STRAIN DETERMINATION ON CURVED SURFACES
BY OBJECTIVE WHITE LIGHT SPECKLES

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ABSTRACT: A close-range objective white light speckle method has been used for strain determination on simply curved surfaces. The speckle field is not the artificially printed random dots but only the radiance distribution of object surface which was slightly treated before the test to produce fine structure of optical details. The holographic film, instead of holographic plate, is attached to the curved surface when illuminated by a flash light. Whole field fringe patterns are obtained with high sensitivities and large adjustable range. There is no longer a requirement to derive the speckle movement on the image plane from the object surface. Defocusing problem has been avoided. It can be practically applied to engineering problems with considerable convenience because of the very simple recording system and little demand for environmental stability.

KEY WORDS: objective speckle, white light, simply curved surface.

I. INTRODUCTION

Speckles, according to the recording methods, can be divided into two groups. If recorded through a lens, they may be referred to as subjective speckles. If recording is done by exposing them directly on a photosensitive material without the use of a lens, they may be referred to as objective speckles. According to the light sources used in recording, the speckles can also be classified into two categories: the laser light speckles and the white light speckles. (see Fig. 1)

![Fig. 1. The categories of speckles](image)

In applying subjective laser speckles (the first method in Fig. 1) to curved surface deformation measurement, not only is the sensitivity limited by the numerical aperture of the lens, but also it is rather complicated to derive the equations which relate the surface movement of the object to the speckle movement on the focused plane, and which, in turn, relate it to the speckle movement on the image plane. These relationships are influenced by the angles of illumination and receiving, as well as by the surface element orientation and defocused distance. The parameters vary from point to point on the curved surface \(^{1,2}\).

Received 9 September 1986.
In applying subjective white light speckles (the second method indicated in Fig. 1) to strain determination on curved surface, the random dots are artificially printed on the specimen surface [3]. The relationship between the speckle movement and the surface movement of the specimen is simplified, but the defocusing problem still exists. This focusing error will reduce the high frequency portions of the optical transfer function (abbreviated OTF) to such an extent that the effective cutoff is much lower than the diffraction limited cutoff. So the sensitivity drops rapidly due to the fact that the image plane is out of focus.

In 1982 and 1983, F. P. Chiang and C.C. Kin proposed a far-field objective laser speckle method for general curved and flat surface strain determinations [4,5], which may be referred as the third method. In this method, a scattering plate such as ground glass is illuminated by an expanded laser beam, a volume of speckles is formed in the space covered by the scattering wavelets. If a specimen with its surface coated with a thin layer of photosensitive material is placed inside the field, the speckles will register themselves onto the specimen surface. When it is deformed and the second exposure on the photosensitive coating is made after deformation, speckle movement is registered on the emulsion which can then be developed and processed in a manner similar to the other speckle method. In this method the speckle displacement is effectuated by the movement of the recording medium. So the analysis is simplified and no defocusing problem exists. This method presents itself as one of the very few techniques that is capable of measuring strains on general curved surfaces. But it is difficult to obtain whole field visual information. Only pointwise filtering can be made. Before testing the specimen surface must be coated with photosensitive material, which is inconvenient for the determination of the strain distributions under multiple loading steps.

In this paper, the fourth method, called objective white light speckles, has been proposed for the strain determination of simply curved surfaces. All the preparations, recording and analysis processes are simplified.

II. BASIC PRINCIPLES

When an optically rough surface is illuminated by a coherent laser beam, random interference pattern called speckles are formed. They can be used as the displacement gauging elements. Meanwhile, numerous extra speckle noises are produced by the laser light, because it is highly coherent and very sensitive to the defects and fine dusts which may exist on lenses or other optical arrangements. These extra "speckles" contain no useful information. They result in rough fringes and blur the useful information. When the same surface is illuminated by white light, the radiated light is spatially incoherent. But we may regard the surface as a collection of independent point radiators, the strength of which varies from point to point according to some information-bearing characteristic of the surface (e.g. its reflectance). In general the radiance of a surface is a function of the angle at which the surface is viewed, or the orientation of the surface element. An image-forming system, no matter with or without lenses, maps the radiance distribution of the object into an irradiance distribution at the image plane. As to an optically rough surface, the radiance distribution is a random function which is influenced by the optical details of the surface and can also be used as displacement gauging elements. We call it "white light speckles". The white light speckles are recorded in white light and do not suffer from the effects of extra speckles.

The recording set up for the close-range objective white light speckle method is shown in Fig. 2. A piece of flexible holographic film, instead of a holographic plate, is adhered to one point...