Indian Society for
Non-Destructive Testing
Hyderabad Chapter

Proc. National Seminar on
Non-Destructive Evaluation
Dec. 7 - 9, 2006, Hyderabad

A Method for Real Time and Continuous Acquisition of Interferogram of ESPI for Non-Destructive Evaluation

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Abstract

Electronic Speckle Pattern Interferometry (ESPI) is a highly sensitive optoelectronic whole field technique used for measuring surface displacement strain analysis, surface roughness, surface contour etc. This nondestructive evaluation technique permits measurement of deformations in the micrometer and sub micrometer ranges produced in a test specimen under different loading conditions. In ESPI technique, the speckle patterns act as information carriers of different deformation states of the test specimen. These speckle patterns of the object before and after loading are electronically detected and digitally processed to generate interference fringes. In this paper a method for real time and continuous acquisition of ESPI images and the simultaneous electronic processing is discussed.

Keywords: *ESPI, Speckle interferogram, NDE*

1. Introduction

Electronic Speckle Pattern Interferometry (ESPI) is a fast developing whole field optical technique used for the measurement of optical phase changes under object deformations and has evolved as a powerful Non-Destructive Evaluation (NDE) tool [1, 2]. In ESPI the speckle patterns of the object before and after loading are digitally processed to generate an interference pattern. The deformation caused by defects in a material produce fringe anomaly, since there will be stress/strain concentration close to the defect [3, 4]. Even the subsurface and inner defects can generate a fringe anomaly if the loading is sufficient. These fringe patterns are displayed in real time in a monitor and thus on line inspection of the test specimen is carried out.

Real-time display of the fringe patterns in ESPI is possible only by on-line acquisition of speckle interferograms at different loading states and also by the simultaneous electronic processing. In many cases, the images are grabbed and saved at different loading states and at a later stage the image processing are carried out to generate interference fringes. The present study is to report a method for real time and continuous acquisition of ESPI images for non-destructive evaluation. Dataflow diagrams are developed using Imaging Graph software for on line arithmetic operations of the specklegrams to yield visible fringe patterns.

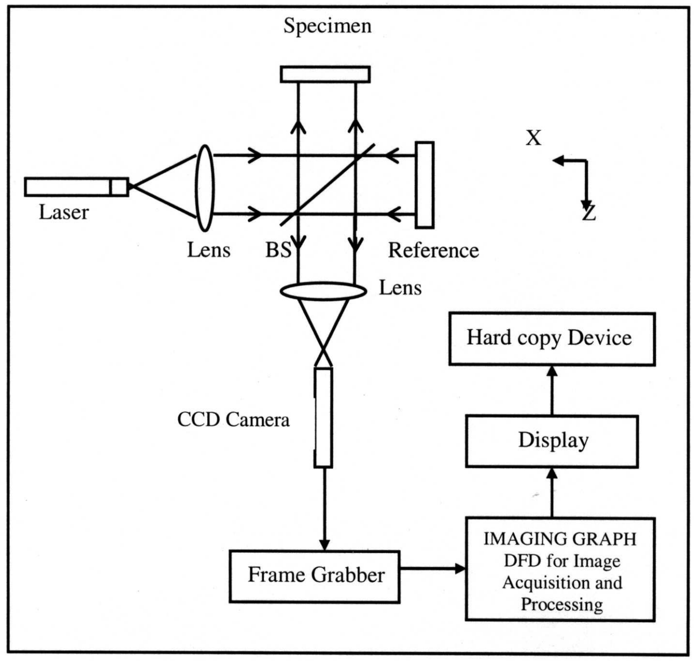

Fig. 1: Lay out of the ESPI system with out of plane optical configuration

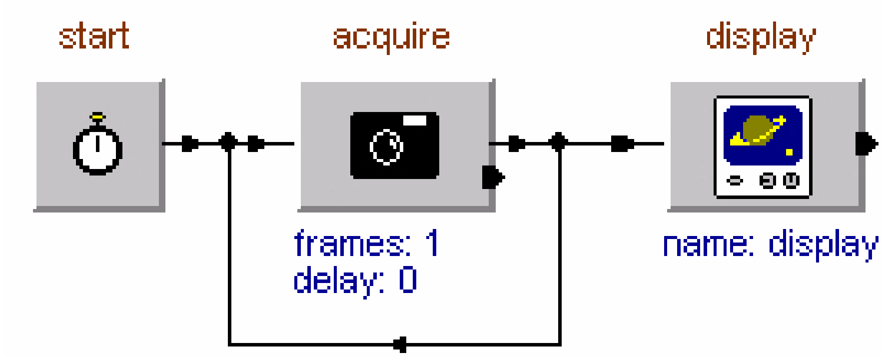

Fig. 2: Data flow diagram for continuous acquisition of images

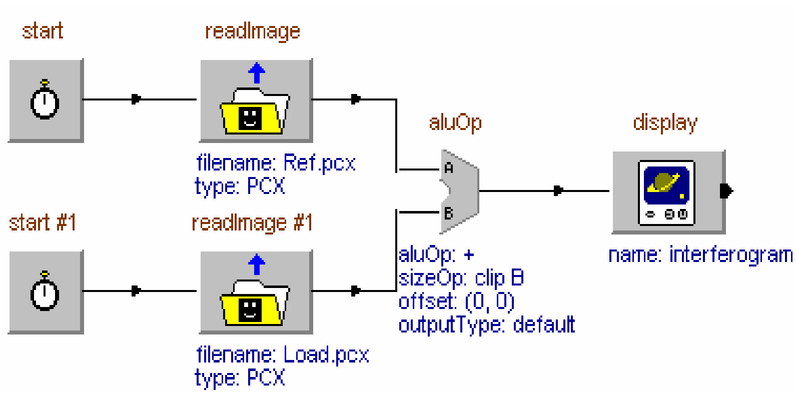

Fig. 3: Data flow diagram for continuous subtraction or addition of images

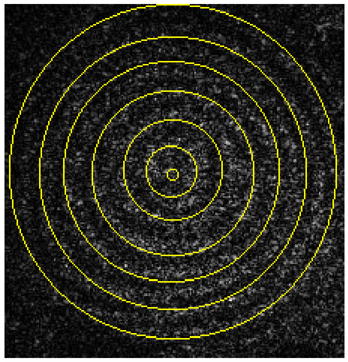

Fig. 4: Fringe pattern generated for a defect free specimen

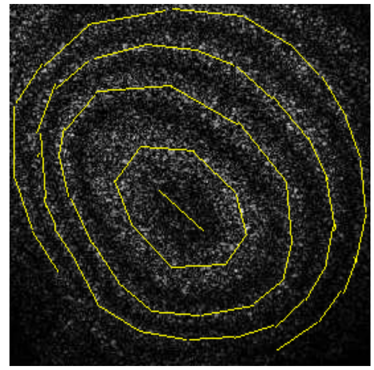

Fig. 5: Fringe pattern generated for a defective specimen

2. Basic Theory and Experimental Setup

The ESPI fringe patterns are generated either by subtraction or by addition method. Generally the speckle interferogram of the test specimen under different stress conditions are subtracted from the reference specklegram that is grabbed before loading the specimen. The ESPI fringe patterns are formed due to the change in optical path length when the specimen is displaced. The phase change δ due to the displacement of specimen is given as[3],

$$\delta = \frac{2\pi}{\lambda}[w\,(1+\cos\theta) + u\,\sin\theta]$$

where, w and u are displacement components in the Z and X direction and θ the angle of illumination.

The lay out of the system used is shown in fig.1. The optical configuration of ESPI interferometer used for the experiment is sensitive to out of plane displacement. The CCD used is an interline-transfer colour video camera module designed for RGB image processing. It has high performance horizontal resolution of 570 TV lines with a signal to noise ratio of 58dB and sensitivity of 2000 Ix . The video capture card is capable of digitizing live images at the rate of 30 frames/sec. The image processing system used for the analysis of fringe pattern is an algorithm developed by using Imaging Graphs.

3. Continuous Acquisition of Specklegrams

The data flow diagram developed for continuous acquisition of images is shown in fig 2. The frame grabber card properly installed in the system is operated for enabling the frame grabber item on the menu. This item on the frame grabber window has been selected for displaying live video images. After controlling frame grabber parameters such as grab size and input channel selection, the individual frames of the images are grabbed. The data flow diagram developed using different Imaging Graph operators is executed for continuous acquisition of live images under different loading conditions. This method of continuous acquisition is very effective for fixing the optimum load for getting visible fringe pattern after subtraction. The start operator is used as the starting point of an Imaging Graph, because most operators require at least one input. The acquire operator grabs a currently stored image from the frame grabber. The number of images for grabbing is decided by fixing the frames parameters. It is seen that if frames are set to one, then a single image is the output. If the number of frames selected is greater than one the sequence of images are grabbed and the out put is obtained as a vector sum of the images. In this case, the delay parameter sets the time interval between images grabbed in sequence. The *display* operator creates a pop-up frame containing the data of the object received at its input port. If the object is an image, then the pop-up is presenting a rendered image. If the object is not an image, then display will pop-up a frame with text showing all the pertinent data contained within the object.

4. On-line Generation of Fringe Pattern

In order to get fringe patterns, a large number of trial experiments are performed by deforming the specimen at different loading conditions. At each stage, the grabbed specklegram of the specimen under loading condition is subtracted from the reference pattern. To avoid this time consuming and tedious process, a data flow diagram has been developed for continuous live subtraction of specklegrams for generating ESPI fringe pattern and is given in fig. 3. Here, the option is given either for subtraction or addition of frames. This algorithm is very effective for NDT applications in experimental stress analysis because the live fringe patterns with and without anomaly is instantly displayed on the monitor for further analysis and study.

The live fringe patterns generated for a defect free and defective specimen using the present set up is shown in figs. 4 and 5.

5. Conclusion

A method for continuous acquisition of specklegram, on-line generation and processing of fringe pattern is presented using data flow diagrams with Imaging Graph software. The interferograms obtained in the ESPI experimental set up are studied using this methodology. The processed fringe patterns obtained for specimen with and without defect are easily identified for effective interpretation of defects.

6. References

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