STRESS ANALYSIS USING FIBER OPTICS

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This investigation explores the potential of passing laser light through multimode and monomode fibers used individually; or, as elements in coherent and incoherent fiber bundles, to perform laser-based stress analysis in remote areas of a structure. In particular, fiber optics are used to record displacement over the full-field with speckle and/or holographic techniques. Results indicate that the use of optical fibers in stress analysis leads to a reduction in the number of optical components to be adjusted, allows deformation to be monitored in remote areas of a structure and can ultimately help to ease environmental requirements during in situ investigations.

The characteristics of coherent light passing through an optical guide have been studied by several investigators.[1,2] Speckle patterns produced by laser light transmitted through optical fibers of different types have been experimentally studied in a statistical manner.[3,4] Other investigators have studied the visibility of interference fringes produced by a wavefront of coherent light passed through a single fiber, divided and recombined;[5] or, produced by wavefronts of two beams of coherent light passed through two different fibers.[6] These investigations lay a firm foundation on which to build speckle interferometric studies using fiber optics.

In addition, light emitted from the exit end of an optical fiber has been used as the reference wave in recording a hologram and/or the illuminating wave in reconstructing it.[7] Mechanical flexibility of fibers has added a new degree of freedom to holographic reconstruction; for example, a fiber has been used to scan a small holographic array.[8] Fiber optics have also been used in both the object and reference beams to record and reconstruct holograms with a negligible reduction in diffraction efficiency.[9] A recent investigation, carried out by one of the authors, indicates that fibers can be used to holographically record deformation in remote areas of a structure.[10]

Many fibers; for example, those of the step-index type, have relatively large numerical apertures. Some rays or modes trace coarse zigzag paths down the guide and take longer to reach the exit end than those traveling along the axis. Consequently, the fiber is classified as multimode, exhibits dispersion and has a radiation pattern in the far-field which resembles a speckle pattern due to the overlap of light corresponding to the many guided modes present. An important observation; however, is that spatial coherence is practically preserved in the transmitted wavefront.

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Fibers that transmit single modes which are of the graded-index type, are classified as monomode. Since there is no modal conversion in these fibers, they are much less susceptible to changes in external conditions, such as, stress and temperature changes during stress analysis, indicating that fibers of this type could be used to ease environmental requirements during in situ investigations.

Monomode and multimode fibers can be collected into bundles. If the fibers in the bundle are properly oriented, an image can be transmitted. Bundles of this type are called coherent; incoherent bundles transmit light but cannot be used to image.

Experiments carried out in this study to assess feasibility for full-field displacement analysis use incoherent and/or coherent multimode fiber bundles to illuminate and a multimode coherent fiber bundle to record deformation holograms and/or speckle interferograms. Illumination using monomode fibers is also documented. Inherent difficulties encountered with individual fibers and/or bundles are also discussed and guidelines are established for further studies designed to improve the process of recording displacement using fiber optics.

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