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Digital Image Correlation Applications in Biomedical and Aerospace Engineering

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Abstract

Digital Image Correlation (DIC) is a non-destructive method of testing that has grown in popularity substantially in recent years. DIC is the process taking a digital image of a surface before it has been deformed, and then again after to track the movement of pixels which will allow for the calculation of strain to the material. It can now be used in any number of fields, including aerospace and biomedical engineering. The application of this method has led to a whole new realm of understanding in everything from how to keep our aircrafts safe and operational to how to assess damage to the bones. The applications further increase as the option of two dimensional versus three dimensional DIC is considered. The benefits of this this technique can be seen in its ease of implementation and its accuracy as compared to alternative methods, which tend to be manual allowing for greater human error. Further explored here are the ways in which DIC can be applied to aerospace and biomedical fields, in addition to the methodology behind this technique.

Digital Image Correlation

Digital Image Correlation (DIC) is a non-destructive method of testing. This method can track the deformation of a surface to calculate the strain distribution [1]. A speckle pattern is painted on the surface of the sample, and digital images are taken before deformation and after various degrees of deformation. Tracking of the displacement of small subsets of the images from the unique speckle pattern, allow for the mapping of deformation gradients.

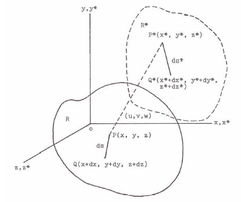
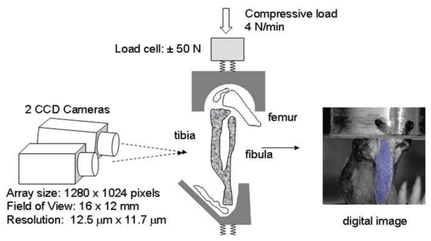


Figure 1: The line segment PQ is shown before and after deformation. This shift will be tracked [1].

Biomedical Applications of DIC

Within the biomedical field, it is more common to see volumetric DIC being implemented, because biological structures can less often be reduced to 2D images. In the studies by Moerman et al. [2], DIC was used to track the deformation of tissues in vivo which required the use of 3D DIC. For this method, two cameras are needed.



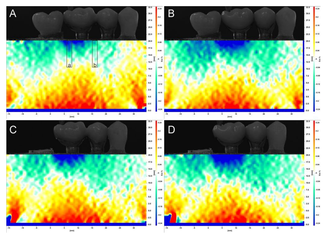


Figure 2: DIC was used to map the strain of different molar implants [3].

Figure 3: (Left image) A load was applied to a mouse tibia and DIC used to map the surface strains across the bone [4].

Aerospace Applications of DIC

In aerospace engineering, it is common to see both 2D and 3D DIC. 3D DIC was found to be an adequate tracker of surface displacement on small satellite antennas [5]. DIC has also been with nuclear weapons to track the behavior of fragmentation and calculate the projectile's motion [6].

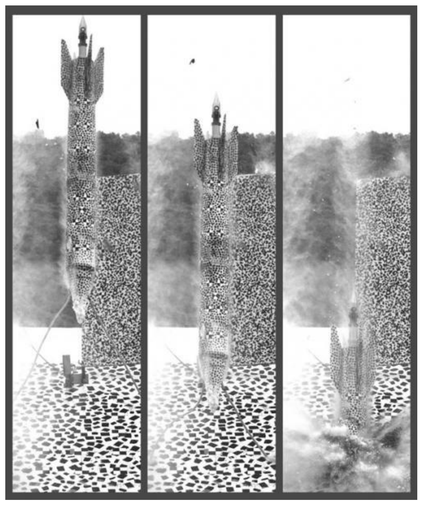
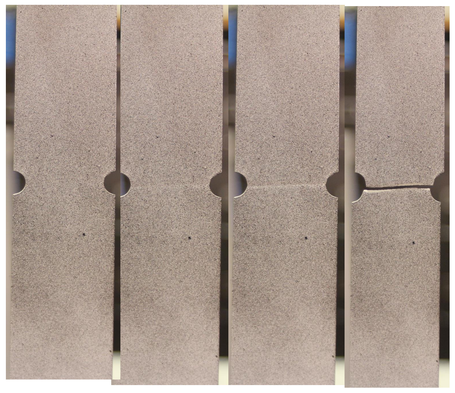


Figure 4: A speckle pattern was applied to a B61-11 ground-penetrating bomb and images captured with a high speed camera [6].

Sample Deformation

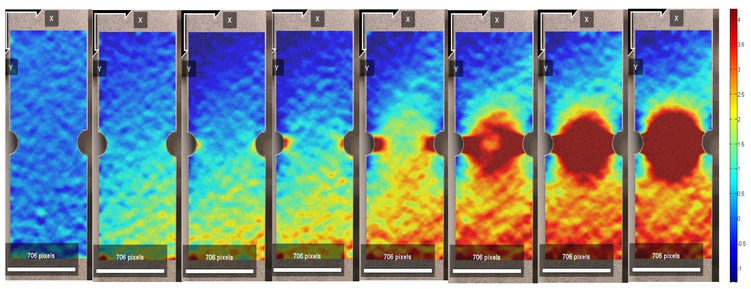


Images at Increasing Amounts of Loading: Speckle Pattern and Deformation can be easily seen

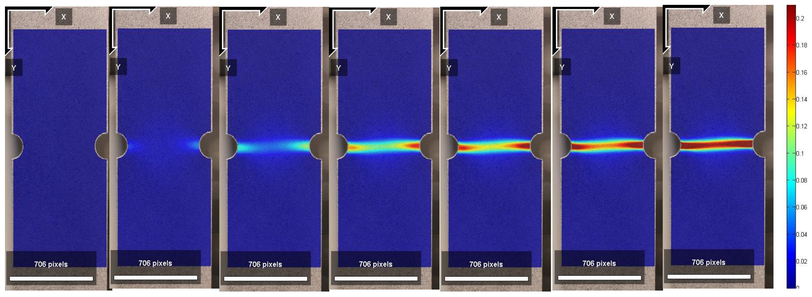
Results

Aluminum samples, 10"x1.5"x.06", were created with a semicircle notch, diameter 3/8", removed. They were painted flat white, then a random speckle pattern was applied. They were then subjected to tensile loading until failure. DIC analysis was run to plot the distributions shown below.

Sample 1 with Speckle Pattern after Failure



Eyy Plot to Show the Strain Concentration as Increasing Loads are Applied



Eyy Plot showing the Formation of the Line of Failure

Discussion and Conclusions

The results showed a large degree of stress concentration through the center of the plate, origination at the innermost point of the cutout region. This concentration found supports the hypothesis that stress would concentrate around the most narrow part of the sample. When the same test was repeated with the other four samples, same dimensions but not pictured, the load vs extension curves were nearly identical and the line of failure occurred in the same place.

Once the range of strain depicted was altered, it was easier to see the formation of the line of failure. It started, as seen in the previous images, at the outer edges of the center and progressed through the width until failure. This concentration line matches perfectly with the breaking line in the actual samples, confirming that it is in fact the line of failure.

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