ISSN: 2278-0181
NCICN-2015 Conference Proceedings

Holographic Interferometry by Double Exposure Technique

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***Abstract*—Holography is the biggest promise to the future technologies as an answer for the unending thirst for security authentication. A hologram is a recording of the optical interference pattern that forms at the intersection of the two coherent optical beams. The two main principles of holography are interference and diffraction of light waves. This gave rise to the field of Non Destructive Testing (NDT) using holographic interferometry. This technique is now widely used for testing, analysis and studies of stability in materials. Holographic interferometry is a technique which enables static and dynamic displacement of objects with optically rough surfaces to be measured to optical interferometric precision(i.e., to fractions of a wavelength of light).These measurements can be applied to stress, strain and vibration analysis, as well as to non-destructive testing. It can also be used to detect optical path length variations in transparent media. Double exposure holographic interferometry helps to determine the variations in the fringe pattern by the application of stress, strain etc and thereby used for security applications.**

Keywords—Holography; Non-Destructive Testing(NDT); Interference; Holographic Interferometry(HI); Double Exposure Hologram..

I. INTRODUCTION

A hologram may also project a three-dimensional image into the air a life like image that can be photographed although it cannot be touched. Because they cannot be copied by ordinary means, holograms are widely used to prevent counterfeiting of documents such as credit cards, drivers licenses, and admission tickets. When the hologram is illuminated by the reference beam alone, the diffraction pattern recreates the wavefronts of light from the original object. Thus, the viewer sees an image indistinguishable from the original object. The word hologram comes from the Greek roots holos meaning whole and gramma meaning message. The process of making a hologram is called holography. Each section of a hologram, contains a complete image of the original object, viewed from a vantage point that corresponds to the sections position on the hologram. Holographic interferometry is a technique which enables static and dynamic displacements of objects with optically rough surfaces to be measured to optical interferometric precision. These measurements can be applied to stress, strain and vibration analysis, as well as to non-destructive testing. It can also be used to detect optical path length variations in transparent media. Double exposure holographic interferometry helps to determine the variations in the fringe pattern by the application of stress, strain etc.

II.BASIC PRINCIPLE OF HOLOGRAPHY

A hologram is a recording of the optical interference pattern that forms at the intersection of the two coherent optical beams. There are two physical phenomena as the principles of the holography: interference and diffraction of light waves. Holograms are photographs of three dimensional impressions on the surface of light waves. Therefore, in order to make a hologram you need to photograph light waves. This presents something of a dilemma,it can be problematic to take a photograph of a quickly moving object. When a person moves too quickly in a photograph, their image blurs. Try to imagine the problems associated with trying to photograph a photon. To start, a light wave moves at the speed of light. Considerably faster than someone's hand waving. In fact, it is so fast that the very idea of even capturing it on film would appear impossible. What we need is a way to stop the photon so it can be photographed. And this technique is called interference. Laser light differs drastically from all other light sources, manmade or natural, in one basic way which leads to several startling characteristics. Laser light can be coherent light. Ideally, this means that the light being emitted by the laser is of the same wavelength, and is in phase.

III. HOLOGRAPHIC INTERFEROMETRY

Interference is the property of all types of waves to form characteristic stationary variations of the intensity by the superposition of two or more waves. It may be defined as the phenomenon of redistribution of light energy on account of superposition of light waves coming from the two or more coherent source of light. When two waves of the same amplitude superimpose in phase with each other i.e. the crest (trough) of one wave meets the crest (trough) of the other one, results in a wave with twice the amplitude of the individual waves. This type of interference is called constructive Interference. Let the same two waves but they are exactly out of phase i.e. the crest (trough) of one wave meets the trough (crest) of the other one. The waves tend to cancel each other out. As a result, no wave is produced. This type of interference is called destructive Interference. Conditions for interference are the sources must be coherent and monochromatic.

By off-axis holography, interference fringes of 3D images by deformation, displacement, or rotation of the object. In transparent objects, fringe patterns are formed by change in refractive index or object thickness. Holographic interferogram is the interferometric comparison of two or more waves.

IV. DOUBLE EXPOSURE HOLOGRAM

Exposures are made using a standard off-axis holographic imaging system.First,the object in its initial unstressed state is created and the hologram is recorded by exposing the photographic plate to the object and reference waves.Again a second hologram is made with the object in its stressed state is made on the same plate.Then the plate is developed and illuminated by a reconstruction wave identical to the reference wave used to record it, to obtain the interference pattern. During reconstruction, the two images interfere as though there were two copies of the object present.Fringes appear to shift.

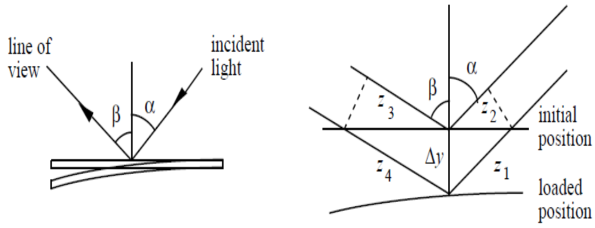

Fig.1.Fringe Shift

Bright fringes occur when the displacement is an integral number of wavelengths. The change in optical path length ΔO due to the shift in position Δy of the surface is

$$\Delta O=(z1+z4)-(z2+z3)$$

Using the angles

$$\Delta O=\Delta y(\cos\alpha+\cos\beta)$$

The conditions for interference can be written as

$$\Delta O=n\lambda/2$$

Odd and even integers imply dark and bright fringes

Equating the above two equations

$$\Delta y=n\lambda/2(\cos\alpha+\cos\beta)$$

V.EXPERIMENTAL SETUP

A.RECORDING OF A HOLOGRAM

In transmission holograms the object and reference beam incident from the same side of the film and image is viewed by transmission of the reconstructing beam through the developed film. The fringes in light intensity are formed perpendicular to the plane of the film. Transmission hologram is reconstructed using laser or quasi-monochromatic source. A typical optical system for recording transmission holograms is shown in figure. Making a hologram involves recording a two-beam interference pattern. Any change in the phase difference between the two beams during the exposure results in a movement of the fringes and reduces modulation in the hologram. Accordingly, to avoid mechanical disturbances, all the optical components, as well as the object and the photographic film or plate, should be mounted on a rigid surface resting on shock absorbers.

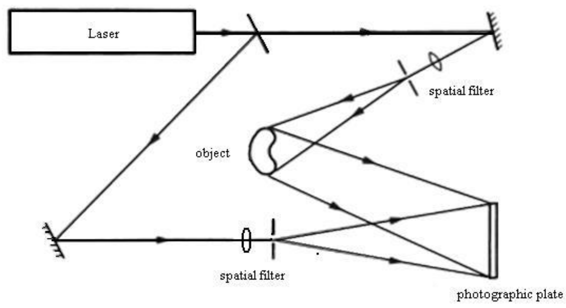

Fig.2.Recording Setup

The shape and intensity of the fringes depend on the phase and amplitude of the two different waves. Because one of the beams carried information about the object, the interference pattern also contains information about the object. The photographic film is exposed to the light and then developed with conventional techniques. The film preserves the interference pattern produced by the two beams and hence, preserves the information about the object. The resulting piece of developed film is the hologram. The system is adjusted to have a low natural frequency of vibration (1 Hz). An accurate power meter should be used to measure the intensities of the object and reference beams in the hologram plane, in order to set the ratio of the beams.

B.RECONSTRUCTION OF A HOLOGRAM

A common arrangement for reconstructing (or viewing) the hologram is shown in Figure. The hologram (the developed film) is re-illuminate by the reference beam alone. One may remove the object, or block the object beam, or remove the hologram completely to a different location and illuminate the hologram with a laser beam travelling at the same angle to the film as the original reference beam. This beam is called the reconstructing beam.

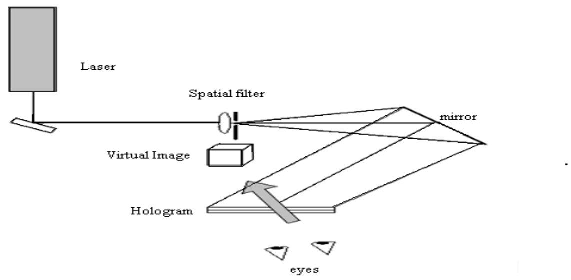

Fig.3.Reconstruction Setup

When the hologram is illuminated by the laser light at the same angle as the original reference beam, two images of the object are produced by light diffracted by the hologram. One may consider the original process of hologram formation as a method of producing a type of diffraction pattern, a closely spaced array of interference fringes, the exact shape of which depends on the nature of the object. When this diffraction pattern is illuminated, the diffracted light has properties that are dictated by the original object.

Let us consider the two different images of the object that are formed during reconstruction of the hologram. An observer will see an undistorted view of the object, just as if it were still present. The image is three-dimensional; that is, one may look partway around the object. This image is called a virtual image because it requires a lens to form it. According to elementary optics, one requires a lens to form a virtual image. The lens of the human eye or the lens of a camera can be used. Thus, one can look at the light diffracted by the hologram and see the original object.

A second image is formed by light diffracted in a different direction from the virtual image. This is called a real image; it can be projected directly onto a screen and does not need a lens to form it. The real image must be projected onto some surface in order to view it. There will also be some light transmitted directly through the hologram, without being diffracted. This undiffracted light will emerge from the hologram travelling in the same direction as the reconstructing beam. This undiffracted light is not of great interest. The two other distributions of light that correspond to the two images will be on opposite sides of the undiffracted beam.

VI.RESULTS AND DISCUSSION

The optical setup for recording the hologram has been designed and the recording is done in transmission type hologram. The laser used throughtout the experiment is the Argon Ion laser. It is a continuous wave laser in the green wavelength region (514.5 nm).For the recording and reconstruction of good quality hologram it is necessary to have a uniform beam that is used to illuminate the object as well as for reference. Inorder to achieve beam uniformity we did spatial filtering, which involves design and creation of pinholes with diameter suitable for the particular laser wavelength and the focal length of the objective lens used. Inorder to obtain clear and high contrast images the necessary optical elements like mirrors are made from glass slides by vacuum coating.The spatial filter is mounting on the isolation table by using square magnet and post is used for adjusting its height. The spatial filter mount includes two holes, one for placing the microscopic objective lens and the other one for placing the pinhole. The microscopic objective of 5X, 10X, 20X magnification lens is present. Here 20X magnification lens is used for producing large spatial filtered area, for covering an object and for covering the whole holographic plate uniformly. The diverged clean laser beam output from the spatial filter is used in both reference beam path and object beam path. At the reference beam path before falling to the holographic plate, there place a large collimating lens. This is for producing collimated reference beam to fall on the holographic plate uniformly. The Optimum Conditions for recording high efficient holograms are(i) Proper spatial filtering,(ii) The large profile of object beam and reference beam,(iii) Sufficient exposure time,(iv) Small path length difference between reference beam and object beam,(v) Proper developing process.

VII.CONCLUSION

Holographic interferometry technique enables static and dynamic displacements of objects with optically rough surfaces to be measured to optical interferometric precision. These measurements can be applied to stress, strain and vibration analysis, as well as to non-destructive testing. It can also be used to detect optical path length variations in transparent media, which enables, for example, fluid flow to be visualised and analysed. It can also be used to generate contours representing the form of the surface. Holography enables the light field scattered from an object to be recorded and replayed. If this recorded field is superimposed on the 'live field' scattered from the object, the two fields will be identical. If, however, a small deformation is applied to the object, the relative phases of the two light fields will alter, and it is possible to observe interference. Double exposure holographic interferometry helps to determine the displacements caused due to stress, strain or any other dynamic strain. The fringe pattern analysis can be studied by the double exposure holographic inteferometry for security application.

VIII.REFERENCES

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