RESEARCH ARTICLE

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Deformation Analysis in Aluminium Magnesium Alloy Using Digital Image Correlation

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Abstract

Image processing is extensively used to examine surface deformations. Digital Image Correlation (DIC) detects two-dimensional subpixel displacements in two images to analyze deformations in geomechanical structures. In this study, the analysis is done on an aluminium-magnesium alloy. An optical microscope is used to capture the image, which is then processed and utilized to anticipate material deformation. To acquire findings of strain points on the material, the Ncorr application in the MATLAB environment is employed. . Strain graphs on the Exx, Exy, and Eyy axes, as well as U-displacement and V- displacement graphs, are generated to detect the deformation.

Keywords: Image processing, Digital Image Correlation (DIC), strain, displacement, MATLAB.

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Introduction

When a material is subjected to an external force, its size and shape will change. The material will be strained as a result. Theterm "deformation" refers to a change in dimensions or form.[1] Metals can be deformed in the following ways:

Excessive Elastic Deformation is a term used to describe the phenomenon of excessive elastic deformation (EED) This is simply a blip on the radar. When the elastic zone deforms, thisis what happens. The material will alter when it is subjected tothe external load. The deformation increases in proportion to the size of the load until it reaches a maximum value at the yieldpoint. Excessive deformation occurs as the load increases.[2]

- Strain CurveA-Proportionality Limit
- B-Upper yield point (Elastic limit)
- C-Lower yield point
- D-Ultimate load point (Necking starts)
- CD-Strain hardening region

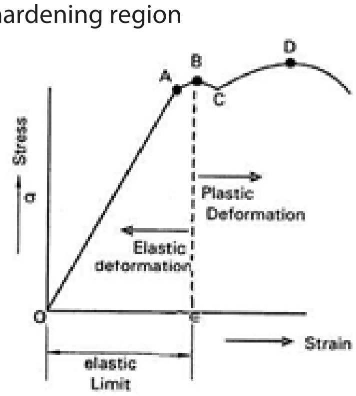

Figure 1: Stress-Strain Curve

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Excessive Plastic Deformation (EPD) is permanent. It is the deformation that occurs outside of the elastic zone. The material will alter under the effect of external load. The deformation increases in proportion to the magnitude of the load until it reaches a maximum value, which corresponds to the ultimate point. Excessive deformation occurs when the load exceeds the capacity of the material. Plastic deformation occurs beyond point B, and the alterations are permanent, with the material unable to return to its strain-free state. The material will not return to its free state after the external load is removed. It will have put it under stress. Wall cracks of varying degrees are common as the building ages. The existing maintenance measures include artificial observing, which is inaccurate and labor-intensive, and equipment monitoring, which needs a lot of equipment for overall detection. Crack detection based on image processing mainly focuses on pavement distress detection, and they aim at the effective acquisition of image information and the present situation monitoring of the road.[3]

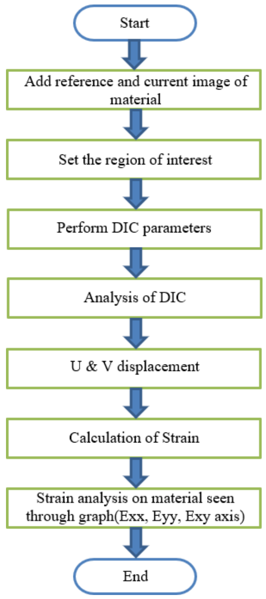

Figure 2: Block Diagram

Literature Review

Digital Image Correlation (DIC) is a non-contact, 3-D full-field optical approach for measuring contour, deformation, vibration, and strain on any material. For static and dynamic applications, the approach can be employed with a variety of tests, including tensile, torsion, bending, and combination loads.[4] The approach can be used on small (micro) to large (macro)testing regions, and the findings can be compared to FEA or strain gauge results. Surface deformations have been studied extensively using photogrammetry and image processing. DIC detects two-dimensional sub-pixel displacements between two images to quantify deformations in a geo-mechanical system. DIC is used to rebuild the corresponding strain and displacement fields, which are then compared to the Finite Element Method.[5]

DIC is used to investigate the material's key hysteresis impactduring loading and unloading operations.

The findings suggest that DIC is a reliable technique foranalyzing a material's elastic behavior. The primary idea behindDIC is to compare two photographs of a component before andafter it has been deformed. Correlating the position of pixel subsets or blocks in the original and distorted image, usually based on contrast, determines displacements and stresses (i.e., grey intensity levels).[6]

NCORR: - Ncorr is a MATLAB tool for 2D digital image correlation that is open source. It boasts an easy-to-use interface, employs several unique 2D DIC methods, is entirely contained within the MATLAB environment, and includes plotting tools for figure production.[7]

Block Diagram and Working

In this project, two images (a reference image of the material and a deformed image) are analyzed and predicted, and it is concluded where the point of breakage is most likely to occur. After the two images are uploaded, seed points are set. The purpose of setting the seed is that, while the analysis the displacement of the pixel due to deformation is tracked by the motion of the seed. Load the top element of the queue and thendelete it from the queue. After the DIC Analysis, the U and V displacements and the E_{XX}, E_{XY}, and E_{YY} strains are obtained.

Steps for Deriving Strain Data

- Open MATLAB software
- To open Ncorr type "handles_ncorr=ncorr" in the commandprompt
- Add reference image
- Add current image
- Selecting Region of Interest
  - Click on the "Region of Interest" tab and select the "SetReference ROI" option.
  - Select the "Draw ROI" option in the dialogue box
  - Click on "Poly" from the drawing options mentioned.
  - Draw the area of the material you want to analyze.
- You can use the Zoom/Pan section and "ROI Preview" section for detailed selection and convenience. Select "Finish" when you are satisfied with your selection.
- Setting DIC Parameters
- Click on the "Analysis" tab and select "Set DIC Parameters"
  - Set the "Subset radius" and "Subset spacing" as per yoursample image
  - Click on "Finish"
- Performing the Analysis
  - Go to the "Analysis" tab and click on "Per-form DICAnalysis"
  - Click on "Select Region"
  - Then select "1 Seed"
  - Click on "Finish"
- Calculating Strain
  - Select "Format displacement" from the Analysis tab
  - Click Finish after doing any adjustments and plot-ting
- Visualization of Strain pattern
  - Select the "Plot" tab and you will see the results of the DIC as Exx, Exy, Eyy analysis
- Collection of Strain values
  - Using the X and Y positional grid, note down the value ofstrain and the position of value not-ed for a particular graph.[8]

Hardware and Software Overview

MATLAB is a programming environment geared toward engineers and scientists. It is one of the most effective programsfor image processing and digital image correlation. Following the examination of the material, statistical analysis of the data is required.

The examination of this data aids in determining the relationship between various parameters and the material's

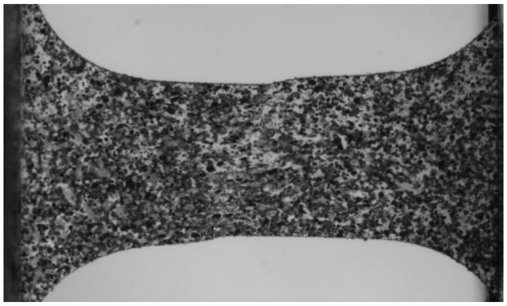

Figure 4: Deformed Image

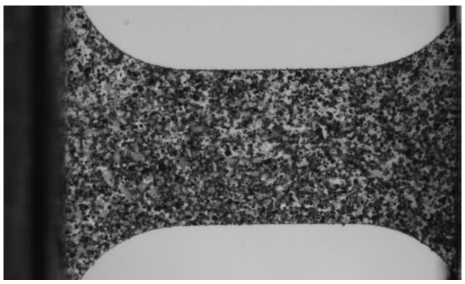

Figure 3: Reference Image

deformation impact. For statistical analysis of such data, a variety of methods are available.[9]

For the analysis, the most applicable instruments available canbe employed. The most appropriate instruments available can be used for the analysis. Image Processing Toolbox™ provides a comprehensive set of reference-standard algorithms and workflow tools for image processing, analysis, visualization, and method creation. Among the future accessible are picture segmentation, image enhancement, noise reduction, geometric transformation, image registration, and 3-D image processing.

Results

Specifications of the material used:

- Experiments are carried out on rolled sheets of aluminium-magnesium alloy.
- The thickness of 0.8 mm
- 95.5(5) % aluminium and 4.5(5) %magnesium

The table shows the maximum, minimum, and median values of the displacements and strains. It was observed that:

- Maximum, median, and minimum U-displacement are negative.
- Maximum, median, and minimum V-displacement are positive.
- Maximum strain is observed in Exx-Strain plot.
- Minimum strain is observed in Eyy-Strain plot.
- Exy strain remains constant as shown in the strain plot graph.

Using the Vector grid method and keeping X and Y distances same in the Region of interest of the strain images, documentation of the strain data. Consider 3 horizontal strips

Table 1: Parameter Statistics

Sr no.	*Parameters*	*Max*	*Median*	*Min*
1	U displacement	-0.0046	-0.0156	-0.0339
2	V displacement	0.0079	0.0014	0.0047
3	Exx strain	0.5944	0.1581	0.0845
4	Exy strain	0.0152	-0.002	0.0386
5	Eyy strain	-0.0169	-0.0469	-0.1214

across the material - One each at the top, middle, and bottom where the strains are maximum, and one vertical strip each (Exx, Eyy, and Exy).[10]

Formula for Median:

$$\mathrm{Med}(X) = \begin{cases} X[\frac{n}{2}] & \text{if n is even} \\ \frac{(X[\frac{n-1}{2}] + X[\frac{n+1}{2}])}{2} & \text{if n is odd} \end{cases}$$

X = ordered list of values in data set

n = number of values in data set

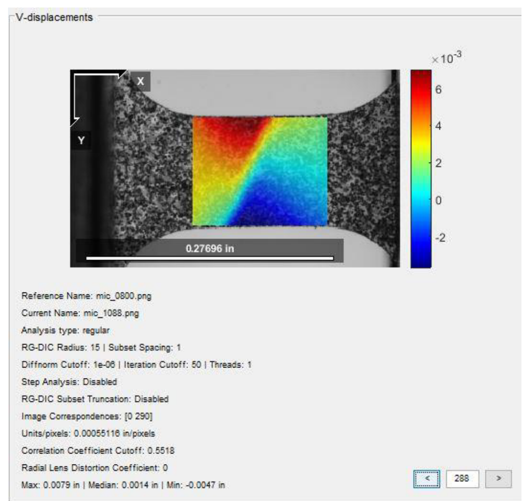

Figure 5: Displacement along V-axis

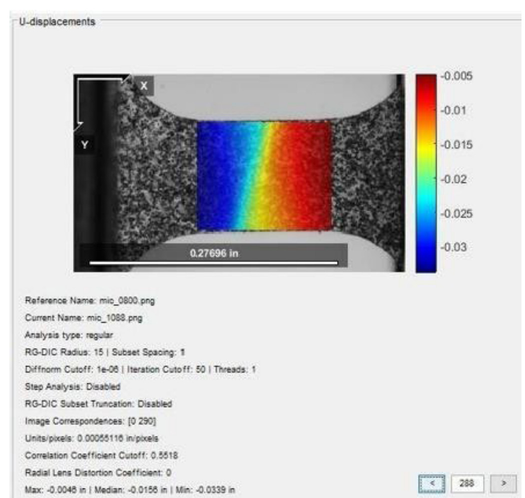

Figure 6: Displacement along U-axis

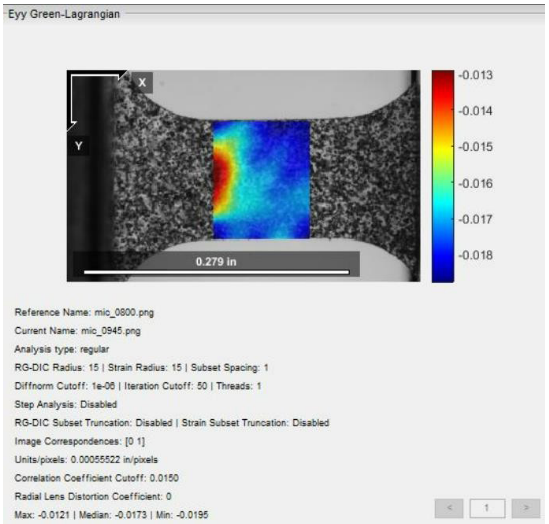

Figure 7: Strain in Eyy

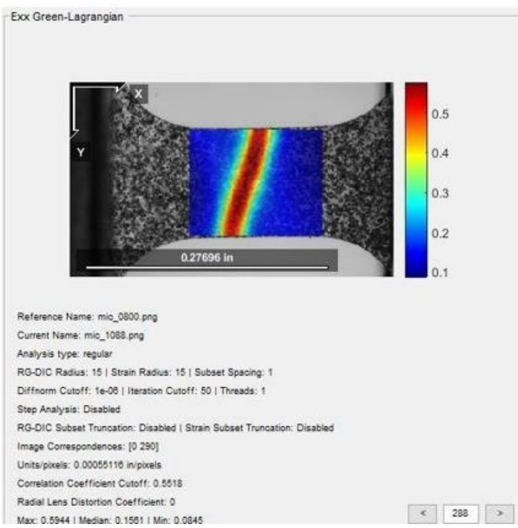

Figure 8: Strain in Exx

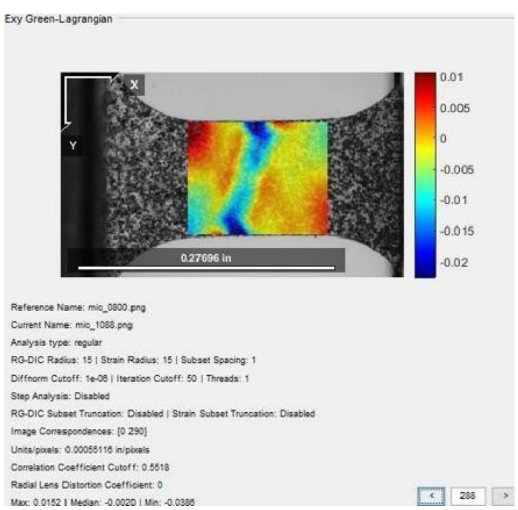

Figure 9: Strain in Exy

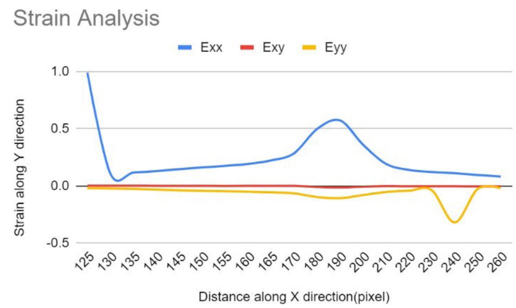

Figure 10: Strain Analysis Graph

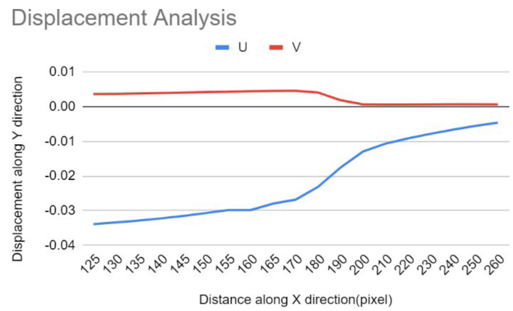

Figure 11: Displacement Analysis Graph

Graph Plots

The above graphs represent strain data along the X and Y axes of multiple points on the surface of the material. They all indicate high tensile strain across one particular section of the material and are shown in the figure highlighted in red colour during the DIC analysis procedure. The sample image ran in theanalysis was Image No. 800, and the material breaks at Image No. 1088.

Prediction of the breakage of cross section using Ncorr programand was cross checked by mapping graphs with the strain data obtained.

Conclusion

Examination of how deformations in materials develop when strain is applied. In materials, several forms of deformations have been found. Statistical analysis of the offered material was successfully done to fully comprehend them. The substance on which the tests are carried out is aluminium. Employed Digital Image Correlation to analyze thedeformation in the sample material (DIC).

An optical microscope is used to capture an image of the material, which is then processed and utilized to anticipate material deformation. To acquire findings of strain points on thematerial, the Ncorr application in the MATLAB environment isemployed.

By setting up the region of interest, DIC parameters, running DIC analysis on the material, and specifying the displacement axes, the reference image and the current picture were submittedto the N_{CORR} algorithm. Strain graphs on the Exx, Exy,and Eyy axes, as well as U-displacement and V-displacement graphs, are generated. The material's deformations have been investigated and assessed.

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