DOI: 10.17277/amt.2019.01.pp.045-048

The Composition and Technological Aspects of Obtaining Water-Swelling Elastomeric Materials

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Abstract

The paper deals with the kinetics of water-swelling of cross-linked elastomeric materials filled with polyacrylamide. The dependence of the swelling degree of the samples on the polyacrylamide content and vulcanization conditions was studied. The analysis of the technological properties of water-swelling elastomeric compositions was conducted. It is established that the rate and the maximum swelling degree of the samples increases with increasing the polyacrylamide dosage. In order to ensure the swelling degree of elastomeric materials more than 200 %, at least 60 wt. h. PA should be introduced in the composition; the vulcanization time should be 40 minutes at a temperature of 130 °C.

Keywords

Hydroisolation; elastomers; swelling; polyacrylamide; vulcanization.

Introduction

In the construction industry, water-swelling elastomeric materials in the form of cords, tapes, mastics are used for hydroisolation of the so-called “cold welds” and construction joints. The swelling degree of materials of different nature and composition ranges from 100 to 600 %. Water-swelling seals (cords and tapes) are often made on the basis of rubber compositions and bentonite clay [1 – 4]. However, under cyclic “wetting-drying” conditions, the use of such materials is limited, since bentonite systems may lose their original properties after drying, and the sealing ability of these materials is reduced. In addition, they are not used in expansion joints due to the low rate of swelling, especially in the initial period. Materials based on water-swelling acrylate, polyurethane compositions are also known [5 – 6]. These are mainly foreign-made materials, so the development of domestic hydroisolating elastomeric materials requires affordable raw materials and technology, which largely determine the economic potential, production capacity and intensive development of industry in the Russian Federation.

At present, hydroisolating materials based on elastomers with various water-swelling additives are widely used in construction. Acrylamide-based polymers are the most promising additives, providing the necessary water-swelling of elastomeric hydroisolating materials [7 – 9].

When creating water-swelling materials it is important to ensure that the integrity of the seal is maintained during the entire life cycle. One of the technological methods is the vulcanization of the rubber matrix. However, it should be taken into account that cross-linking reduces the ability to swell an elastomeric composition filled with water-swelling components [10].

Water-swelling elastomeric compositions (**WEC**) are made on the basis of rubbers of various chemical nature, among which ethylene-propylene, styrene-butadiene and butyl rubber are most often used [11]. Their choice is based on the advantages of the rubber properties when used in the composition of sealing materials for construction purposes, operating in conditions of oxygen, atmospheric factors, corrosive media. It should also be noted that the technology for producing seals is based on extrusion and subsequent vulcanization without pressure. Therefore, in the manufacture of non-mold seals, rubbers and mixtures based on them must have good technological properties, and the selected vulcanization modes must meet operational requirements.

The aim of the research was the development of elastomeric vulcanized hydroisolating materials based on polyacrylamide, including the selection of the optimal parameters of WEC vulcanization, the study of properties and the development of recommendations for their use.

Experiment. Materials and methods

The objects of the study were water-swelling elastomeric compositions based on SKS-30ARKM-15 rubber. Dibenzothiazole disulfide – 3.0; sulfur – 2.0; zinc oxide – 5.0; stearic acid – 1.0 were used as the vulcanizing group in wt. h. per 100 wt. h. rubber. In order to ensure the skeleton profile and to reduce the cost of the composition, the mineral filler – 20 wt. h. was included. To provide a better dispersion of the components, a softener – 4 wt. h. was introduced. A polyacrylamide-glycerin composition (**PA**) was used as an additive in the amount of 50–80 wt. h. to provide rubber water-swelling. Using this composition eliminates the technological difficulties associated with the uniform distribution of polyacrylamide in the elastomeric matrix.

Rubber compounds were prepared on rollers LB 320 160/160 (with a friction of 1 : 1.14 at a temperature of (60 ± 5) °C). At the first stage, a masterbatch was prepared, including filler, zinc oxide, stearic acid, softener and PA. After curing the mixture, a vulcanizing group (dibenzothiazole disulfide and sulfur) was introduced for 2 hours. Washers of 30 mm diameter and 5 mm thickness were cut out from the obtained rubber mixture sheets with a dagger knife, and then they were pressed at a pressure of 20 MPa and a temperature of 100 °C for 1 minute to give them a specific shape. The vulcanizates were obtained without pressure in a thermostat at a temperature of 130 °C, the duration of vulcanization was 30, 40, 50 minutes.

The ciphers were assigned to the samples, which reflect the composition and conditions of their production, for example PA(80)-130-30: (80) – the content of water-swelling additive in wt.h. per 100 wt. h. rubber, 130 – the vulcanization temperature, °C, 30 – the vulcanization duration, min.

The swelling of the samples in tap water was assessed by the increase in their mass over 168 hours (7 days) and 672 hours (28 days), which is due to the requirements of the regulatory and technical documentation for the designed seals for construction purposes.

The swelling degree by weight was determined from the expression:

$$\alpha = 100\left(m_1 - m_0\right)/m_0 ,$$

where α is the swelling degree by weight, %; m_0 is the mass of the original sample; m_1 is the mass of the sample after swelling.

Since the technological process of manufacturing non-mold seals involves the use of processing equipment (rollers, extruders), then when developing a composition, it is necessary to ensure satisfactory technological properties of rubber mixtures. Therefore, the Mooney viscosity of the obtained compositions (GOST R 54552–2011) was evaluated using a BP-2 viscometer.

Results and discussion

The previous studies [3], as well as literature data [1, 2] show that elastomer seals, differing in a given service life – from 24 hours to several weeks, the maximum degree of swelling from 100 to 600 %, are widely used in the construction industry. An important indicator is the swelling rate of the seals in the first hours of the contact with water.

It was found that for unvulcanized samples containing more than 20 wt. h. PA within 24 hours of exposure in water, there is a strong swelling, especially in the surface layers, leading to destruction. Therefore, it is necessary to conduct studies to substantiate the choice of vulcanization modes, providing a high swelling degree, integrity and strength of the samples.

The kinetics of swelling of elastomeric seals samples with different content of PA, obtained by varying vulcanization modes, is shown in Figs. 1, 2.

The analysis of changes in the swelling degree of the samples from the time of exposure in water showed that the swelling degree increases for all studied vulcanization modes with the increase of PA content.

An interesting fact is that the samples, depending on the content of PA, showed a different character of swelling kinetics, especially at the initial stage. For example, during the first 3 hours (see Fig. 2.) a sharp increase in the mass of the samples is observed, caused mainly by the swelling of the near-surface elastomer layers due to the free access of water molecules to PA. This is confirmed by the appearance-like characteristics, namely, the change in the surface of the samples from smooth at the initial stage to rough and shagreen after swelling. The roughness degree increases with increasing PA content. It was established that the selected vulcanization modes at all dosages of PA ensure the integrity of the samples for 168 hours (see Fig. 1). High rates of speed and maximum swelling degree were obtained for the samples vulcanized for 30 minutes.

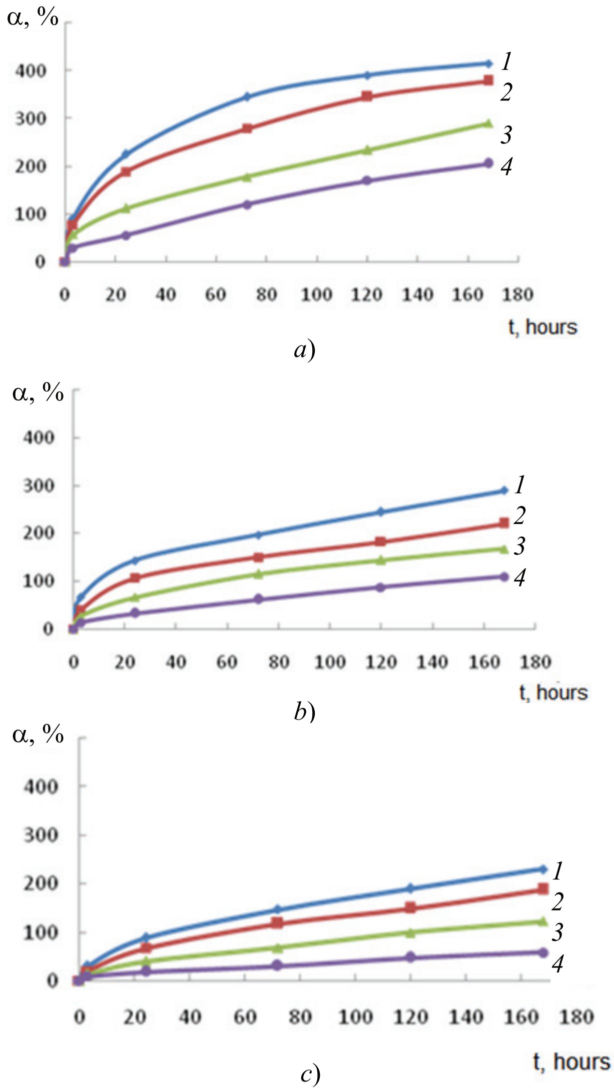

Fig. 1. WEC swelling kinetics with PA content (wt. h.):
1 – 80 PA; *2* – 70 PAA ; *3* – 60 PA, 50 PA ;
Vulcanization modes:
a – 130 °C, 30 min; *b* – 130 °C, 40 min; *c* – 130 °C, 50 min

For the same series of samples, a greater influence of PA content on the swelling degree was noted. When increasing the content of PA to 30 wt. h., the swelling degree increases by 210 %. At the same time, for the same series of samples, vulcanized for 40 minutes, the swelling degree increases by 180 %, vulcanized for 50 minutes – by 170 %. Thus, increasing the duration of vulcanization from 30 to 40 minutes leads to the sharp decrease in the maximum swelling degree. The further increase in the duration of vulcanization to 50 minutes leads to the slight decrease.

Fig. 3 presents a generalized data on the swelling degree of the samples after 168 hours of testing. The standard swelling indicator was 200 %.

It was found that to ensure the standard indicator it is required to introduce 50 wt. h. PA at the duration of vulcanization of 30 min, 70 wt. h. PA at the duration of 40 min and 80 wt. h. PA at the duration of 50 minutes, which confirms the inappropriateness of increasing the duration of vulcanization above 30 minutes. At a vulcanization temperature of 130 °C for 30 minutes, it is possible to obtain samples of the required quality with a maximum swelling degree from 205 to 415 %, depending on the content of PA. It should be noted that the swelling degree of the PA sample (60)-130-30 corresponds to the swelling degree of the PA sample (80)-130-40 and is 290 %.

Table 1 shows Mooney viscosity values for unvulcanized samples.

It was established that all the studied samples have Mooney viscosity indicators ensuring good processing on equipment and preserve integrity during operation. Since elastomeric seals, the life of which should be more than 7 days, are used in the construction industry, swelling tests on samples within 28 days (672 hours) were carried out. The data obtained are presented in Fig. 4.

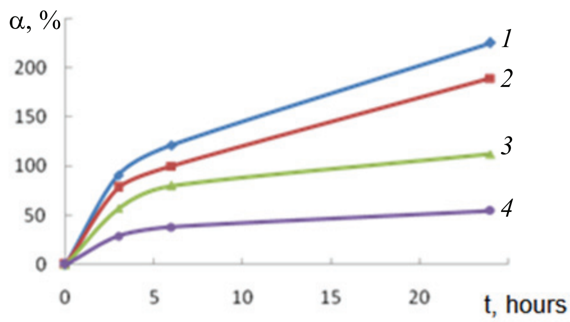

Fig. 2. WEC swelling kinetics in the first hours of exposure in water with PA content (wt. h.):
1 – 80 PA; *2* – 70 PA; *3* – 60 PA; *4* – 50 PA.
Vulcanization mode: 130 °C, 30 min

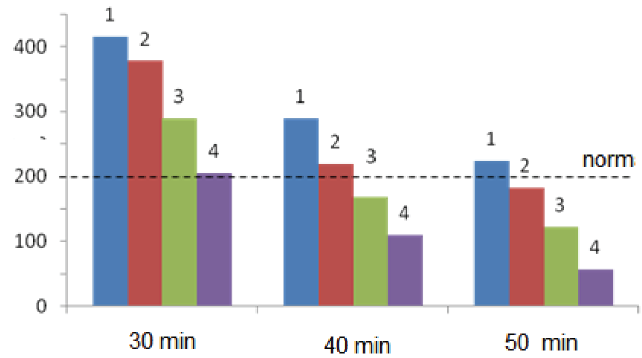

Fig. 3. Dependence of swelling degree of WEC samples on duration of vulcanization with different content of water-swelling additive after 168 hours of testing:
1 – 80 PA; *2* – 70 PA; *3* – 60 PA; *4* – 50 PA

Table 1

Mooney viscosity indicators of experimental samples with different content of water-swelling additive

Sample	Mooney viscosity, unit
PA(80)	36
PA(70)	36
PA(60)	38
PA(50)	38

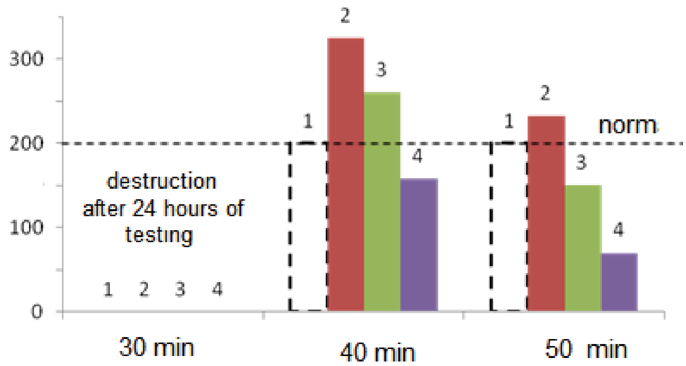

Fig. 4. The dependence of the swelling degree of the WEC samples on the duration of vulcanization with different content of water-swelling additive after 672 hours of testing:
1 – 80 PA; *2* – 70 PA; *3* – 60 PA; *4* – 50 PA

The obtained data shows that not all selected vulcanization modes ensure the integrity of the samples during 672 hours of testing. The samples cured during 30 min destructed or lost integrity before the expiration of the specified time. The samples PA(70)-130-40; PA(60)-130-40; PA(70)-130-50 showed the high swelling degree without destruction. The highest swelling degree 325 % was shown by the sample PA(70)-130-40.

Conclusion

The findings showed that the swelling rate of the samples increases with increasing PA dosage. T he maximum swelling degree of the samples increases with increasing PA content. The increase in the time of vulcanization leads to the hardening of the WEC polymer matrix, which increases their durability, but at the same time reduces the maximum swelling degree and rate.

The WEC samples, vulcanized for 50 minutes, showed low values of the maximum swelling degree and rate compared to the samples obtained with a vulcanization time of 30 and 40 minutes.

Thus, to ensure the WEC swelling degree by more than 200 %, at least 60 wt. h. PA should be introduced in the elastomeric composition, the vulcanization time at a temperature of 130 °C should be 40 minutes.

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