Advancements in Interferometric Strain/Displacement Gage Measurements

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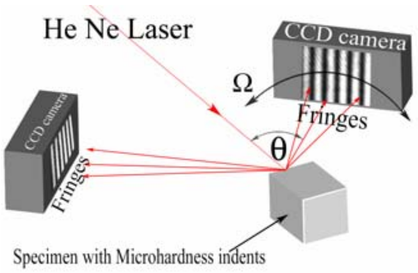
Introduction

Micro-electro-mechanical systems (MEMS) is a relatively new field that is full of unexplored material behavior at the micro scale. Many devices have benefited from the research and development of MEMS. Some devices include inkjet printer heads, accelerometers used as sensors for airbag deployment, tips used in Atomic Scanning Microscopes, and the list continues to increase and develop. In order to properly study the micro-material used in the fabrication of the MEMS devices, robust and reliable measurement systems are required. The Interferometric Strain/Displacement Gage (ISDG) is a non-destructive measurement device that has established that the system can perform direct strain measurement with stout precision and accuracy.

Basics of the Interferometric Strain/Displacement Gage (ISDG)



The variables in the equation represents:

θ - the angle between laser source and the resultant fringe pattern

λ - the wavelength of the incident laser

d_o - the initial gage markers spacing

$\Delta\phi$ - the phase shift

•A coherent beam of light from a Helium-Neon laser (wavelength = 632.8 nm) source is used to illuminate 2 or more specially placed reflective markers on the sample surface.

•Resultant interference fringes are captured on a pair of Charged Couple Device (CCD) cameras that window of 600 x 800 pixels with individual pixel dimension of 4.65 mm square.

•Fringe motion is captured and processed through a specially created LabVIEW program.

•The corresponding fringe phase shift is proportional to the strain in the specimen through the following equation [1]:

$$\varepsilon = \frac{\left(\frac{\Delta\phi}{2\pi}\right)\lambda}{d_0 \sin\theta}$$

The LabView program is an essential part of the ISDG that performs all of the calculations for analysis and measurement of the displacements. The following descriptions address the different analysis of the captured data which is performed at real-time.

•The CCD cameras collect the fringes that are reflected off the markers which are read by the computer as different voltage values depending on the intensity of the light impinging on the individual pixels.

•Then the program averages the fringes along the columns and produces a raw fringe pattern.

•Next the raw fringe pattern data is corrected from its offset and Hamming is performed on the data to prepare the data for analysis by Fast Fourier Transform (FFT) and then plotted.

•Once the FFT is performed, the Power Spectrum of the FFT is performed and plotted to depict the characteristic that comprises the fringes.

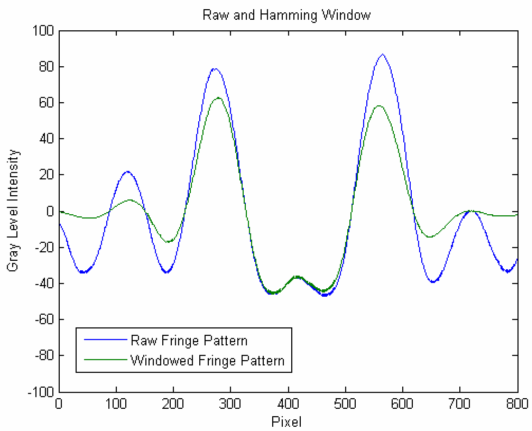
•The peaks that are found in the Power Spectrum plot are the characteristic frequencies that are tracked during the progress of the testing.

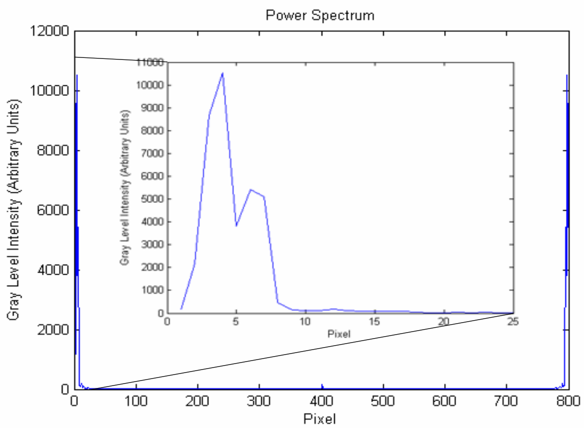
•Finally, from the equation on the left, the strain of the micro-sample can be computed at real-time.

Proposal

Using the ISDG system, relative in-plane displacement of micro-samples are routinely measured and analyzed for material characterization. A relative full-field in-plane strain/displacement mapping is currently being researched and developed. Currently, experimental tests are conducted to demonstrate the feasibility of the of full-field in-plane strain/displacement mapping. An addition of another marker that is in the same lateral position as the usual two marker arrangement is used where the distance between the markers are not equal. If analysis can be performed on 3 markers, multiple markers should be possible to extend to measure full-field in-plane strain/displacement and would only be limited by the coherent electromagnetic wave source diameter.

Preliminary Results





From the Raw and Hamming Window graph, the 3 marker arrangement shows a fringe pattern that is different from the 2 marker arrangement. Also, note the a symmetry that is apparent near the 400 pixel location which suggests that this fringe pattern has a unique periodicity but lacks a window size large enough to capture more data to prove/disprove this statement. The Hamming Window does a wonderful job of preparing the Raw data for FFT to Power Spectrum analysis.

As seen in the Power Spectrum graph, two distinct peaks (pixel location of 4 and 7) are depicted as characteristic frequencies. From a mathematical standpoint, there should be three distinct peaks in the Power Spectrum. The ‘lost’ of a peak may be caused by the lack of windowing data, resolution of the laser beam, and/or other factors.

Future/On-going Work

•Once experimental results are satisfactory for a 3 marker arrangement, the expansion to multiple marker arrangement will be developed until an multiple marker array can be developed to produce a relative full-field in-plane strain/displacement mapping capable ISDG system.

•A mathematical model that will provide theoretical the fringe pattern depending of the marker spacing and the reflective area of the marker

References: [1] Application of Fourier Analysis to the Laser Based Interferometric Strain/Displacement Gage - Marc Zupan and K J Hemker, Experimental Mechanics Vol 42, No. 2, June 2002