Measuring the Amplitude of Vibration of a Reed

By HENRY J. SCHERR

IN THE FIELD of physical testing, dynamic mechanical testing is assuming increasing importance. Many would like to perform this type of test but are reluctant to invest in expensive sophisticated equipment until they are sure of the instrument requirements necessary for their test material. For instance, one should have some idea of the type of instrument (attenuation, resonance, stress-strain), the precision requirement, and the frequency range.

When this laboratory undertook the study of the dynamic mechanical properties of leather[1] a decision as to the type and quality of the instrumentation was necessary. After considering all available types, it was decided that the forced vibration resonance tester based on a vibrating reed was best suited as an interim device. This type of dynamic tester, if properly constructed, has good precision, covers a reasonable range of frequency, is easy to assemble, and is relatively inexpensive.

REFERENCE: H. J. Scherr, **"Measuring the Amplitude of Vibration of a Reed,"** *Materials Research & Standards*, Vol 6, No. 12, December, 1966, pp. 614–616.

ABSTRACT: The forced vibrations of a reed in a dynamic modulus test were optically slowed by a stroboscope in which state the reed was shown on the screen of a viewer. The combination of stroboscope and viewer resulted in a more accurate and convenient measurement of the free-end amplitude than is possible with a conventional microscope using ambient light. A traveling microscope was used to measure the amplitude. Extraneous attachments to the reed's free end were eliminated, permitting soft flabby materials to be tested.

KEY WORDS: dynamic tests, vibration, leather, plastics, stroboscope, optical viewer, measuring microscope

[1] L. P. Witnauer and W. E. Palm, "Preliminary Studies of the Dynamic Mechanical Properties of Leather," *The Journal of the Am. Leather Chemists Assn.*, Vol 56, No. 2, Feb. 1961, pp. 58–67.

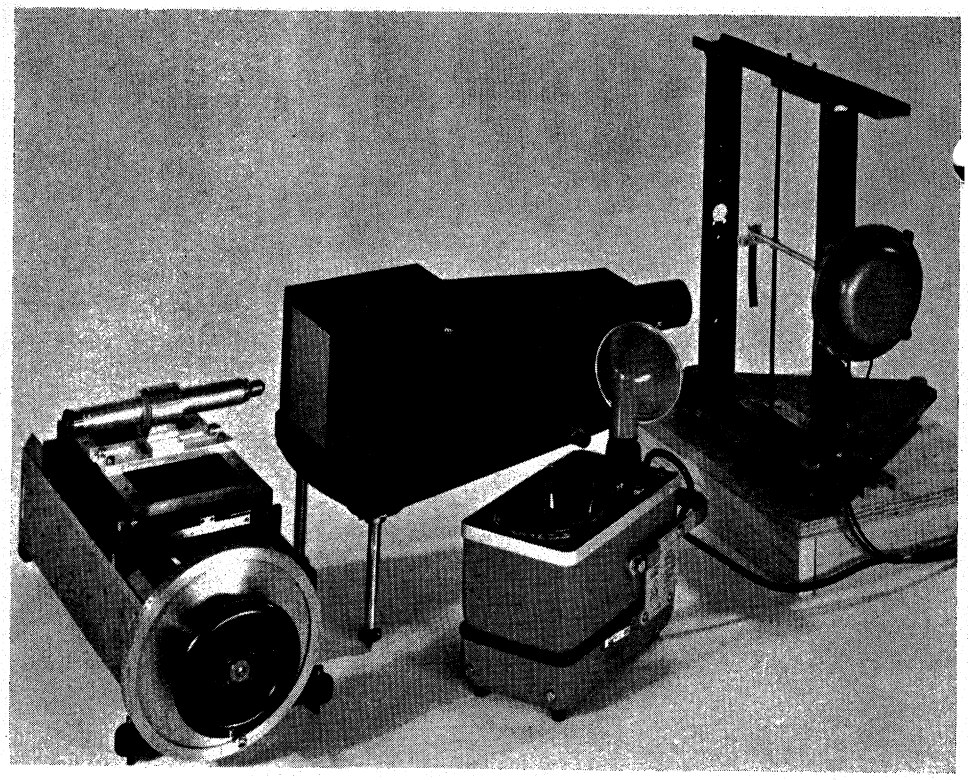

Fig. 1—Test setup.

Driving and Detecting Are Functions of Instrument

This instrument must perform two functions. First, it must vibrate the test material (reed) at a steady and adjustable rate in a transverse direction and in a sinusoidal wave pattern. This is the driving part of the instrument. Second, it must measure the amplitude of the reed's end excursions with sufficient precision to provide meaningful data. This is the detecting part of the instrument. Since the driving part of the instrument is essentially the same as similar parts described elsewhere[2,3] this paper will deal only with the detecting part of the apparatus.

In the forced vibration resonance instrument described here, the reed specimen is positioned vertically, the upper end being clamped to the vibrating mechanism while the lower end is able to swing freely. The experimental technique of this test requires that both the clamped- and free-end amplitudes be measured with respect to the frequency of vibration. Since the driving force at the clamped end is kept very low and held constant for all tests (otherwise, the validity of the tests would be questionable), the amplitude of the clamped end is very small and can be ignored. The amplitude of the free end, then, is the variable to be measured; unfortunately, this is a problem with soft, flabby test materials.

One technique for measuring this amplitude is to attach or apply a piece of metal or silver coating to the free end of the reed, and then measure the amplitude by noting the disturbance to either a magnetic[2] or electrostatic field[3] surrounding the free end. On rigid materials, such extraneous attachments do not seriously affect the accuracy of the measurement. However, on soft, flexible materials such as thin strips of leather and plasticized plastics, this technique does not always produce reliable results. This is caused by static strain induced by an added mass or the stiffening of the sample due to an added conductor, either condition being detrimental to proper functioning within the sample of the applied dynamic stresses. An optical transducer using a photo cell seemed to be the solution to this problem, and later on such a system was designed at this laboratory.[4] In the meantime, a device that did not require too great an expenditure of time and effort was needed, because at this time only a preliminary study of leather was being made.

Stroboscope Teamed with Microscope

For these reasons, it was decided to base our reed amplitude detector on the classical optical method of measuring the amplitude of a small displacement with a microscope. It was realized at the outset that the microscope method had a serious drawback, namely, the eye's inability to determine the exact points of the reed's peak travel due to the blurred image. Also it was recognized that an optical method based on a stroboscope would eliminate the blur, since the stroboscope could be used to optically slow down the motion of the reed and so make it possible to pinpoint the extremities of the reed's

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[2] S. Strella, "Vibrating Reed Test for Plastics," *ASTM Bulletin*, No. 214, May 1956, pp. 47–50.

[3] S. Newman, "A Vibrating Reed Apparatus for Measuring the Dynamic Mechanical Properties of Polymers," *Journal of Applied Polymer Science*, Vol 2, No. 6, 1959, pp. 333–336.

[4] H. J. Scherr, "Optical Transducer for Detecting Resonant Frequency and Free-End Amplitude of a Vibrating Reed (Low Driving Force)," *Journal of Applied Polymer Science*, Vol 5, No. 24, 1962, pp. S66–S67.

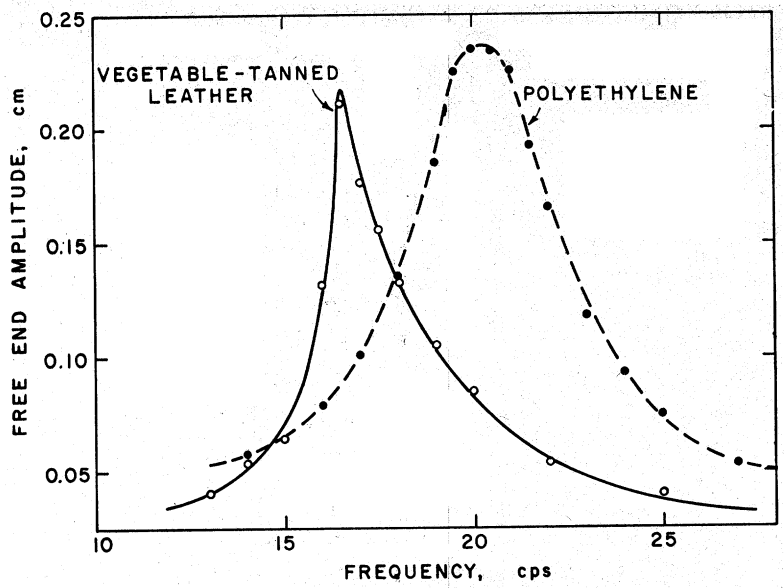

Fig. 2—Data for leather and polyethylene reeds.

free-end excursions. However, even though the reed's motion was optically slowed down, attempting to measure the amplitude directly with a microscope still presented problems.

To obtain greater accuracy and convenience when measuring the free-end amplitude, a magnified real image (5×) of the stroboscope-illuminated reed is projected onto a fixed-focus, ground-glass projection viewer, the peaks of the free-end swing of this image are pinpointed, and the distance between them measured with a low-power traveling microscope. The microscope used can measure to a thousandth of a millimeter; however, this precision for the measuring microscope is not necessary for accurate results.

Apparatus Described

Figure 1 is a photograph of the apparatus. In addition to the improved measuring accuracy and convenience, the viewer also reduces the chance of parallax in the measurement. The projection viewer is built around a Bausch and Lomb[5] f/2.1, 3.5-in. E.F. snooperscope lens.

The fixed focus of the viewer ensures that the optical magnification is always the same (this assumes that the image of the reed is always properly focused). Approximate resonance of the reed is determined simply by turning the frequency dial of the oscillator and noting at what frequency the extent of the blur of the free swinging end is greatest. Having determined the approximate resonant frequency in the ambient light, the stroboscope's illumination is then directed onto the reed and the rpm control adjusted until the image as seen on the ground glass slowly moves to and fro (strobe flashing rate slightly greater or less than reed's frequency) at a convenient speed for measuring the amplitude of motion of the free end. The oscillator frequency is further adjusted until the greatest free-end amplitude is obtained. This is easily seen on the ground glass of the viewer, as are the amplitudes for the off-resonance frequencies immediately above and below resonant frequency.

[5] Mention of commercial products does not constitute an endorsement by the U. S. Department of Agriculture.

Only fundamental frequencies were used to vibrate the specimen (one node at the clamp) and in the operation of the stroboscope. Due to the type of material tested (leather, rawhide, and plasticized plastics) and the geometry of the specimen, resonant frequencies were low and ranged from 5 to 100 cps. Figure 2 shows a plot of frequency versus amplitude made from data obtained with this instrumentation. The geometry of the reed specimens was tailored so that their frequency response fell in the same range. From this plot the resonant frequency and the band width between the two frequencies on opposite sides of resonance for which the amplitude has 0.707 times its maximum value can be obtained. The resonant frequency, the band width, plus the density and geometry of the specimen are all the experimental information needed to calculate the real and imaginary parts of the dynamic mechanical modulus of the material.[2]

Instrument Can Measure Other Vibrating Motion

It must not be inferred that the detecting instrument can be used only with a vibrating reed. This device can be used whenever the vibrating motion to be measured is in line of sight of the stroboscope and the projection viewer. One can obtain rapid dependable measurements with this instrument, and only a modest expenditure of time and money is needed to set it up.

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