PHYSICOMECHANICAL PROPERTIES OF TORSION SUSPENSIONS
FOR ELECTRICAL MEASURING INSTRUMENTS

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For the first time in the world history of instrument-making, from January 1961 an All-Union State Standard has been introduced in the USSR for torsion and ordinary suspensions GOST 9444-60. Electrical Measuring Instruments. Torsion Suspensions and Suspensions).

The basic characteristics of torsion suspensions have thus been standardized, including the restoring torque, elastic fatigue and electrical resistance. These data on torsion suspension are, in the majority of cases, completely sufficient for computing and designing electrical measuring instruments.

In designing high-precision or special-purpose instruments which have to operate under difficult climatic conditions it is important to have, in addition to standardized characteristics of torsion suspensions, also data on their tensile strength, elastic limit, normal modulus of elasticity, coefficient of rigidity, limiting current density, thermal emf between the suspension and copper, and the relation of these characteristics to ambient temperature.

It was found in practice that the physicomechanical properties of materials in microcomponents differ considerably from those obtained in reference books, which are normally determined for larger size components.

Characteristics of Torsion Suspensions Made According to GOST 9444-60

<table>
<thead>
<tr>
<th>Torsion suspension material</th>
<th>Microhardness HV</th>
<th>Tensile strength, σ_t</th>
<th>Tensile limit of proportionality, σ_p</th>
<th>Normal modulus of elasticity, E</th>
<th>Coefficient of rigidity, G</th>
<th>Elasticity temperature coefficient, α_E : 10^-4, per °C (in the range of -40°C to +100°C)</th>
<th>Coefficient of the elastic fatigue, α_σ : 10^-2, per °C (in the range of -40°C to +40°C)</th>
<th>Temperature coefficient of the elastic fatigue, α_α : 10^-4, per °C (in the range of -40°C to +100°C)</th>
<th>Res. temperature coefficient, α_p : 10^-4</th>
<th>Linear temperature coefficient, α_ρ : 10^-5</th>
<th>Res. per °C</th>
<th>Thermal emf between the suspension and copper, μ V/°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>BrSnZn4-3</td>
<td>250</td>
<td>115</td>
<td>80</td>
<td>11500</td>
<td>4500</td>
<td>-4.5</td>
<td>0.1</td>
<td>0.9</td>
<td>0.09</td>
<td>15.5</td>
<td>15.5</td>
<td>2.0</td>
</tr>
<tr>
<td>BrBe2</td>
<td>400</td>
<td>160</td>
<td>100</td>
<td>13500</td>
<td>5000</td>
<td>-3.0</td>
<td>0.2</td>
<td>0.9</td>
<td>0.06</td>
<td>15.5</td>
<td>15.4</td>
<td>1.0</td>
</tr>
<tr>
<td>PtAg20</td>
<td>575</td>
<td>200</td>
<td>160</td>
<td>17500</td>
<td>7000</td>
<td>-2.5</td>
<td>0.05</td>
<td>1.2</td>
<td>0.3</td>
<td>10.5</td>
<td>14.5</td>
<td>8.0</td>
</tr>
<tr>
<td>Co40NiCrMoV</td>
<td>800</td>
<td>300</td>
<td>190</td>
<td>21000</td>
<td>8000</td>
<td>-3.0</td>
<td>0.02</td>
<td>-5.5</td>
<td>1.0</td>
<td>3.0</td>
<td>15.0</td>
<td>1.0</td>
</tr>
</tbody>
</table>
The torsion suspensions made in microsizes according to GOST 9444-60 use such materials as PtAg20 and Co40NiCrMoV, whose characteristics are not given in existing reference books. Neither do the reference books include some of the characteristics important in instrument-making, for instance, the elastic fatigue in strips and wires after twisting.

It was, therefore, necessary to conduct special research into the physicomechanical properties of torsion suspensions. Tests were carried out on standard torsion suspensions made of BrSnZn4-3, BrBe2, PtAg20 and Co40NiCrMoV. Their length was chosen according to the requirements of the particular characteristic to be measured and amounted to 10, 25, 75 or 100 mm. The variation of the sample properties with respect to temperature was measured in the range of -50°C to +100°C.

The tensile strength \( \sigma_t \), the limit of proportionality \( \sigma_p \) and the normal modulus of elasticity \( E \) were determined on a test machine type Mi44 from a photographic reproduction of torsion-suspension strain diagrams.

The mean values of tests made on a large number of samples are given in the table attached, from which it will be seen that the cobalt-chrome-nickel alloy torsion suspensions possess the highest strength and elasticity.

The relation of tensile strength, the limit of proportionality and the normal modulus of elasticity to temperature was also determined on the test machine type Mi44, which is equipped with special cooling and heating devices. These relations are given in Fig. 1.

![Fig. 1.](image)

It will be seen from Fig. 1 that the tensile strength and limit of proportionality of all the material under investigation decrease proportionally to rising temperature. The variations in these characteristics are small and are about the same for all types of torsion suspensions.

The elasticity temperature coefficient was calculated by the variation in the value of the torsion suspensions' restoring torque with respect to the test temperature.

It was found to be negative for all the materials but differed in its value. The torsion suspensions made of BrSnZn4-3 had the largest elasticity temperature coefficient.

The torsion suspensions' elastic fatigue \( \beta \) was measured by means of instrument type U1003 [1] and determined as the deviation of the luminous marker from zero after the untwisting of the torsion suspension.

The testing technique consisted of the following: sample torsion suspensions 10 mm long were twisted through angles of 90° and 180° and were kept in that position for 2 hours.

The relations of the torsion suspensions' elastic fatigue to the sample length, to the duration of its twisted exposure, and to the angle of twist are not shown in this article, since they have been given in [2].

The temperature coefficient of the elastic fatigue was determined in the range of -40°C to +40°C.

The bottom right-hand graph of Fig. 1 shows the relation of the elastic fatigue to the test temperature.

The temperature coefficient of the elastic fatigue of the bronze type BrSnZn4-3 and BrBe2 torsion suspensions is positive in the above temperature range, whereas that of alloys type Co40NiCrMoV and PtAg20 is negative. The values of \( \alpha_\beta \) for all the materials are given in the table.

The electrical resistance of the torsion suspensions was measured on a Wheatstone bridge. The resistance temperature coefficient was measured in an oil bath at temperatures of +10, +30 and +40°C.

*In all the graphs the parameters of torsion suspensions made of the same material are denoted by the same figures as shown below: 1) BrSnZn4-3; 2) BrBe2; 3) PtAg20; and 4) Co40NiCrMoV.*