ON MOIRE METHOD APPLIED TO THE DETERMINATION OF TWO-DIMENSIONAL DYNAMIC STRAIN DISTRIBUTIONS

by

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Abstract

A technique is proposed whereby the moiré methods are extended to general two dimensional dynamic problems.

Introduction

The use of moiré fringe method for the determination of dynamical strains has the following advantages: that being an optical method it has no drift nor lag in response; that it can be applied to actual material; and that the moiré information is sufficient for whole-field determination of strains. The last two abilities are lacking, for example, in the technique of dynamic photoelasticity. In applying moiré method to static problems one usually prints a cross grating on the specimen and uses a unidirectional grating for master and obtains the u-field and v-field patterns by rotating the master grating 90°. This procedure of course cannot be applied to dynamic problems. Moiré workers are reluctant to use cross-grating as master because the resulting moire fringes are usually so entangled together that it is difficult or even impossible to distinguish the u and v families. As a result, the problems that are accessible to moiré methods so far are problems involving symmetry. In such cases either a unidirectional grating is sufficient for the complete determination of strain field [1] or one can use two unidirectional gratings with perpendicular orientation printed on two halfs of the specimen [2]. This of course puts a severe limitation on the applicability of moiré methods to dynamic problem. Furthermore, the technique of using the unidirectional gratings also runs the risk of having larger shear errors if the two sets of lines are not exactly perpendicular [3].

In this paper the technique of optical spatial filtering is extended to dynamic moiré patterns whereby cross gratings can be used both as model and master gratings and the resulting dynamic moiré patterns are optically filtered to yield u-field and v-field fringes individually. Thus the ambiguities of cross-fringes are completely eliminated, so is the possibility of shear errors due to misalignment. With the proposed technique, the moiré method can then be used to solve general two-dimensional dynamical problems.

The Experimental Set-up

The problem chosen for the demonstration of the technique was a flat plate under the impact of a falling weight. The model was made of urethane rubber and one face of it was printed with a cross-grating of 300 lpi. The master grating (also of 300 lpi cross) was erected in front of the model with a gap of about 1/8 inch. The reason for introducing a gap in between the gratings is the following: traditionally master and model gratings are in close contact to yield moiré patterns of deformation. While this approach is perfectly sound for static problems, it raises questions as to its applicability to dynamic problems because of the fact that frictions between two gratings may strongly influence the characteristics of the propagating wave. The use of lubricating oil between the gratings will reduce the friction but not completely eliminate it. With the introduction of a gap friction is completely eliminated and the initial moiré pattern thus created corresponds to a compressive linear mismatch [4, 5, 6] which can be utilized advantageously for the interpretation of moiré patterns [7, 8].

The camera was then focused on the master grating and the aperature was set such that the model grating was within the depth of field. (The film and the lens system should be of such quality that the lines of the master grating can be recorded.) The schematic of the experimental set-up is shown in Fig. 1. The wave was captured by microflashes and a series of pictures showing the waves at different stages of propagation is shown in Fig. 2a.

Separation of Dynamic Moiré Patterns

The spatial optical processor described in reference [9] ,!as used for the separation of the dynamic moiré patterns. The negatives of the picture shown in Fig. 2a was inserted at the object plane of the processor and filtering was performed at the first image plane by placing a mask with a small hole to let through the first order along the horizontal axis of the diffraction spectrum to yield the u-field fringes and then the first order along the vertical axis to yield the v-field fringes. The resulting patterns are shown in Figs. 2b and 2c, respectively. It is interesting to note the striking difference in quality between the patterns so obtained and that shown in Fig. la. The original patterns are of poor contrast (partly due to the gap effect) although they were printed on No. 5 paper; and the fringes are not well defined especially near the loading point. The filtered version however not only possesses good contrast (printed in No. 2 paper) but also have sharply defined fringes. Without filtering one would hardly be able to estimate correctly the positions of the twisted fringes especially near the loading point and to assign them correctly to their respective families. Although the fringes near the loading point do not necessarily have significant meaning in the analysis of the present problem they do however demonstrate the powerful potential of the presented technique in clearing out the ambiquities of moiré patterns.

Discussion

From the patterns in Figs. 2b and 2c, the displacement components u and v are given at each and every point in the field and they are sufficient for the complete determination of strains. As a result it is no longer necessary to resort to the symmetry of a problem and obtain u and v individually from corresponding points at different parts of the model.

The key, point of the technique is the ability of the film to resolve the lines of the master grating which is necessary for the diffraction of the light. This of course puts a limitation on the ratio of object to image size. Furthermore, the tolerance of the relative movement between film and object during exposure is also smaller than that required in conventional high speed photography, because excess relative movement can easily smear the image of grating lines while it may not influence the image of the fringes.

Conclusion

It may be concluded that the proposed technique has extended the applicability of moiré methods to general two-dimensional wave propagation problems.

Acknowledgment

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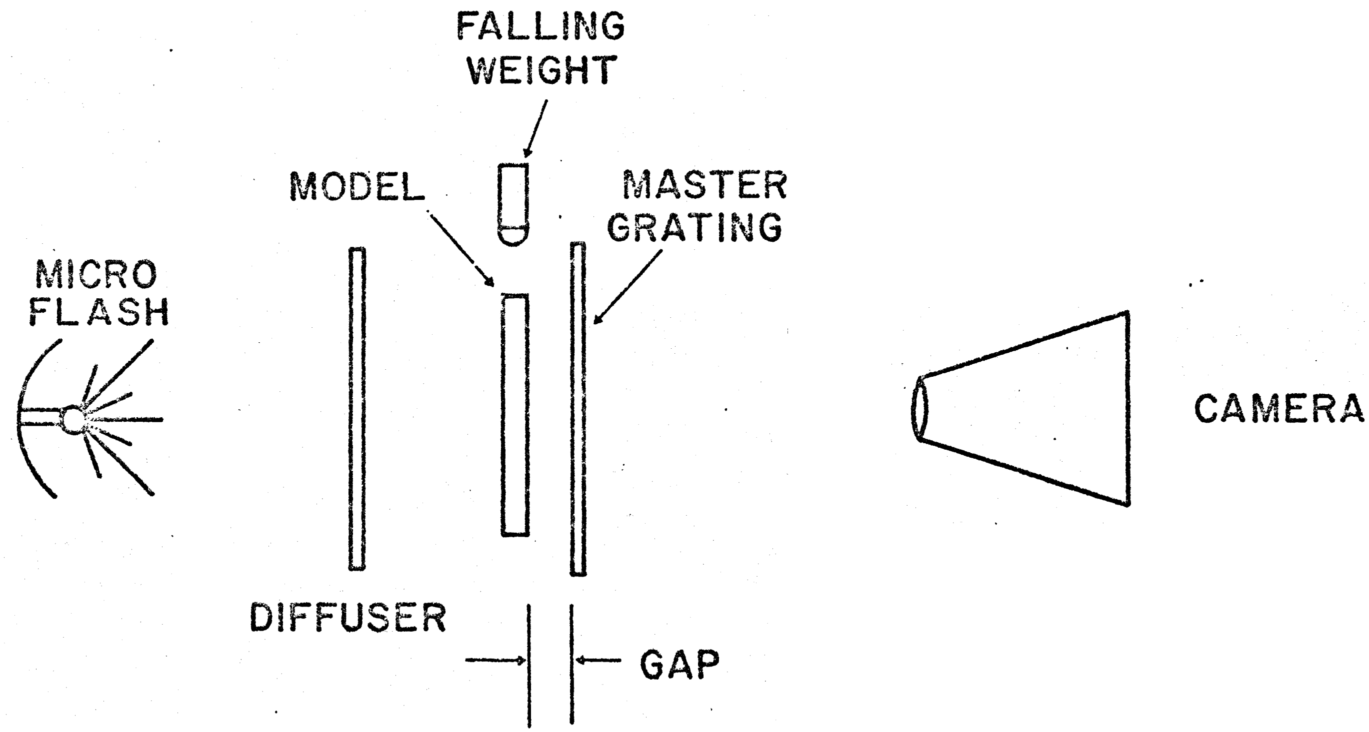

FIG. I SCHEMATIC OF THE EXPERIMENTAL SET-UP

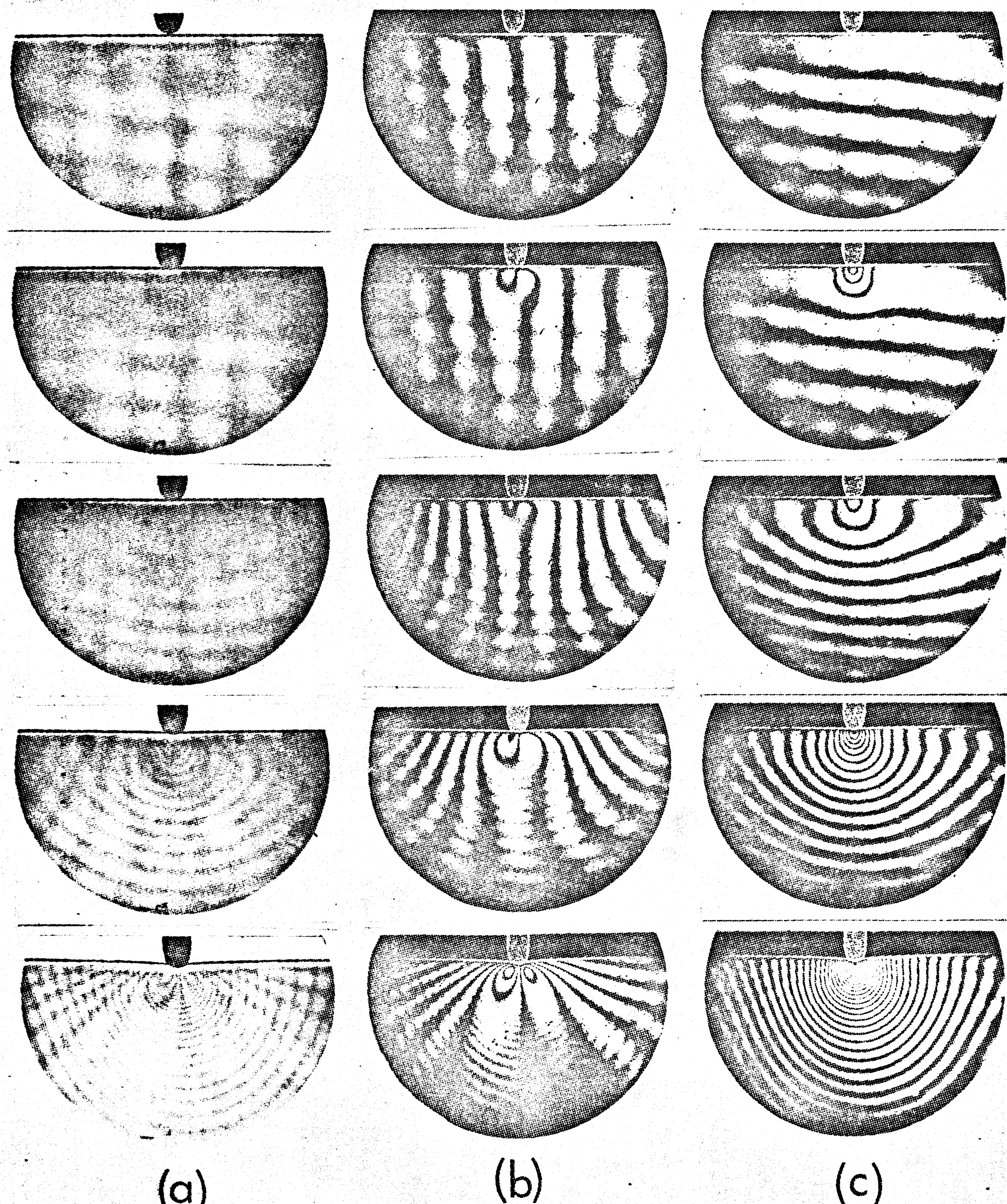

Fig.2. Optical Separation of Displacement Fields from Dynamic Moiré Patterns
(a) Combined U-and-V field Moiré Fringes
(b) U-field Fringes only
(c) V-field Fringes only.