Aalto University
School of Engineering

Guide for uniaxial tension test at room temperature with DIC measurement

Preparation for the Measurements

1. Clean the surface of the samples before testing. Mark the serial number for each test.

Figure 1 Samples before cleaning (left) and afterwards (right).

2. Use the vernier caliper and stereo microscope to accurately measure the dimensions of the samples.

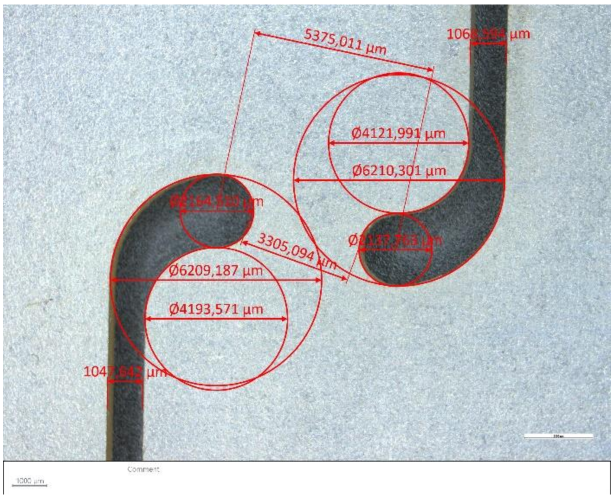

Figure 2 An example of the detailed measurements using stereo microscope

3. Paint the samples at the day of testing. First, apply an even layer of the white background with white spray (Glossy white RAL 9003, Maston). Then use the black spray (Matt Lackspray RAL 9005, Wuerth) to produce the speckle patterns with contrast.

Figure 3 Spray colors for DIC patterns

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4. Review the condition of the pattern using the Vic-snap (version 9) to acquire a static image. Check the following conditions:

- Digital image correlation (DIC) pattern that is too coarse (i.e. fewer than 3 features per intended subset size) or too fine (i.e. features that are smaller than 3 pixels)
- Defects in applied pattern (e.g. scratches, smudges, foreign objects)
- Out-of-focus regions of the image, overexposed or underexposed regions
- Poor contrast, resulting from the color and thickness of the paint
- Non-uniform lighting, either across the field-of-view (FOV), in time, or between two cameras in stereo-DIC
- Dirt or foreign object on lens or camera detector, glare from the lab environment
- Vibrations or other camera motion (some of which can be detected by zooming in on a live image and looking for non-random motion)

DIC system setting

1. Warm-up the cameras by turning them on and operating at the target frame rate, check the signal and image acquisition from Vic-snap program until a stable operating temperature is reached.

2. Place the sample inside of the gripping system of the tensile machine, then set up for the cameras by adjusting the following parameters:

- Distance between the test frame and the cameras, a coarse adjustment by moving the tripod with tape measure.
- Distance between two cameras (for stereo-DIC).
- Angle between the target and the cameras.

Note that only move the system along one single degree of freedom at each time, such as translating the rig backwards away from the test frame, or rotating the bar on which the two cameras are mounted…

- Adjust the lightening, ensure the contrast is sufficiently large and uniform across the entire target for both cameras for stereo-DIC, if necessary, adjust the exposure time.
- Adjust the aperture and focus of the cameras, the brightness and focus may differ slightly depending on the quality of the pattern on the sample. Therefore, check the live image from Vic-snap 9 program, until the image quality is acceptable.

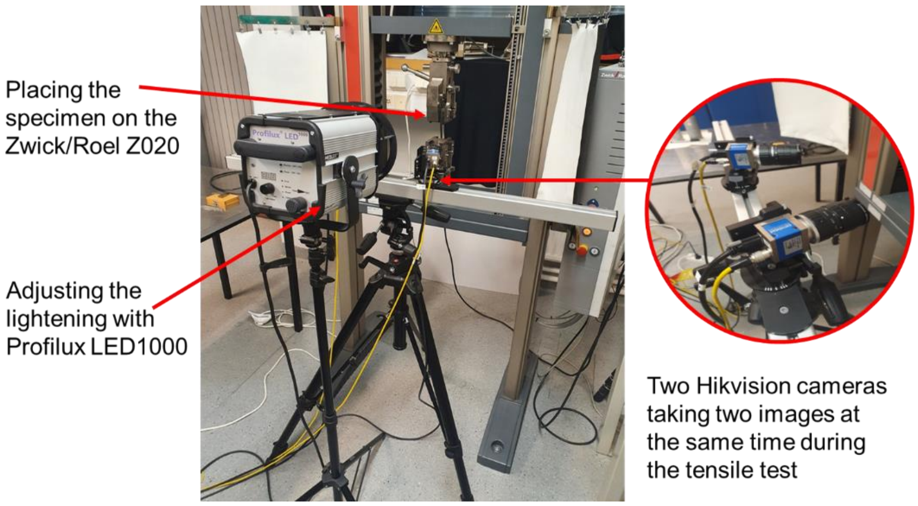

Figure 4 DIC system setup

3. For stereo-DIC measurements, ensure the two cameras are synchronized to each other. Review the data acquisition plan, and ensure any external signals (i.e. force, extensometers, strain gauges, etc.) are synchronized with the DIC camera(s).

4. Fine tunning the cameras with sensitive adjustment. The DIC camera detector has a resolution of 20 pixels/mm and the distance to the sample is 305 mm (SDB) and 170 mm (NDB).

5. Changing the FOV with extension ring (recommended only for SH profile only).

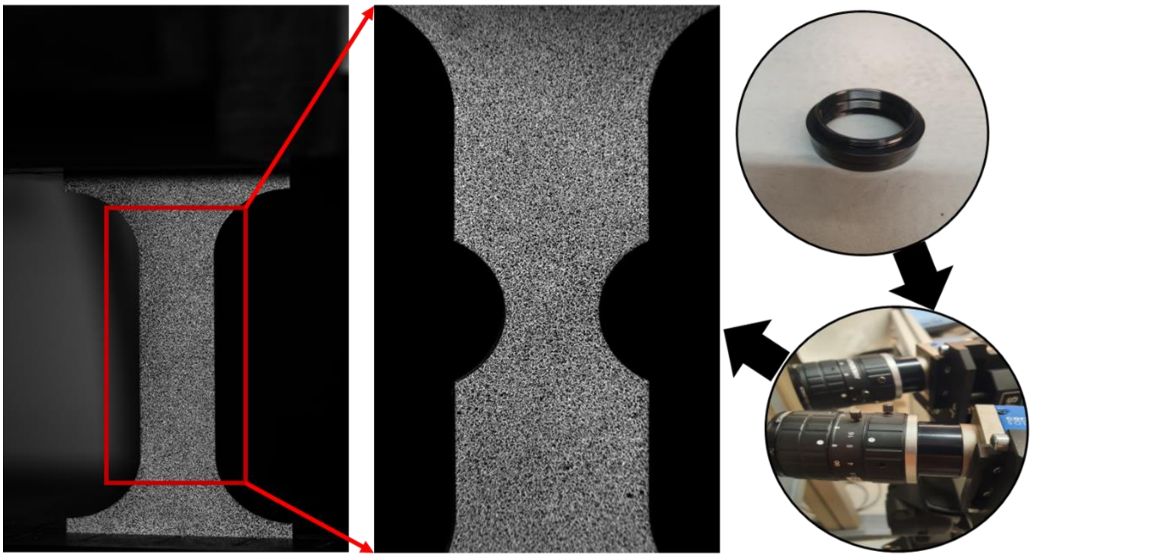

Figure 5 Camera with extension ring of 15 mm

Calibration DIC system

1. Select a calibration target of an appropriate size. e.g., 14×10×4 mm target plate for the 30×100 mm SDB specimens without extension ring, and 14×10×3 mm for the 30×100 mm SH samples with extension ring.

2. Move the calibration target in the following positions and orientations to acquire 30-40 images.

- Rotate about the horizontal image axis.
- Rotate about the vertical image axis.
- Plunge towards and away from each camera, along its optical axis.
- If the calibration target is smaller than the FOV, translate horizontally and vertically, so that features from the calibration target fill the entire FOV of each camera.
- Rotate 90 degrees about the optical axis and repeat the above steps.
- Perform combinations of the above positions and orientations (i.e. rotate about the horizontal and vertical axes simultaneously while plunging along the optical axis).

3. Save the images within a folder named after the actual date of the calibration before closing the program.

DIC measurement during tension test

1. Change the parameters for the tensile machine. To aim at a quasi-static strain rate of the test, the maximum force and crosshead velocity shall be calculated. The equation for crosshead velocity shall

be, strain rate = crosshead velocity (mm/s) / gauge length. (e. g. crosshead velocity is 0.36 mm/min with a strain rate of 2×10^{-4} for the SDB samples with gauge length of 30 mm, and 0.18 mm/min with a strain rate of 1×10^{-4} for the notched samples with gauge length of 30 mm).

2. Open the program Vic-snap 9 and create a new folder with the testing information, where the testing images shall be saved.

3. Synchronize the image frequency and the testing frequency (saved frame per time) on the Vic-snap and start synchrony the tensile test and the recording of the images. Ideally, use the same frequency for both systems, e.g., record one set of images per 2 seconds, and output one force data per 2 seconds.

4. When the test is finished, check the quality of the images with a coarse calculation and proceed further.

Postprocessing of the data

1. Start the program Vic-3D (version 9).

2. Import the files of the sample images as the field speckle images together with the calibration images.

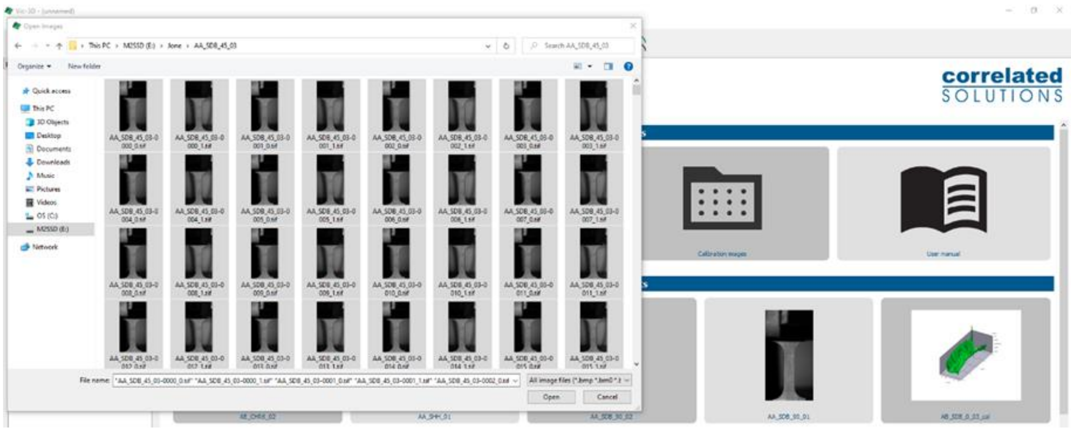

Figure 6 Import speckle images

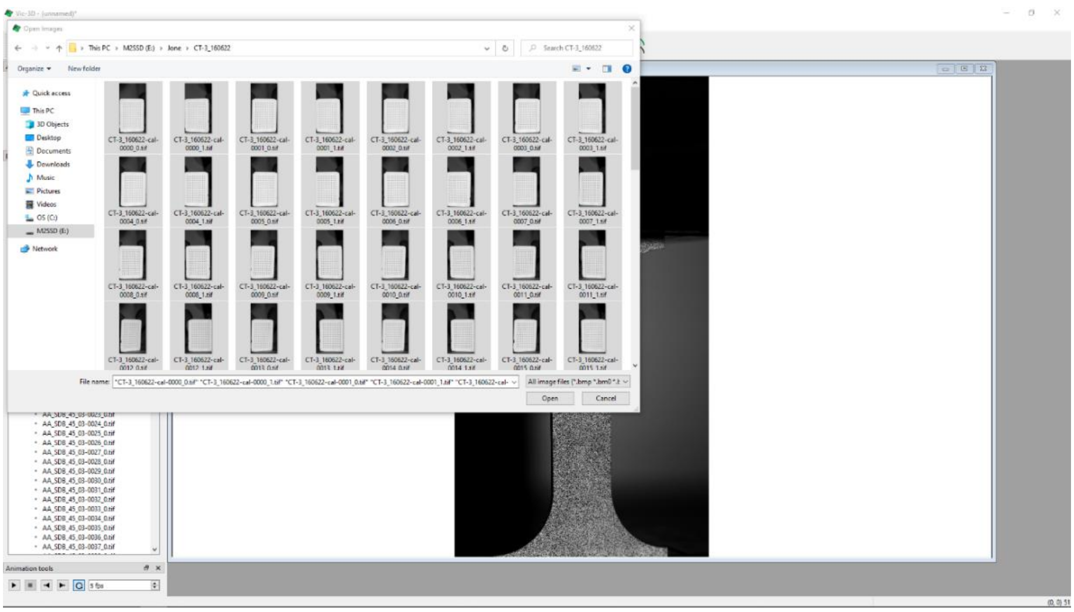

Figure 7 Import calibration images

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3. Save the project file and the upcoming outputs in a new subfolder under the testing image path.

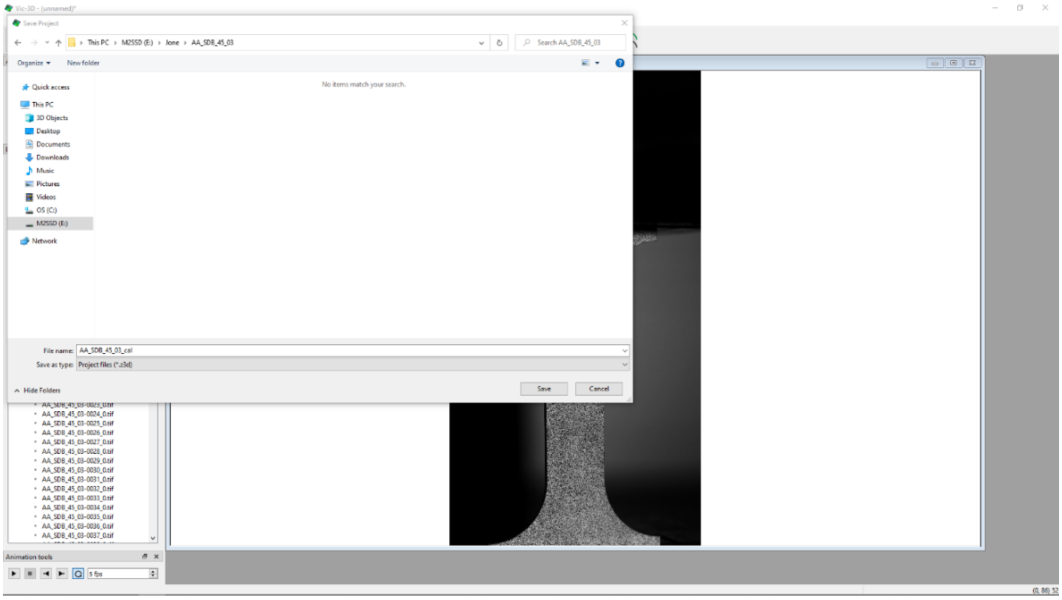

Figure 8 Save the project file and outputs in a subfolder

4. Start the calibration from the toolbar by clicking on the calibrate stereo system. The score value shall be around 0.030. By accepting the results, the calibration is finished.

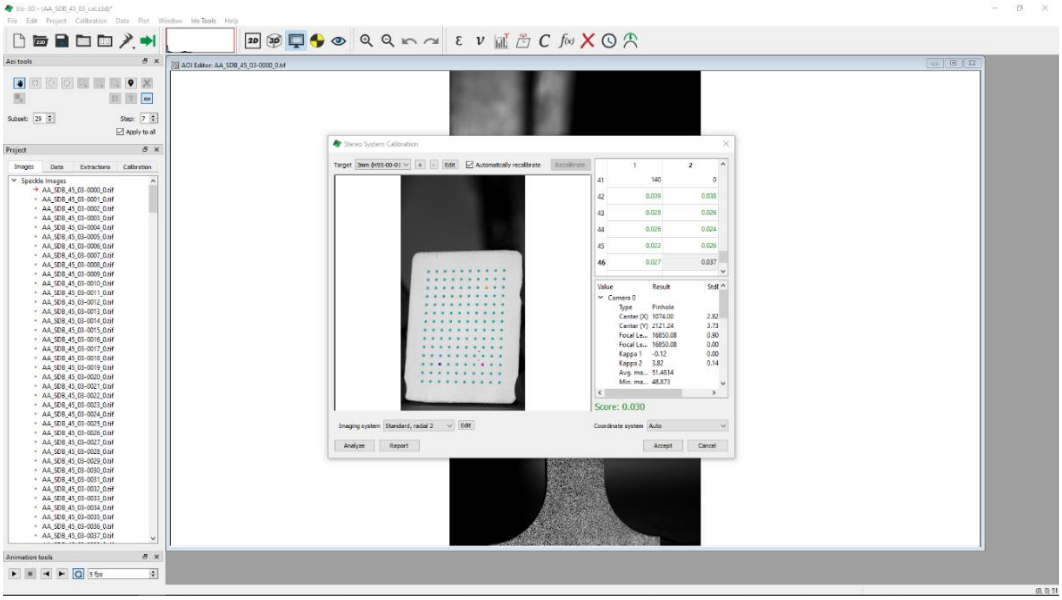

Figure 9 Calibration of the stereo system

5. Select the area of interest of the sample with Aoi tools (keep one pixel distance away from the edge of the sample to filter out the noise). Rectangular selection tool is recommended to generate the initial selection, and then manually set the positions of the points to make finer adjustment.

6. Place the location points at both ends since the sample will fractured into two parts. These location points mark the starting point and ending point for the calculation.

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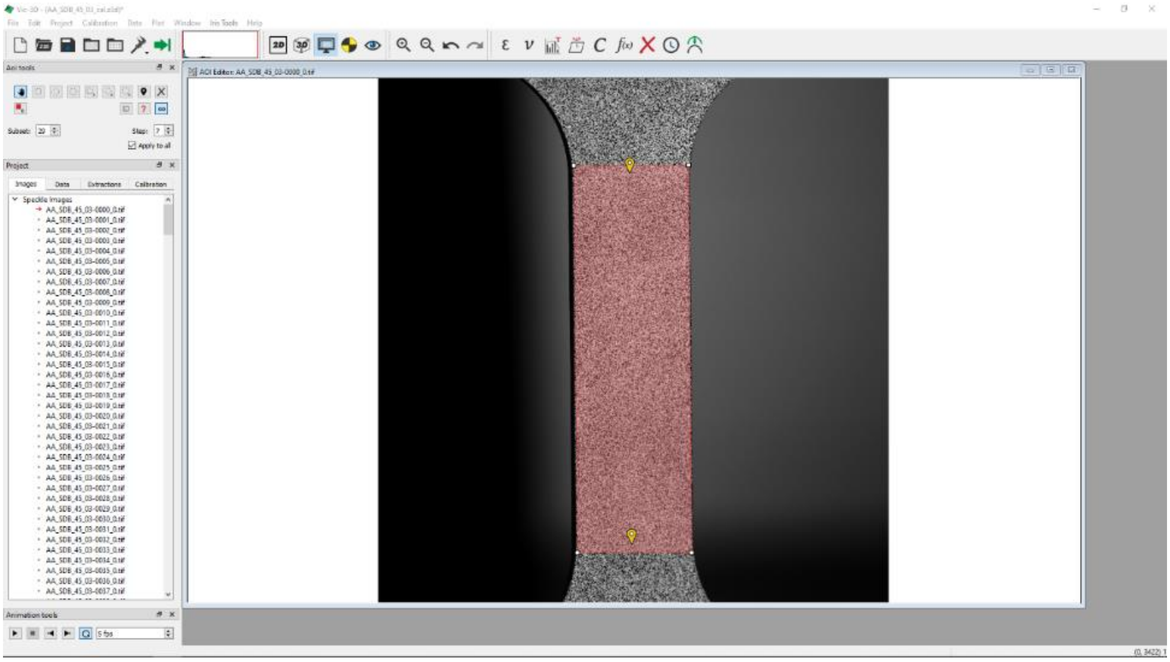

Figure 10 Area of interest and location points

7. Click on the red question mark '?' icon on the Aoi toolbar and checkout the suggested parameters. Keep in mind of the rule of thumb principle among the subset size, step and filter size, 2× subset ≤ filter size × step.

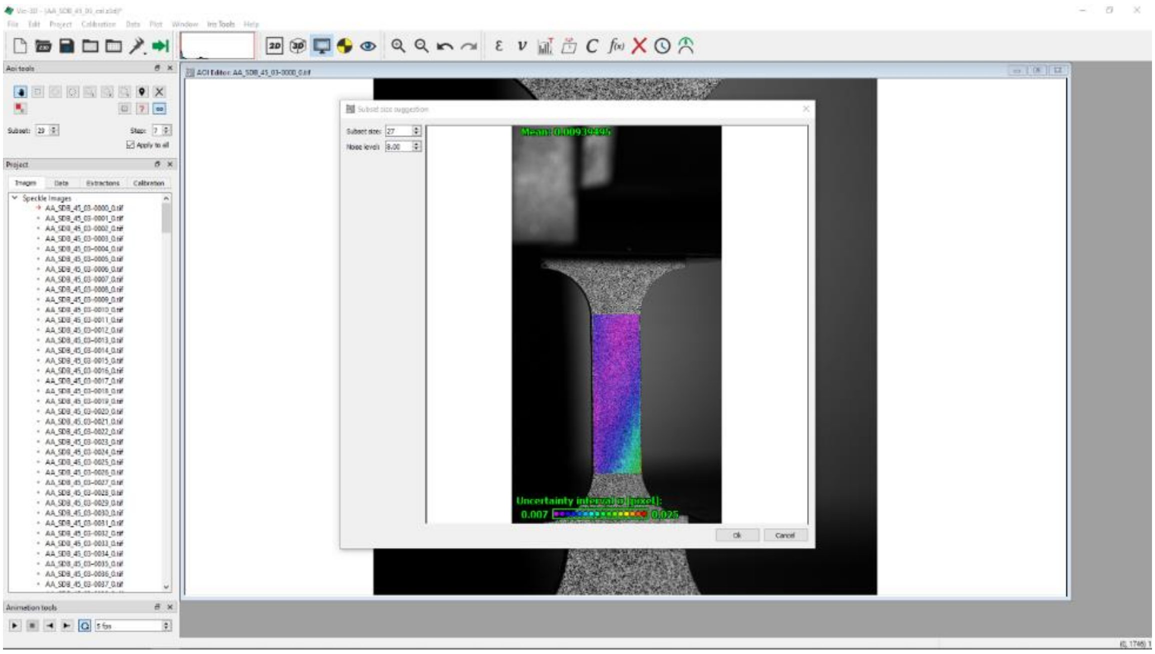

Figure 11 Subsets and step size

8. Start the analysis by clicking on the start analysis from the Data menu. Save the output of the results into the project folder.

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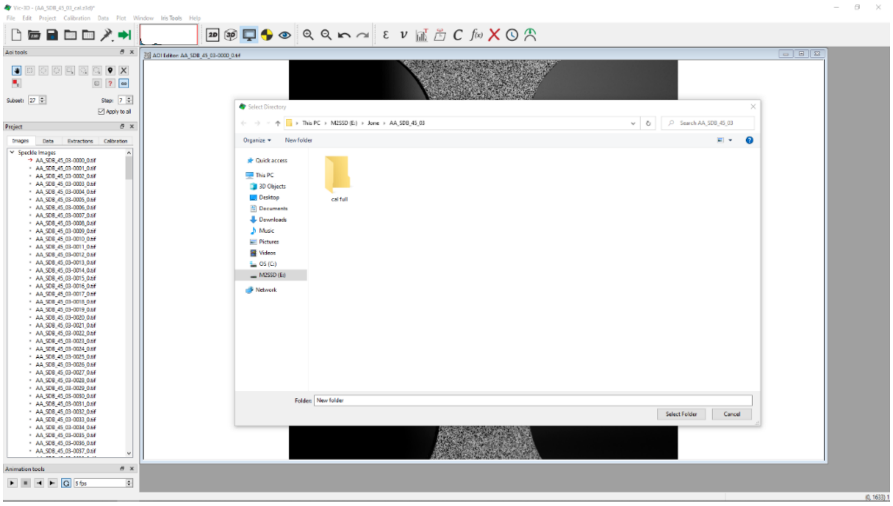

Figure 12 Save the outputs into the project folder

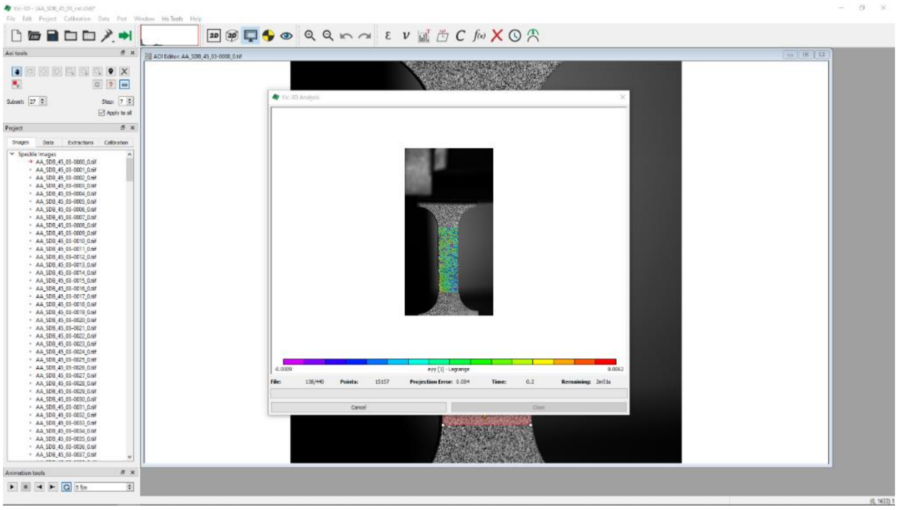

Figure 13 At the end of the analysis

9. After the analysis is finished, a post calculation to get further variables (e. g. von Mises strain value) is possible. Keep in mind that the filter size must be set as equal value as the former analysis Start the calculation by clicking on the calculate ε strain from the Data menu.

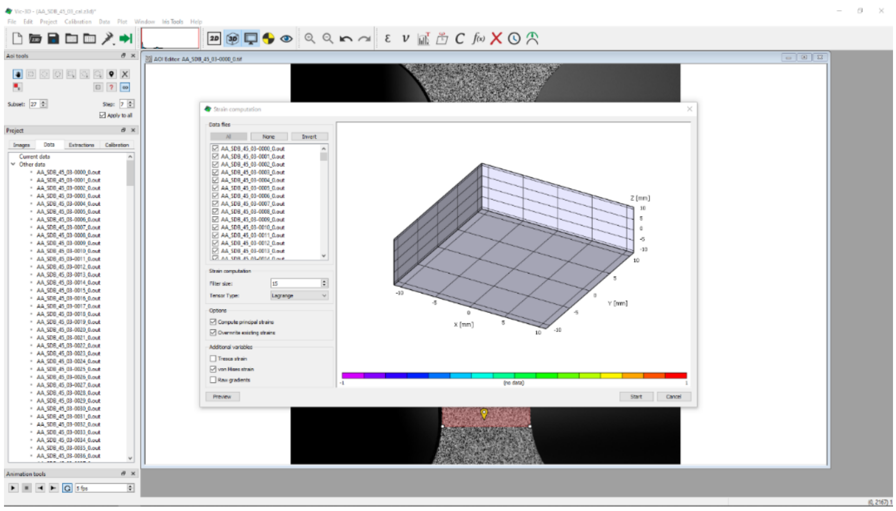

Figure 14 von Mises strain calculation

Calculating the global deformation with virtual extensometers

1. After the calculation is finished, select one of the output data, right click on it to select the 2D perspective view from the pull-down menu.

2. Place the extensometers using the inspector tools (length of the extensometer should be equal to the gauge length, e.g., 30 mm). For SDB samples, the extensometers both along vertical direction and horizontal directions are necessary especially for anisotropic materials. For fracture sample with other features on stress states, along vertical direction would be enough.

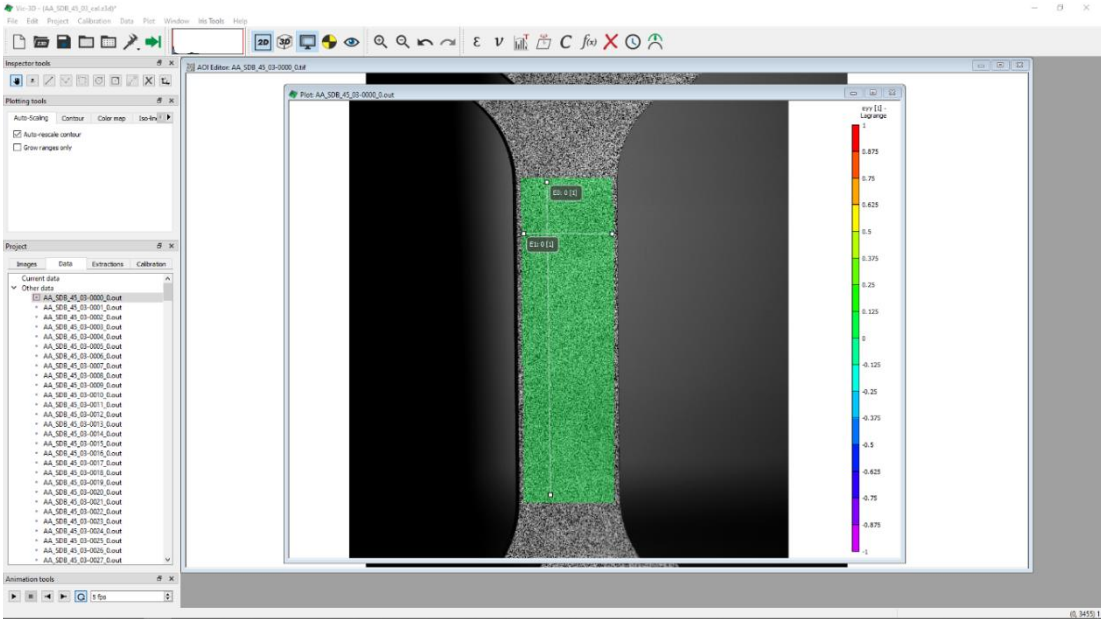

Figure 15 Calculation with virtual extensometers

3. Right click on the output plot and click on the Extraction. Select the Export field from the left panel, save the data into .csv format.

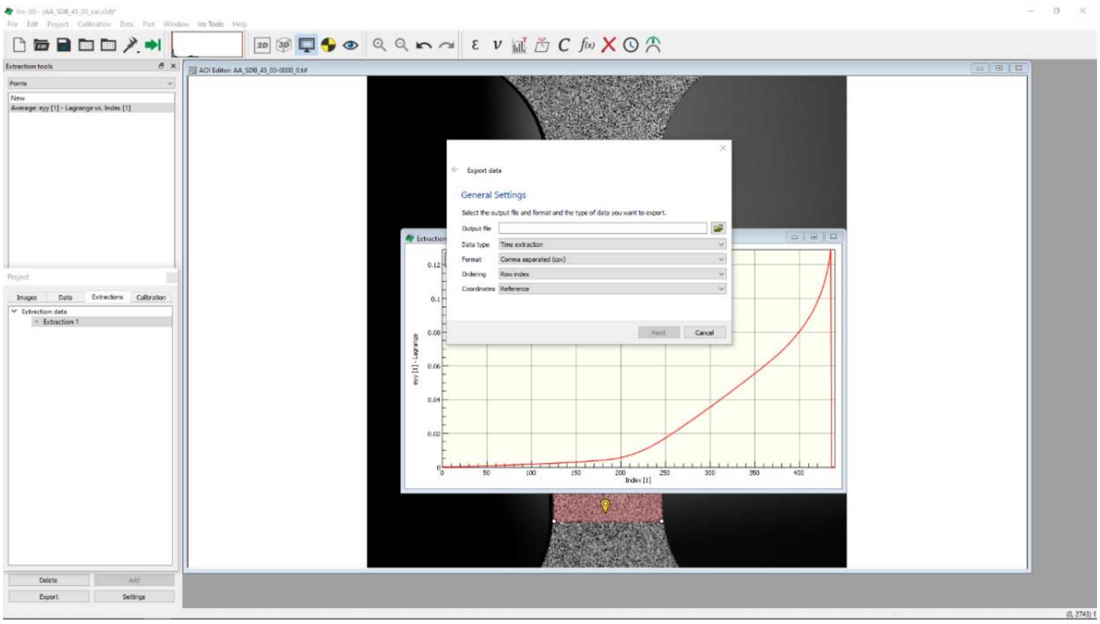

Figure 16 Data extraction

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Extraction local deformation on critical points

1. After the calculation is finished, select one of the output data, right click on it to select the 2D perspective view from the pull-down menu.

2. Select the critical points with the inspector tools.

3. Extract the data into .csv format.

4. Save the project once again before closing the program.

5. Export the force/stress data from tensile test machine.

6. Combine the force/stress data together with the displacement/strain values into one spreadsheet.

Export video

1. After the calculation is finished, select the first of the output data, right click on it to select the 2D perspective view from the pull-down menu, choose the right value that needed to be extract (eyy-Lagrange).

Note: To enhance the quality of the video, maximize the data tab and zoom up.

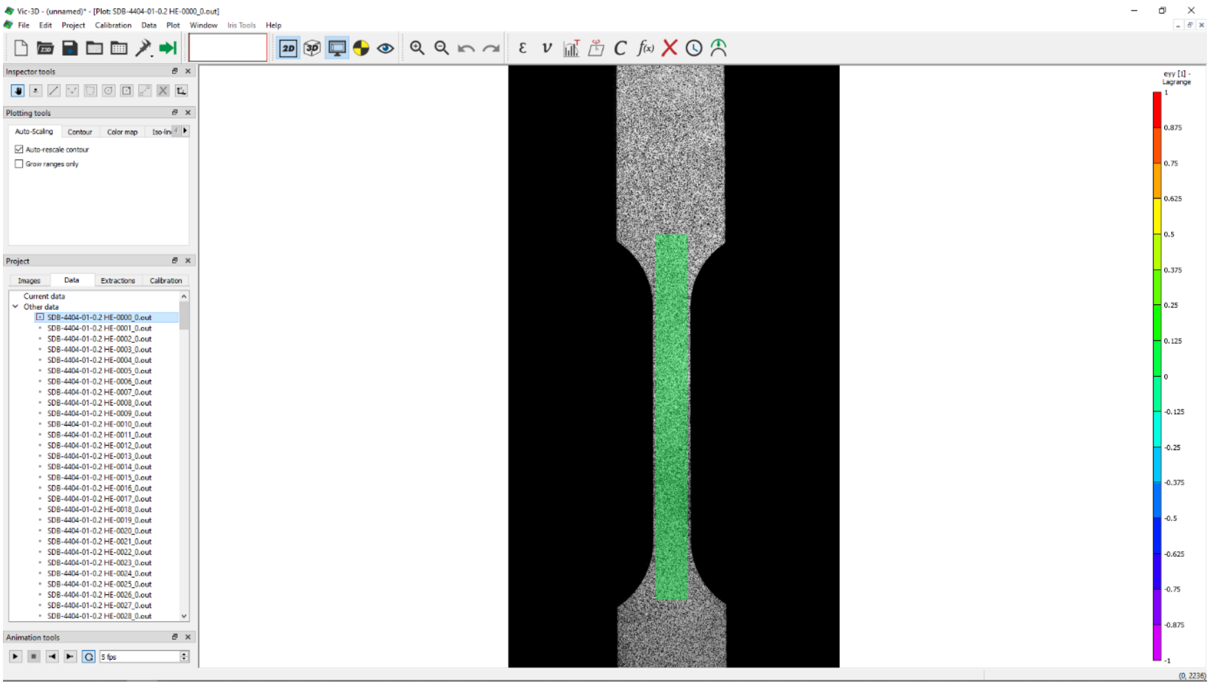

Figure 17 Data page with good zoom

2. Right click and press export video. Choose yes if rescaling prompt. Choose the name (format .avi) and set to a video format. Choose export.

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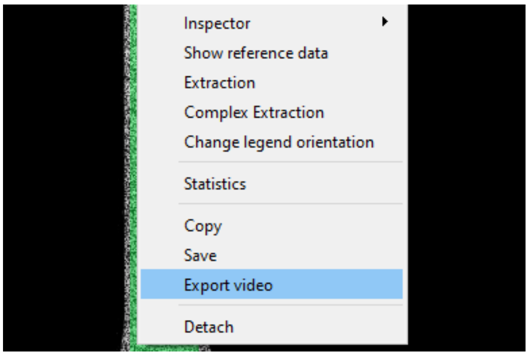
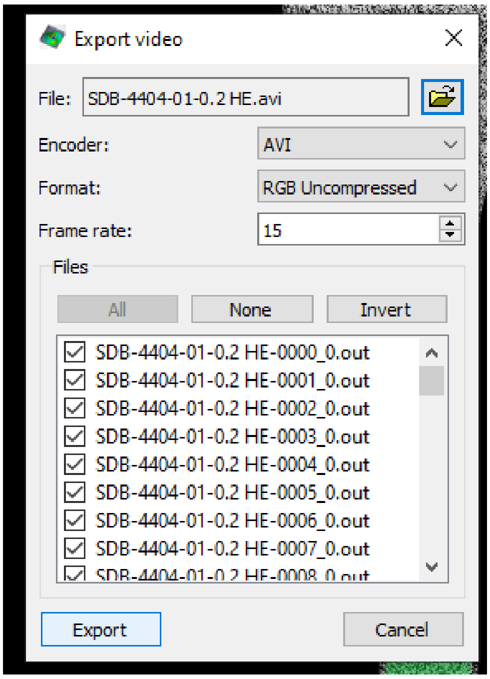
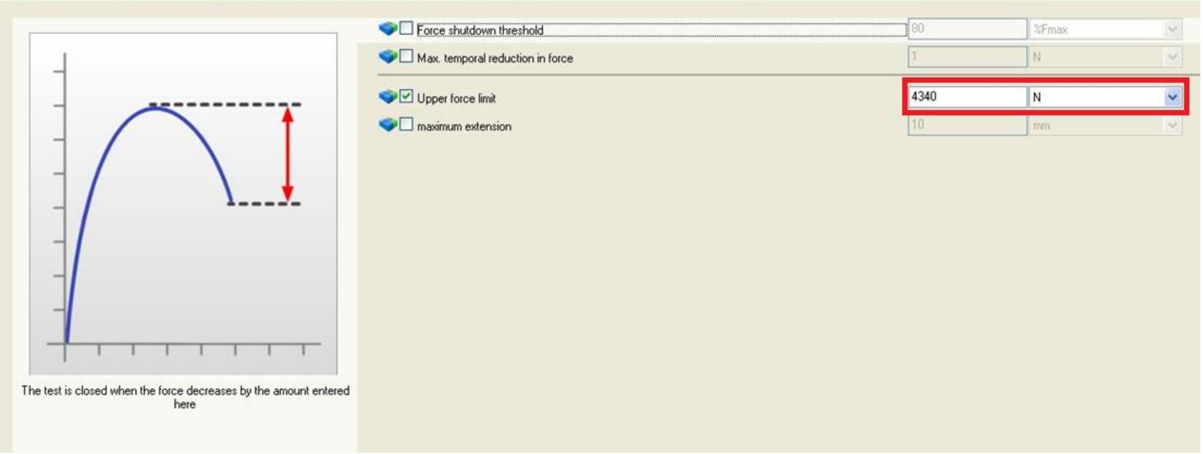




Pre-strain procedure

1. Find the force that associate with the desired strain rate, let it be x (N).

2. In the tensile machine, go to Wizard -> End of Test -> Upper Force Limit and enter x.



3. Do the test. The machine will stop when the specimen reaches the force, hence achieving the corresponding strain.

4. When the test finishes, allow the camera to run a few seconds extra so it captures the reloading behavior of the specimen.

If the specimen is tested right away, it can be left on the machine and continue the process. The VIC 3D program shouldn't be closed but used in one process.

Post process will give one cvs file. Combine with the force file taken from the tensile test, remove the excess data and combine as wanted.

The lowest strain during reloading will correspond to the starting force of the next test.

If the specimen needs to be taken out, ask the technician for help. In case of no technician available, reduce the load on the specimen by going to the monitor (not the computer) to the right of the machine. Choose Pos-> move down as slowly as possible as too much will compress the specimen. When the load is showing on the screen is smaller than 10N, take the specimen out.

The last strain value of the pre-strain cvs will be added into the strain of the new test. This will shift the value to the correct pre-strain condition.