LOW TEMPERATURE TESTS OF PVC-COMPOSITES PRODUCED FROM OLIGOMER-POLYMER MODIFIER COMPLEX CONTAINING TWO BASIC COMPONENTS

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ABSTRACT

The changes of the physical-mechanical characteristics of PVC-composites containing Oligomer-Polymer Modifier Complex (OPMC) at normal temperature, indicating the levels of compatibility of its components with those of the studied PVC-composites, have been analyzed previously.

In this paper the study of OPMC continues, with an attempt to establish the behavior of two basic components of OPMC at low exploitation temperatures, as well as the concentration limits of their positive influence. This study enlarges the possibilities for the correct interpretation of the influence of the individual components in the OPMC system. An epoxy-novolac resin and a polyacetal were tested as modifying substances in electro-isolation PVC composites at -20°C.

The physical-mechanical investigation presented in this paper, confirms that at low temperatures Polymer-M is not a typical plasticizer. The elasticity modulus of the composites containing up to 2 % \( m_{\text{max}} \) of the two modifiers does not significantly differ from that of the control composition. For the composites containing Oligomer, that fact is valid for the entire concentration range. The participation of Polymer-M as a modifier in the whole investigated concentration range increases the modulus of the elasticity of the composites.

Keywords: modification, polyvinylchloride electro-isolation composites, Oligomer-Polymer Modifier Complex (OPMC), oligomer of the epoxy-novolac resin, polymer of the acetal type.

INTRODUCTION

The modifier ability of the Oligomer-Polymer Modifier Complex (OPMC) at 20°C has been analyzed previously. [1, 2, 5]. It was established that the Oligomer (oligomer of a novolac-epoxy resin) and Polymer-M (polymer of the acetal type) improve the insulating and the dielectric parameters of the composites and support the processing of the dry blend [3]. This provoked investigation of the influence of the modifiers on the strength-deformation characteristics at low temperatures.

So far the independent effect of the two basic components of OPMC at low temperatures has not been studied. The aim of this investigation is to examine the independent effect of two components of the Oligomer-Polymer Modifier Complex (OPMC) at -20°C and their influence on the physical-mechanical properties of PVC-composites for cable insulation as components of the Oligomer-Polymer Modifier Complex (OPMC).

EXPERIMENTAL

Objects

Basic components of OPMC are: Oligomer - a partially cross-linked oligomer of the epoxy-novolac resin and Polymer-M - a polymer of the acetal type. They participate in the PVC-composites without any other OPMC components.

PVC-composites, containing both types of modifiers in amounts of 0.1 up to 10 % \( m_{\text{max}} \). The complexity of the task of describing the OPMC action necessitated to use of a designed experiment (Fig. 1). Composites were prepared and data gathered in accordance with this design for preceding partial studies [1, 3].
Methods of investigation: Strength-deformation tests were performed according to ISO 527n, ISO 6239 type 4a TGL 1436.

RESULTS AND DISCUSSION

The strength-deformation characteristics of the PVC-composites containing Oligomer and Polymer-M at -20°C are presented in Table 1.

The average values of the indices of two control mixtures are used for comparison and control. Fig. 2 and Fig. 3 show the graphic dependences of the tensile strength and relative elongation at -20°C, depending on the amount of the modifiers. At each point the results are the average value of 3 parallel experiments.

The data for the modulus of elasticity E at -20°C of the composites are presented in Table 2, and the graphic dependence is given in Fig. 4.

Independent action of the modifiers at -20°C

The property of relative deformation, \( \varepsilon_r \), is a sensitive criterion for the behavior of the PVC-composites at negative temperatures.

The relative deformation of the electro-isolation PVC-mixtures, intended for cables and conductors is a basic index, on which the exploitation of the product at different working temperatures depends. It is standard for each article and always has to be within fixed limits.

The control recipe is a realistic recipe, used in manufacturing of electro-isolation PVC composites. That is why, the comparison of the relative deformation of materials.

Table 1. Relative deformation and tensile strength at -20°C.

<table>
<thead>
<tr>
<th>Quantity of the modifier</th>
<th>Oligomer</th>
<th>Polymer-M</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Relative deformation</td>
<td>Tensile strength</td>
</tr>
<tr>
<td>% mass</td>
<td>( \varepsilon_r, % )</td>
<td>( \sigma_0, \text{MPa} )</td>
</tr>
<tr>
<td>0.1</td>
<td>21.23</td>
<td>65.97</td>
</tr>
<tr>
<td>0.5</td>
<td>24.90</td>
<td>66.15</td>
</tr>
<tr>
<td>1</td>
<td>20.30</td>
<td>67.33</td>
</tr>
<tr>
<td>2</td>
<td>71.31</td>
<td>71.31</td>
</tr>
<tr>
<td>5.5</td>
<td>9.23</td>
<td>53.53</td>
</tr>
<tr>
<td>10</td>
<td>10.17</td>
<td>70.78</td>
</tr>
<tr>
<td>Control (average value)</td>
<td>24.88</td>
<td>61.64</td>
</tr>
</tbody>
</table>
the modified mixture with that of the control has a direct connection with the applicability of the achieved effect of the modification.

In general, on the basis of Table 1 and Fig. 2, the following can be suggested for Oligomer and Polymer-M: The curves in the Figure have the same form in the range from 2 up to 10 %\textsubscript{mass}. In concentrations below 2 %\textsubscript{mass} the deformation changes in many directions, similarly to the results at +20°C [1].

On the whole, the curves lie below those of the control composition. The curve for the Oligomer composites for concentrations below 2 %\textsubscript{mass} is the closest to it. The relative deformation of Polymer-M composites is much smaller in the same concentration range, which might mean that at low temperatures Polymer-M does not play the role of a typical plasticizer.

\textit{Tensile strength - }$s_h$

The curves describing the tensile strength, $s_h$, for the composites containing Oligomer and Polymer-M have maximums, which are in an antiphase, and this is retained within the whole investigated range. The data for them, with concentrations of 0.1 to 2 %\textsubscript{mass} are located above the curve for the control composition. What impresses is that only one point of each curve has values lower than the reference: that of 5.5 %\textsubscript{mass} Oligomer and 10 %\textsubscript{mass} Polymer-M (Fig. 3).

An abrupt change at 5.5 %\textsubscript{mass} was registered in the course of the curves, presenting the rheological and electric properties of the composites [3]. Similar minimums and maximums in antiphase are present in the parameters of the two modifiers Oligomer and Polymer-M at 20°C. Such a coincidence shows that these are not due to incidental errors in the preparation of the composites and their testing. It can be suggested that the larger contents of the modifiers - above 5.5%\textsubscript{mass} regardless of the type of OPMC (or in what proportions the two main modifiers are used) results in an abrupt change in the structure of the PVC composite, probably due to another type of distribution of the components of the polymer matrix.

The investigated PVC composites in their physical - mechanic behavior are very much alike the elastomer blends - they harden at low temperatures and their tensile strength increases significantly. However, the absolute increase of $s_h$ at -20°C cannot be used as an indicator for improvement of the properties of the composites. In order to clarify whether a certain additive improves a certain parameter it is necessary to compare the results at two working temperatures.

\textbf{Modulus of elasticity, }$E$

The data are presented in Table 2 and Fig. 4.

\begin{table}[h]
\centering
\begin{tabular}{|c|c|c|c|c|}
\hline
Quantity of & Module & Control deviation, $D$ & & \\
the modifier & $E$ & $E_o$ & % & % \\
\hline
Oligomer & 210 & 230 & -5 & 5 \\
Polymer-M & 230 & 230 & 5 & 5 \\
Oligomer & 260 & 230 & 18 & 5 \\
Polymer-M & 210 & 260 & -5 & 18 \\
Oligomer & 250 & 300 & 14 & 36 \\
Polymer-M & 240 & 380 & 9 & 73 \\
control & 220 & 220 & 0 & 0 \\
\hline
\end{tabular}
\caption{Module of elasticity, $E$.}
\end{table}

By the formula

$$D = \frac{E - E_o}{E_o} \cdot 100$$

the Deviation, $D$, of the modulus value of the respective PVC-composite from the control composition is calculated in %. In the formula, $E$ is the modulus of elasticity of the investigated composition, MPa, $E_o$ – the modulus of elasticity of the control composition, MPa.

With Oligomer containing PVC – composites, the modulus of elasticity in the entire tested concentration range (from 0.1 to 10 %\textsubscript{mass}) does not significantly differ from the modulus of the control composition: the deviation from it is from -5 to 18 %, which is within the experimental error limit. This allows to include a larger amount of the Oligomer in PVC composites, which

Fig. 2. Dependence of $s_h$, on the quantity of the modifier in the PVC-composites.
results in increasing their specific volume electric resistance [3].

With composites containing Polymer-M, a similar small deviation is registered only from 0.1 to 2 %\textsubscript{mass}.
To the end of the tested range the modulus increases linear and the deviation, D, varies from 5 to 73%.

From the view point of this parameter it can be said that the modification in the concentration interval up to 2 %\textsubscript{mass} is successful with both of the modifiers. These composites with low percentage of modifiers are better due to the fact that at -20°C they hardly change their modulus of elasticity. Here both Oligomer and Polymer-M act in the direction of preservation of the values of E, as the deviation is from -5% to +18%.

Comparing the curves for E after the 5,5 %\textsubscript{mass} concentration, an increase of E at 10 %\textsubscript{mass} for Polymer-M and a decrease of the modulus at the same concentration for Oligomer is observed. It is supposed that here the different compatibility of the PVC-matrix with Polymer-M and Oligomer, observed also in the electric and rheological studies, manifests itself [1-3].

**CONCLUSIONS**

The physical-mechanical properties of electro-isolation PVC composites containing two modifying additives separately - Oligomer and Polymer-M at -20°C have been investigated.

The graphic dependences of the relative deformation, tensile strength and modulus of elasticity at -20°C for the concentration range of 0,1 up to 10 %\textsubscript{mass} of each one of the modifiers have been analysed separately. The physical-mechanical studies confirm that at low temperatures Polymer-M is not a typical plasticizer. At low temperatures the elasticity modulus of the composites containing up to 2 %\textsubscript{mass} of the two modifiers does not significantly differ from that of the control composition. For the composites containing Oligomer that observation is valid for the entire concentration interval. The participation of Polymer-M as a modifier in the whole investigated concentration range increases the modulus of elasticity of the composites.

**REFERENCES**