glect of strain derivatives might lead to inaccurate results in some shell problems.

Author's Closure

The author had seen Dr. Paul's paper but had overlooked the discussion by Mr. Recker and the closure by Dr. Paul. It appears that the solution in that discussion and closure is the same as the short plug (α < 1.1872) solution presented by the author.

Measurement of Surface Displacement Normal to Line of Sight by Hol-Moiré Interferometry

J. A. Clark, V. J. Parks, and A. J. Durelli

Out-of-Plane and In-Plane Displacements

Using holographic methods only displacements of a surface in some out-of-plane direction can be measured directly. Another operation is necessary to determine the in-plane displacements and so far this has been a time-consuming pointwise numerical method. The authors have found a novel solution to this major difficulty. They have shown that the data reduction can be achieved by an optical whole-field method.

Three Approaches

Three approaches can be used today to analyze the whole-field of a body without using models, gages, or coatings: holography, moiré, and speckle interferometry. Since all three of these optical methods use the interference of grating like patterns, it is helpful to distinguish the methods by their fundamental gratings.

(a) Moiré methods use a geometrically regular grating applied to the test specimen either by printing, etching, projection or reflection.

(b) Holographic methods produce a real optical grating image which can be recorded directly on film (the hologram).

(c) Speckle methods use a virtual, optical grating image which can be photographed with a camera and appropriate spatial filters such as a combination of two separated pinhole apertures.

All of these optical methods of detection can be combined with a variety of optical processing methods to reduce the data to the desired information. For example, the contribution of Hung and Taylor can be recognized as a holographic method of measurement combined with a novel application of moiré for the data processing.

The improved holographic method calls for a critical comparison with other optical methods to reassess the relative practicality of the approaches. An attempt will be made to compare results obtained by the authors with moiré measurements such as shown in the discussers' Fig. 1 [1, 2].

Displacement Sensitivity

The sensitivity of moiré displacement measurements is a function of the grating density. The pitch of the grating is limited to about 12.5 microns which corresponds to a grating density of 80 lpm. Denser gratings are available but the precision of measurements taken over a large area does not appear to exceed that of those obtained with 80 lpm.

Holographic measurements of displacement are also functions of the grating density. Sensitivity to out-of-plane displacements can be practically achieved down to a pitch of about 1 micron equivalent to 1000 lpm. The method of Hung and Taylor permits whole field determination of in-plane displacements with that same order of sensitivity. The displacement sensitivity of moiré measurements can be improved by fringe multiplication methods of optical processing similar to that illustrated in Fig. 1, but fringe multiplication by more than 2 or 3 is generally difficult to perform and susceptible to other sources of errors which limit the accuracy of the measurements. The holographic method of Hung and Taylor therefore achieves a substantial improvement in the state of the art of displacement measurements.

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Fig. 1 Spatial derivatives of displacement (isoparasagoces) obtained by filtering the diffraction pattern of two superposed crossed gratings. Determination of cross derivatives and 3 components of strain [(du/dx), (dv/dy), (dx/ax, dy/az)] equivalent to a rosette strain gage are illustrated.
DISCUSSION / BOOK REVIEWS

Strain Sensitivity

Most of the times displacements are obtained for the purpose of determining strains, and comments on the possible strain sensitivity of the methods may be appropriate.

Moiré measurements facilitate the whole-field determination of strain fields. This can be done by shifting either isotherics or deformed gratings. In the last case sensitivity is limited by the requirement for photographing the deformed grating lines. Images of gratings denser than about 40 lpm are difficult to resolve with current optical systems. For a typical shift of 5 mm, assuming precision to 1/10th of a fringe, 5 × 10^−4 can therefore be achieved. A variety of optical processing methods can also be employed such as the spatial filtering of crossed, superposed gratings to completely determine all components of the in-plane strain tensor as illustrated in Fig. 1. It is not clear to the discussors whether similar optical processing methods can be applied to the holographic methods.

Technical Requirements

Preparation of models for moiré measurements is admittedly still a process requiring considerable specialized technical expertise. However this difficulty does not seem to be substantially greater than that imposed by size, rigidity, and coherence requirements for holographic measurements.

As a final indication of the practical situation, one might consider the difficulties to be encountered with holographic alternatives to the moiré measurements shown in Fig. 2; this picture has been taken from a 18 cm × 38 cm steel plate loaded within a furnace, at 600°C.

References