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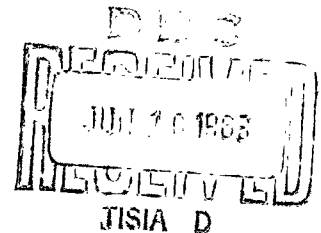
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Final Report  
EXPERIMENTAL AND THEORETICAL STUDY  
OF WAVE PROPAGATION AND VIBRATION PROBLEMS

by  
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EXPERIMENTAL AND THEORETICAL STUDY  
OF WAVE PROPAGATION AND VIBRATION PROBLEMS<sup>1</sup>

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The work under this contract was aimed toward the further development of the birefringent coating technique and the construction of a high speed camera and light source to be used in conjunction with the coating. The overall purpose is to study the deformation of structures, whether they be made of metal or other material, when they are subjected to dynamic loading causing perhaps permanent deformations. With this technique one should be able to observe the waves progressing through the metal structure, whether these waves be elastic or plastic. A theoretical approach to such a problem is possible only under strongly limited conditions. This is the reason why a working experimental technique is needed, although here again there are great difficulties primarily because of the high speed of the waves.

In principle a layer of birefringent material bonded to a metal surface can be used to measure the deformations at that surface. Up to the present, the technique can be used reliably only in static work, and it is our aim to continue its development toward dynamic applications. One effort has been directed toward the construction of a high speed camera

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and light source capable of taking consecutive photographs of the dynamic photoelastic pattern as it advances in the birefringent coating. The difficulties to be overcome were:

(a) Short exposures, down to  $40 \times 10^{-9}$  sec. (40 nanoseconds) necessary to record the fast moving fringe pattern.

(b) Short intervals between exposures down to  $200 \times 10^{-9}$  sec.

(c) High light intensity and film sensitivity needed not only for the very brief exposures but also because of the very high losses of intensity at the Kerr cell shutter, the polaroids, the diffused reflection from the metal surface, and the small proportion of light intensity collected by the mirror. The various parts of the camera system as presently designed are the following.

(a) Light source: gas discharge lamp, used with a bank of capacitors (280  $\mu$ F), a 10,000 V. power source and electronic trigger. Constructed and operating.

(b) Kerr cell shutter: Operated from a special square pulse generator of 18,000 V. amplitude,  $40 \times 10^{-9}$  to  $2 \times 10^{-6}$  sec. duration, and a repetition rate 4 to 20 times the duration of each pulse. Pulse generator exists. Kerr cell shutter to be ordered.

(c) Rotating mirror. Size almost  $1\frac{1}{2}$  square, designed to rotate at 100,000 rpm with a special high-speed electric motor and frequency converter. Balancing has been done to 20,000 rpm. Special supports for balancing above 20,000 rpm have been designed, constructed, and are presently in use.

Concurrently with the above, a study is in progress on the problem of the interpretation of a given photoelastic pattern as obtained with the coating. A number of reports have been issued on this subject. This work is, in general, a continuation of that described in References (1-3). Under the present contract two reports on this subject have been issued, (4) and (5). These reports need not be summarized here since they have been reported on previously. However, the work under Reference (4) is continuing so that a word in this respect is needed. The report entitled, "The Elastic Wedge under Mixed Boundary Conditions," presents the elasticity solution for the state of stress at a corner of a quarter infinite sheet when one edge is free and the other has applied displacements. As expected the stresses at the corner increase indefinitely. This study was motivated by the desire to know the influence of the ends of a birefringent coating on the observed fringe pattern. For instance, how far from the ends of the coating are the results no longer affected by the infinite stresses at the corner? Other questions of a similar nature were answered. Since the publication of this report, experiments have been carried out to find this state of stress experimentally. However, the theoretical results do not agree entirely with those obtained experimentally. The reason for the discrepancy is important since one must finally know whether or not the end of the coating produces only local effects or whether these effects extend for some distance. Work along these lines is continuing.

In addition work has progressed in the problem of separation of membrane and bending stresses in shells with the use of birefringent coatings. Earlier tests were made with square plates coated on both faces and subjected simultaneously to anticlastic bending and to in-plane tension (6). Considerable difficulty and errors were caused by the finite bending of the plate, requiring the application of the membrane forces along the tangents to the deformed surface. In the present tests the in-plane loading has been abandoned, and the effect of a membrane stress is frozen in the birefringent coatings. Preliminary tests have shown a very high accuracy in loading and photoelastic effects. In fact the measuring accuracy is better than the errors caused by spurious residual stresses and thickness variations in the coatings. Extensive efforts are being made to cast as perfect plates of epoxy resin as possible. Special casting and curing techniques have been developed but good plates are not systematically produced. A selection of the best plates is made from a large number of castings. It is expected that better results will be obtained with improved casting methods.

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