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RESEARCH OF CHARACTRISTICS OF POLYMERIC HEAT-SHRINKABLE SLEEVES

The results of testing of polymeric heat-shrinkable sleeves used for forming the fixed joints of pipelines are presented in the article. During the production sleeves of this type are exposed to radiation and orienting drawdown. It was determined the dependence of the performance characteristics of heat-shrinkable sleeves on the technological parameters of their production, in particular on the nature of the used polymer material and the exposure degree after molding. Quality assessment of the obtained sleeves was assessed by such indicators as the degree of crosslinking of the material in the product, the degree of parison swell of products after conducting the orientation (drawing), and the force and pressure of compression of pipe-shells by sleeves. The mode to obtain sleeves with an excellent set of operational characteristics is determined in the work.

Key words: heat-shrinkable sleeve, polyethylene, degree of crosslinking, orientation drawing, force of compression, pressure of compression.

Introduction. Belarus as well as the countries of near and far abroad produce a wide range of thermoplastic polymer based sleeves which are used for pipe joints waterproofing. In most cases, these products are made of polyethylene which after the forming process further undergoes cross-linking. In practice, polyethylene cross-linking can be performed in various ways – by the action of chemical reagents, corona discharge, radiation emission, etc. [1, 2]. Furthermore, in the manufacture of heat-shrinkable sleeves different producers may also use different grades of polyethylene. For this reason, parameters of performance properties of these products made by different manufacturers can vary significantly.

This type of products is relatively new, and therefore reasonable requirements to the sleeves have not yet been worked out by industrial enterprises. In this regard, the article attempts to outline the basic specifications for the most important performance characteristics of heat-shrinkable sleeves. The influence of the polymeric material cross-linking degree on consumer properties of sleeves has been analyzed there, too.

Main part. This paper describes the results of the research of sleeves made from polyethylene and subjected to additional radiation cross-linking and orientation stretching. At the manufacturing stage a space network from cross-linked polymer macromolecules originates in the sleeve samples, which should provide increased sleeves tensile strength, as well as higher heat resistance, chemical resistance, resistance to low temperatures, resistance to cracking. In particular, the paper presents the results of studying the sleeve shrinkage degree depending on the temperature in the free state, the sleeve compression load, a Shore hardness of the surface and the polymeric material cross-linking degree (by polyethylene extraction in *para*-xylene).

During the work technological properties and performance of sleeve samples, manufactured by LLC “Sarmat-Termo-engineering” from mantle pipes made of different polymer grades and characterized by different diameters have been studied (Table 1). Part of the sleeve samples was irradiated with a gamma unit PGAs-420 (a single dose of sleeve radiation was 9 Mrad; a two-dose – 18 Mrad, a four-dose – 27 Mrad) (samples No. 1–4, 6–9, 12–15). The second part of sleeve samples studied during the work was irradiated using accelerated electrons (radiation dose – 9 eV) (samples No. 5, 10). As an analogue, the sleeve sample manufactured without radiation was also considered (sample No. 11).

The degree of polyethylene cross-linking in sleeves was determined by the content of the gel fraction in the material as a result of polymer sample extraction in *para*-xylene. Test results of sleeve samples on the degree of polymer cross-linking are shown in Table 2.

Based on the data presented in Table 2, it can be concluded that sleeve samples No. 13 (91.5%) and No. 8 (98.2) possess the highest degree of cross-linking. During the manufacture of these samples the polymer material was subjected to fourfold irradiation. A little lower degree of polymer cross-linking is observed in the sleeves, during the manufacture of which the polymer was irradiated 1 or 2 times.

The above mentioned sleeve samples are characterized by a relatively high durability. In this case due to the polymer cross-linking the maximum allowable operational temperature of the products increases and the product deformation characteristics decrease.

Furthermore, the cross-linked sleeves are also characterized by high chemical resistance, resistance to impact loads, and elastic resilience. In the manufacture of sleeves due to the cross-linking stage it is possible to preserve the form of products both before and after thermal shrinkage.

Table 1

Characteristics of sleeve samples used in tests

Sleeve sample number	Polyethylene (PE) grade	Amount of irradiation doses	Diameter before blowing, mm	Mean wall thickness, mm
1	PE 80, grade Lukoten F 3802 B	1	110	2.56
2	PE 80, grade Lukoten F 3802 B	2	110	2.60
3	PE 80, grade Lukoten F 3802 B	1	160	2.93
4	PE 80, grade Lukoten F 3802 B	2	160	3.03
5	PE 63	1	110	3.26
6	PE 63, grade 273-83	1	160	3.10
7	PE 63, grade 273-83	2	160	3.00
8	PE 63, grade 273-83	4	160	3.06
9	PE 80, grade Lukoten F 3802 B	2	110	2.46
10	PE 63	2	160	2.63
11	PE 100	0	125	2.83
12	PE 80, grade Lukoten F 3802 B	4	160	3.30
13	PE 80, grade Lukoten F 3802 B	4	110	2.50
14	PE 80, grade Lukoten F 3802 B	2	160	3.06
15	PE 63, grade 273-83	2	160	3.00

Table 2

Characteristics of heat-shrinkable sleeves

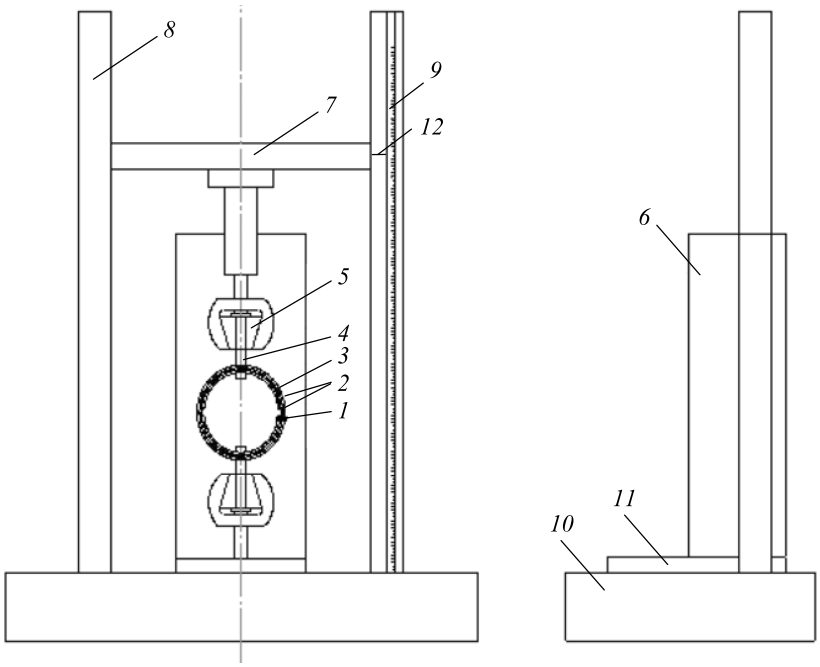
Sleeve sample number	Degree of sleeve cross-linking, %	Degree of sleeve blowing, %	Pipe compression force, N	Pipe compression pressure, MPa
1	27.20	111.06	468.27	0.106425
2	21.78	109.84	550.69	0.125157
3	11.45	110.33	561.42	0.087722
4	30.28	110.21	502.76	0.078556
5	23.40	112.11	480.52	0.109209
6	24.05	110.92	516.91	0.080767
7	18.29	109.45	508.44	0.079444
8	98.20	109.57	405.37	0.063339
9	49.60	113.27	560.08	0.127291
10	39.30	108.72	357.12	0.055800
11	–	111.19	491.79	0.098358
12	55.71	109.67	589.28	0.092075
13	91.50	113.21	484.44	0.110100
14	50.34	109.77	501.49	0.078358
15	69.50	110.25	435.71	0.068080

As a rule, by increasing the dose of radiation we can practically increase the degree of polymer cross-linking. However, after analyzing the data presented in Table 2, it can be seen that the increase in the radiation dose does not always lead to a significant increase in the degree of cross-linking of the material. So, in many cases the increase of the sample irradiation frequency is impractical.

It should also be noted that the method of cross-linking for one and the same polymer has a significant impact on the ability of the sleeve to shrink. This is due to the fact that in the course of irradiation with accelerated electrons only surface layers of the sleeve material are subjected to cross-linking, whereas under the action of γ-radiation the entire volume of the sleeve is cross-linked.

An important characteristic of such products is also a degree of sleeves blowing, calculated with respect to their original diameter (Table 2). The degree of blowing determines the degree of the subsequent sleeve shrinkage when heated (thermal shrinkage). In the course of research, the parameter value was determined for all samples studied by measuring their diameter before and after the procedure of orientation stretching.

Having analyzed the data presented in Table 2, it can be seen that a high degree of blowing is characteristic for sample No. 5 (112.11%) which was irradiated by accelerated electrons. This can be explained by the fact that in such conditions the cross-linked network is formed only in the surface layers of the polymeric material. A high degree of blowing is also characteristic for samples No. 1, 9, 11, and 13.



Installation diagram for determining compression force
and pressure of mantle pipes by a heat-shrinkable sleeve:
1 – test sample; *2* – half rings; *3* – rubber gasket; *4* – half rings mounts; *5* – jaws;
6 – heat-chamber; *7* – upper cross bar; *8* – guide pin; *9* – reference scale;
10 – installation frame; *11* – heat-chamber slats; *12* – pointer

The values of compression force and pressure in the work were determined on a universal testing machine – tensometer Instron 2020 using unique methods, developed and patented by the authors [3–5], according to the scheme shown in the figure.

After analyzing the data presented in Table 2, it can be concluded that the samples characterized by a high blowing degree (samples No. 5, 9, and 13), also provide a high compression force of mantle pipes. Since in the course of tube manufacture they were irradiated different number of times, it can be concluded that the contribution of the orientation stresses in the product at blowing, exerts much more significant influence on the amount of compression force than the processes of cross-linking under irradiation.

Conclusion. It was established experimentally that the optimum degree of sleeve cross-linking is around 50%, as sleeve samples, characterized by such a degree of cross-linking exhibit enhanced strength characteristics, and their practical use makes it possible to obtain more durable butt joints of pipes [5]. Sleeves, characterized by a lower value of the cross-linking degree, do not provide a reliable connection of pipes. A higher value of the sleeve cross-linking degree is also expedient, as a further increase in this parameter does not lead to a significant increase in the pipe compression force.

The research also states that the maximum compression force is provided in the case of sleeves which are made of PE 80 (grade Lukoten F 3802 B), and are twice additionally irradiated (0.1273 MPa). The reason may be that these sleeves, when compared with other tested samples, are characterized by a higher degree of stretching and orientation, which allows to reach higher shrinkage values of the indicated heat-shrinkable sleeves while in operation.

Due to radiation cross-linking, in practice, it is possible to achieve improved physical and mechanical properties of polymeric materials. Thus, the increase of the irradiation dose increases the cross-linking degree of the material – space lattice (network) density increases which in turn increases the strength and performance characteristics of the material. An important role is also played by the material irradiation method. Apparently, during sample irradiation by accelerated electrons, only surface material layers undergo cross-linking, and therefore the sleeves which have been cross-linked in such a way are characterized by low parameters of cross-linking degree. In the result of research it has been ascertained that it is reasonable to cross-link sleeves by γ-irradiation, rather than by accelerated electrons.

Thus, based on the results of the research conducted it has been revealed that in industry it is advisable to use heat-shrinkable sleeves manufactured from PE 80, grade Lukoten F 3802 B and irradiated by dose 18 Mrad (sample No. 9), because such sleeves have a better set of operating characteristics and good physical and mechanical properties.

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