SOME CHARACTERISTICS OF THE STRENGTH PROPERTIES OF CRYSTALIZING RUBBERS AT ELEVATED TEMPERATURES

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A study has been made of the reasons for the considerable scatter of the strength properties and the failure of specimens based on crystallizing rubbers outside the gauge length when tested in accordance with Soviet standard GOST 270-53 at elevated temperatures. The relation between the strength distribution and degree of vulcanization is clarified; it is shown that the strength properties of the product are affected by the thermal prehistory of the rubbers.

From experience in testing the strength of uncompounded vulcanizates based on natural (NK) and isoprene (SKI) rubbers at elevated temperatures it is known that the results of such tests are very widely scattered (the coefficient of variation of the strength characteristic may reach 60%), while a considerable number of the specimens fail outside the gauge length.

In this article an attempt is made to clarify the nature of this effect.

EFFECT OF CRYSTALLIZATION OF NK SPECIMENS UNDER TENSION ON THEIR STRENGTH DISTRIBUTION AT +100 °C

A characteristic feature of NK and SKI rubbers is their ability to crystallize when stretched. Since specimens of noncrystallizing rubbers when tested under similar conditions do not exhibit such a large scatter, it is natural to suppose that the anomaly in the behavior of specimens of NK and SKI rubbers is directly connected with their ability to crystallize under tension. The results of the experiments described below tend to confirm this.

The test blend was prepared in accordance with specifications for batching-off, dyeing, and testing NK and vulcanized at a temperature of 143° C (for varying periods of time). Thirty-five specimens were subjected to a tensile test at +100° C for each vulcanization time. Histograms (Fig. 1) were constructed from the results of these tests. It is clear from the graphs that the shape of the strength distribution curve heavily depends on the duration of vulcanization. Thus, for specimens vulcanized for 10 min and specimens highly overvulcanized (30-40 min) the distribution curves have a single maximum (curves 1, 3 of Fig. 1). The distribution curve for specimens with an intermediate vulcanization time (15-20 min) differs strongly from the Gaussian and has two maxima (one is the region of high, the other in the region of low strengths). The coefficient of variation of the strength of these specimens is maximal, 60%.

The general nature of the relationship between the coefficient of variation of the ultimate tensile strength and vulcanization time is illustrated in Fig. 2. The least scatter for the highest mean value of the strength is exhibited by specimens vulcanized for 10 min. An increase in vulcanization time sharply increases scatter and reduces the mean value of the strength. A further increase in vulcanization time leads to a reduction in scatter associated with a sharp decrease in the mean value of the strength. Obviously, for the batch of rubber investigated a vulcanization time of 10 min must be considered optimal.

It appears to us that the observed relationship between the magnitude and scatter of the strength
Fig. 3. Relations between mean ultimate tensile stresses $\sigma_t$ and strains $\varepsilon_t$ and deformation curves $f_\varepsilon$: 1) relation between ultimate tensile stresses and strains $\sigma_t$ and $\varepsilon_t$ for NK vulcanizate with a large number of initial centers of crystallization, 2) the same for an intermediate number of centers of crystallization, 3) the same for a small number of centers, 4) deformation curve (4.1, 4.2, and 4.3 are for NK vulcanizate with a large, intermediate, and small number of initial centers of crystallization, respectively). The broken-line curves show the field of scatter of curve 2 ($\sigma_t - \varepsilon_t$): $\varepsilon_{\text{cr.1}}$, $\varepsilon_{\text{cr.2}}$, and $\varepsilon_{\text{cr.3}}$ are the mean strains at which crystallization hardening begins; $\varepsilon_t$, $\varepsilon_t$, $\varepsilon_t$ are the mean tensile strains; $f_{\text{t.am}}$ is the mean strength of specimens in the amorphous state; $f_{\text{t.cr}}$ is the mean strength of specimens in the maximally crystallized state.

Fig. 4. Strength at +100° C of NK vulcanizates as a function of the duration of freezing of the preheated rubber. $\Delta$ is the strength of vulcanizates made from rubber not subjected to heat treatment.