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Noise reduction for DIC measurements

Martin Reis[1,*], **Stefan Diebels**[1], and **Anne Jung**[1]

[1] Saarland University, Applied Mechanics, Campus A 4.2, 66123 Saarbrücken

Digital image correlation (DIC) is well known as a contact-less, full-field strain and displacement measuring method. The use of the method is widely spread in experimental mechanics. Nevertheless, there are error sources such as light settings, speckle pattern and noisy images, which strongly affect measurement quality, but often stays uninvestigated. Therefore, this work outlines a simple routine to identify errors and enhance the accuracy of DIC measurements. A calibration sample adapted to the specifications of the setup using the beam theory to link machine displacement, DIC measurements and forces. All evaluations are done in the commercial software ISTRA4D. The noise in the measurements is reduced to an error of under two per cent. The routine allows estimating the quality of the images before performing the experiments. Furthermore, the routine is transferable to all experimental setups. The calibration of the setup allows getting reliable experimental results with a known error. With this estimated stochastic error, the advantages of DIC can be used to evaluate mechanical experiments such as three-point bending tests on single struts of an open cell metal foam.

1 DIC in experimental mechanics

During mechanical testing, it is often necessary to measure local and global strains. For specimens with a simple and even surface as a standard dog bone specimen in tensile test, strain gauges or extensometers can be used. For very small specimens, rough and uneven surfaces or heavily accessible setups optical measurement is often unavoidable. One of such optical measurement methods is Digital Image Correlation (DIC). This method calculates displacements and strains from images captured during the experiment. Therefore, one image is chosen as a reference image and subdivided into subsets. The software now identifies these subsets in all following images and calculates the deformation from the distortion of the subset, a detailed explanation can be found in literature [1]. This identification is based on cross-correlation of a grey value matrix and requires unique matrices. For specimens with irregular surfaces and large contrast differences over the surface the natural pattern can be used and no further preparation is needed, for all others, a random pattern has to be applied. The most used method is spray painting this speckle pattern. Besides the speckle pattern, image brightness and environmental influences affect DIC quality.

2 Noise measuring and reduction routine

In most experimental procedures, the investigation of noise in DIC measurements stays unattached even if the improvement potential is high. Thus, this publication presents a three-step routine to measure noise in DIC and improve the measurement accuracy of an experimental setup, which can be used for each experimental setup and is not bounded to the used test rig.

Static Attempts: With no movement in the setup, the expected displacement in the DIC measurement is zero. Any measured displacement is noise. In this case, several image sets of 50 images in six different brightness levels with neither the camera nor the specimen moving were recorded. As subset size $19 \times 19\ \mathrm{px}^2$ is chosen, for further details see [4]. **Fig. 1** displays an image of each brightness with the corresponding grey value histogram and the measured displacement. With the white vanish and the black speckles, the ideal grey value distribution would have two maxima. One maximum close to zero for the black points and a second one close to 255 for the white background. In dark images, **Fig. 1** (a) brightness 1 and 2, the distribution of grey values is small and close to zero, which results in high noise up to 1 µm. If the image is to light, as brightness 6, the range of grey values is also small, but on the other side of the scale at 255. Brightness 4 shows a good distribution of grey values, using the complete range. This results in a low error and provides the light settings for the following experiments.

Rigid Body Movement: With the improved setup, the study is expanded to rigid body movement (RBM). Here, a specimen is moved through the field of view and a second specimen stays steady. To eliminate vibrations, the difference between the displacement of the steady and moving specimen is calculated. The resulting movement is compared to the machine stroke. As a result, a constant error over the entire stroke is measured. The maximum error is under two per cent of the stroke.

Calibration Target: As second validation step a calibration target inspired by Patterson et al. [5] is used. This target allows to compare a DIC measured deflection with a sensor measured force. In the work of Patterson et al. [5] a four-point bending target was used. Due to the small dimension of the setup in the presented work here, the target needs to be changed to three-point bending specimen. A detailed explanation of target, setup and analysis can be found by Reis et al. [4]. Calculating the force using Bernoullian beam theory and comparing it to the sensor measured force presents impressive results. The pathway of the force-deflection-curve is identical for all tests, which indicates reproducible experiments. Further, the error between the

* Corresponding author: e-mail martin.reis@uni-saarland.de, phone +49 681 302 2168, fax +49 681 302 3992

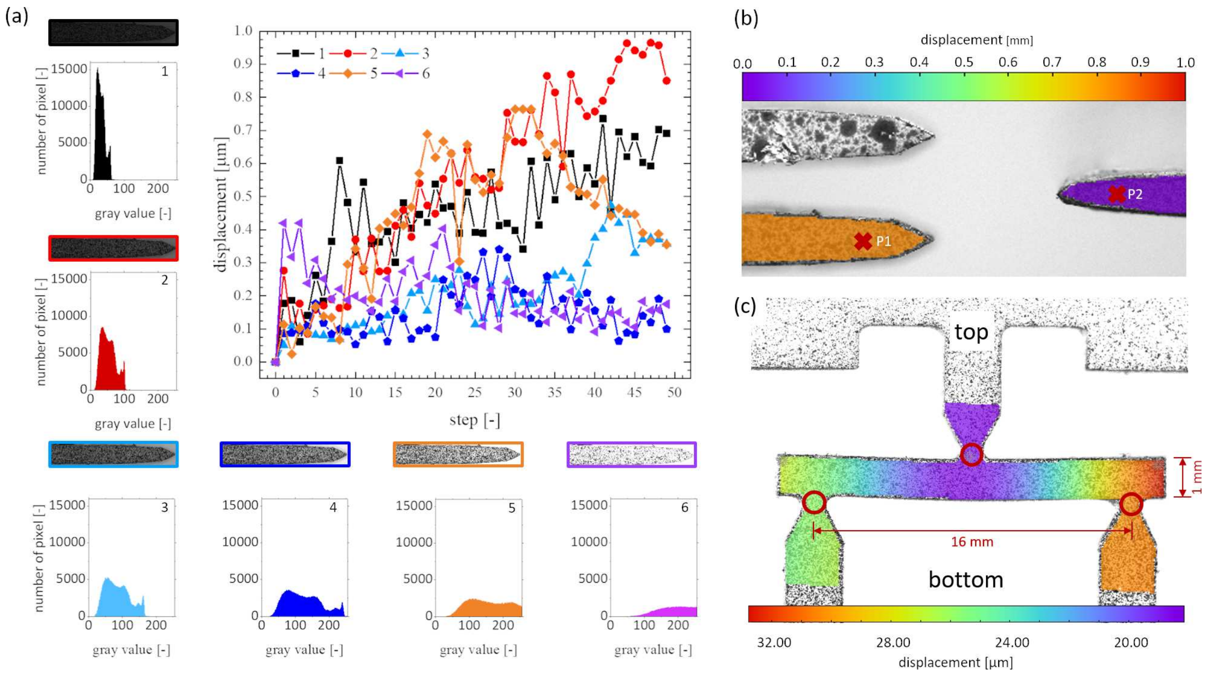

Fig. 1: three step routine, (a) static images in different brightness levels 1-6 with displacement measured over 50 steps, (b) specimens for RBM measurement with export points P1 and P2, (c) deflected calibration target

calculated and the measured force is very small. The maximum of the absolute error is located at the beginning with a value of 0.3 N. With arising deflection the error decreases to almost zero.

3 Experimental application

The presented three-step routine enhances the DIC quality and reduces the noise with static images. All settings found in the first step were used for the following steps. The high quality of the measurement in these steps validates that images with no movement can indicate the error and the noise level of DIC measurements and should be used in all experiments to quantify the noise level of DIC measurements. **Fig. 2** presents the full field displacement measurement on a single strut during a three-point bending test. Thereby, the presented routine allows achieving sufficient accuracy to perform the shown evaluation.

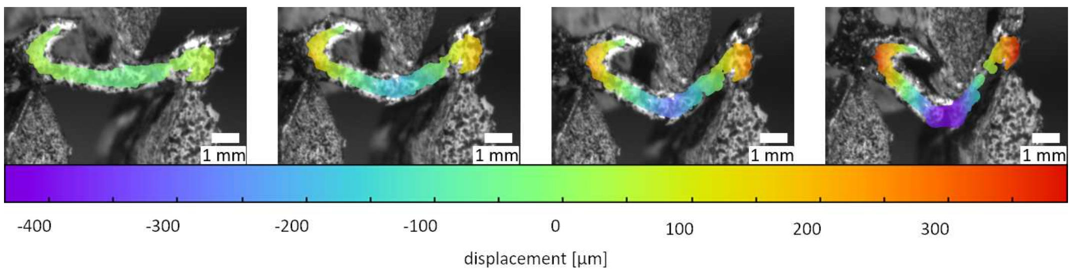

Fig. 2: full field displacement measurement on a single strut during three-point bending test

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