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REGARDING THE DETERMINATION OF VISCOELASTIC CHARACTERISTICS OF RECOVERABLE SILICONE RUBBER

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Abstract: The paper presents the main elements that define some viscoelastic properties of recoverable silicone rubber. There are presented the variations of the storage modulus (E') and loss modulus (E) as well as loss factor, using specific methods on two pieces manufactured of silicone rubber recovered from composite electrical insulators.

1. INTRODUCTION

Due to its properties, recovered silicone rubber obtained through specific techniques is the most stable polymer available currently, offering increased reliability and long term usability, advantages obtained at advantageous production costs. It offers the best resistance/time ratio both in normal and hard conditions.

The applications of silicone rubber are not novelty in precision engineering and medical domain. For this reason, using recovered silicone rubber provides viscoelastic properties at least as good as the original material, especially in case of sensor technique tools and measuring tools.

2. VISCOELASTIC PROPERTIES OF RECOVERABLE SILICONE RUBBER

Viscoelastic materials such as silicone rubber present both viscous and elastic properties.

If applying a traction strain on a viscoelastic material, the specific deformation can be determined from a differential equation of the form:

$$\sigma = E\varepsilon + \mu \frac{d\varepsilon}{dt} \tag{1}$$

Where σ – unitary traction effort

E – elastic deformation in which the process energy is stored as potential energy and reused for recovering the initial shape

μ - viscoelastic flow of the system, in which the energy is dissipated as heat when the strain ends

If E and μ are constants of time dependent, (1) is an ordinary linear differential equation. Considering:

$$\sigma(t) = \sigma_0 e^{iwt} \tag{2}$$

$$\varepsilon(t) = \varepsilon_0 e^{iwt} \tag{3}$$

It results

$$\varepsilon_0 = \frac{\sigma_0}{E + i\mu\omega} \tag{4}$$

Also

$$\varepsilon = \frac{\sigma_0 e^{i\omega t}}{E + i\mu\omega} = \frac{\sigma}{E + i\mu\omega} \tag{5}$$

The denominator of (5) can be written as:

$$E = E' + iE'' \tag{6}$$

Where E – complex modulus
E' – storage modulus
E" = ωμ – loss modulus

Relation (5) becomes:

$$\varepsilon = \frac{\sigma}{E} \tag{5'}$$

The complex modulus becomes:

$$|E| = \sqrt{E'^2 + E''^2} \tag{7}$$

The phase difference is:

$$\delta = tg^{-1}\frac{E''}{E'} \tag{8}$$

The variation $\sigma = f(\varepsilon)$ in case of a viscoelastic material (silicone) is presented in figure 1. The graph indicates that this behavior is valid for small deformations.

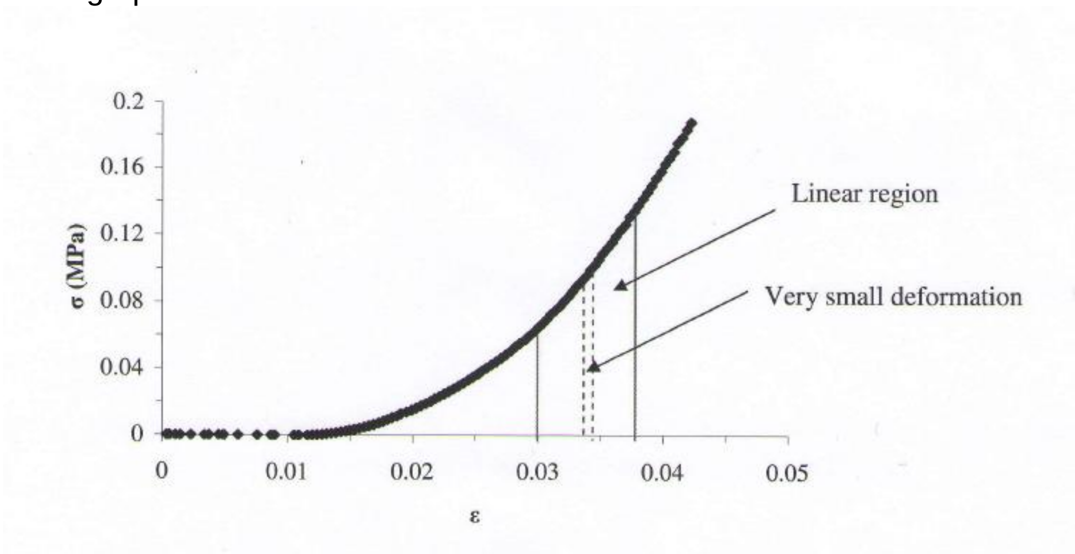

Figure 1. Linear viscoelastic characteristic of silicone

3. EXPERIMENTAL DETERMINATION OF VISCOELASTIC CHARACTERISTICS OF DIFFERENT RECOVERABLE SILICONE RUBBER VARIANTS

Determining the elasticity modules E and E' represents the most common method for studying the viscoelastic behavior of polymers.

In this case, sinusoidal strains are applied and the specific deformation of the material is measured. This allows determining the dynamic modulus E from its components.

Specific measurements were performed on pieces manufactured from silicone rubber recovered after a specific functioning time of the composite electrical insulator.

Silicone rubber, due to its physical and chemical properties, only allows recovery through mechanical operations, in order to maintain its initial properties. In the end there were obtained two technological products presented in figures 2, 3, from the solid component of the used insulator coating (40%) and a liquid component (60%).

Figure 2. Antivibration insulating mat used in railway transport command systems

Figure 3. Antivibration insulating element

There were employed surface structure and characterization techniques such as SPM (Scanning Probe Microscopy) and nano-indentation using a nano-mechanical characterization G200 equipment (Agilent Technologies) in different modes. The device offers ISO 14577 compliant nano-indentation methods, which makes is suitable for industrial applications as well (figure 4).

Figure 4. Nano indenter G200

The device has the following specifications:

- Displacement resolution: 0.01 nm;
- Force resolution: 50 nN;
- Maximum force: 500 mN;
- Maximum indentation depth: 500 μm;
- Positioning precision: 1μm.

The properties that can be measured are: hardness, elastic module, critical adherent forces, resistance to wear, stress-strain characteristic, etc.

The following tables present the main viscoelastic characteristics of the material from which the two technological products are manufactured.

Test #	Storage Modulus MPa	Loss Modulus MPa	Loss Factor
1	26.076	4.933	0.189
2	29.179	2.759	0.095
3	25.786	3.082	0.120
Mean	27.014	3.591	0.134
Std.Dev.	1.881	1.173	0.049
% COV	6.96	32.67	36.49

Table 1. Technological product 1 characteristics

Test #	Storage Modulus MPa	Loss Modulus MPa	Loss Factor
1	25.512	2.341	0.092
2	23.152	2.590	0.112
3	26.798	3.293	0.123
Mean	25.154	2.741	0.109
Std. Dev.	1.849	0.494	0.016
% COV	7.35	18.01	14.50

Table 2. Technological product 2 characteristics

4. CONCLUSIONS

A. The technology for recovering silicone rubber from the coating of the used composite electrical insulators is valid because it offers superior properties such as:
   - Longer life span
   - Robustness and reduced specific weight
   - Low maintenance costs
   - Hidrofobicity
   - Resistance to chemical and atmospheric wear

B. Mixing the solid coating component (40%) and a liquid component (60%) is superior to previous mixing methods.

C. The values of the storage modulus, loss modulus, loss factor, etc. are superior to those obtained through previous methods.

D. The value of the equivalent elasticity modulus is superior than in case of regular rubber.

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