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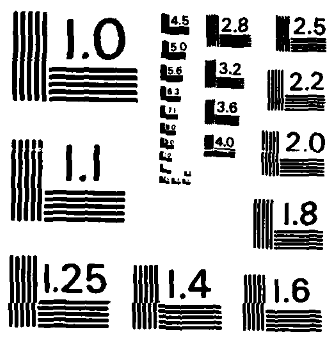

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PRELIMINARY STUDY OF HOLOGRAPHIC INTERFEROMETRY APPLIED TO CARBON FIBRE SPECIMENS

by

Brian L. LAWRIE

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16. Abstract

Holographic interferometry has been used to examine two carbon fibre compression specimens with known defects. Photographs of the reconstructed images of the specimens clearly indicate the location of the defects.

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SUMMARY

Holographic interferometry has been used to examine two carbon fibre compression specimens with known defects. Photographs of the reconstructed images of the specimens clearly indicate the location of the defects.

POSTAL ADDRESS: Director, Aeronautical Research Laboratories,
P.O. Box 4331, Melbourne, Victoria, 3001, Australia.

CONTENTS

Page No.

1. INTRODUCTION

The increased use of carbon fibre materials in modern aircraft design has led to the requirement for a non destructive technique to quickly examine large areas of carbon fibre surfaces. The ability of holographic interferometry to detect very small deformations over large areas has led to research in holography as a technique of inspection. This report gives details of a preliminary study of the use of holographic interferometry to locate impact damage and simulated delamination in 20 ply compression F/A-18 type, graphite epoxy specimens.

2. THEORY

2.1 Holography

Holography is the science of recording an entire optical wavefront, both phase and amplitude information, on a suitable recording material. Such a record is called a hologram.

To construct a hologram, a beam of laser light (which is both monochromatic and coherent) is split into two beams as shown schematically in Fig. 1. Each beam passes through a spatial filter, which consists of a microscope objective with a pinhole (10 μ) at its focus. This spatially filters the light and converts the plane wave beam into a diverging spherical wave. One beam illuminates the object which is to be holographed, the other, acting as a reference beam illuminates a photographic plate which is to record the hologram. The light rays reflected and scattered from the object interfere with the reference rays. Because the light of both beams has temporal and spatial coherence, constructive and destructive interference will occur. The photographic plate, located in the region of interference, records phase and amplitude information of the combining rays. After processing, the plate is illuminated in light of similar wavelength to the recording light. The silver particles in the emulsion diffract the light rays and 'replay' an exact duplicate of the original wavefront coming from the object. The wavefront reconstructs an image which is identical in appearance to the original object.

2.2 Holographic Interferometry

Holographic interferometry consists of recording two successive holographic exposures of an object in two different positions (eg. before and after the application of stress). The two exposures are recorded on the same plate. The object is stressed between exposures and upon reconstruction of the double exposure hologram, combined images of the object will be formed. Since both reconstructed images are formed in coherent light and exist at approximately the same location in space, they will interfere with each other and produce a set of bright and dark interference fringes in the reconstructed hologram.

Each fringe represents a surface displacement of approximately half the wavelength of the laser light. The fringes could represent shifts in all three planes - X, Y and Z. However in these experiments most of the displacement would be changes in distance between the surface of the specimen and the photographic plate (Z axis).

3. EXPERIMENTAL

3.1 Introduction

The recording of holograms requires extreme stability of all optical components, as minute vibrations will prevent the recording of the object's wavefront. To ensure adequate stability it is necessary to have a stable optical table with good vibration isolation from the floor and adequate damping characteristics.

3.2 Set Up

The optics table consisted of a terrazzo slab supported by a welded angle iron framework. Rubber blocks separated the slab and the framework. The framework was isolated from the floor by partly inflated rubber tubes, which rested on felt pads. An interferometer assembled on the table indicated that some vibrations were reaching the table top, but were not of sufficient intensity to prevent double exposure recordings.

The light source for the experiments was a continuous wave, 3 watt multi-line argon-ion laser. In this case the distance between fringes is 257 nanometers or 0.25 of a micron. Therefore a count of 4 fringes is a total surface shift between the two points of 1 micron. A Fabry-Perot etalon was fitted into the rear cavity enabling it to be tuned to a single line longitudinal mode of operation at approximately 514 nm, thus ensuring a long coherence length. The laser was on a different table to the optical components to prevent vibrations from its water cooling system entering the optics table.

To construct the holograms the optical components were arranged in the manner described in section 2.1 and shown schematically in Fig. 1. Fig. 2 shows the actual experimental arrangement, with the exception of light stops and screens which were removed to enable all of the optical components to be seen. The components were positioned so that the reference beam and object beam pathlengths were approximately the same. Power output from the laser was set at 140 milliwatts. The light intensity ratio of the reference beam and reflected object beam upon the recording plate was set at approximately two to one. This was achieved by adjusting the variable beamsplitter and monitoring shadow intensities on the plate area.

3.3 Specimens

Two carbon fibre specimens, both with some form of defect, were examined. The first of these was a 20 ply coupon compression F/A-18 type graphite/epoxy specimen having two 15 mm diameter, 0.05 mm thick Teflon discs located on top of each other between the second and third layers. The lay up of this specimen simulated a delamination defect.

The second specimen was also a 20 ply coupon compression F/A-18 type graphite/epoxy coupon. However the defect in this case resulted from impact damage. This damage was caused by dropping an impactor onto the laminate while it was supported by honeycomb core material. The impactor, of total mass 1.37 kg, had a head of 25 mm diameter and was dropped from 500 mm above the specimen.

3.4 Recording and Reconstruction of Holograms

Prior to recording the hologram the specimen was heated to about 50^{o}C with a hot air blower. A "G" clamp held the specimens in place on the table. During cooling two exposures of 1 second each were taken with a time interval of 1 minute between exposures. The surface movement which took place during this interval is represented by the fringes in the reconstructed hologram. Exposure was controlled by a camera shutter mounted in the beam path at the laser's aperture. The plates were developed in Kodak D19 developer for 4 minutes at 20^{o}C, then completely bleached out to form a phase hologram.

The images were reconstructed by placing the plates in a diverging beam of light similar to the original reference beam used in the construction of the holograms. The images were photographed with a 35 mm camera using a standard 50 mm lens fitted with a 10 mm extension ring. Film used was Kodak type Technical Pan 2415. Image speckle was eliminated by setting the aperture of the camera at f5.6.

4. RESULTS

Reconstructed images of the front surface of the simulated delamination specimen, and both surfaces of the impact damaged specimen are shown in Figures 3-5. Ultrasonic C-scans are shown in Figures 6 and 7 for comparison with the reconstructed images.

5. DISCUSSION

The relative surface movements during stressing, as shown in the reconstructed images, clearly indicates large surface shifts in the region of the defects. These surface shifts were revealed as a series of circular contours, which enables a measurement to be made of the defect's position. At this stage no quantitative fringe interpretation has been attempted. However some qualitative information can be obtained.

In Figure 5, showing the rear surface of the impact damaged specimen, the fringes towards the lower right of the damaged region display discontinuities. The discontinuities of the fringes form lines which are approximately parallel to the direction of fibres in one of the layers. This could indicate fibre damage in a particular layer. The general similarity between the delaminated specimen and the impact damaged specimen may indicate that delamination has occurred during impact damage. A comparison of the size of the area covered by the fringes on the front and back surfaces of the impact damage specimen reveals that the area of damage tends to expand through the depth of the specimen.

6. CONCLUSION

Two carbon fibre coupon, compression F/A-18 type specimens, with known defects representing delamination and impact damage, have been examined using holographic interferometry Double exposure holograms were taken during contraction of the specimen, after heating to 50°C. The locations of the defects were clearly visible in the reconstructed images.

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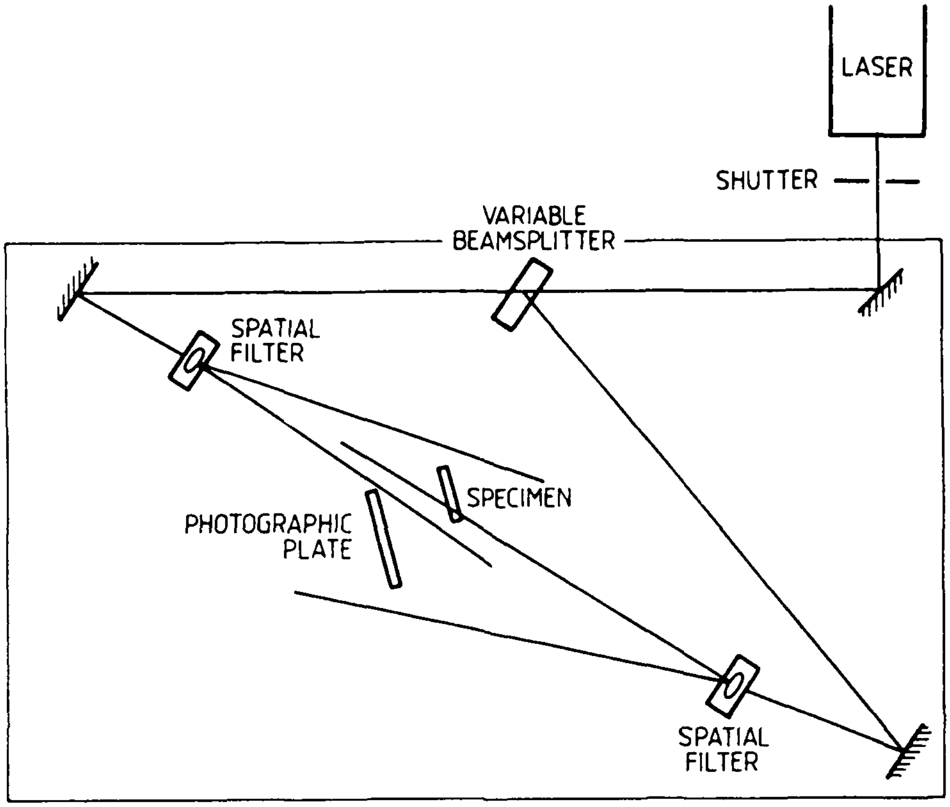

FIGURE 1: DIAGRAM OF OPTICAL COMPONENTS ON THE TABLETOP FOR THE CONSTRUCTION OF THE HOLOGRAMS

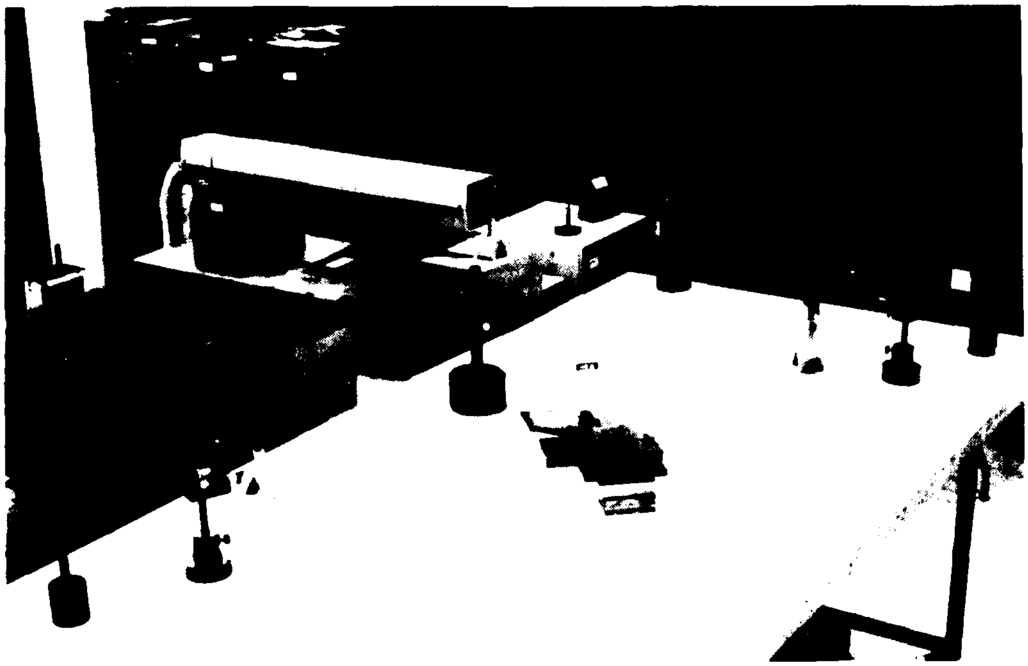

FIGURE 2: OPTICAL ARRANGEMENT FOR THE CONSTRUCTION OF THE HOLOGRAMS

FIGURE 3: FRONT SURFACE OF SIMULATED DELAMINATION SPECIMEN

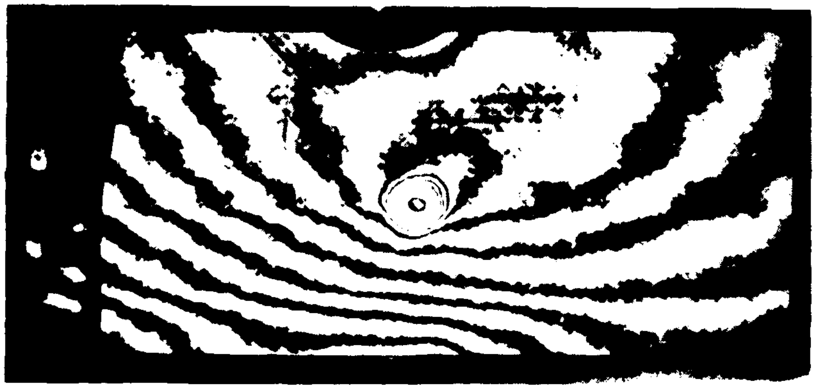

FIGURE 4: FRONT SURFACE OF IMPACT DAMAGE SPECIMEN

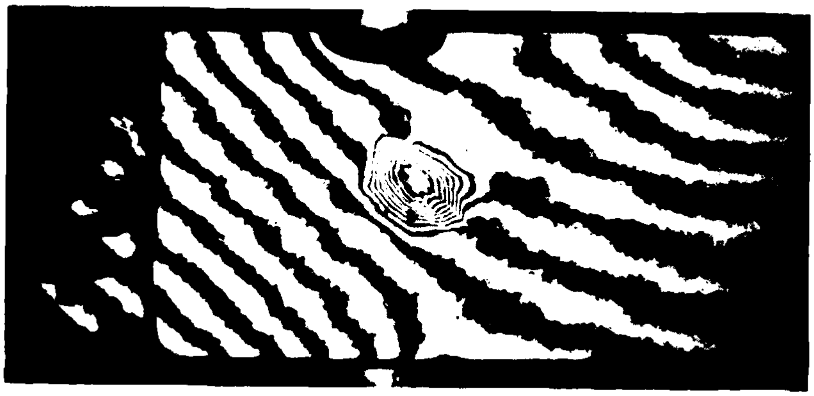

FIGURE 5: REAR SURFACE OF IMPACT DAMAGE SPECIMEN

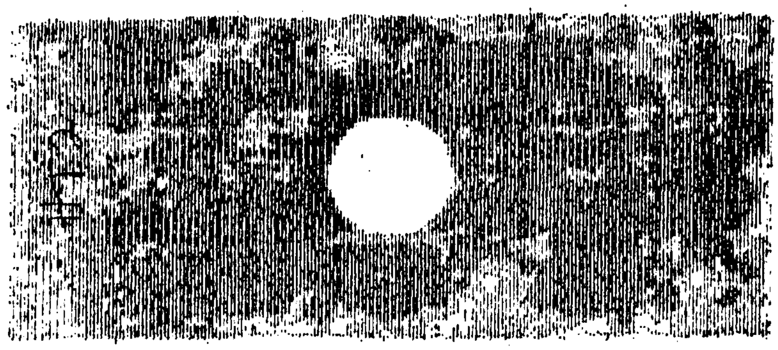

FIGURE 6: ULTRASONIC C-SCAN OF ARITICIALLY DELAMINATED SPECIMEN

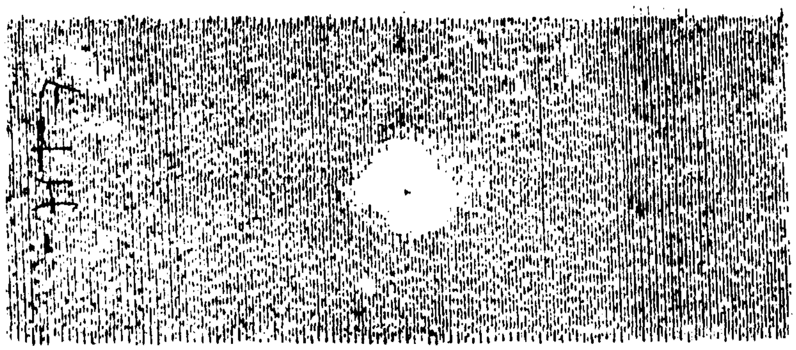

FIGURE 7: ULTRASONIC C-SCAN OF IMPACT DAMAGED SPECIMEN

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