Aalto University
School of Engineering

MEC-E6007 - Mechanical Testing of Materials

Digital Image Correlation Lab Report

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Contents

1 Introduction

Objective of this laboratory exercise was to perform a mechanical test to some specimen and to use Digital Image Correlation (DIC) to analyze the specimen throughout the test. In DIC you use either single or multi-camera setup to acquire high resolution pictures of predefined pattern from the specimens surface, and with those pictures you follow the movement of the pattern which can be lead to, e.g., displacements which again can be lead to strains and stresses. When it comes to the pattern definition, for example, spray paint can be used to highlight patterns on the surface.

The topic of this exercise was to conduct a tensile test to a specimen while employing DIC. A specimen made of AISI 301LN stainless steel was shaped to conform to the standard profile outlined in ISO 6892.Digital Image Correlation (DIC) is a non-contact and optical measurement method, which performed the image analysis to acquire the full-field deformation and strain fields of various scales. The fundamental assumption of the DIC method is based on the gray scale intensity of a point in the reference image as well as in the deformed image.With the help of the DIC technique, the in-plane surface during tensile testing was registered, and the force and displacement were simultaneously recorded. The stress, defined as the given force divided by the initial cross-section, registers the same value for the DIC method and the strain-gauge measurement

2 Method

Tensile testing was performed with MTS Insight Electromechanical 30 kN Standard Length testing machine. The DIC system utilized was manufactured by Correlated Solutions and comprised two cameras mounted on a horizontal beam attached to a tripod, with an adjustable light source positioned behind it. The software employed for image analysis was VIC Snap 9, operated on a standalone computer. Additionally, a mechanical strain gauge was initially employed at the outset of the test for supplementary measurements.Because the tests were fast (ones to tens of milliseconds), they images were recorded using a high-speed camera. The recorded images were then uploaded to the evaluation software and calibrated (based on the initial width of samples that was measured prior to test)

Table 1. Equipment used for the tensile test.

Parameter	**Value**
Performed test	Tensile test with DIC
Test machine	MTS Insight Electromechanical 30 kN Standard Length
DIC system	Correlated solutions
DIC software	VIC Snap 9
Specimen material	AISI 301LN
Specimen profile	ISO 6892
Additional strain gauge	Used at low strains

Prior to conducting the actual tensile test, calibration of the DIC system was necessary. The calibration parameters utilized in this study are presented in Table 2, and were established during the following calibration procedure:

1. Open the apertures on both cameras to the largest setting (16).
2. Adjust the depth of field on both cameras until the sharpest image is achieved.
3. Adjust light source intensity and the apertures on both cameras until the brightest image without reflections is attained. If required, relocate the light source to facilitate this adjustment.

4. Calibrate the software using a suitable calibration plate, as illustraded in Figure 1:
   - Move and tilt the calibration plate around the field of view.
   - Take at least 20 calibration images.
5. Capture rigid motion pictures (speckle images).
6. Perform the correlation. It should hold true that $step\_size \cdot filter\_size \geq 2 \cdot subset\_size$.

Figure 1. Calibration of the software using a calibration plate.

Table 2. Parameters used for calibrating the DIC system.

Parameter	**Value**
Aperture setting	≈8
Calibration plate used	14 mm x 10 mm
Calibration images taken	27 pcs
Calibration image RMS deviation	0.021
Rigid motion pictures captured	15 pcs
Subset size	49
Step size	7
Filter size	15

The tensile test was performed after the calibration sequence. First. the specimen was attached including the external strain gauge to the test machine, as illustrated in Figure 2. Next, the tensile test parameters presented in Table 3 were inputted into the test machine and the test machine was set to apply a constant strain to the specimen. The external strain gauge was removed before encountering high strains, and the tensile test was resumed. The specimen broke approximately one hour into the test.To compare DIC data with traditional method Multiple points were selected on the specimen around the placement of extensometer. The strain values were out of normal due to the flaking of paint and the actual images of the necking region and the strain area could not be taken. As a result the ratio of error was quite high and the reliability of the test was compromised.

Figure 2. Tensile test specimen setup to the test machine, including the additional strain gauge.

Table 3. Parameters used for the tensile test.

Parameter	**Value**
Test speed	1.125 mm/min
Strain rate	0.00025 1/s
Acquisition interval	1000 ms

3 Results

Below in Figures 3 to 5 you can see the test strains in y-direction on the specimen in the beginning of the test, right before the paint started to flake off of the specimens surface, and when the paint has came off totally, therefore making the test results unusable quite early in the test. There is also an line result attached below the contour images.

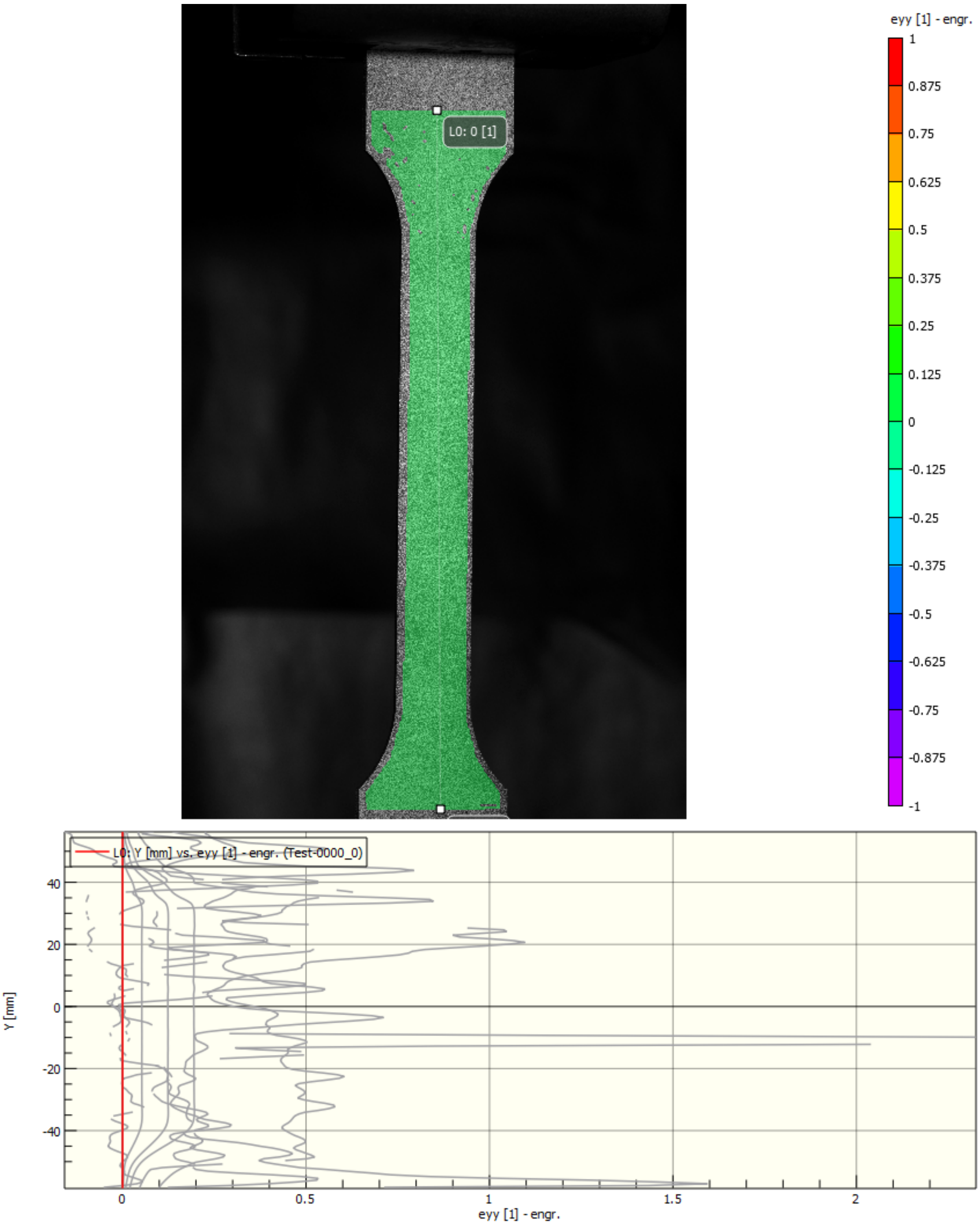

Figure 3. Strain contour in y-direction with y-direction strain-displacement line results in the beginning.

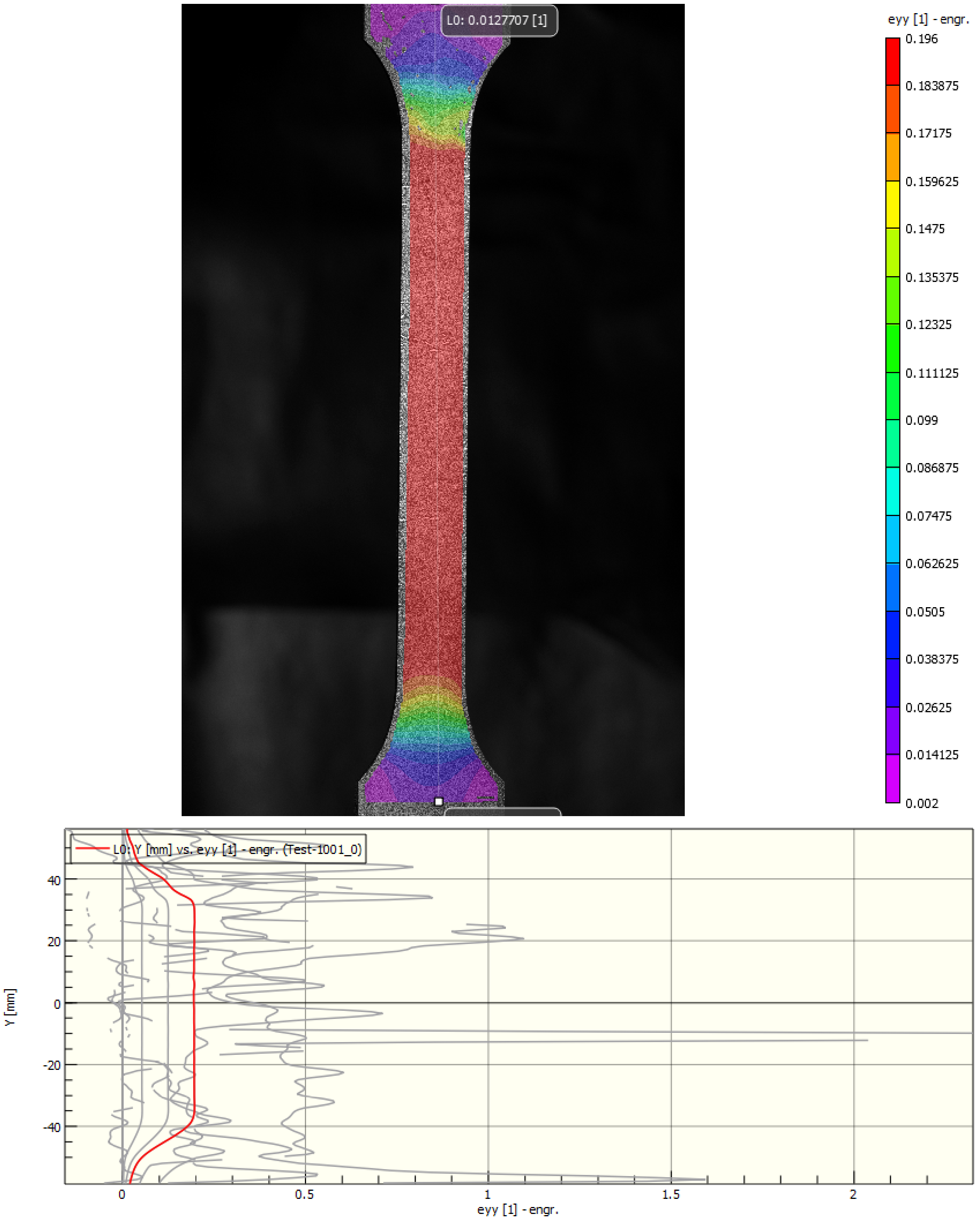

Figure 4. Strain contour in y-direction with y-direction strain-displacement line results before paint flaking.

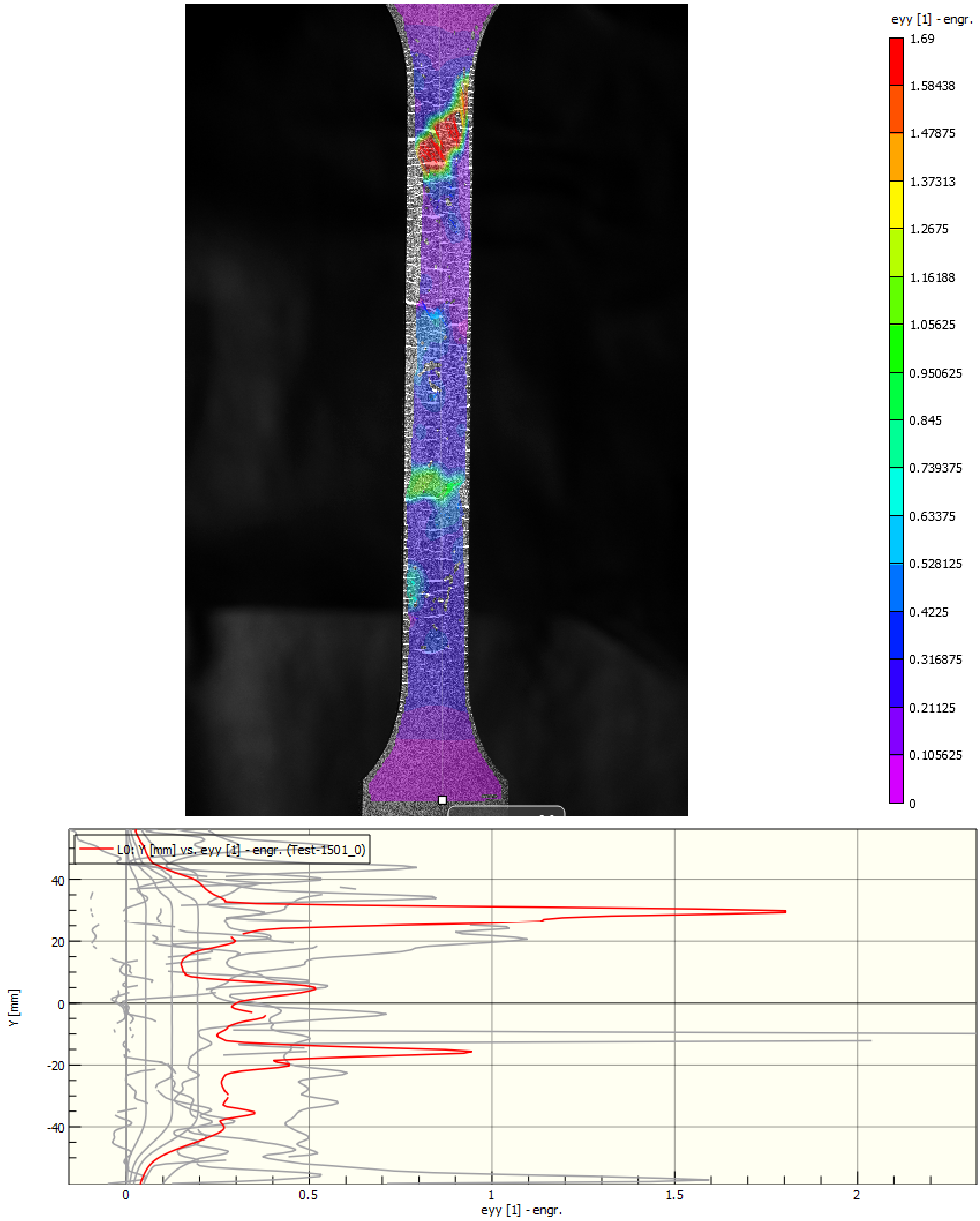

Figure 5. Strain contour in y-direction with y-direction strain-displacement line results when results are unusable.

During the tensile test, the paint started to flake off of the specimen, as presented above in Figures 3 to 5 and below in Figure 6. This resulted in compromised data, thus making it impossible to draw any conclusions after the flaking.

Figure 6. Paint flaking of the specimen during tensile testing.

While looking through the results that were acquired before the paint started to flake, some extreme distortion could be seen. This was later on noticed to be the effect of setting the region of interest on top of the extensometer that was used in the beginning of the test. The behaviour of sample under the influence of constantly increasing force was normal. The elongation and the ultimate stress that as applied to the sample was in range of the sample actual stress values.

4 Discussion

The failed test showed why it is of utmost importance to prepare the specimen flawlessly before the test. The surface of the specimen should be prepared for painting, although keeping in mind that some surface treatments, such as bead blasting will affect the micro structure of the specimen, possibly interfering with the test results. It is also important to clean the specimen properly before applying a paint coat to it, as for example oily fingerprints can affect the binding of the paint to the specimen. Likewise, a good binding paint should be chosen, as some paints stick considerably better to specific surfaces. However, the paint should not require any heat treatment, as this can again affect the micro structure of the specimen. The paint should also be ductile, due to a stiff and brittle paint fracturing when elongated. Naturally, the paint should be applied according to the manufacturers instructions. As the prime reason for failure of the test was paint flakes so it was difficult to gauge either the assumption regarding the points set on the specimen was actually to any value or not.

The failed test did also show why it is important to prepare more specimens than required, whenever possible. Especially, if the specimens are made from a widely available, inexpensive and easy to process material, it is better to have more on hand than having to pause the testing due to a lack of specimen. Likewise, extra time should be reserved for to re perform failed tests.

5 Conclusion

A tensile test using digital image correlation (DIC) was performed. The DIC system was successfully setup and calibrated, followed by an unsuccessful tensile test. There were issues with the paint flaking of from the specimen, resulting in false data. Therefore, no conclusive conclusions could be made from the gathered data. Moreover, there seemed to be some other factor contributing to the false data gathered from the test, which implies that the whole calibration sequence should be performed from the beginning before retesting.