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SOLUTIONS

Speckle Kit User Manual

Version 6
2024


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JET BLACK

Speckle Kit User Manual

The speckle kit provides tools to help produce an ideal speckle pattern. An ideal speckle pattern provides good signatures throughout the area of interest so that consistent sized subsets may be tracked with certainty. Therefore, the certainty of our results is often defined by the quality of the speckle pattern.

What Makes a Good Speckle Pattern?

In order to provide good tracking information, your speckle pattern should consist of the following:

Random & High Contrast

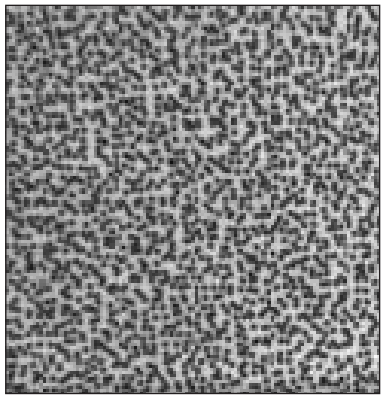
The best results come from irregular patterns of dark black dots on a bright white background or bright white dots on a dark black background. Note that false matching can occur if patterns repeat, so irregular patterns are preferable.

Consistent Dot Size

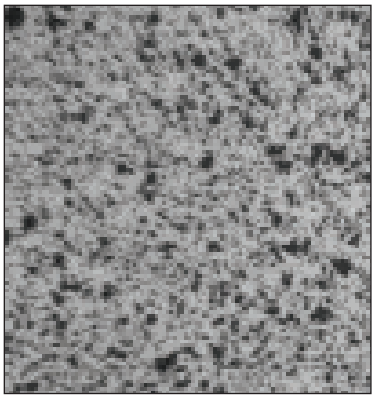
The dots should ideally be 5-10 pixels in size in order to optimize spatial resolution, but the most important thing is that the dots are mostly consistent in size and not too small (less than 3 pixels in size is too small and can cause aliased results). Dots larger than 10 pixels are also acceptable as long as they are reasonably consistent in size.

50% Coverage

Ideally, there will be equal amounts of white and black on the surface. Therefore, it is important to make sure the pattern is dense enough, which typically requires 2-3 applications using the roller or the stamp.



Ideal speckle pattern



Imperfect speckle pattern

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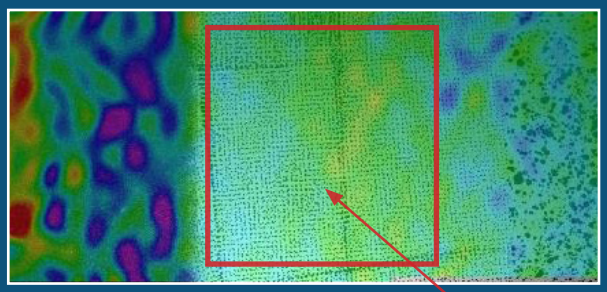
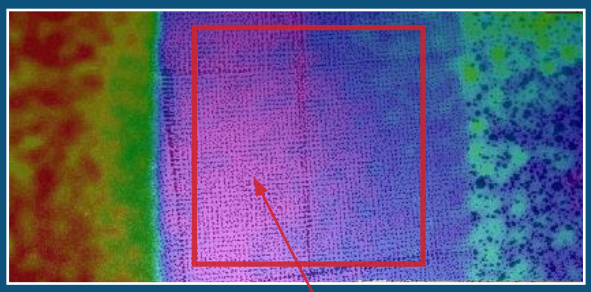
Why Do We Need a Good Speckle Pattern?

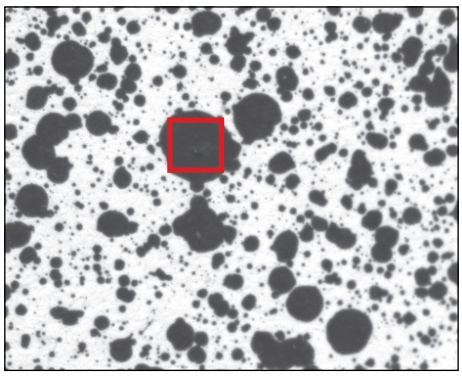
In digital image correlation, using an optimal speckle pattern is one of the most important factors in reducing measurement noise and improving overall results. A good pattern will allow the correlation to be made with high confidence and produce low noise. Below is strain noise and sigma (confidence) measurement data for a flat plate with different speckle patterns. **The middle region was created with the Correlated Solutions Speckle Kit and illustrates an optimal pattern for this particular test**, while the left and right regions were created with different speckling techniques.

Strain Noise (Exx)



Correlation Confidence (Sigma)





Speckles should neither be too small nor too large. In practice, there is a wide range of how large speckles in the pattern may be and still achieve excellent results. However, having an optimal pattern will give the most flexibility.

If the pattern has speckles that are too large, or if it is too sparse, we may find that certain subsets may be entirely on a region of black or region of white (shown at left). This prevents good correlation, because everywhere in that region is an exact match. We can compensate for this by increasing the subset size, but this is done at the cost of spatial resolution.

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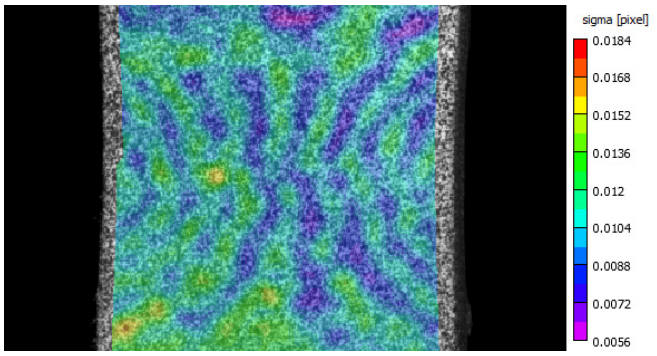
Conversely, if the pattern has speckles which are too small, the resolution of the camera may not be enough to accurately represent the specimen; in information terms, we call this aliasing.

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 showing a pronounced moiré pattern in the results (shown at right).



Speckle Kit Components

In order to provide consistent speckle patterns for various sample sizes and materials, the speckle kit includes:

- Stamp Rollers (6 sizes)
- Stamp Rockers (6 sizes)
- Accessories (ink pad, extra ink, hard-shell padded carrying case)

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Step 1 - Apply the Base Coat

The first step to applying any speckle pattern is to apply the base coat. The purpose of the base coat is to create as much contrast as possible. Speckle patterns may have a white base coat and black speckles OR black base coat and white speckles.

For the stamps, black ink is used, so the base coat must be white. For the rollers, you may use a white base coat and black speckles OR a black base coat and white speckles.

In rare cases, the material might be light enough or dark enough in color and have no glare so that a base coat need not be applied. For most cases, flat or matte black or white spray paint is applied for the base coat.

Note: there are limitations on shipping spray paint (hazardous material), so spray paint is not provided in the speckle kit. Spray paint can be found at local hardware or automotive stores. Flat or matte paint should be used.

To apply the base coat, swipe the spray paint across the sample quickly to create a thin layer. Repeat 3-10 times in order to provide full coverage.

For high strain applications (more than 15-20%), primer spray paint might be desirable for the base coat. Rust-oleum Clean Metal Primer holds 40% strain before it cures. However after about an hour, the primer will cure and become brittle.

For strains higher than 40%, it is typically best to use no base coat and ink-based speckles (the stamps work well for this), so that the pattern does not crack and deteriorate.

Most of the time strains this high are polymers, which tend to be light in color and non-reflective so a base coat may not be required. If the high strain material is clear, you may backlight it (careful that there are not visible fibers or elements within the material, since this is a surface measurement only).

When using the stamps, you must wait until the paint is dry to the touch (typically about 5-10 minutes will be sufficient). From here you may apply the speckles using Step 2A or 2B.

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Step 2A - Apply Speckles with Stamp Rollers

The series of stamps provide patterns for different fields of view (FOV), depending on the camera resolution (remember, we aim for 5+ pixels per dot). Below are the stamp sizes and corresponding field of view ranges for various camera resolutions. Choose the stamp size based off the field of view and camera resolution. If there are two stamps that work for your field of view, typically the smaller of the two is selected for better spatial resolution.

	0.007″ (0.18 mm) Dot Size	0.013″ (0.33 mm) Dot Size	0.026″ (0.66 mm) Dot Size	0.05″ (1.27 mm) Dot Size	0.10″ (2.54 mm) Dot Size	0.20″ (5.08 mm) Dot Size
1 MP Camera 1024 px across	0.9″ - 2.4″ 2.3 cm - 6.1 cm	1.7″ - 4.4″ 4.2 cm - 11 cm	3.3″ - 8.9″ 8.4 cm - 23 cm	6.4″ - 17.1″ 16 cm - 43 cm	12.8″ - 34.1″ 33 cm - 87 cm	26.6″ - 68.3″ 65 cm - 173 cm
2.3 MP Camera 1920 px across	1.7″ - 4.5″ 4.3 cm - 11 cm	3.1″ - 8.3″ 7.9 cm - 21 cm	6.2″ - 16.6″ 16 cm - 42 cm	12.0″ - 32.0″ 31 cm - 81 cm	24.0″ - 64.0″ 61 cm - 163 cm	48.0″ - 128.0″ 122 cm - 325 cm
5 MP Camera 2448 px across	2.1″ - 5.7″ 5.4 cm - 15 cm	3.9″ - 10.6″ 10 cm - 27 cm	8.0″ - 21.2″ 20 cm - 54 cm	15.3″ - 40.8″ 39 cm - 103 cm	30.6″ - 81.6″ 78 cm - 207 cm	61.2″ - 162.2″ 155 cm - 415 cm
16 MP Camera 4872 px across	4.3″ - 11.4″ 11 cm - 29 cm	7.9″ - 21.1″ 20 cm - 54 cm	15.8″ - 42.2″ 40 cm - 107 cm	30.5″ - 81.2″ 77 cm - 206 cm	60.9″ - 162.4″ 155 cm - 413 cm	121.8″ - 324.8″ 309 cm - 825 cm

**All specs in the table above refer to the larger of the two camera dimensions. This is especially important for the 2.3 MP sensors provided by Correlated Solutions, which have a large aspect ratio (1920 x 1200 pixels). The same method is used on the labels that are on the rollers.*

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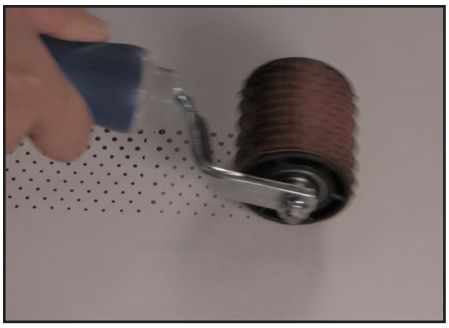
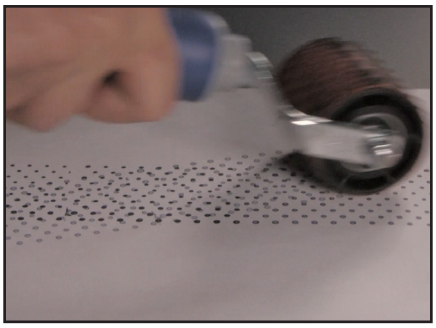
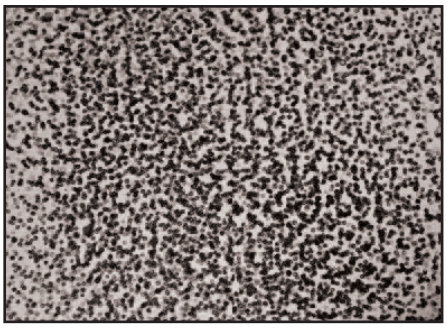
Prepare Roller

The rollers are designed to be used with a flat ink pad (included). Extra ink for the ink pad is also provided in the kit. The flat ink pad (used in conjunction with the extra ink) creates much darker dots than previous self-inking versions. Darker dots mean better contrast (better pattern/lower noise in data). After you determine the appropriate size roller, unscrew the wing-nut from the handle and slide the roller into place. Replace the wing-nut and tighten.

Apply Speckles

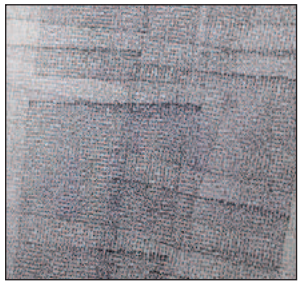
You can roll the stamp in patches over large areas. The stamps only have about 10% coverage, so you have to apply several times (5-10 times) for each patch. These patches may overlap so you can cover a larger field of view.

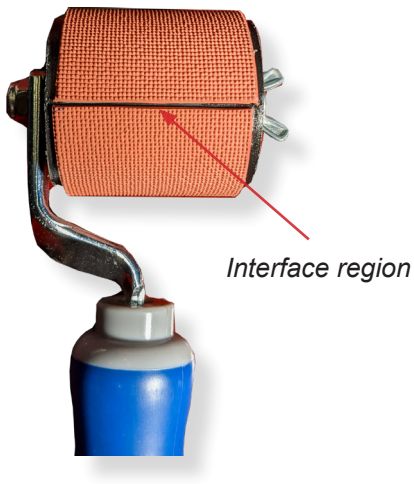




Notes for the 0.007" and 0.013" Rollers

The interface on the roller can leave a line, which is more visible for the smaller 0.007" and 0.013" rollers. Sometimes it is best to avoid a full rotation and the interface. Since the small dots are for smaller fields of view, the full rotation is not necessary to cover the entire field, as it would be to cover a larger field.

The two images below show patterns made with the same roller. The pattern on the left was created by continually rolling over the surface without regard for the interface region. The pattern on the right was created by avoiding the interface region entirely and represents a better dot coverage.



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Step 2B - Apply Speckles with Stamp Rockers

The speckle kit also comes with a series of 5.75”x5.75” flat stamps with cling backings. The cling backings allow for the stamps to be mounted to an acrylic rocker mount, which also comes with the system. The speckle sizes for the rocker stamps are the same as the stamp rollers (with the same corresponding fields of view). The rocker mount is used with the same ink pad that the rollers use.

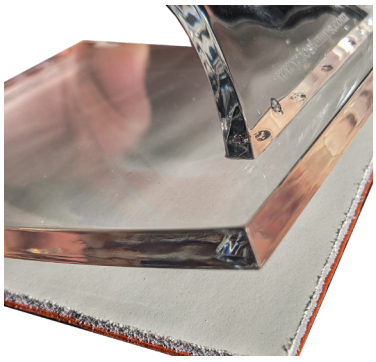
Select Stamp Size

The series of flat stamps provide patterns for different fields of view, depending on the camera resolution. These are the same dot sizes that are available for the stamp rollers, so refer to the table on page 6 to select the stamp size based off the field of view and camera resolution. Again, if there are two stamps that work for the field of view, typically the smaller of the two is selected for better spatial resolution.

Note: larger dot sizes are available by request.

Mount Stamp to Rocker

The back surface of the stamp uses static to stick to the acrylic rocker.



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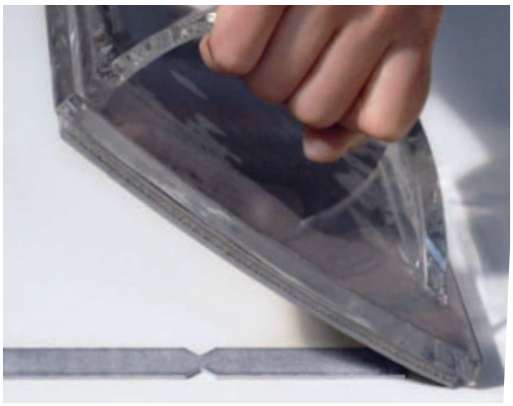
Apply Stamp

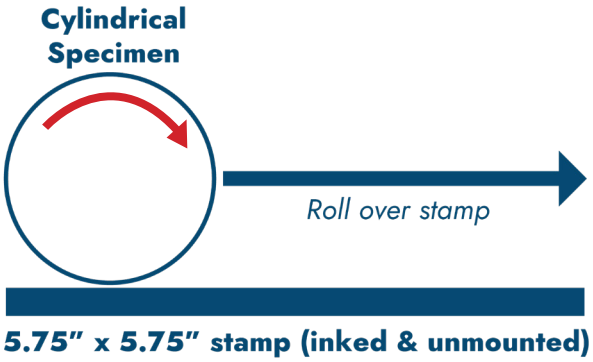
Similar to the roller, you can apply the stamp rocker in patches over large areas. The stamps only have about 20% coverage, so you have to apply several times for each patch (about 5-10 times). These patches may overlap so you can cover a larger field of view.



This stamp mount has a slightly curved surface so that you may rock it over the sample for more effective coverage.

Cylindrical Samples

For larger cylinders, the stamp rollers usually work well. However if the cylinder is smaller (less than a foot or so in diameter), sometimes a better method is to ink the flat stamp (the 5.75”x5.75” stamp, but leave it unmounted from the rocker) and lay the stamp face up on a flat surface. You can then roll the sample over the flat inked stamp.



Challenges for Roller & Rocker Stamp Applications

The rollers and rocker stamps have trouble with surfaces that have a lot of texture, divots, indentations, and ridges. The stamps simply cannot get into such indentations on the surface. However, if you have a marker that creates similar sized dots, you can use that to add dots in regions that the stamp missed. Sharpie markers work well.

Another challenge is that the stamp ink can be reflective. Please be careful to check if there are white reflections creating glare within the black dots. If glare is present, then the lighting will need to be adjusted. If the testing is semi-static and you can test under ambient/room lighting, this is typically ideal because the lighting will be diffuse. Polarizing filters can eliminate glare and reflections as well.

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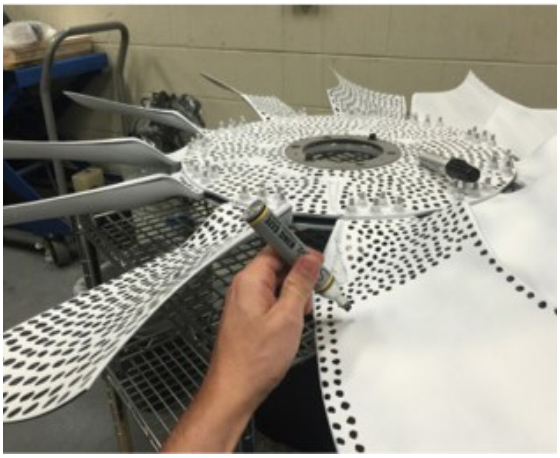
Step 2C - Apply Speckles with Other Techniques

The speckle kit is designed to work for most applications, but since DIC is applicable to such a wide range of applications, it cannot possibly work for all instances. Details of speckle pattern preparation and speckle method suggestions are elaborated on in the **Speckle Pattern Fundamentals Application Note** which is available at *correlatedsolutions.com/support*. Some examples of other speckle pattern application methods are discussed below.

Sharpie/Permanent Marker

Sharpies/Permanent Markers provide the ideal pattern for a very wide range of shapes and materials. If the base coat is white, they provide perfect contrast. Sharpie dots have consistent sizes. Ink-based speckles, like Sharpies, strain much higher than paint-based speckles, and applying the dots is very controlled. A 50% dot coverage can be applied throughout the whole surface, no matter what the shape and texture. There are several point sizes available (ultra-fine point, extra fine point, fine point, marker, and bold point).



There are several sharpies included in the Tool Kit that comes with most standard VIC systems. The only significant disadvantage of this method is the application time, which is substantial compared to other application methods. Also worth noting is that often times many markers are typically needed for just one sample because they dry out after hundreds/thousands of dot applications.

Silver Metallic Sharpies are available to speckle specimens that are dark in color and require a dark base coat. The silver images more matte than one might think and provides good contrast against the black.

Printed Adhesive Labels

Printed patterns are one of the most controllable speckle methods. There is a speckle pattern generator available for free download at *correlatedsolutions.com/support*.

This program allows for adjustment in dot density, dot size, variation and field size. You may print on any printer. Adhesive labels can work very well (perfect contrast, consistent dot size, 50% coverage, ideal pattern), but they must adhere to the surface well enough to deform with the surface. Any slippage on the surface will not represent the strains occurring on the actual surface that is being tested. Another challenge with adhesive labels is avoiding folds and bubbles when applying. Folds and bubbles will also not accurately represent the behavior on the material's surface.

High Heat Applications

There are spray paints available at most local hardware stores that are designed for conditions up to 1200 degrees F. Enamel paints are available up to 2000 degrees F.

There are also inks designed for high heat applications. The Industrial Sharpie Pro is rated for 500 degrees F.

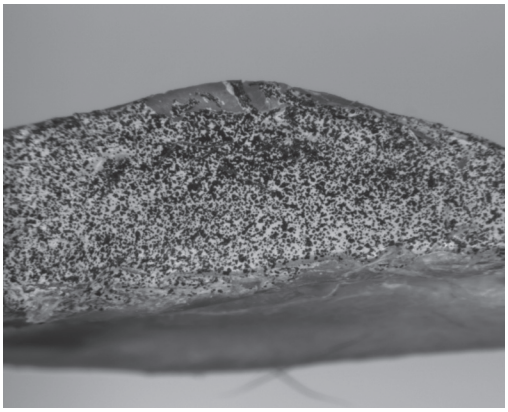
Small Pattern Application: Printer Toner/Carbon Black/ Graphite Particles

Also for fields of view ranging 0.25” - 2”, particles such as printer toner, carbon black and graphite work well. The particles have a tendency to clump, so applying evenly spaced dots is very challenging. You can simply wipe the particles across the surface, or use compressed air to blow the particles on. Using air to blow the particles typically works better. You may use compressed air from a can, a compressor or even a rubber dust blower. The particles typically statically cling to a painted surface well, but can rub off if the surface touches anything. Applying the dots while the base coat is still wet can make the particles adhere better. Heating the surface will fuse the particles very well. Some printer toner will melt under heat and create a good looking pattern. This is acceptable if the heating has occurred before the testing, but printer toner is not ideal for high heat testing.

Note that for small fields of view, the images can be diffraction limited. If images are diffraction limited, speckles 10+ pixels in size are recommended.

Small Pattern Application: Airbrush

For fields of view ranging 0.25” - 2”, airbrushes work well. Airbrushes produce dots that are much more consistent than a spray painted pattern. Again, if images are diffraction limited, as they often are with high magnification applications, speckle sizes of 10+ pixels are recommended.



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Spray Paint

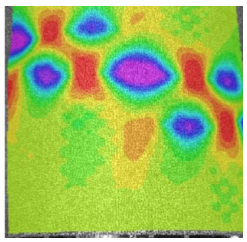
Perhaps the most readily available, quickest, and simplest methods of applying speckles is with spray paint. There are several methods of application. If creating small dots, take quick passes with a thin mist of paint across the sample (this is typically good for a 1" - 3" field of view). If creating large dots, one may create a "sputter" with the can by applying pressure to the nozzle, but not enough pressure for a full spray mist to come out. This will create big drops of paint. For most fields of view, it is hard to create consistent dot sizes. There often is a fine mist of dots mixed with larger dots, effectively graying the basecoat out and reducing contrast. Because of this, spray painted patterns may not be ideal patterns for applications that require a very low noise floor, for example if strains are 100-1000 microstrain and if the desired displacement resolution is less than 1/50,000th of the field of view (for instance, less than a 20 micron resolution for a 1 meter field). If strains are more than a percent and if the desired displacement resolution is more than 1/50,000th of the field of view, then often times a spray painted pattern is sufficient.

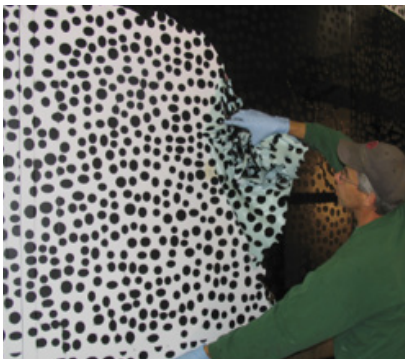
Be Creative

Throughout the years, customers have created clever pattern applications that suit their specific applications. There might be a speckling solution yet to be discovered for your unique application that presents different challenges. Here are some unique DIC applications that have required creative speckling solutions:

- Biomedical applications often involve wet tissues. Ink works for many applications, but sometimes the tissue must be submerged in fluid, presenting additional challenges. There are microbeads that bond well to biological materials that have been used in those situations.
- Very large scale applications can include bridges, trucks, or planes that are 10's or 100's of meters. Using a very large stencil, like a large vinyl sheet can work very well. The dots will be so big that you can simply roll paint over the stencil (using rollers that are used to paint interior building and home walls).
- Very high heat applications get very challenging. Some applications are so hot that most materials emit IR and glow at that temperature. Some applications are hot enough that materials combust.
- There are VIC-2D and 3D systems than can image down to an 800 micron field of view. Speckling a field that small is very challenging. Photolithography printing and vapor deposition can create patterns for very small fields. Particles like carbon black are small enough, but it's almost impossible to apply the powders without clumping on that small of a scale. However, TEM grids can be used as templates/stencils and the powder can be pressed through the grid, creating patterns for down to an 800 micron field of view.







Clean up

Speckle rollers/stamps that have been used with archival inks can be cleaned with a drop of dish soap and a soft brush or a wet wipe. Wet the roller/stamp and the brush, add a little soap to the brush, and scrub the rubber ever-so-lightly to clean off the ink. Rinse the rubber and repeat as necessary.

Note: light staining may occur on rubber and acrylic mounts.

Fundamentals of Speckling Video

Scan the QR code below for free access to a video which covers the fundamentals of creating an effective speckle pattern for digital image correlation. This tutorial covers the theoretical background of DIC, reviews general speckle pattern requirements, and outlines some common application methods.

Support

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