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Strengthened Layered Polymer-Knitted Films and Coatings

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Abstract. The article presents the results of a study of the properties of a new multi-layer reinforced composite material based on polyethylene and mesh knitted fabric. The physical and mechanical and operational properties of the reinforced polymer laminates depend on the type of raw material, the geometric dimensions and shape of the lumen of the mesh knitted fabrics, on the methods and modes of formation of the multilayer material.

Keywords: molding, natural fibers, polyethylene, knitwear, layered non-woven material, polymer, technology, structure.

I. INTRODUCTION

In all industries: construction, agriculture and in daily life, polymer films and film materials are widely used. Currently, there is a variety of film materials based on various polymers and their compositions with organic and inorganic fillers. Among them, reinforced layered film (non-woven) materials are different with their improved physical-mechanical characteristics and handling properties. Laminated (non-woven) materials provide new opportunities for solving global problems associated with the use of local raw materials and ensuring their reproducibility. The development of hardened polymer coatings and films, taking into account their demand, product variety, compliance with the requirements of the domestic and foreign market conditions is an urgent task [1]. This paper presents the results of a study of the properties of a new reinforced sheet roofing material, created on the basis of the polymer-canvas composition, considering the integration development of the knitwear technology capabilities and the achievement of chemistry [2]. For the best realization of the properties, the net filler of the sheet plastic mass is a knitted fabric of a little loose fillet weave, the structure of which consists of multidirectional anisotropic elements. In [3], the bending properties of a hybrid composite made from both natural and synthetic fibers are discussed.

II. METHODOLOGY

The matrix of the roofing material is a thermoplastic plastic mass, a composite containing polyethylene resin, dioctyl phthalic acid ester, chalk, calcium stearate and other additives. The composition is presented in Table 1.

Table 1. Formulation of the polymer matrix of the layered material

№	Names of raw materials	Quantity per batch, kg
1	PE resin	150
2	Dioctyl phthalate	65
3	A piece of chalk	20
4	Stabilizers and other additives	17
Knitted mesh structure in accordance with the requirement (type of raw materials, proportionality and geometric shape of gaps, width) is supplied by the knitting industry in a stabilized form, corresponding to the surface treatment.		

The formation of a layered composite material is carried out by pre-fabricating the lower layer of the composite, then the upper one before the formation of the tape and duplicating them together with the lower one with the feeding of the mesh frame-filler between them in subsequent processes [4]. When forming reinforced films and coatings, an important point is the degree of penetration of the polymer into the substrate, i.e. pass-through or surface penetration. It is established that the solidity of the reinforced film materials is achieved on the basis of the composition "polymer-mesh fabric". In the study [5], reinforcement and matrix, obtained from the same type of thermoplastics, were used for polymorphism of composite materials. In practice, reinforced laminates are more common, in which the reinforcing element is mesh [6, 7]. Mesh fabric is formed by an openwork weave, in which the warp threads besides the weft additionally intersect with each other. The experience of manufacturers suggests that the production of such mesh fabrics is possible only at low speeds of weaving looms [8].

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In layered sheet materials, due to the linear arrangement of he reinforcing frame, individual threads are pulled out under the influence of small forces. When sewing a layered material, the moving ability is also visible in the finished product, which negatively affects its quality. The task of expanding the range and improving the performance properties of polymer films and coatings is more deeply solved by using knitted fabrics of a filament weave [9] made of cotton yarn, threadlike raw materials of artificial and synthetic origin with a surface density of 10-100 g/m^2 as a reinforcing framework. Moreover, the cells of the gaps have uniform or combined forms of polygons with a side length of not more than 10 mm or a circular shape with a diameter of 1.5-7 mm. The features of the mesh woven and knitted reinforcing frames and the shape of the cells of the lumen are shown in micrographs of the pictures taken with a high-magnification microscope "Nikon" (Fig. 1).

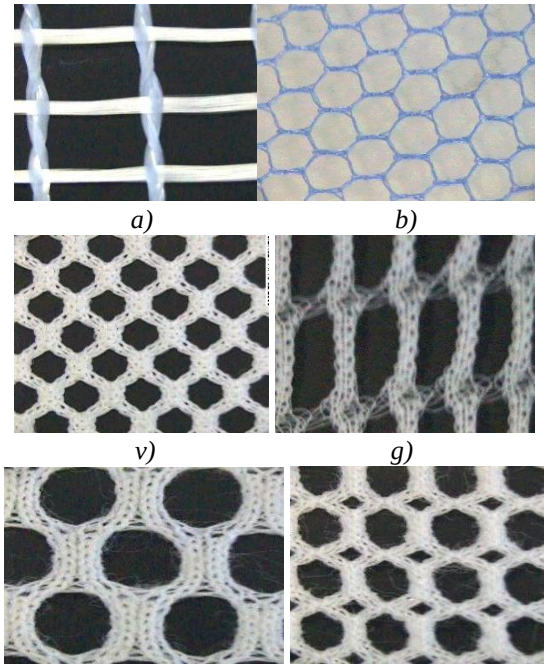

Fig. 1. Mesh textile fabric used in the form of a reinforcing element: a) woven glass mesh; b) knitted fillet with uniform hexagonal gaps of dyed polyester yarn; c) fillet knit with hexagonal clearances of polyester yarn; d) loin knitwear with oval gaps from nylon thread; e) knitted fillet with oval gaps from cotton yarn; f) knitted loin with cotton yarns of various geometric shapes The principle of obtaining new reinforced polymer coatings and films in the presence of ready-made layers of films and a layer of reinforcing mesh frame located between them is to duplicate all components under a certain temperature [10]. Reinforcing elements of reinforced polymer films and coatings are yarns, bundles consisting of fibers, textile cloths (nonwoven, woven, knitted), as well as polymeric meshes, grids and materials [11, 12], obtained in various ways. Changes in the structure during the formation of multilayer composite materials are associated with processing parameters and material properties [10]. Multi-layer biaxial weft knit fabric, has excellent mechanical properties [13]. In [14], a three-layer knitted fabric with biaxial weft was used as reinforcing elements. Multi-layered fabric with biaxial weft knit, made of glass fiber E and cross-linked with polyester yarn, which is a kind of inflexible fabric, was impregnated with epoxy resin using resin film infusion technology for manufacturing composite plates [15].

III. RESULTS AND DISCUSSION

The strength characteristics of reinforced polyethylene films by mesh knit, made of cotton yarn, polyester and nylon yarn from the relative elongation under tension in the longitudinal and transverse directions were studied (Fig. 2, 3). The same linear density of the threads and the geometric dimensions of the gaps of the paintings allow a comparative assessment of the fabrics of various types of fibers. In all cases, the strength of the reinforced films is much greater, and the magnitude of the relative elongation is several times less than in the original polyethylene film. Moreover, the nature of the dependence of strength on the relative elongation is more smooth compared to the film, reinforced with woven glass mesh. In the graph of the reinforcement of PE mesh knitted cotton yarn there is a wavy character of the increment. This phenomenon is explained by the adhesion of the tips of individual fibers, i.e. components of cotton yarn, which is clearly seen in the micrograph of their structure (Fig. 1., d,e,).

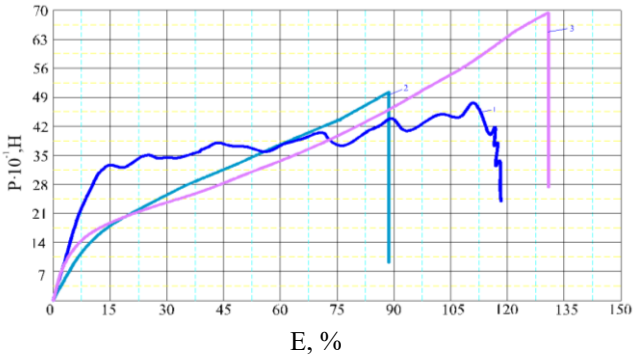

Fig. 2. Dependencies of strength of reinforced layered PE films with a reinforcing element of mesh knitted fabric, with a hexagonal clearance in the longitudinal direction of the relative elongation under tension: 1 - knitwear from cotton yarn; 2 - knitted polyester yarn; 3 - knitwear from capron thread The strength of knitted-reinforced films in the variants of their knitting from cotton yarn and polyester yarns is less than that of films reinforced with woven glass mesh.. And the strength of the final material, reinforced with nylon knitwear is higher than when using woven glass mesh. The relative elongation in all cases of knitted nets is much greater than when using woven glass mesh.The cumulative hardening effect is preferred in the case of reinforcement of polymer films with a mesh knitted fabric. When the temperature of duplication of polyethylene films is 60-80 ° C, the cotton fibers of the yarn in the knitted fabric remain in the crystalline state, and the polyester and nylon yarns are in a highly elastic state. Moreover, the state of polyester filaments is closer to viscous, and the state of nylon filaments is closer to glassy. Thus, the physical state of the kapron threads affects the final result.

The adhesion forces of the interaction of polyester yarns with polyethylene are due to the mutual melting of polymers, and cotton yarn fibers due to lint and surface roughness. The adhesive forces of the interaction of nylon filaments with polyethylene are less durable, but the strength at break of the nylon filament itself is higher than that of other filaments. As a result, the dependence of the strength of the films reinforced with knitted cloths made from cotton yarn and polyester yarns on the relative elongation has a character correlated with the original polyethylene.

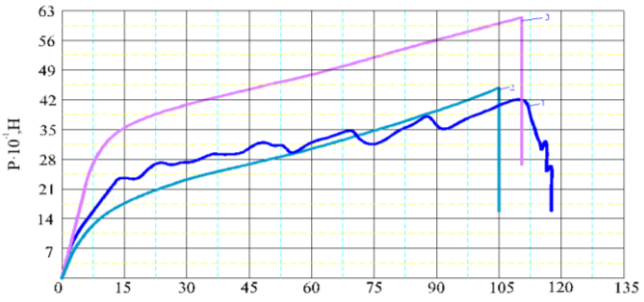

Fig. 3. Dependencies of strength of reinforced layered PE films with a reinforcing element of mesh knitted fabric, with a hexagonal gap in the transverse direction of the relative elongation at break: 1 - knitted cotton yarn; 2 - knitted polyester yarn; 3 - knitwear from capron thread

Polyethylene films reinforced with nylon knitted mesh have high and almost identical strength, both in longitudinal and transverse directions.

The stretchability of the knitted frame has a significant effect on the relative elongation of the films. This indicator in knitted-reinforced films is 4-6 times less in the original polyethylene, but an order of magnitude higher than in films reinforced with glass mesh.

The averaged values of the physicomechanical properties of polyethylene films reinforced with mesh textile material are given in Table 2.

Table 2. Physical and mechanical properties of reinforced polyethylene film materials

Reinforcing element	Thickness, mm	Strength, H	Conditional strength MPa	Relates elongation %	Over the top density, g / m2
Woven glass mesh *	0,37	530	28,6	12,6	223
		472	27,5	4,5	
Knitwear with hexagonal gap	cotton yarn				
	0,6	480	12,0	118,0	200,3
		420	10,5	117,2	
	polyester thread				
	0,4	510	25,5	88,5	198,2
		445	22,2	105,0	
	from kapron thread				
	0,4	690	34,5	131,0	198,2
		614	30,7	110,3	

Note: * the numerator longitudinally, the denominator transversely according to the orientation of the polymer matrix and the formation of a reinforcing frame

As can be seen from the data of Table 2 thickness, surface density, strength and elongation under tension varies with the nature of the material of the reinforcing frame. Reinforced film with mesh knit cotton yarn turned thicker. However, it has minimal performance compared with other materials.. The smallest value of the relative elongation has a reinforced film woven fiberglass. The maximum value of tensile strength, relative elongation at stretching at lower values of thickness and surface density has a polyethylene film reinforced with a nylon knitted mesh.

The results of the study of the physical and mechanical properties of layered (non-woven) materials made it possible to establish that the tensile strength of reinforced polyethylene films increased several times as compared with non-reinforced polyethylene films. Thus, in reinforced polyethylene films, the tensile strength increases for PE with a knitted mesh of cotton yarn 3.24 times, and so on. And the relative elongation under tension decreases for PE with a knitted mesh of cotton yarn 2 times as compared with non-reinforced materials..

The polyester knitted mesh has a lower melting point, and the cotton yarn knitted mesh is more strongly bonded to the plastic film due to the piled surface. Highly oriented woven glass mesh elements are easily pulled out of reinforced sheet laminate.

Comparative analysis of reinforced layered materials (woven glass mesh, knitted mesh made of cotton yarn, polyester and nylon yarn) showed that the physical and mechanical properties of all reinforced films are much better than the original film and the most efficient knitted mesh made of nylon yarn, especially with oval shaped lumen.

Table 3 shows the basic requirements for the physical and mechanical properties of layered (nonwoven) materials used in industry and daily life as an insulating water and airtight material.

Table 3. Physical and mechanical properties of layered materials

The name of indicators	Value of indicators	
Reinforcing element	fiberglass	knitted fabric
Thickness, mm	1,2±0,2	1,15
Conditional strength at break, kgf / cm² in the longitudinal direction	160, not less	181
Relative elongation at break,%	200, not less	225
Air premeability at a pressure of 0.08 MPa for 30 s	non permeable	non permeable
Water resistance	resistant	resistant
Flexibility when bending a sample on a rod with a radius of (5 ± 0.2) mm at a temperature of minus 25 ° C	there should be no cracks and flaking	cracking and flaking not
Water absorption, g / cm2	0,1; not less	0,07
Heat resistance, ° C	100, not less	100
Vapor permeability, kg / (m s Pa)	$0{,}13 \cdot 10^{-12}$, not less	$0{,}11 \cdot 10^{-12}$
Relative residual elongation,%	80	80
Resistance to static punching for 24 hours at a pressure of at least 0.001 MPa	no water on the sample surface	missing

Depending on the purpose and requirements for the operating conditions, there is the possibility of varying the nature of the material and the geometric dimensions of the mesh reinforcing frame.

IV. CONCLUSION

A new multi-layer reinforced composite material based on polyethylene and mesh knitted fabric has been developed. The nature of the material, methods of creating knitted mesh, technological parameters for their use in the production of layered polymeric materials are studied and identified.

The physical and mechanical and operational properties of the reinforced polymer coatings and films depend on the type of raw material, the geometric dimensions and the shape of the lumen of the mesh knitted fabrics, on the methods and modes of formation of the multilayer material.

Using local raw materials obtained hardened polymer coatings and films. The production technology of reinforced composites based on polyethylene with a reinforcing element - mesh knitted fabric of small sizes and lots for packaging, household, decorative and other purposes is proposed.

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