# NASA TECH BRIEF

*Langley Research Center*



## Vibration Analysis by Time-Average Holography

Holography (a three-dimensional lensless imaging technique) may be a suitable method for analyzing high-frequency structural vibrations. Through the use of holographic interferometric techniques and time-average holography, vibration modes as high as 100 kHz can be photographed. Previously, structural vibration analyses were limited mainly to the lowest five to ten vibration modes. For many structures, it was assumed that the effort needed to obtain data on the higher modes was too excessive and costly when compared to the effects on the structure itself. However, in certain cases such as radar antennas, the higher vibration modes may be an integral multiple of the operating frequencies, affecting the operation of the entire system. Analyses of the higher modes (up to 100 kHz) in these cases can be an extremely important part of the design and development processes.

Holographic interferometry involves the double exposure of the hologram: the first, when the object being studied is in one condition; and the second, when the object is in another condition. Two images are formed, and the coherent light waves that form them interact with each other to create interference fringes. The fringe patterns are then analyzed in terms of the variations in the two conditions.

Time-average holography is similar to time-exposure photography in which the lens aperture remains open during several cycles of the event being photographed. For instance, the time-exposure photograph of a swinging pendulum would be accented at those portions of the swing where the velocity is at a minimum (at both extremes) and would be diffused at the maximum velocity points (through the center of the swing).

The analogy to the pendulum might be a cantilever beam. First, the beam would be set into vibration in one of its resonant modes. The hologram would be made by exposing the photographic plate for several vibration periods. Since the vibration would be sinusoidal, the hologram would be exposed primarily when the vibration amplitude is at its maximum (and the velocity is zero). The resulting hologram would contain fringe patterns representing peak-to-peak displacement in a normal mode. Analysis of the fringes would give a measure of the surface displacements of the vibrating body, including the higher-frequency modes.

Just as time-average holography can be used to analyze high-frequency modes in a vibrating structure, it could also be adapted to measure vibration decay or damping characteristics. In this instance, the photographic plate or hologram would be exposed while the beam passes through several vibration periods after the initial excitation has been removed. As the vibration decays, the transient response would be recorded on the plate in very much the same fashion as in high-frequency recording, yielding the measurable interference fringes.

It may be possible to relate the formation of interference fringes to the initial amplitude $A_0$ and the damping coefficient $\delta$, assuming that the vibration damps out as $A_0 e^{\delta t}(\cos \omega t + \Theta)$, where $\omega$ is the frequency of vibration and $\Theta$ is the epoch angle. A fringe is formed whenever a certain function $F(\delta, A_0)$ is zero. If the initial amplitude $A_0$ is known, it is possible to solve the equation $F(\delta, A_0) = 0$ to find $\delta$. This technique allows damping to be measured at any point on a vibrating structure that can be reproduced in a time-average hologram.

(continued overleaf)

Because of present state-of-the-art of holography, there is a limit to the size of structures that can be analyzed. However, scaling factors are so well established that modeling techniques can be used to considerable advantage, regardless of the ultimate size of the structure.

Seismic disturbances and vehicular traffic, which are sufficient to move the structure more than one wavelength of the light used in making the hologram, can cause interference with time-average holography. This interference can be compensated for by placing a small metal stud or support at the node of the desired mode. (When the structure is excited, standing waves, which help locate the node, are set up.) The constraining action of the stud prevents the fundamental and other low-frequency modes from being excited by the background noise; but because the stud is located at the node of the desired mode, the structure can resonate freely in this mode.

## Note:

The following documentation may be obtained from:

National Technical Information Service
Springfield, Virginia 22151
Single document price $3.00
(or microfiche $0.95)

Reference:
NASA-CR-1671 (N71-14807), Applications of Holography to Vibrations, Transient Response, and Wave Propagation

## Patent status:

No patent action is contemplated by NASA.

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