, select the tool, click on the first ellipse, and drag to the second.



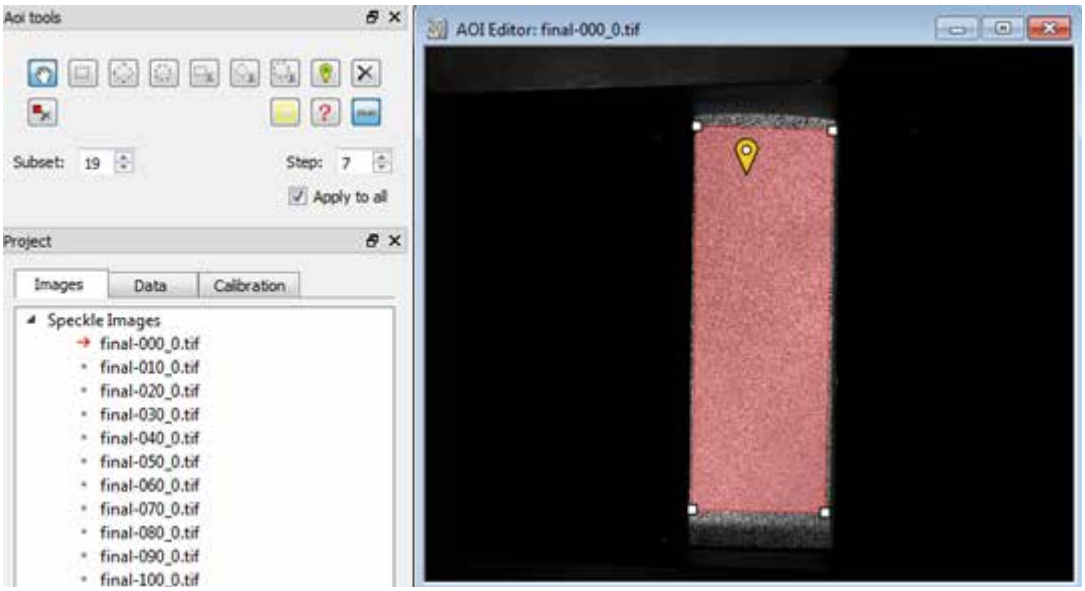
Here, a 5mm pitch grid was used, and there are 7 spaces in between, so the distance is entered as 35mm.

When AOI selection and scale calibration (if applicable) are complete, click the green Start analysis button in the toolbar. Click the Run button in the next dialog to analyze. The analysis dialog appears.



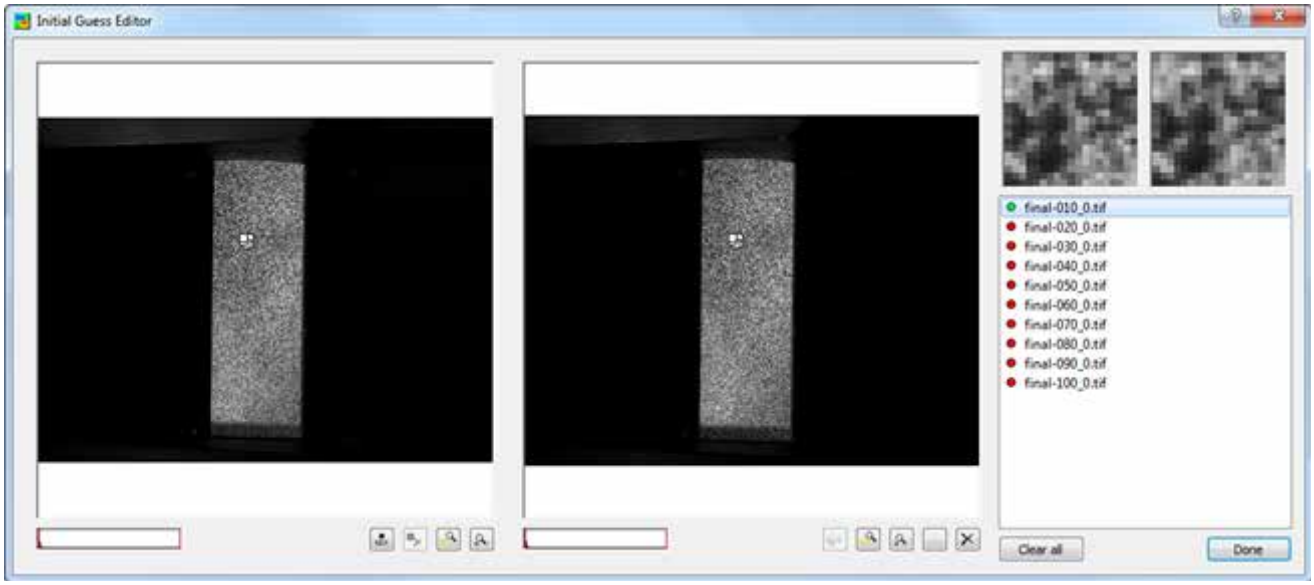
For each image, the dialog lists the file number, the number of points correlated, the average match confidence, the analysis time of that image, and the analysis time remaining for the other images. You also see a preview of your results; you can right-click in the plot to select different variables. Here, we see V, the vertical displacement.

If no points are returned, it may indicate a problem with the images (no speckle pattern; pattern too coarse, sparse, or dark). It may also indicate that a manual initial guess is needed. To perform an initial guess, use the AOI icon indicated in the image.



In order to select a good initial guess point (also called a seed point), an area with good definition and contrast should be selected in order to allow a successful automatic guess. The seed point subset should look similar in the reference and deformed subsets. Also a seed point with low strain should be selected. The seed point should be in an area of low motion; i.e., in a tensile test, this would be the side of the specimen nearest the fixed grip.

Toggle the mouse over the seed point that was placed in order to see if the initial guesses were all found. If it does not say 100%, then the seed point was not found for every image. In this case, right click on the initial guess and click "Edit Guesses."



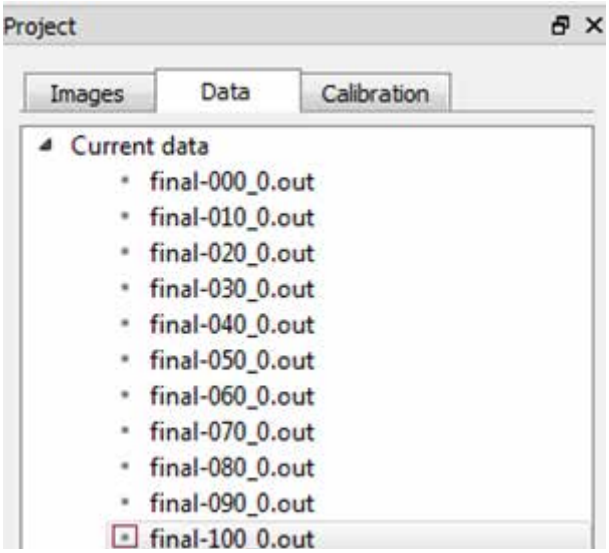
Here, the left image is the reference image and the right image is the selected deformed image. In the upper left, the subset is shown for the reference image (left) and the selected deformed image (right). We can see that a green circle is displayed for the first deformed image in the image list at the bottom right. This indicates that an initial guess was successfully found. If the list shows a red circle, make a manual initial guess, by selecting the image file, shown on the right in the image above and then:

1. Locate the area which roughly matches the seed point, displayed at the top right.
2. Find a matching point in each image. Click the point in both the reference and deformed image. The subsets shown in the top right should now look the same and look like the reference subsets.
3. Right-click on the subset you placed, and then right click again to accept. The image should then have a green circle by it.

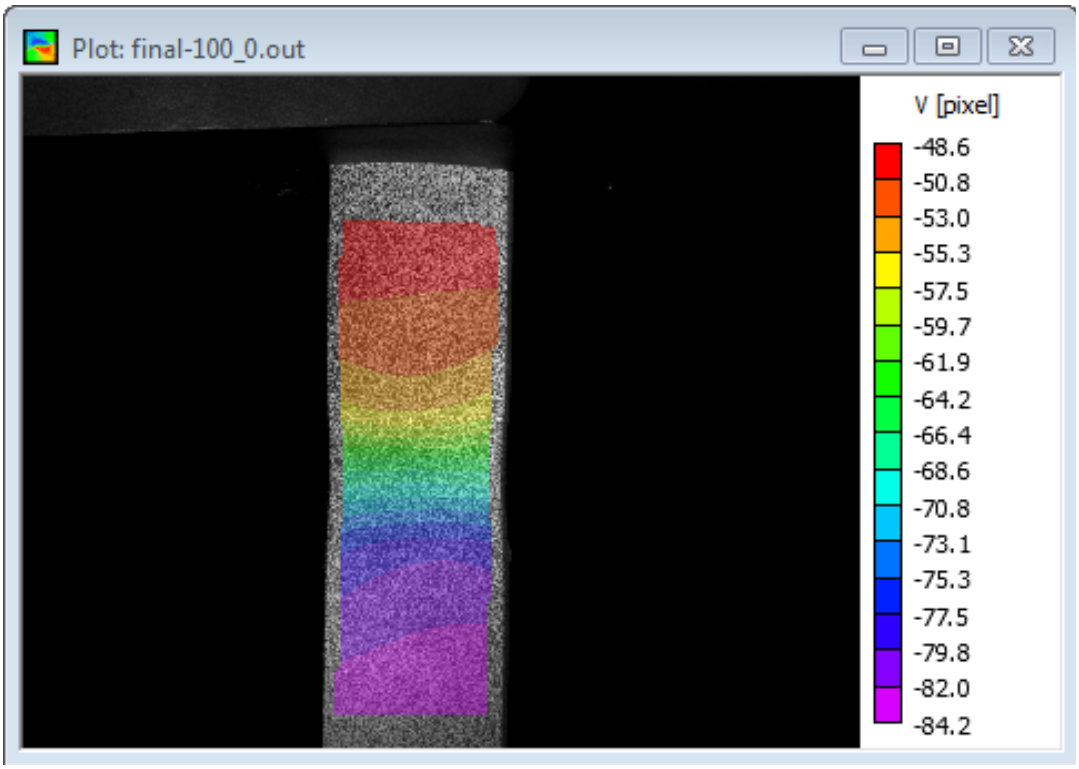
You can also change the shape of the subset in this dialog by dragging the subset nodes to change the shape and orientation.

VIEWING AND REDUCING DATA

To view your data, click Close on the analysis dialog once complete. The new data will be displayed in the Data tab at left:



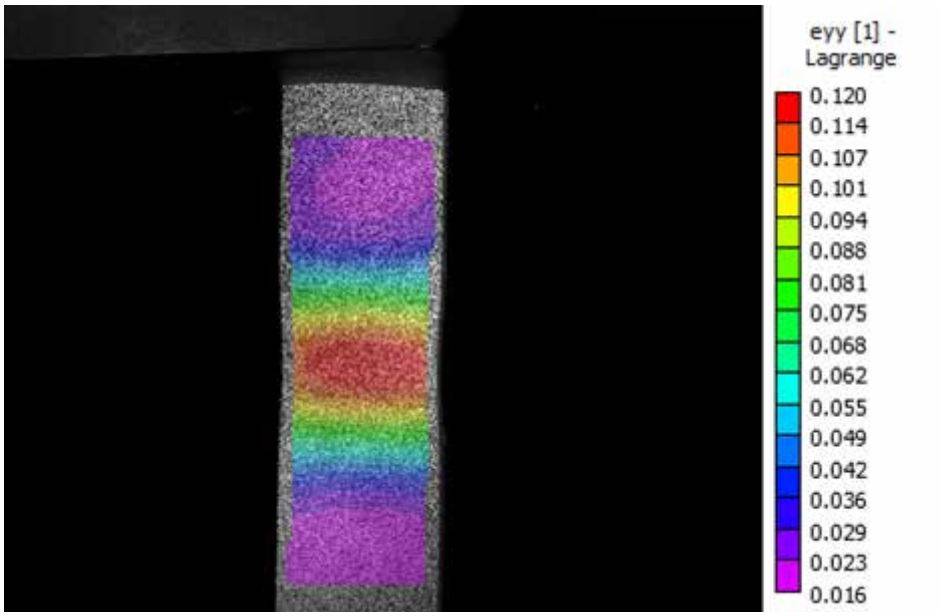
Double-click on a file to view:



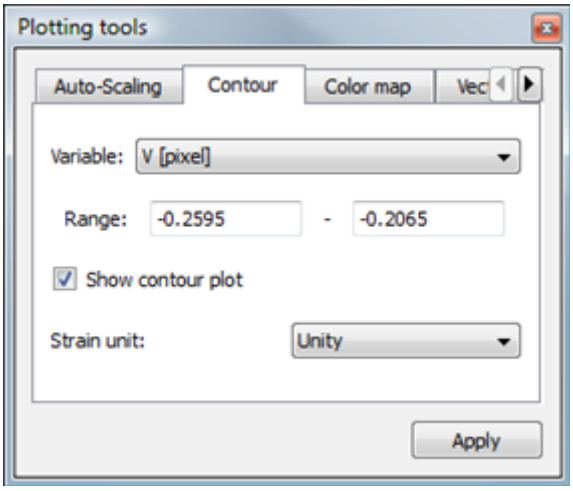
You can use the mouse wheel to zoom in and out, and click and drag to pan around the image. Right click to select different contour variables.

Available variables will be:

- **x [pixel]** – x location of the point in the image (in pixels)
- **y [pixel]** – y location of the point in the image (in pixels)
- **u [pixel]** – x (horizontal) displacement of this point (in pixels)
- **v [pixel]** – y (vertical) displacement of this point (in pixels)
- **sigma [pixel]** – the confidence interval for the match location (in pixels)
- **exx [1]** – the strain in X
- **eyy [1]** – the strain in Y
- **exy [1]** – the shear strain
- **e1 [1]** – the major principal strain
- **e2 [1]** – the minor principal strain
- **gamma [1]** – the principal strain angle, in radians



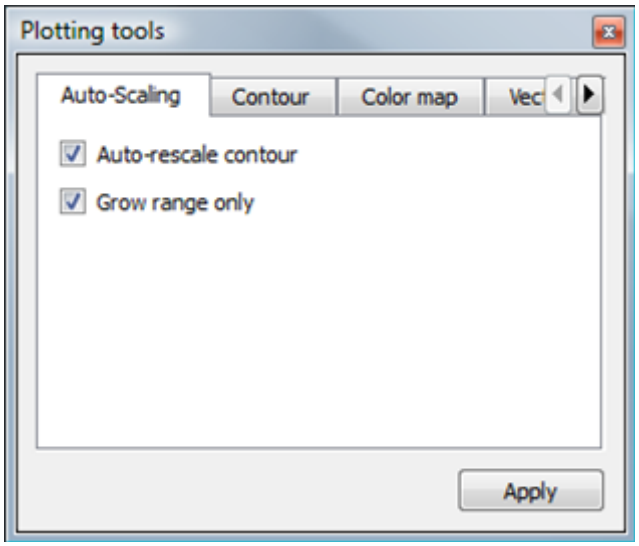
To edit axis and contour limits, use the Plotting tools toolset, at the left.



You may either auto-scale the contour limits, or clear the Auto-rescale box and manually enter limits.

To animate through the images, use the Animation toolbar:

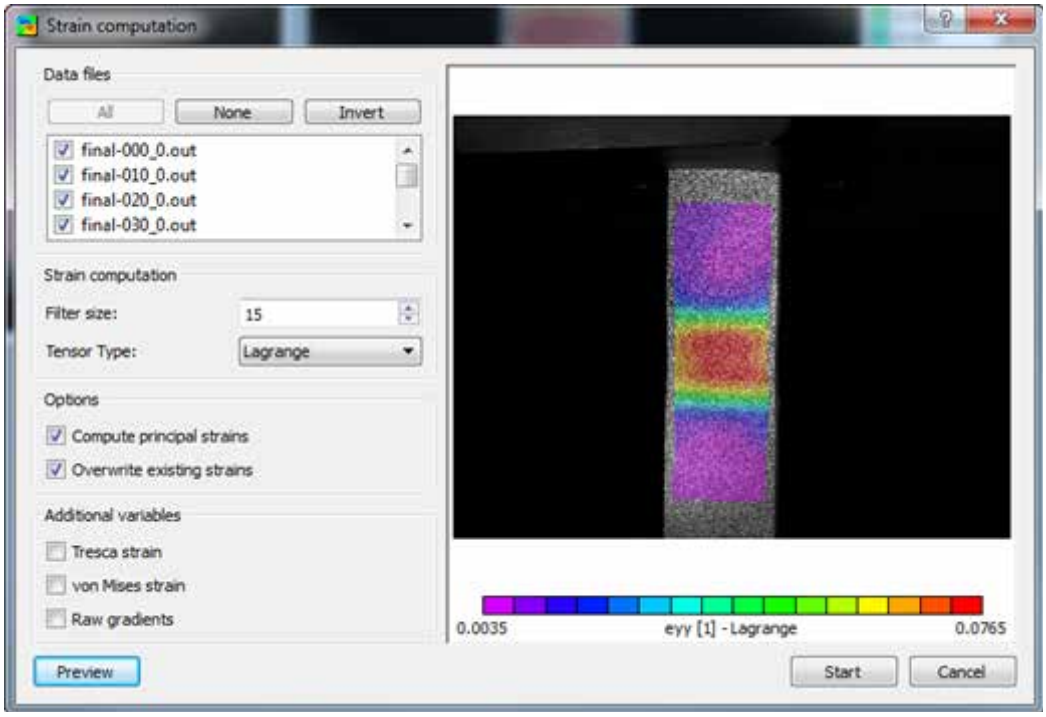
Or, videos can be exported by right-clicking in the plot and selecting *Export video*. You may want to set the contour scale to encompass the limits from all plots; to do this, turn on auto-scaling and the **Grow range only** option.



Then, play through all images; the scale will adjust to the global top and bottom limits. Then, export or display the video.
To save plots as images, right-click on the plot and select Save; or, you can right-click on any plot in Vic-2D and select *Copy* to copy the plot to the clipboard.

CALCULATING STRAIN

In Vic-2D, strain is automatically calculated at analysis time. To recalculate strain – with a different algorithm or filter size - select *Data… Postprocessing options… Calculate strain.*



Several options are available but the most commonly used will be the **Filter Size**. It may be necessary to make this value larger to resolve strain when strains are very small. To achieve better spatial resolution and see strain concentrations clearly, use smaller values.

You can calculate strain for all files by clicking **Start.** Alternately, you can adjust settings and see the effect on a single file by clicking **Preview**.

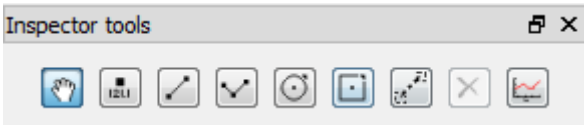
After strain calculation is complete, there will be new strain variables in the data set; right-click on the contour plot to view them. By default, you will see strain in the x- and y-axes (exx, eyy) and shear strain (exy), as well as first and second principal strain (e1, e2) and principal strain angle (gamma).

REDUCING DATA

Vic-2D provides a number of facilities to reduce data from the initial point cloud.

To export aggregate statistics only, you can select *Data… Export statistics.* Select the files and variables for export; the result will be a CSV file.

Tools for probing and extracting data are located in the Inspector Toolbar, and can also be selected by clicking PLOT... INSPECTOR in the main menu bar.



From left to right, the tools are:

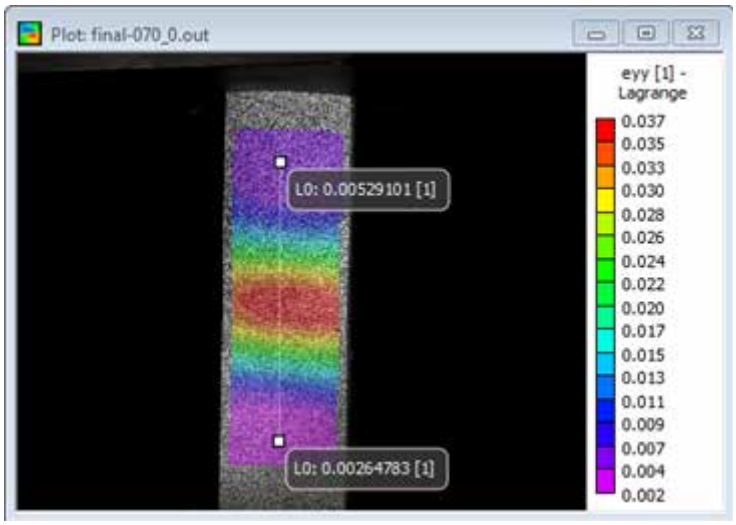
- Pan/Select: Pans around the contour image, when zoomed in; selects existing extract points. To select an item, click on the small square handle.
- Inspect point: select this tool and click to probe at a single point. The value for the currently selected contour variable, at the chosen point, will be displayed.
- Inspect line: select this tool and click once to start a line; click again to finish. The value will be displayed at each node.
- Inspect polyline: select this tool and click to create line nodes; double-click to finish. The value will be displayed at each node.
- Inspect circle: select this tool and click to define a center; click again to define a disc. The value at the center will be displayed.
- Inspect rectangle: select this tool and click to define a center; click again to define a rectangle. The value at the center will be displayed.
- Extensometer: select this tool and click two points; this tool shows the extension (change in length divided by initial length) between the two points.
- Delete: choose this tool and click on an existing point/line/area to remove it.
- Extract: click to open the Extraction dialog.

Once a tool is selected, you can place it on the plot by clicking.

- For the point tool, click once to place the point.
- For the circle, rectangle, extensometer and line tools, you can click once to place the first point, and again to define the shape.

Once a tool is placed, you can use the Pan/Select tool to move the inspector or to adjust the control points.

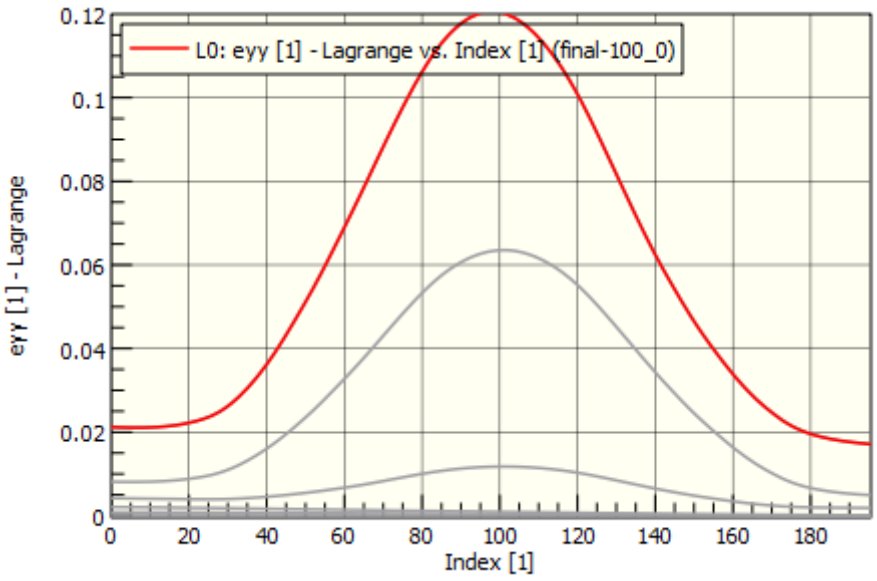
To look at a 2D slice of the data, open a 2D contour plot. Select the Inspect line tool from the Inspector toolbar:
Next, select a line by clicking two endpoints.



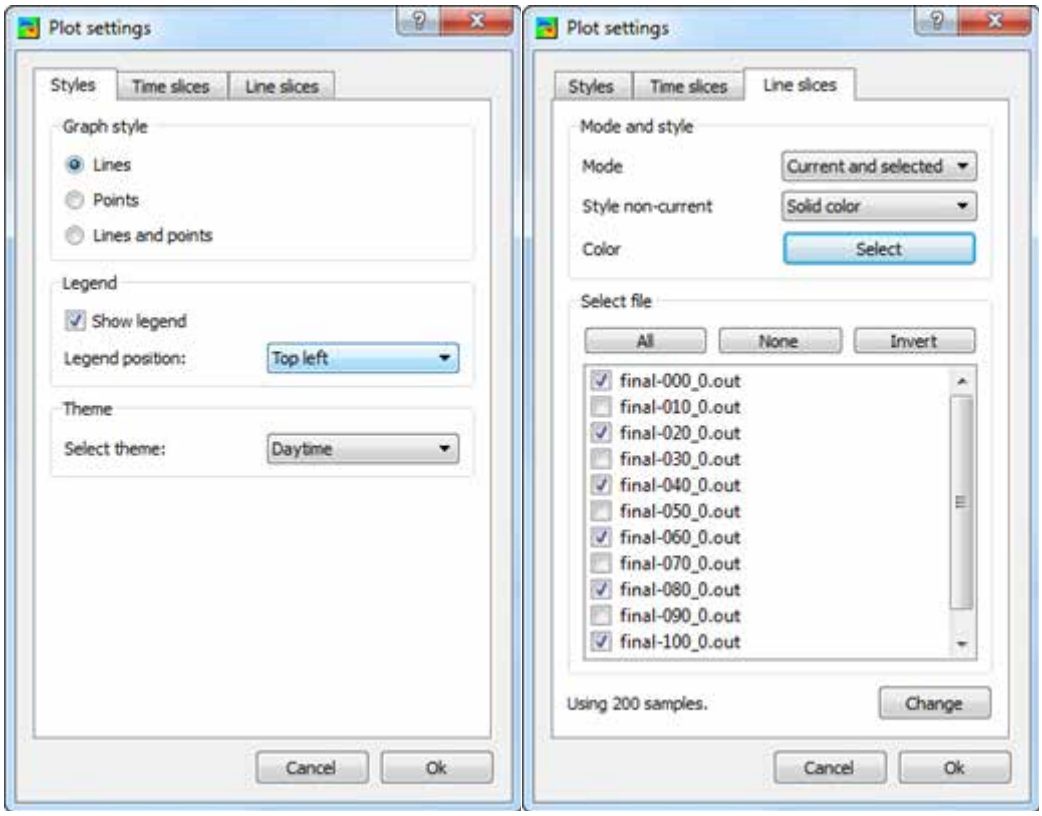
Next, click the **Extract** button in the Inspector toolbar.

You will now have an extraction plot, with your menu on the left side of the screen, which looks like the image above. Select “Line Slices” from the drop down. Next, select your variables for the X and Y axes and hit the apply button, ↵, for each of them.

You will see a plot of data along the line; you can select the data to plot from any of the available variables.

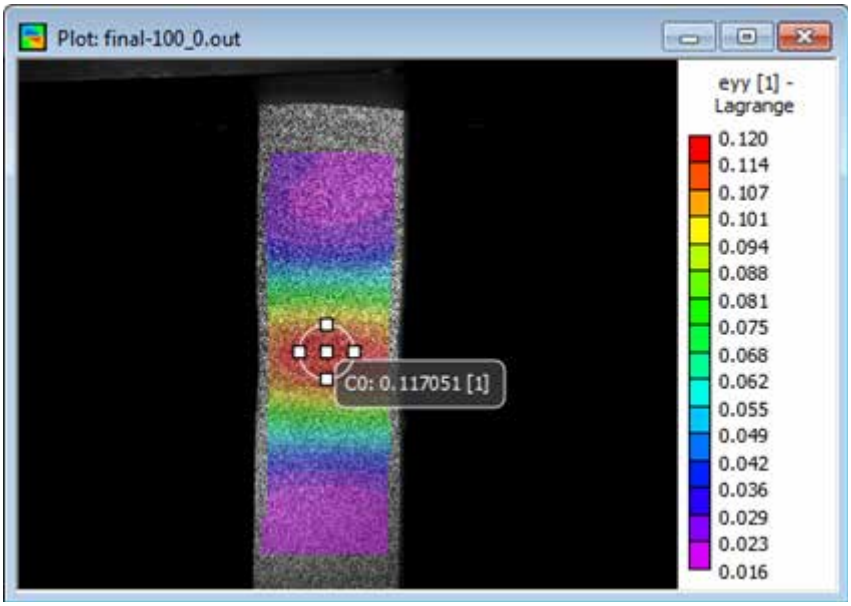


Here the current file (the .out file selected in Current Data) is red and the other lines that are shown are grey. In the Extraction Tools, the Settings will allow you to format the graph with the Styles Tab. The Line slices Tab allows for the user to select which files are shown in this line plot as well as additional format options for the lines.

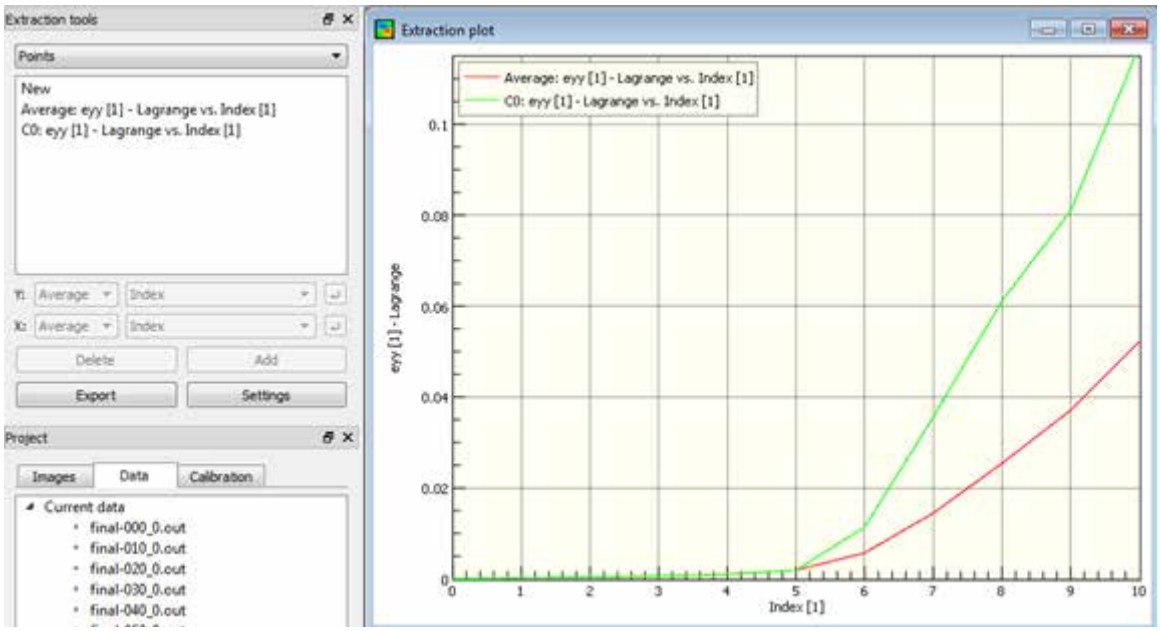


To save this extraction from one or many of the data files (csv format), click **Export**. To save an image of the plot, click **Save Plot.** You may also right click on the line plot and copy it to your clipboard.

You may extract data for a single point or area, over many data files. To begin this, click the point, disc, or rectangle icons in the Inspector tools while viewing a plot. Click in the plot to select the point or region to analyze; in this case, we'll select a small disc in the central region of the specimen.



Then, we click the **Extract** button in the Inspector toolbar. The following dialog appears:



Notice that the Average data automatically extracts, as well as the localized user-defined circle, labeled here as C0. The average data is the average of the entire AOI. Again the variables can be selected for each line here. You can select "New" to add several variables or data sets to the same plot. You can plot your data directly against your analog data with this interface too. The dropdown will also have an option for analog data if you have imported the data into the project (see next section).

ANALOG DATA

To bring in voltage and time data, you can select **Project… Analog Data** from the menu bar. Select the CSV log file for the project; it will appear under **Analog data** in the project tab. You can double-click on the file to view it as a spreadsheet.

After this, you can use the analog data as the X- or Y-axis in the **Extract Sequence Data** plot. This is useful for plotting, i.e., load against strain.

SUPPORT

If you have any questions about this document or any other questions, comments, or concerns about our software, please feel free to contact us at support@correlatedsolutions.com, or visit our web site at www.correlatedsolutions.com.

CSI APPLICATION NOTE AN-525

SPECKLE PATTERN FUNDAMENTALS

INTRODUCTION

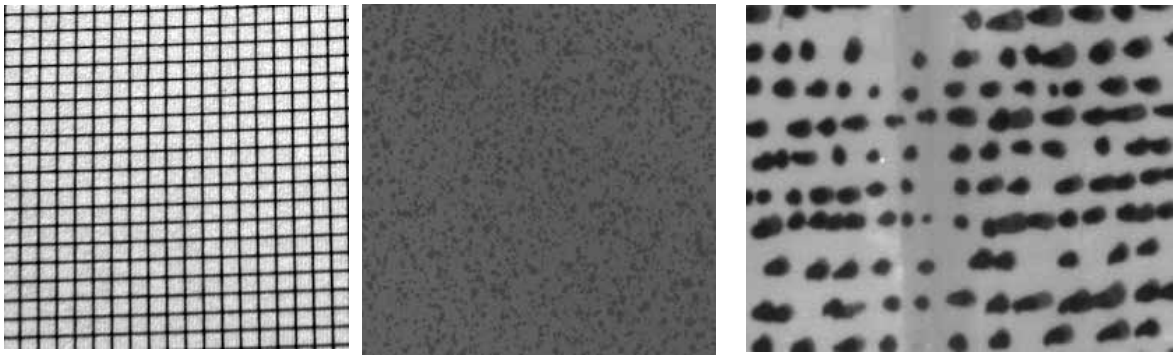
The digital image correlation technique relies on a contrasting pattern on the surface of the test specimen. This pattern can be painted; naturally occurring; or even projected on the surface, but a few tips will help to give the best pattern and the best results.

PATTERN REQUIREMENTS

To achieve effective correlation, our pattern must be

- Non-repetitive
- Isotropic
- High contrast

That is, the pattern should be random; should not exhibit a bias to one orientation; and should show dark blacks and bright whites. Below are examples of patterns that lack these characteristics to some degree.



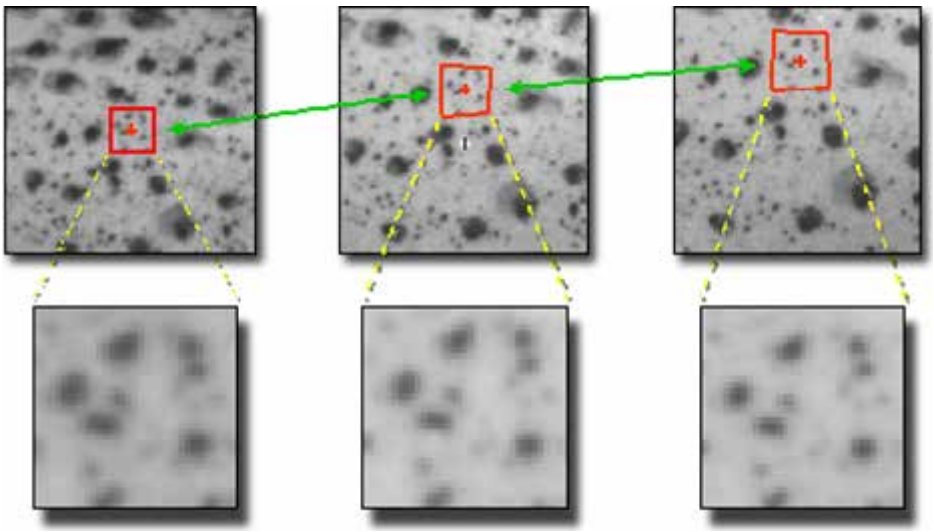
Repetitive **Low contrast A** **nisotropic**

BLACK VS. WHITE

While we refer to these patterns as speckle patterns, the software only sees a contrasting field; the speckles themselves are not the analysis unit. So, white speckles on black can work as well as black speckles on white, or a high-quality pattern may consist of neither.

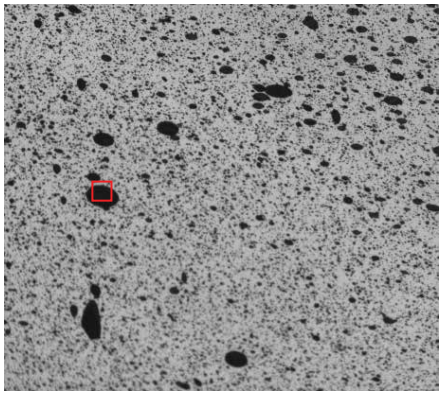
PATTERN SCALE

In addition to the above requirements, speckles should be neither too small nor too large. In practice, there is a very wide range in how large a speckle pattern may be, and still achieve excellent results, but having an optimal pattern will give the best flexibility. To understand what makes an optimal pattern, a bit of background on the theory will be helpful.

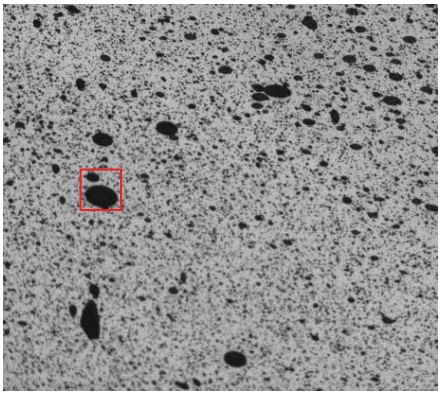


In DIC, a small subset of the image is tracked as the specimen moves and deforms. To perform the tracking, the subset is shifted until the pattern in the deformed image matches the pattern in the reference image as closely as possible; this match is calculated as the

total difference in gray levels at each point.
If the pattern is too large, we may find that certain subsets may be entirely on a black field or entirely on a white field. This does not allow us to make a good match, as we have an exact match everywhere in the field. We can compensate for this by increasing the subset size, but at the cost of spatial resolution.

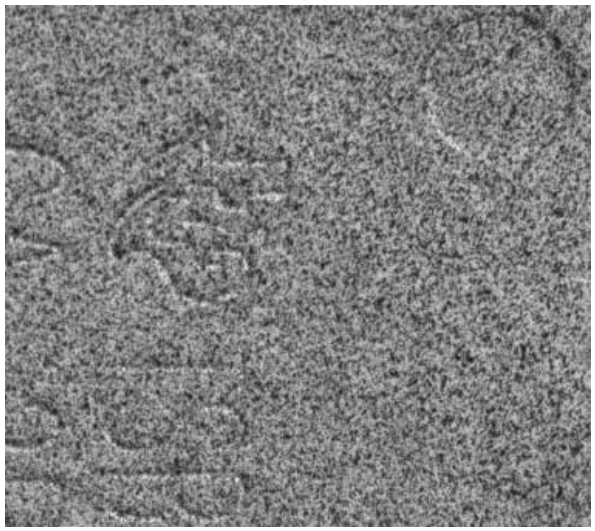


Subset too small for pattern – errors may result in black areas

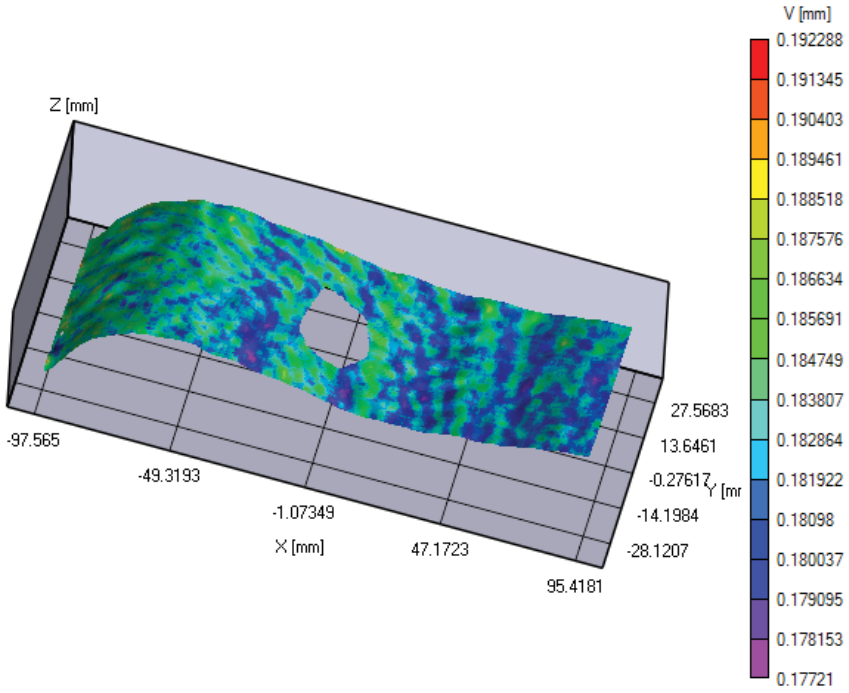


Larger subset will work, but reduces ability to measure fine gradients

Conversely, if the pattern is too small, the resolution of the camera may not be enough to accurately represent the specimen; in information terms, we can call this aliasing. Instead of appearing to move smoothly as the specimen moves, the pattern will show jitter as it interacts with the sensor pixels; resulting images often show a pronounced moiré pattern in the results.



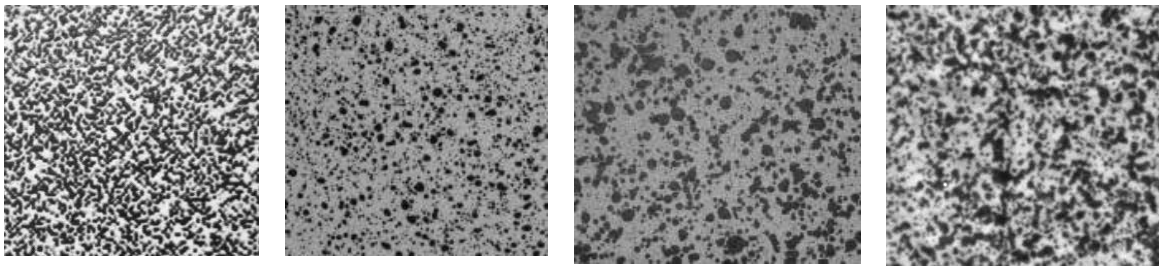
Pattern is too fine – aliasing could result



Characteristic moiré pattern due to aliasing

In addition, patterns that are too fine are very sensitive to defocus – out of focus regions may simply become gray. In general, speckles should be at least 3-4 pixels in size to avoid these issues. Put another way, speckles should be visible as distinct features, as opposed to random 'salt and pepper' noise.

The following patterns show a good contrast and size distribution:

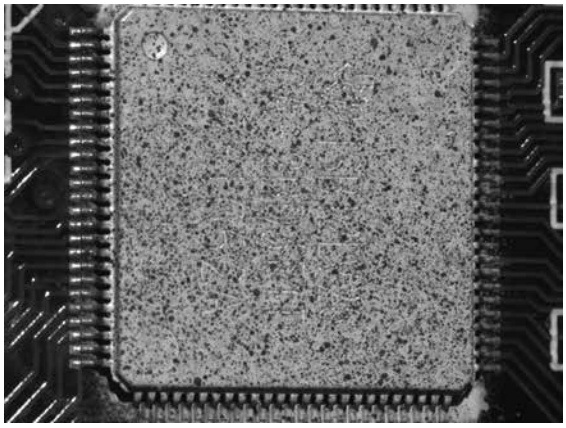


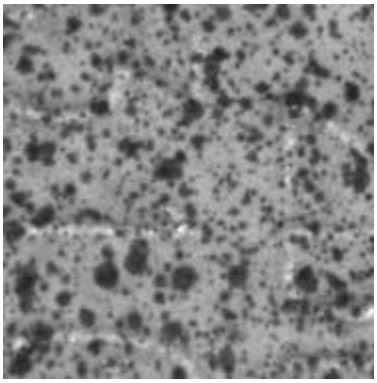
TECHNIQUES

SPRAY PAINT

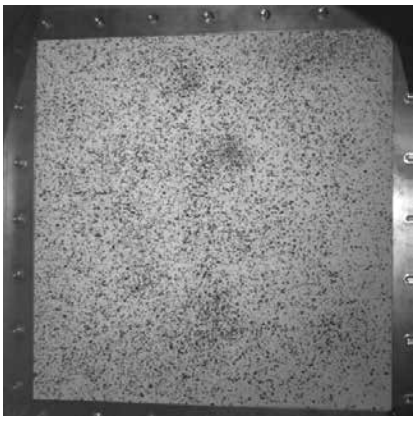
The most common technique for applying a speckle pattern is with ordinary paint. Paint can be used with any intermediate-sized specimen that will not be chemically affected by the paint, nor stiffened by it. This is usually the best choice for metal, ceramic, and composite specimens from ~1" (25mm) to ~48" (1.25m).

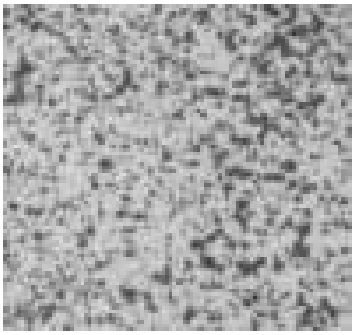
Choose matte paints; satin or gloss paints will show specular reflections, especially under intense lighting. Typically, the surface is coated with white paint, in several very light coats. Heavy coats may lead to drips which change the shape of the surface.
The speckle coat should be applied after the base coat becomes at least tacky; if the undercoat is wet, the paints will blend and blur. For smaller patterns, simply spraying the paint quickly past the surface in a sweeping motion can give a good speckle size. The specimen below is a 1" IC that was coated in this manner.





For larger fields, larger blobs must be produced. This can be effected by either modifying the nozzle, or throttling the spray. One effective technique is to place the surface horizontally, and spray over it. If the spray nozzle is barely pushed down, large blobs will come out and fall on the surface; the finer mist will spray over the surface, leaving a good, coarse pattern. The 48” panel below was painted this way.

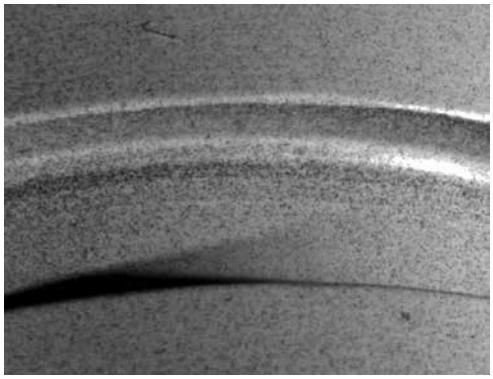


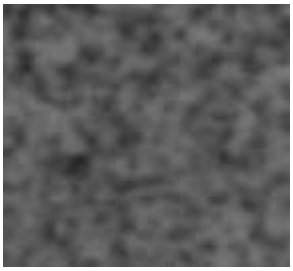


Note that spray paint techniques are prone to very fine mist on the surface, which can sometimes cause aliasing.

TONER

For very small specimens, a very fine pattern can be applied with toner powder. This method works well for specimens smaller than ½” (12mm). For this technique, the specimen should be coated white. Then, toner powder can be blown with a small lens blower, or by mouth, onto the surface. The pattern below was made with toner in a 2mm groove in a steel rod.

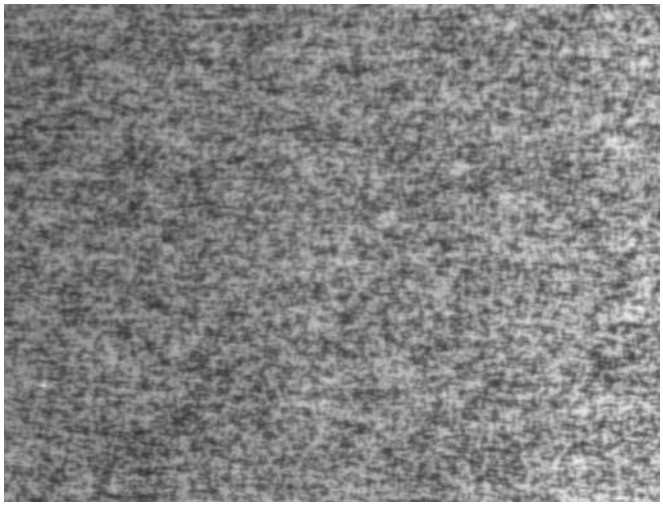




In some cases the toner can be blown onto a dry surface and static will keep it in place. For a more durable finish, the toner can be fused in an oven.

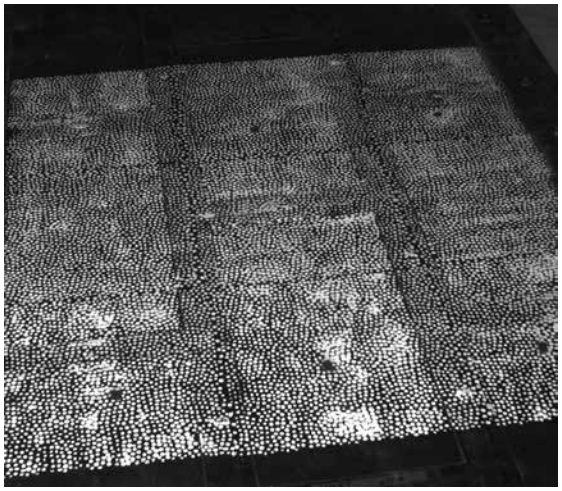
LITHOGRAPHY

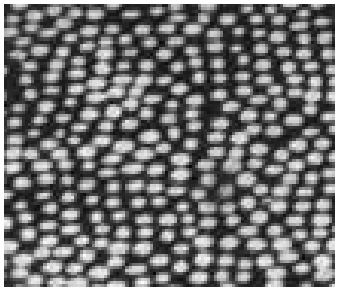
For extremely small specimens, patterns can be created with lithography or vapor deposition. The pattern below is chrome on glass and the field of view is ~0.02” (500 microns).



STENCILS

For very large specimens, a stencil can be used to roll or spray a perfect speckle pattern. Stencils can be made from thin vinyl with water or laser cutting techniques. The pattern below was applied to a 16’ (5m) panel.



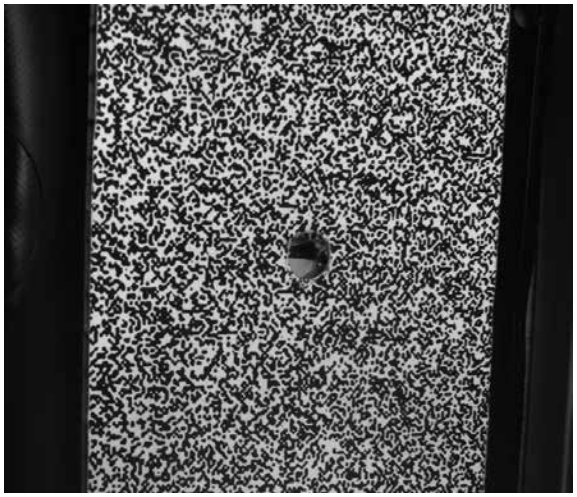


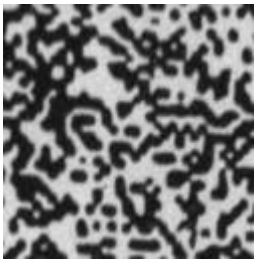
While this pattern appears somewhat regular, which violates our ‘random’ condition, there is more than enough variation for effective correlation.

PRINTING

For medium through large panels, printing of speckle patterns can be very effective. This technique has been used with specimens from 1” (25mm) through 12’ (4m).

Raster speckle patterns can be generated and printed on paper or vinyl appliqué. For specimens that will strain, vinyl is recommended. The pattern may be generated in software; printed using a laser printer or commercial roll plotter; and applied to the surface. The pattern below was printed on a full-sheet laser label.

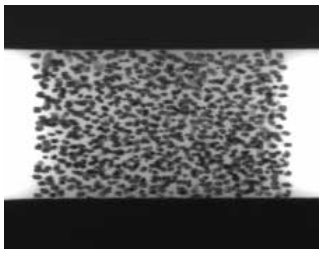


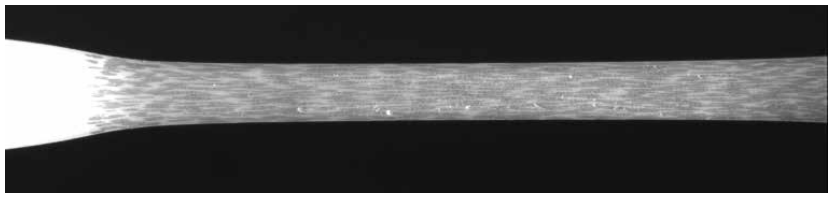


INK

For some specimens, ink – placed with a marker – is a good technique. This technique affects the surface minimally, and allows measurement of very high strain. The ink can simply be dotted onto the surface with a marker. This technique can be very time consuming for larger specimens.

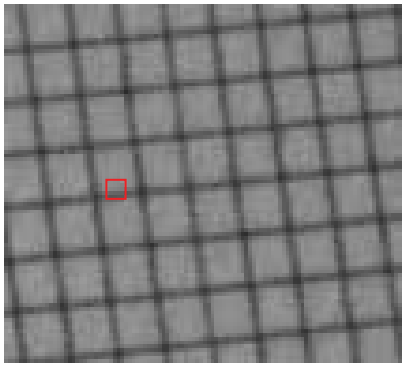
The pattern below was placed on a ½" (12mm) wide dog-bone of HDPE. The specimen is displayed before and after deformation; the correlation was successful at strains up to 400%.



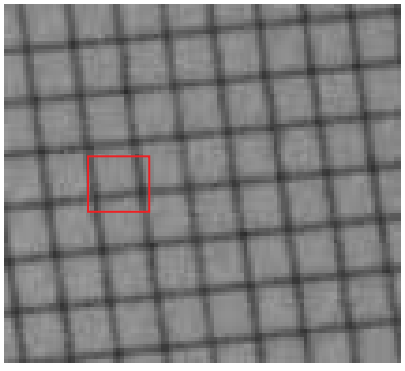


GRIDS

While grid patterns are neither necessary nor optimal for DIC, they may be used, with caution. Initial guesses must be selected carefully; with a nearly-perfect grid, it's possible for DIC to find a good match that is actually off by 1 or more grid spacings. In addition, the subset size must be large enough that at least one grid intersection is always contained.



Subset too small – multiple matches along line



Larger subset – constrained in both axes

INHERENT PATTERNS

Some materials such as wood or concrete display an inherent pattern. These patterns may be used for correlation if they have sufficient contrast, although an applied pattern is still usually optimal.

TEXTURES

Some specimens exhibit an apparent speckle pattern due to an inherent texture; examples include sand, rough metal, and concrete. Extreme caution must be used when using these textures as a pattern; because the shading comes only from light and shadow, it may often be inconsistent between the left and right camera, or may change in unexpected ways when the specimen moves or deforms. Because of these issues, this technique should only be used when alternatives are not available.

CONCLUSIONS

This information should serve as a guideline, but very good results have been achieved in specimens and patterns that fall far out of these guidelines. For help with challenging specimens and techniques, or for information about analyzing difficult or poorly prepared images, please feel free to contact support@correlatedsolutions.com, or your local representative. We'll be happy to help you look at options for preparation and analysis that will result in the best achievable results.