XLVI CILAMCE
VITÓRIA - ES - BRAZIL - 2025
XLVI IBERO-LATIN AMERICAN CONGRESS ON COMPUTATIONAL METHODS IN ENGENEERING

Detection of Displacement Points on a SAE 1020 Steel Specimen Under Tensile Loading

Gabriel D. Dehete-Many[1], Esther M. Nascimento[2], Rafael M. Ferro[3], Rodolfo G. M. de Andrade[4]

[1]*Master's student in Metallurgical and Materials Engineering, Instituto Federal do Espírito Santo – Campus Vitória*
Av. Vitória, 1729, 29040-780, Jucutuquara, Vitória-ES, Brazil
gabriel_delboni@hotmail.com
[2]*Undergraduate student in Civil Engineering, Instituto Federal do Espírito Santo – Campus Vitória*
Av. Vitória, 1729, 29040-780, Jucutuquara, Vitória-ES, Brazil
esthermoraes254@gmail.com
[3]*Department of Mechanical Engineering, Instituto Federal do Espírito Santo – Campus Aracruz*
Av. Morobá, 248, 29192-733, Marobá, Aracruz-ES, Brazil
rafael.ferro@ifes.edu.br
[4]*Department of Building Construction, Instituto Federal do Espírito Santo – Campus Vitória*
Av. Vitória, 1729, 29040-780, Jucutuquara, Vitória-ES, Brazil
rodolfo.andrade@ifes.edu.br

Abstract. This study proposes a method for detecting interest points in images acquired during a uniaxial tensile test, following the ABNT NBR ISO 6892-1 standard, to estimate the strain of an SAE 1020 steel specimen. Images were captured using a fixed tripod under controlled lighting and processed through preprocessing, segmentation, and feature extraction techniques with the OpenCV library (GaussianBlur, Canny, findContours). Analysis showed that detection accuracy strongly depends on the contrast and uniformity of the region of interest. Uniform surfaces and well-defined point arrangements provided high reproducibility and precision, while tonal or textural variations and surface imperfections reduced both the quality and quantity of detected points. The results indicate that the proposed method is reliable for standardized specimens, provided that acquisition conditions and detection parameters are carefully controlled.

Keywords: Digital image processing, Tensile test, Strain, OpenCV library, Python

1 Introduction

Optical monitoring techniques have become a valuable tool in various fields of knowledge, enabling the capture, recording, and analysis of dynamic phenomena with high spatial and temporal resolution. Advances in optical sensors, digital cameras, and image processing algorithms have expanded observation capabilities, making it possible to perform tasks ranging from real-time monitoring of industrial processes to the study of structures. By integrating image acquisition systems with analytical methods, video monitoring allows visual data to be transformed into quantitative information, offering a non-intrusive, precise, and reproducible means of characterizing physical and mechanical behaviors [1–3].

In engineering, this approach has gained prominence in experimental applications such as strain and displacement measurements. For instance, digital image correlation (DIC) techniques use sequences of high-resolution images to track patterns applied to the surface of a specimen, thus enabling the calculation of full-field strain and displacement maps [4].

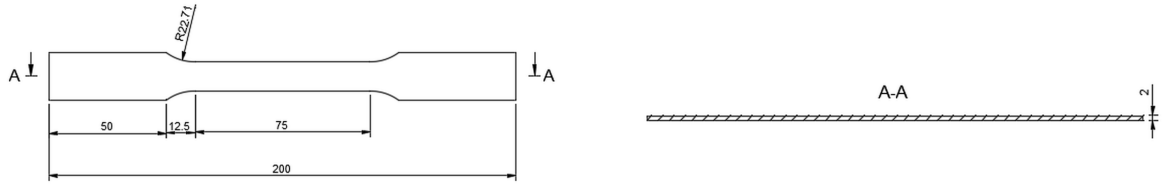
Therefore, these optical approaches make it possible not only to determine global parameters such as the modulus of elasticity and Poisson's ratio but also to analyze local heterogeneities, stress concentration zones, and crack propagation. They represent an excellent complementary alternative to traditional methods, such as extensometers or strain gauges, for different types of materials [5, 6].

In this context, this study proposes an image processing algorithm to determine the specific strain of SAE 1020 steel specimens, standardized according to ABNT NBR ISO 6892-1, based on optical monitoring of their elongation during room-temperature tensile testing [7].

2 Method

2.1 Tensile test and specimen preparation

The test specimen was made of SAE 1020 steel, with standardized geometry (Figure 1), and subjected to a tensile test at room temperature according to ABNT NBR ISO 6892-1 (2024) [7]. Before the test, its surface was prepared by painting with white acrylic-based paint, creating a high-contrast background. On top of this layer, black dots were applied using a fine-tipped brush, arranged in an approximately matrix-like pattern along the gauge section of the specimen.



(a) Top view (b) Cut A-A

Figure 1. Test specimen.

This procedure differs from conventional methodologies, such as those based on Digital Image Correlation (DIC) that use random speckle patterns, by adopting a regular pattern, which facilitates mark detection by the algorithm. However, due to manual application, the alignment between points is not perfect, being only sufficiently accurate for measurement purposes.

2.2 Video acquisition and experimental data

The test was carried out on a universal testing machine equipped with a load cell and strain gauge. Displacement and applied force were recorded by the machine's system and exported as a function of time.

Simultaneously, a video capture system recorded the gauge section of the specimen throughout the entire test, with a resolution of 1080 × 1920 pixels and a frame rate of 60 fps. The framing was adjusted to ensure that all black dots remained visible during the test. Figure 2(a) shows the EMIC DL/10000 machine used in the test along with (b) the extensometer, and also makes it possible to observe the applied matrix pattern of dots.



(a) EMIC DL/10000 Universal Testing Machine (b) Extensometer coupled to the test piece

Figure 2. Tensile test arrangement with extensometer.

It is noteworthy that, at this initial stage, no optical or camera perspective corrections were applied. Thus, measurements were taken directly from the acquired frames, assuming that the region of interest was sufficiently close to an orthogonal projection.

2.3 Digital image processing

Processing was implemented using the free Visual Studio Code source code editor in Python, employing the OpenCV computer vision library and NumPy for numerical analysis [8, 9]. The developed algorithm follows the steps shown in the flowchart in Figure 3 and described below.

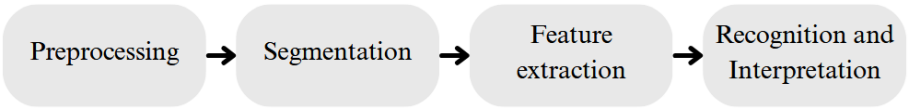
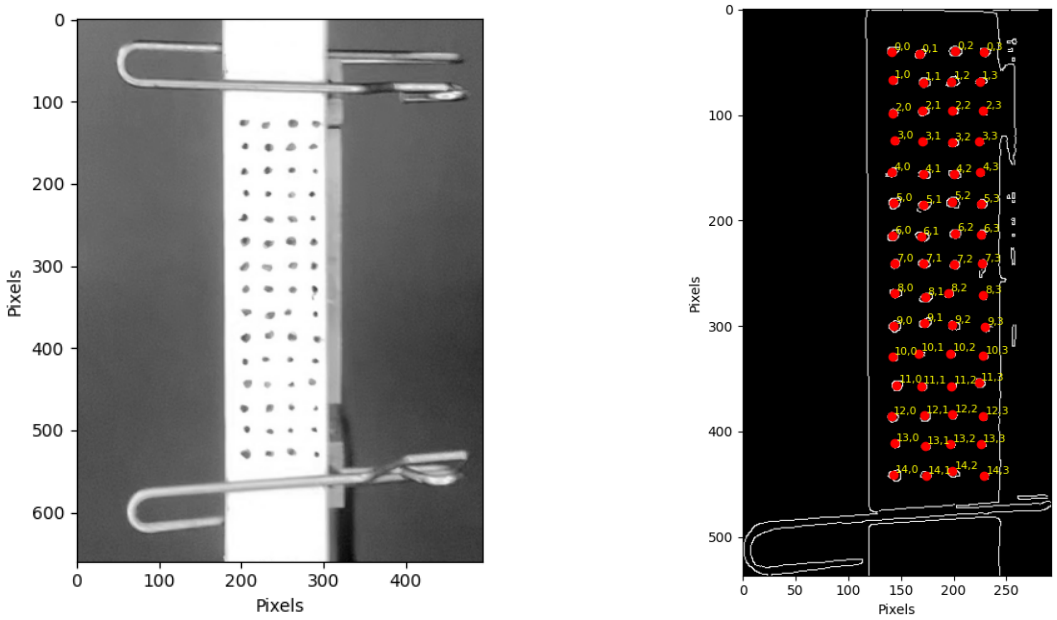


Figure 3. Flowchart of digital image processing steps

In the preprocessing stage, each frame is converted to grayscale along with the application of enhancement techniques, noise removal, and feature highlighting, such as Gaussian filtering.

Subsequently, the region of interest in the image is located, and the contours present in it are detected using the Canny method [10]. These elements are then extracted using the `findContours` function, which applies the Suzuki and Abe method to locate the area centers, or centroids, of the black dots [11]. Recognition consists of assigning labels to the objects of interest, the centroids (Figure 4), and tracking them in each frame.



(a) Test specimen image frame zoom

(b) Canny edges with centroids in region of interest

Figure 4. Image frames of the test specimen: zoomed region of the original view and centroids.

Finally, interpretation uses the data on the distance between the points to determine the instantaneous strain using Equation 1. It is not necessary to know the relationship between pixels and a standard unit of measurement, since strain is dimensionless.

$$\epsilon = \frac{L_t - L_0}{L_0}. \tag{1}$$

2.4 Integration with force data

For each processed frame, the specific strain obtained was associated with the force value measured by the testing machine at the equivalent time instant. The true stress was calculated by dividing the force by the initial

cross-sectional area of the specimen. This made it possible to generate the material's stress–strain curve, allowing comparison between the results obtained from the strain gauge and those from optical monitoring.

3 Results

The Figure 5 shows the stress–strain diagram obtained for the SAE 1020 steel specimen tested at room temperature. The chart contains two curves: the first corresponds to the strain measured directly by the strain gauge attached to the testing machine, while the second was obtained through the video extensometer developed in this work.

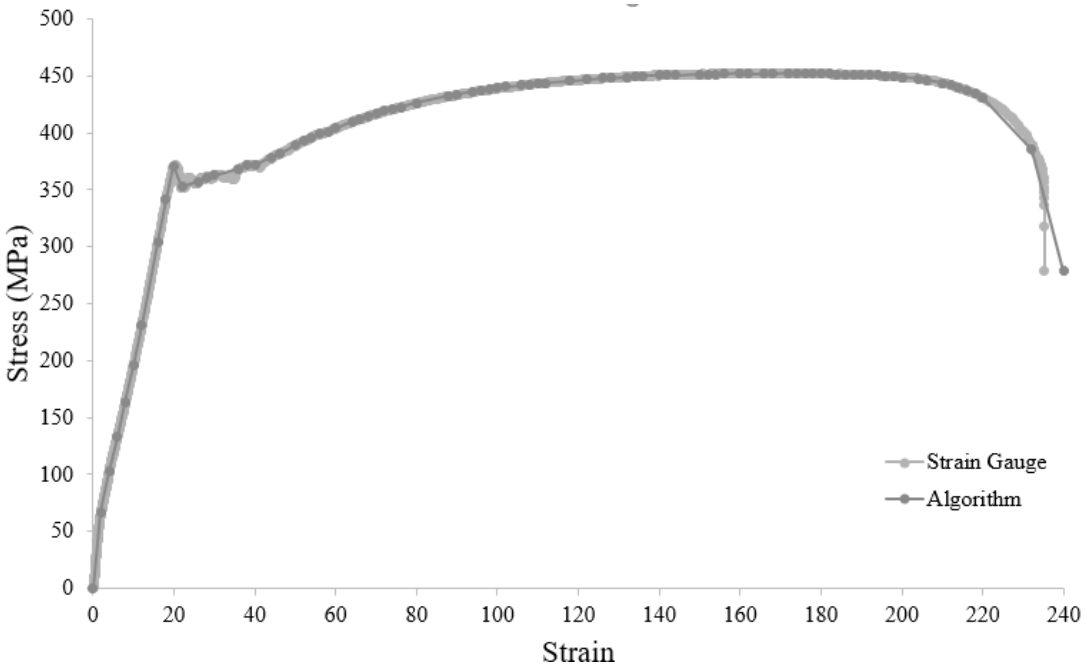


Figure 5. Stress-strain curve: strain gauge vs image processing algorithm

Visually, both curves exhibit the same general trend, with significant overlap in the initial and elastic portions of the test. In the plastic region, small discrepancies become noticeable, possibly associated with differences in the definition of the reference length between the two methods, the distinct dynamic response of the acquisition systems, or the influence of noise.

The curve obtained by the video algorithm was able to accurately identify the yield point, the transition to the plastic regime, and the strain evolution up to failure. The alignment between the two curves indicates that the proposed method has potential to replace, in certain applications, contact extensometers, with the advantage of not mechanically interfering with the specimen.

These preliminary results reinforce that the proposed algorithm is capable of performing reliable strain measurements in tensile tests, provided that adequate lighting conditions, camera stability, and contrast in the reference painting are ensured.

4 Conclusions

The proposed method, combining controlled surface preparation, video acquisition, and digital image processing, proved effective in measuring specific strain in tensile tests of SAE 1020 steel specimens. The integration between optical data and the testing machine's records allowed for the generation of stress–strain curves in good agreement with the strain gauge. In addition to eliminating physical contact with the specimen, the approach enables further analyses based on the visual record, provided that appropriate lighting, contrast, and stability conditions are maintained. Preliminary results confirm the feasibility of the technique for standardized tests and indicate potential for application to different materials and geometries, with possibilities for improvement through advanced computer vision methods.

Acknowledgements. We thank IFES and PROPEMM for their institutional support; CAPES for the scholarship (Process No. 88887.983267/2024-00); FAPES and CNPq for their support via PRONEM (Announcement 06/2019, T.O. 502/2020, SIAFEM 220-765DF); and everyone who contributed to this work.

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