ELECTRODYNAMIC VIBRATOR FOR MEASURING DAMPING IN VISCOELASTIC BODIES AND LIQUIDS BY MEANS OF THE RESONANCE METHOD

(UDC 681.2:534.28)

G. S. Rosin

Translated from Izmeritel'naya Tekhnika, No. 4, pp. 32-34, April, 1966

The evaluation of damping in viscoelastic bodies [1, 2] and liquids [3, 4, 5] in the presence of vibrations is rather difficult owing to various reasons (the requirement for additional transducers, complicated computations and insufficient precision).

It is the relative viscosity which is determined in the vibration resonance method, thus requiring the calibration of instruments with standard liquids.

Below we describe a method for measuring the absolute viscosity by means of vibrational movements of a sphere in a viscous liquid. The electrodynamic vibrometer described below is suitable for measuring damping in viscoelastic bodies and liquids. The instrument can also be used for measuring the dynamic elasticity moduli in sound and vibration-insulating materials.

The vibrometer (Fig. 1) has two electrodynamic transducers (power and measurement) located one above the other on a common axis. The lower transducer which consists of magnet 11 and coil 9 serves to excite vibrations. For this purpose a current is fed to the coil from an audio-frequency generator. The measuring electrodynamic transducer is made like the power transducer and intended for recording vibrations. The movement of its coil in the field of magnet 8 induces in it an emf which is proportional in its magnitude and phase to the speed of its movement. The power and measuring coils are interconnected by rod 6. This rod is fixed either to table 3 or a sphere for measuring damping respectively in viscoelastic bodies and liquids. Suspensions 1 and 2 serve to support and center the moving system. The table carries tested specimen 5, whose upper surface is cemented to solid bracket 4, which is securely mounted on the instrument stand.

The instrument operates with a mechanical vibrations generator GMK-1. In order to reduce the pickup due to the inductive coupling between the power and measuring coils, the core of the driving system magnet carries compensation coil 10 which has a common bifilar winding with the power coil (130 turns of 0.15 mm wire).

The core of the driving system magnet is provided with a 1 mm bore. As a result of these measures the pickup is reduced to one tenth, and in the measuring frequency range it does not exceed 1%.

The circuit of the measuring equipment (Fig. 2) comprises vibrometer 1, driving, compensation and measuring coils 4, 5 and 6, audio-frequency generator 2, cathode-ray oscillograph 3, and fixed resistor 7 which carries the generator current. The measuring coil emf, which is proportional to the speed of movement, is fed to the vertical plates of the oscillograph. A voltage proportional to the generator current and, hence, to the exciting force is tapped off the resistor and fed to the horizontal plates of the oscillograph. At resonance, when the phase shift between the applied force and the speed of movement is equal to zero, the oscillograph screen displays a slanting straight line. The circuit can be provided with a frequency meter for more precise measurements of frequencies.

Measurement of damping in viscoelastic bodies. The moving system of the instrument together with the tested specimen can be represented by the following movement equation

\[ m x + k x = \omega_0 e^{i \omega t}. \]  

where \( m \) is the mass of the instrument's moving system, \( x \) is the displacement
Material

Soft wood-fiber plate:
\[ \delta = 1.2 \text{ cm}, \gamma = 0.2 \text{ g/cm}^3 \]
\[ \delta = 2.4 \text{ cm}, \gamma = 0.14 \text{ g/cm}^3 \]
Sponge rubber
Hair felt
Mineral felt with synthetic binding
Slag felt
Plastic foam PKhV

<table>
<thead>
<tr>
<th>Specimens’ damping decrement ( \psi_2 )</th>
<th>Frequency in Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.314</td>
<td>225</td>
</tr>
<tr>
<td>0.189</td>
<td>144</td>
</tr>
<tr>
<td>0.376</td>
<td>132</td>
</tr>
<tr>
<td>0.720</td>
<td>115</td>
</tr>
<tr>
<td>0.846</td>
<td>78</td>
</tr>
<tr>
<td>0.314</td>
<td>78</td>
</tr>
<tr>
<td>1.75</td>
<td>75</td>
</tr>
</tbody>
</table>

\[ k = k_1 + k_2 = k_0 \left( 1 + j \frac{\psi_1}{\pi} \right) \]  
(2)

is the total complex stiffness of the moving system and the specimen

\[ k_1 = k_{10} \left( 1 + j \frac{\psi_1}{\pi} \right) \]

is the complex stiffness of the instrument’s moving system

\[ k_2 = k_{23} \left( 1 + j \frac{\psi_2}{\pi} \right) \]

is the complex stiffness of the tested specimen; \( \psi_1 \) and \( \psi_2 \) are the damping decrements; \( \psi_0 \) is the amplitude of the force; \( \omega \) is the angular velocity.

At resonance, when the reactance is equal to zero, we find that the value of \(|x| \) taken from [6] becomes equal to

\[ |x|_r = \frac{\theta_0 \omega_0}{k_0 \psi} \]

where subscript "r" refers to resonance.

If the vibration frequency is reduced to \( \omega_1 \) or raised to \( \omega_2 \), so that the resonant velocity amplitude is halved, which can be easily set on the oscillograph, we find that

\[ \frac{|x|_r}{2} = \frac{\theta_0}{\sqrt{\left( \frac{k_1 \psi_0}{\pi \omega_1} \right)^2 + \left( \frac{k_0 - k_1}{\omega_1 - \omega_0} \right)^2}} \]

or

\[ \frac{|x|_r}{2} = \frac{\theta_0}{\sqrt{\left( \frac{k_2 \psi_0}{\pi \omega_2} \right)^2 + \left( \frac{k_0 - k_2}{\omega_2 - \omega_1} \right)^2}} \]

By solving simultaneously (3) and (4) or (3) and (5) and adding the expressions thus obtained, we finally find that

\[ \psi = \frac{\pi}{\sqrt{3}} \cdot \frac{\omega_1 - \omega_2}{\omega_0} \cdot \frac{4\pi}{3\sqrt{3}} \left[ \frac{(\Delta \omega)^2 + (\Delta \omega_0)^2}{\omega_0^2} \right] \]

(6)