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Application of Digital Image Correlation: A Review

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Abstract - *Digital Image Correlation (DIC) is widely used non-contact technique to detect the crack initiation on the surface of concrete. It is an optical method which measures the surface deformation. Full field strain measurement is possible using DIC technique. It obtains the horizontal and vertical displacements. The use of Digital Image Correlation technique eliminates the use of conventional technique i.e. the use of extensometers or strain gauges. DIC develops a strain map which is not created by conventional technique. Adaption of this technique for monitoring the civil engineering structures is presented in this paper.*

Key Words: **Digital Image Correlation (DIC), strain maps, Ncorr, MATLAB**

1. INTRODUCTION

Digital Image Correlation (DIC) is a new technique developed to find the strain developed in concrete. It is a full field, non-contact, optical monitoring technique. This can be used to find displacements on the surface from series of sequentially captured images. DIC technique finds the strain values on the basis of images captured. This test for finding strain is performed along with compression test. For performing DIC test, the sample should be prepared by using speckles. Speckles are the black dot which is dotted by using permanent markers or by spraying paint. Digital Image Correlation system setup consists of camera, light source and computer. Setup of DIC is fixed in front of compression testing machine. The camera is focused on the specimen and light source is adjusted in such a way that it gives proper light orientation. The first image is captured before loading. And after loading remaining images are captured. First image is the reference image. With reference to first image clicked strains can be find. For analysis of data, area is divided into small subsets.

1.1 Digital Image Correlation

Digital image correlation (DIC) used to find strain. The setup of DIC consists of camera, light source and data acquisition system. The camera is adjusted in such a way that it properly focuses on the region of interest. Capturing images and working of compression testing machine done at the same time. For performing test some pre steps should be performed. The surface of specimen is painted by using white paint. On that paint speckles are marked by using marker or black ink roller. A speckle means the black dots. The speckling is done for obtaining grey scale image. Firstly, undeformed image is captured. Then deformed images are captured. Both undeformed and deformed images are correlated. The camera captures 5 frames per second. DIC measures strain values of full specimens. DIC has more advantages over conventional techniques i.e. strain gauges, extensometer. It analyses sample without destructing it. Fig. 1 represents the process of DIC. Using displacement field, strain tensors are calculated to create strain distribution profiles capable of displacing both major and minor strain of the specimen during loading.

The error in DIC measurement could arise due to many sources such as illumination variations, quality of the acquisition system, camera lens distortion, image noise. However, there are several parameters like subset size, step size and strain window size, which can influence the accuracy of measurements.

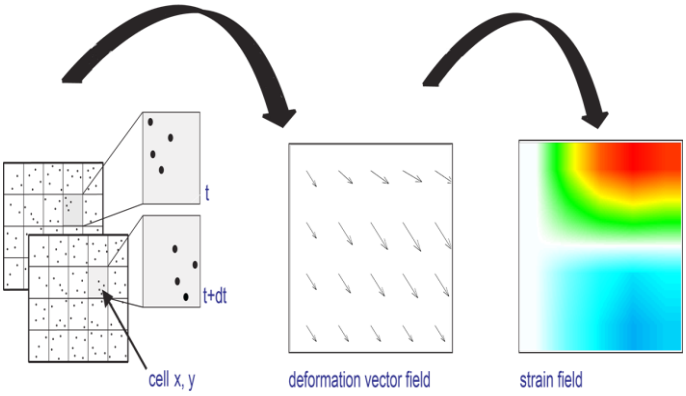

Fig.1: Digital Image Correlation

1.2 Principle of DIC

1. DIC measurement is based on tracking a group of pixels (called subsets) in the deformed and reference image through temporal matching and correlation functions.
2. Initially, digital image is divided into smaller regions called subsets.
3. Subset shape functions are imposed to the reference subset to account for the deformed shape of the subset in the deformed image.

4. The deformed position of the subset may not be at the integer location. Therefore, interpolation functions are used to obtain the grey intensity value at non-integer location.

5. Correlation function (c) is defined to match the similarity between the subset in the undeformed and deformed image.

2. ADVANTAGES OF DIGITAL IMAGE CORRELATION

1. Non-contact measurement
2. Unlimited number of deformation measurements.
3. The possibility of testing samples of any shape and material; the tested surface of the sample does not have to be flat.
4. The ability to measure deformation in all directions (along X-axis, Y-axis, Z- axis), on a plane or in three-dimensional space.
5. Full-field deformation analysis
6. A measurement of the real maximum displacements and deformations
7. A quick preparation of a random pattern of black dots on the white background on the sample surface by spraying paint.

3. REVIEW OF LITERATURE

In this section, the present theories and practices related to the Digital Image Correlation is studied by referring published literature in various journals from abroad. Researchers have been studying the various parameters of Digital Image Correlation. Following the review of Literature gives an outlook on the Digital Image Correlation technique.

Cristina Mayo-Corrochano(2022) et. al analyzed the elastic properties i.e. young's modulus and poisson's ratio of high fired gypsum using digital image correlation. For analysis purpose low budget 2D digital image correlation approach was used. DIC obtained full field strain data but showing RMSE of 0.008% compared with physical extensometer.

Zabala Jorge(2021) et. al focused on the practical and theoretical knowledge of digital image correlation. The author explained the evaluation of three specialized image correlation packages, Digital Image Correlation Engine (DICe), 2D Digital Image Correlation software Ncorr, and finally the GOM correlate software. Nitrile test piece with notches was prepared for study. And load was applied on it and at the same time images were captured to do the strain analysis. Data was show good correlation between these techniques.

Paul Qvale(2021) et. al used digital image correlation technique to identify crack initiation on corroded surfaces from offshore mooring chain. A two-camera setup was used, to be able to capture displacements on different sides of surface features, and to allow for 3D post-processing of DIC images. Nevertheless, the algorithms developed in this work only made use of 2D displacements. The author paired finite element analysis with the DIC measurements. From the correlation, an initiation S-N curve was established. Data was shown DIC provides good correlation data for detecting initiation of crack and crack growth on corroded surface.

Zhangyu Ren(2021) et. al investigated the stress and strain fields in porous structures by using photoelasticity and digital image correlation techniques. It was very challenging to combine those techniques because the speckle pattern cause disturbance in photoelasticity method. The stress value was obtained from photoelastic patterns and strain values obtained from DIC method. The strain fields were calculated based on an open-source and freely available 2D subset-based digital image correlation software package (Ncorr). The results showed good accuracy in determination of full stress and strain field.

Xiaofeng Qiao(2021) et. al used digital image correlation for full strain mapping. The test was performed on corneal sample for checking variation of biomechanical properties. Corneal sample was prepared for testing with uniform white colour and black speckles on it. This sample was subjected to increasing pressure load with constant velocity. Three-dimensional (3D) DIC algorithm was performed to present a map of the full-field strain distribution on the corneal surface. DIC algorithm performed to present a full field strain map. Author concluded that DIC technology gives validated results to characterization of structure-related variation in corneal biomechanical properties.

Valeria Quiceno P´erez(2021) et. al evaluated mechanical properties of self-compacting steel fiber reinforced concrete by using digital image correlation technique. Digital image correlation technique was used to obtain crack openings and vertical, horizontal displacements. In this investigation, the free two-dimensional DIC software for application in solid mechanics, that includes a graphical user interface in MATLAB and circular subsets, Ncorr v1.2 was used. The results obtained showed that digital image correlation technique was a valid and efficient alternative method for finding the mechanical properties.

E. Özaslan(2021) et. al focused on damage mode identification of composite laminates by using digital image correlation and acoustic emission. Full field strain measurement was found out by using digital image correlation. The main objective of DIC was to monitor

damage progress in specimens. Two cameras were used in this study to obtain in-plane and out of-plane displacements. GOM 12 M sensor system was used to measure full-field deformation. The author concluded that the findings of acoustic emission were successfully verified by digital image correlation.

Rims Janeliukstis and Xiao Chen (2021) explained applications of digital image correlation techniques to testing composite structures. DIC technique acquired popularity because of its functions like full field and non-contact strain measurement. Two stereo-vision systems each having two synchronized CMOS cameras were used. The setup details of digital image correlation were mentioned by author. The strain and displacements were measured by using DIC under static loading.

Bob A. Lingga(2019) et. al used digital image correlation technique for the assessment of strains of large scale cemented rockfill. Conventional contact method and non-contact method i.e. digital image correlation techniques were used for analysis purpose. Author recommended that, non-contact method was useful for investigation strain behavior of sample under uniaxial compression testing machine. The image correlation process was run using the VIC-3D 2009 software. Digital image correlation technique was the best tool for studying material testing behavior.

Alice Acciaioli(2018) et. al used digital image correlation technique for measuring small magnitude strain fields. Author investigated different sets of parameters for image processing. Image processing was carried out using dedicated software (Aramis V 6.3.0, GOM mbH, Braunschweig, Germany). The comparison of strain gauges and digital image correlation techniques was done. For finding the trueness of DIC, values of young's modulus and poisson's ratio were compared with values obtained by using strain gauges. The results concluded that DIC was suitable option for measurement of small magnitude strain fields.

Andrzej Rutkiewicz and Artur Jakobczak (2017) presented study on usefulness of digital image correlation technique for finding elastic modulus and poisson's ratio. The advantages of this method mentioned here i.e. non-contact, full surface measurement. The author concluded that, digital image correlation was able to determine young's modulus.

M. Hamrat(2016) et. al presented results of an experimental work on flexural behavior of normal strength concrete, high strength concrete and high strength fibre concrete in the form of crack detection, crack opening, crack development, crack width measurement and strain measurement. In addition, a Digital Image Correlation technique obtained by a digital recording camera ''Aramis" by GOM was used to measure the deflections, monitor the development of the cracks and measure their widths and detect strain components. Comparison between conventional technique and DIC was made to analyze strain values. The results showed that both the techniques were suitable for analysis of strain components. Author mentioned that, digital image correlation technique was best in analyzing the crack opening.

J. Blaber(2015) et. al used new technique digital image correlation with Ncorr package. Ncorr is 2D DIC package which is subset based open source. Author mentioned different algorithms implemented in Ncorr.

Y. H. Huang (2010) et. al studied the comparison between optical strain gauges vs. traditional strain gauges for determination of elastic modulus. Digital Image Correlation technique was the optical method used for determination of strain. Two high-resolution CCD cameras equipped with long working distance lens are used to capture images. This method determined real time strain values without human interaction. Optical strain gauge used was accurate, cost effective and flexible and had more advantages compared to traditional strain gauges.

Stephen R. Heinz and Jeffrey S. Wiggins (2010) performed uniaxial compression analysis of glassy polymer networks using digital image correlation. This non-contact technique developed accurate data of poisons ratio and yield strain. Advanced strain analysis using digital image correlation (DIC) was conducted using a GOM Optical Measuring Techniques ARAMIS 3D Deformation Analysis System. DIC eliminated the use of strain gauges and extensometers and provides accurate results as compared to LVDT. DIC technique was useful in studying pre-yield, yield and post-yield behavior of glassy polymer networks. Digital image correlation technique developed strain data and eliminated erroneous strain data associated with fixture. This technique allowed for calculation of true compression stress and strain.

4. CONCLUSIONS

After analyzing and studying numerous research papers it has been seen that the study of digital image correlation technique for finding strain is carried out at international level. From literature papers it is clear that 2D digital image correlation technique can be used for finding the strains, young's modulus and poisson's ratio. The strain fields are calculated based on an open-source and freely available 2D subset-based digital image correlation software package (Ncorr). The results showed good accuracy in determination of full strain field. So, I adopt 2D DIC for my project work. Digital image correlation technique gives approximate results on comparing with conventional technique. The study of digital image correlation is limited at national level and there is need to study that new technique.

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