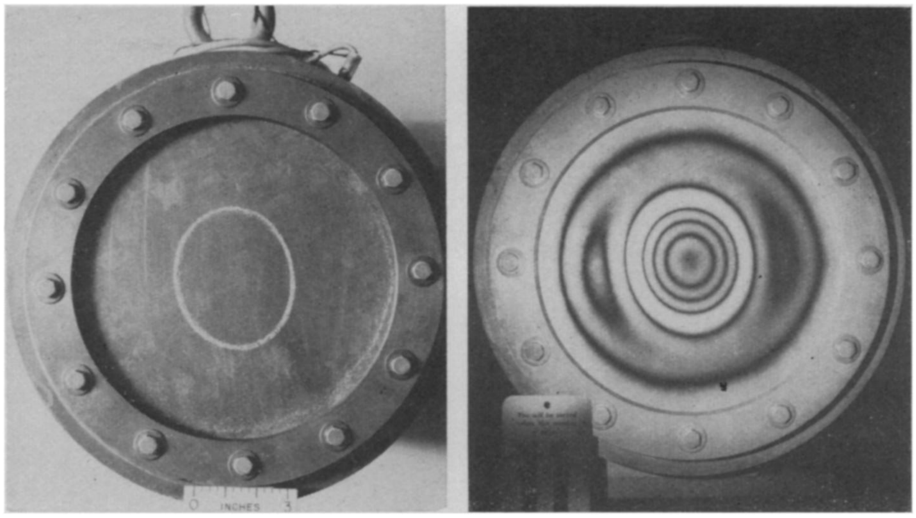
HOLOGRAPHY

Vibration analysis finds a tool

The "wonderful solution" finds a problem to solve



Norman E. Barnett

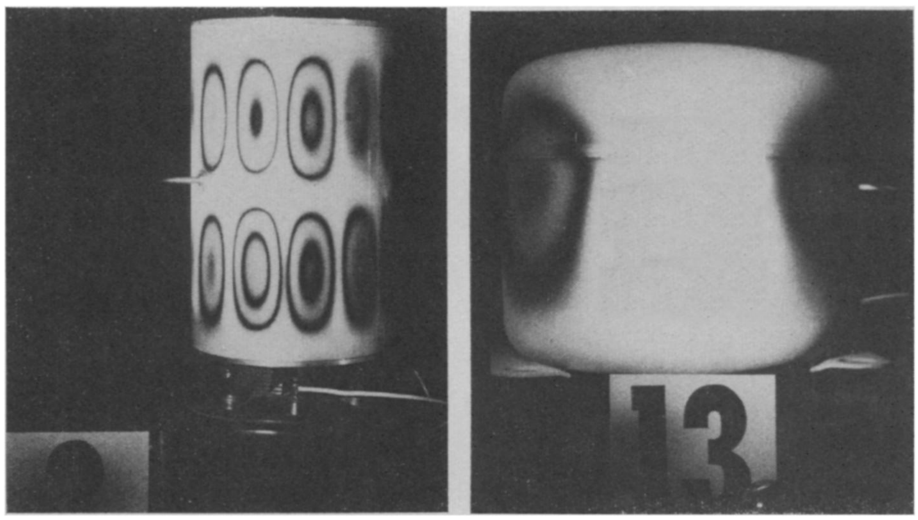
Vibration of a clamped plate: sand pattern and holograph at same frequency.

Vibration is the bugaboo of every mechanical engineer. Any structure has qualities that make it resound with a pulsating force of a particular frequency, and this resonance can cause anything from an annoying rattle to disastrous fatigue and shattering of presumably sturdy components.

Up to now, vibration analysis of all but the most simple structures has been a trial-and-error proposition.

But the new technique of holography is being used by scientists at the University of Michigan to bring to the study of vibration a detail and complexity far beyond anything known up to now. What's more, it may lead to necessary refinements in the theoretical description of vibration in even such simple structures as a cantilever beam and a clamped plate—descriptions which appear in every engineering textbook.

The prospect is a pleasant one to engineers. "The general idea," says Seymour Edelman, head of the National Bureau of Standard's vibration measurements section, "of being able to see a vibrating body in its entirety, and measure the actual displacement at various points, is very exciting."



Norman E. Barnett and Lyman Orr

Complex shapes show up well: cylindrical shell and compressor housing.

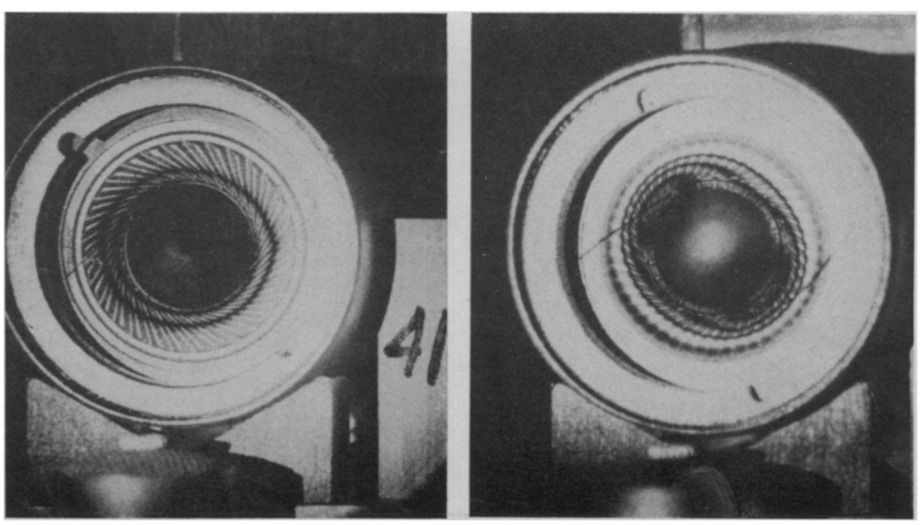
In practical applications, the technique has already been used to pinpoint an unwanted vibration pattern in a microphone and locate resonance frequencies in a compressor housing.

Perhaps more important, it has given a detailed view of vibration patterns that could be predicted theoretically.

"What the holographic technique does," says Dr. Norman E. Barnett of Michigan's Cooley Laboratory, "is put the experimentalist on an equal footing with the theorist."

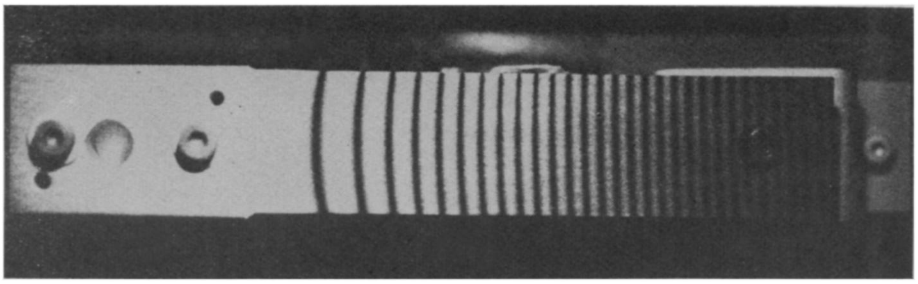
Dr. Barnett's holograms of a round metallic plate clamped tightly at its edges show some of the vibration patterns that are predicted by clamped-plate theory. But at certain frequencies, vibration patterns show up that are totally unexpected.

Some of the vibration modes, such as



Electro-Voice, Inc.

Microphone shows fidelity at one frequency, non-circular distortion at another.



Norman E. Barnett

Many fringes show technique's sensitivity: each indicates vibration amplitude.

a pentagon pattern that showed up at 1,886 vibrations per second, look as though they should rise from some regular cause that could be predicted by an extension of the theory.

Other patterns may be caused by physical distortions in the metal plate or by unequal clamping.

But even if all the unexpected patterns arise from experimental variations, says Dr. Barnett, the technique still provides a way to locate just where the physical arrangement differs from the ideal model.

The important factors in analysis of a vibrating body are the different frequencies at which it resonates and the pattern and amount of vibration at those frequencies. Dr. Barnett uses one holographic technique, called real-time fringe measurement, to determine the resonant frequencies, and another, time-average holography, to photograph the pattern at those frequencies.

Any body has certain frequencies at which it vibrates naturally: a struck bell, for instance, vibrates only at its own resonant frequencies.

If the body is shaken at one of its resonant frequencies, it sets up a pattern of vibration within itself in which some parts of the body don't move at all and others oscillate considerably.

By learning the resonant frequencies, and the pattern of vibration at those frequencies, engineers could avoid designs which caused unwanted effects such as noise and metal fatigue. But up to now this has been a hit-or-miss process, mostly by means of vibration sensors attached to particular points.

Holograms are formed by bouncing coherent laser light off an object onto a photographic plate. Another laser beam goes directly to the plate, and the two beams interfere with each other to form a pattern. When a laser is then shone through the hologram, a three-dimensional image is formed.

In the real-time fringe technique, a hologram is made of the object when stationary. Then laser light is shone through the hologram to form an image, and the hologram is adjusted so the image coincides with the physical object. Looking through the hologram, the experimenter sees both the object and the image, along with a pattern of interference fringes formed because image and object can't be lined up precisely.

When the object is set to vibrating, the interference fringes change. At resonant frequencies, the fringe pattern blurs into a new pattern. By varying the vibrating frequency over a wide range, a large share of the resonant frequencies of the body can be identified.

Once the important frequencies are pinpointed, the time-average technique is used to determine the pattern or mode of vibration. The body is vibrated at a resonant frequency and a hologram is made of it while it vibrates.

When the holographic image is reproduced, those parts of the object that were stationary show up white; those that vibrate are black. The number of rings that show up give a measure of the amplitude of vibration at each point on the body.

There are a number of limitations on the use of holographic vibration analysis, mostly having to do with the size of objects that can be holographed and the amplitude of vibration that can be measured.

But, says Dr. Barnett, size limitations are due to the primitive quality of available lasers, which are being improved all the time. As for amplitude, he has measured vibrations down to five millionths of an inch and as large as three tenths of a mil, which is getting near the amplitude that can be seen by the naked eye under a stroboscopic light.

Ten years ago the laser was jocularly described as a wonderful solution that needs some problems. Holograms, proposed in 1947 before the invention of lasers and impractical without the availability of coherent light, were a dandy problem for lasers to solve.

Some scientists are now suggesting that holography needs a few problems of its own. It seems quite certain that vibration analysis is going to be a very good one.