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Original Paper

Research on the Application of VIC-3D Technology in Civil Engineering

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Abstract

Digital image correlation method has been widely used in various research fields of civil engineering since it was proposed, because of its convenient and simple, full-field measurement, good environmental adaptability and other characteristics. It has become an important measurement method in various research fields. The CCD camera is used to match the position of the same pixel in the two speckle images before and after the surface deformation of the specimen to obtain the displacement vector of the pixel, and record the change of the speckle characteristics of the specimen surface. Combined with computer vision and digital image processing technology, the physical quantities such as the morphology, displacement and strain of the object surface can be accurately measured. Therefore, this paper introduces the application of VIC-3D technology in civil engineering in detail.

Keywords

VIC-3D, civil engineering, displacement, strain

1. Introduction

Strain and displacement measurement is often carried out in civil engineering tests. The traditional measurement method is to measure the strain and displacement data through strain gauges and displacement meters, but the measured data is only the strain at a single point or in one direction, which cannot get the data of the whole field. Moreover, when the deformation of the specimen is too large, it will lead to data loss and even measurement interruption. Since the accuracy of traditional contact measurement is difficult to be guaranteed, more comprehensive measurement methods will be explored. At this time, the Video Image Correlate-3D (VIC-3D) based on Digital Image Correlation (DIC) comes

into view, which not only overcomes the shortcomings of traditional measurement methods, Moreover, the obtained displacement and strain cloud maps are based on the real material constitution, which is also of certain significance to the analysis and research of the follow-up test and simulation data.

2. Introduction to VIC-3D

VIC-3D technology is the essence of many years of scientific research by Correlated Solutions, Inc., the originator and leader of DIC. CSI has a unique 3D micro strain measurement patent, which uses an optimized 3D digital image correlation algorithm. For the test, the shape, displacement and strain data of the full field of view in three-dimensional space were measured.

2.1 Configuration of VIC-3D System

The VIC-3D system includes a variety of configuration computing control unit, analog data collector, LED light source, tripod, head, lens, toolbox, correction board, etc. For special measurements, you can choose large scene light source, backlight, stroboscope, optical distortion corrector, polarizer and other equipment. In the process of test preparation, in order to facilitate data collection by the instrument, white paint was first used to spray the area to be tested on the surface of the specimen. After the paint dried, paint pen was used to randomly paint the specimen, and speckle was arranged. In the process of layout, attention must be paid to covering the whole area to be tested as far as possible, without leakage points and leakage areas, and the diameter of speckle was not less than 2mm. It is easy for the camera to shoot the speckle clearly, and the surface of the specimen should be subject to uniform illumination. Then set up the camera and focus, calibration, and preliminary experiments, through camera to collect the speckle on the surface of the specimen under different loading state diagram, finally based on the initial state, collected speckle figure to make use of computer analysis and calculation, the deformation distribution of the sample. The schematic diagram of the VIC-3D measurement system is shown in Figure 1.

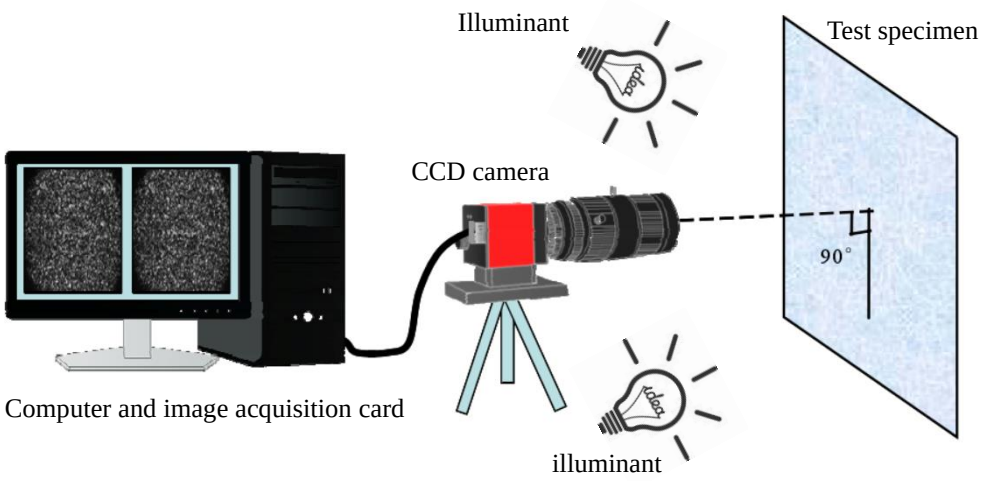

Figure 1. Schematic Diagram of the VIC-3D Measurement System

2.2 Features of VIC-3D

2.2.1 Full-field Measurement

The measurement is not limited to a single point, and the whole range of deformation can be observed; More convenient identification of critical failure points; The attention hotspot can be extracted from the previously acquired image without another trial; Multi-system arrays are available for large or circular objects.

2.2.2 Non-contact Measurement

No strain gauges, paint or grids are required; Precise positioning is not required for effective results; The vibration of the specimen can also be measured; The specimen can be prepared and measured in minutes.

2.2.3 Simple and Easy to Use

Single white light irradiation, safety don't need a laser or other special lighting; Accurate measurement without optical isolation; The system can be calibrated at any time during the test; Automatic data processing saves time.

3. Principles of VIC-3D

VIC-3D is a technology based on image correlation point comparison algorithm, which can calculate the displacement and strain distribution of the surface of the object. As shown in Figure 2, the relative displacement of the speckle pattern can be solved according to the speckle image before and after the deformation of the area to be measured. During the whole measurement process, only one or two image collectors need to take the image of the object to be measured before and after deformation, and the 3D full-field strain data distribution can be clearly seen after calculation. Unlike strain gauges, which take a lot of time to smooth and paste the surface, the strain data can only be measured at a certain point in a

certain direction; It's not as environmentally demanding as fringe interferometry. The data obtained by DIC method are 3D data in the full field. DIC can be used in general indoor and outdoor environments, the strain measurement range is from 0.005% (50 micro strain) to 2000%, and the size of the measurement object can be from 0.8mm to tens of meters. In principle, strain measurement can be carried out as long as the image can be obtained.

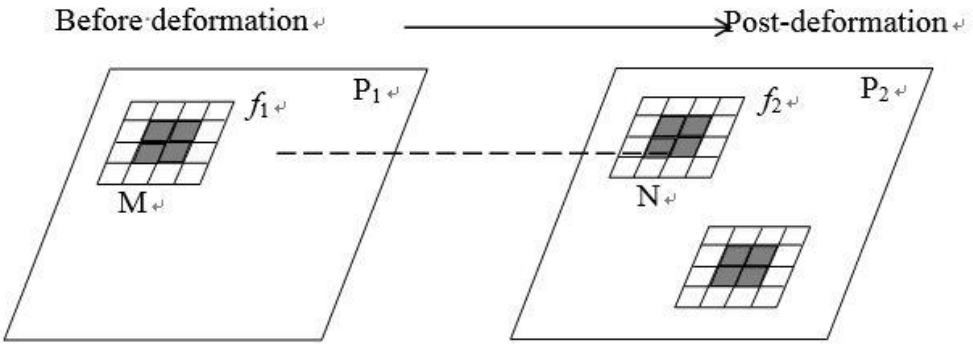

Figure 2. Diagram of Subset Changes before and after Deformation

4. The Application of VIC-3D in Civil Engineering

Since its introduction, VIC-3D has been widely used in deformation measurement fields, including material mechanics, structural mechanics, thermodynamics, vibration and impact, fatigue and crack, etc., due to its simplicity and good stability.

4.1 Application of VIC-3D in Civil Engineering Materials

For VIC-3D can without contact, the whole measuring deformation of the specimen under various stress, thus gradually as an important measurement technique in civil engineering material performance test.

4.1.1 Application of VIC-3D in Concrete

Xie Zi make people such as using digital image correlation technique and clamping method of polymer concrete test extensometer of crack opening displacement and extension length were measured and analyzed. The relative deformation distribution and deformation law of concrete under uniaxial compression test were analyzed by digital image correlation technology in Shenyang. Bai Pengxiang combined with digital image correlation technology to conduct an experimental analysis of direct shear failure of concrete. The experimental results show that DIC technology can obtain the shear strain distribution of concrete more intuitively and comprehensively, and is suitable for the monitoring of shear failure of concrete structures. In the semi-circular bending test of the fracture characteristics of asphalt concrete, Hong Zhe used digital image correlation technology to analyze the displacement during the crack propagation. Based on digital image correlation technology, Ren Huilan studied and

analyzed the full-field deformation and localized failure characteristics of concrete in the process of tensile splitting failure.

4.1.2 Application of VIC-3D in Steel

With the help of digital image correlation technology, Zhang Xinchao captured real-time in-plane strain characteristics of welded rail under different conditions, analyzed the anti-fatigue crack propagation ability of base metal and weld area, and the deformation characteristics of crack surface and tip during crack propagation. Zheng Jian used DIC technology to fit the material coefficients of the modified contour curves of Q235 and Q345 structural steels, providing reference for future research and prevention of ductile fracture of steel structures. Song Xiaoxiao proposed that the VIC-3D measurement technology can be introduced into the teaching process of experimental mechanics, which can not only enrich the experimental content by combining scientific research and experimental teaching, but also strengthen the students' analysis of the stress distribution state of specimens more intuitively. HangChao using digital image correlation technology of TC4 titanium alloy weld deformation was measured in the uniaxial tensile test, the digital image correlation method was verified in the test reliability.

4.1.3 Applications of VIC-3D to Other Materials

With the help of digital image correlation technology, Zhang Manting observed the development of displacement and strain on the surface of red clay soil and the relationship with the evolution of cracks. It was found that this technology could intuitively show the evolution process of cracks in the process of soil drying, and had good promotion value. When studying the fracture failure caused by micro-cracks in high-strength composite reconstituted bamboo, Lei Yang found that VIC-3D technology can accurately determine the crack tip, avoiding the complicated operation of equivalent flexibility method, and showed that this method is an effective measurement method to study the fracture performance of reconstituted bamboo. Li Gaoyang used the VIC-3D strain measurement system as a measuring instrument to measure and shoot the whole process of uniaxial compression test of coal and rock specimens. In the measurement process, the system obtained the displacement evolution cloud map of the positive surface of the specimens in X and Y directions through the movement of specks. Wang LAN used VIC-3D technology to measure displacement and strain in the three-point bending experiment of SBS modified asphalt mixture half-circle specimen, and obtained the change rate of displacement and strain by using this technology, revealing the mechanism of cracking and crack development of the specimen. With the help of DIC technology, Sun Yanan studied the interfacial bonding properties of basalt fiber reinforced polymer (BFRP) bars embedded in concrete, obtained the strain field evolution data of BFRP bars in the process of pulling out from the surface of concrete, and calculated the interfacial bonding stress.

To sum up, it can be seen that the application of digital image-related technology in building materials has been favored by researchers, and it also provides researchers with accurate data to help better analyze the mechanical properties of materials.

4.2 Application of VIC-3D in Structural Engineering

The early digital image related technology was mainly used in the study of material properties. With the continuous progress of technology, a large number of researchers also introduced the VIC-3D technology into the structural test to measure the displacement and strain, and obtain the whole-field displacement and strain data.

When studying the self-reset performance of beer-column joints with built-in shape memory alloy (SMA) bars, Pei Qiang took pictures of the overall displacement and strain of the specimen to be tested in the quasi-static test with the help of VIC-3D technology, and obtained the corresponding vertical displacement and the whole process of the principal strain cloud diagram. Fan Tuanjie used digital image correlation technology to capture the whole process of RC beam crack development under load. Fan Shuang used digital image correlation technology to study the crack development process of concrete surface at the root of full-size column under reciprocating load. Jiang Guoping applied the DIC technology based on light intensity robustness to the static load test of precast concrete shear wall reaction frame, and obtained the strain cloud map and crack propagation path of the precast concrete shear wall specimen. Cong Fanqi used DIC equipment to capture the displacement information of the concrete surface, obtained the displacement field data of the concrete surface through calculation, then processed the data, drew the displacement cloud map, and input it into the neural network to obtain the predicted value of the neural network and compared it with the real value. Thus, the ability of neural network to extract information of concrete surface displacement field and predict internal damage of real concrete structure is verified. Liao Jian used the digital image correlation method to study the whole process of damage development and crack development of RC shear wall under the action of low cycle reciprocating loads, and calculated the full-field displacement and strain data. On this basis, the evolution law of horizontal displacement field, strain field, vertical displacement field, strain field and maximum principal strain field during the failure process was analyzed. When Zhang Yuying carried out the static load test study of pile defects, she found that the displacement meter would change in the process of measuring the failure of defective piles, and it was difficult to accurately measure the position and shape of defects. Therefore, VIC-3D technology is introduced to measure and study the defect location and shape of the defective pile, and through the analysis of strain cloud image, the location and shape of the defect and its failure process can be accurately determined.

Xing Yapeng proposed a non-contact deformation measurement method of bridge based on DIC technology, and compared the data collected by traditional contact sensors to verify the feasibility of DIC technology in non-contact deformation measurement of bridge structures. Based on the digital image correlation method, Wang Dongsheng measured and calculated the deformation components of prestressed segment assembled piers with stainless steel and ordinary energy-consuming rebar, and analyzed the overall deformation components of segment assembled piers.

In addition to the application of digital image related technology in building structures and bridge structures, geotechnical has also slowly introduced non-contact measurement methods into the research.

Li Jiexing combined DIC technology with the monitoring of formation deformation information of high slope. Through the image visual acquisition system and using the camera visual positioning method, he constructed a three-dimensional information recognition system. Wang Huajun points based on DIC instrument test under different working conditions peak times stack effect on slope displacement change.

In the application of digital image related technology in structural engineering, it is not difficult to see that most of them are still applied in building structures, which has made a great contribution to the crack development and damage of beam, column and shear wall structure tests, and has also provided experts with certain convenience and comprehensiveness. When seeing the advantages brought by it, the technology is gradually introduced into the research of bridge and geotechnical fields.

5. Conclusion

The test has always been an indispensable part of the research in the field of civil engineering, and the displacement and strain measurement crack growth in the test is an important data for analysis. The traditional displacement and strain measurement means obtain the average value in the denaturation process, which is not continuous, so the analysis of the test results is relatively incomplete. Therefore, when the researchers found that a better measurement method of VIC-3D technology appeared, they introduced it to provide full-field shape, displacement and strain data measurement in three-dimensional space for the test. Starting from two aspects of civil materials and structures, this paper summarizes and analyzes the current domestic research status in the field of digital related technology. The results show that domestic research on digital-related technologies has always existed, and the number of relevant papers has been increasing year by year, especially in the past five years, VIC-3D technology has been widely used in various tests. According to the survey results, it is more commonly used in material tests, while relatively few are used in building structures, Bridges and geotechnical tests. However, related researchers have shown that the convenience and comprehensiveness of this technology for structural testing are better than traditional measurement methods.

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