Structure and Properties of Heterocomposite Polymeric Materials and Coatings from them Obtained by Heliotechnological Method

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Abstract*: The paper presents the results of the study of the creation of new hetero-composite casting polymer materials and coatings from them. The effect of ambient temperature on microhardness and impact strength of polymer coatings is studied. It has been found that treatment of the polymer composition with solar radiation is an effective way of controlling the curing reaction, saving energy in the preparation of high viscosity epoxy compositions, which is important for their practical implementation in the industry for process equipment and products operating under conditions of corrosive hydroabrasive wear.

Keywords* : heliotechnology, mineral filler, gassypol resin, dibutyl phthalate, epoxy resin, microhardness of coatings, corrosion-hydroabrasive wear.

I. INTRODUCTION

In the industrial and industrial complex of the economy of the oil refining and cotton processing industries, technological and auxiliary equipment are widely used, operated under the influence of pronounced unfavorable factors, such as corrosive environment, abrasive components, temperature difference, ultraviolet radiation. In some cases, these adverse factors act simultaneously, leading to a reduction in the service life of machines, mechanisms, transport systems, lifting and transport equipment and specialized metal structures, tanks, containers and technological equipment for the processing and storage of raw materials.

The greatest technical and economic effect in the fight against corrosion is achieved by isolating metals with the help of various protective coatings - metallic, inorganic nonmetallic, organic. Regardless of the type of coating material, they must have good adhesion, be non-porous and resistant in the environment in which the product is used. Metallic coatings are subdivided into cathode (more electropulsive than the base metal) and anodic (more electronegative, while the coating protects the base metal electrochemically). They are applied in a hot way, immersing the product in a bath with molten metal, electroplating (electro-deposition), thermal diffusion and mechano-thermal (plated) methods [1-3].

It should be noted that today the products of Angren Kaolin LLC are inferior to similar products of foreign production, which reduces its competitiveness in world markets. In particular, one of the main requirements of the buyer of paper kaolin is the level of its whiteness. The whiteness of Uzbek paper kaolin AKF – 78 is 76–78%, while kaolin is in demand in the market, the whiteness of which is not less than 87%, such as, for example, Ukrainian and Russian kaolin [3-5].

At the same time, the purposeful use of Angren kaolins of production brands as fillers for machine-building composite materials opens up new opportunities for improving competitiveness in both the domestic and international markets.

Currently, there are various technological methods that control the structure and properties of composite polymer materials (KPM) and coatings (PPC) of them used on the surface of the parts of the working bodies of technological machines. The most effective, as noted above, are the physical methods: · – irradiation, magnetic and ultrasonic processing [1, 3].

II. MATERIALS AND METHODS

It should be noted that the full-fledged effect of structuring KPM in the magnetic and ultrasonic fields is achieved with a sufficiently long, and also a complex process of continuous action of these fields until the formation (curing) of the coatings is complete. Under laboratory conditions, this can be achieved by treating composite coatings based on thermosetting polymers under cold curing conditions. In the conditions of hot curing, as well as in the processing of composite coatings based on thermoplastic materials, this presents a certain complexity due to the lack of universal equipment that allows simultaneous combination of technological processes of physical modification with the temperature-time mode of formation of coatings. Due to the large dimensions of the working bodies of technological machines, at the present time it is not possible to subject the checkpoints by known methods to their physical modification on the surface of the parts of

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the working bodies of machines.

In this regard, we are conducting studies to improve the properties of transaxlements by the heliotechnological method, that is, the formation of coatings carried out under the influence of solar radiation on a specially designed stand, providing a constant direction to the Sun [6-8].

A thermosetting polymer - ED – 20, cured with polyethylene polyamine (PEPA), was selected as a model binder, providing cold curing. Traditionally used DBP and secondary raw materials - gossypol resin (HS) in the amount of 10 and 10 wt. hours, respectively.

Currently, studies are conducted on available and cheap monomers, other raw materials for the production of anti-friction coatings. The use of available raw materials - gossypolovoy resin - allows to obtain polymers based on epoxy– and nitrogen-containing compounds. The gossypol resin molecule contains an aromatic core, which gives it a high thermal and chemical resistance. Phenolic, hydroxyl and aldehyde groups in the gossypol resin structure are responsible for their high reactivity, which makes it possible to obtain nanocomplex compounds with mechanically activated natural minerals [4–5].

III. THE RESULTS OF EXPERIMENTAL STUDIES AND THEIR DISCUSSION

The regularity of curing epoxy compositions of different composition, cured in the sun and in the shade. The experiments were carried out in August in the conditions of the year of Tashkent at an air temperature in the shade of 30 ± 2 and 42 ± 2 0C in open areas (Table 1). The intensity of natural solar radiation was 710-750 W / m2 [3].

Table 1:The degree of curing of epoxy compositions (in%), depending on the exposure time of solar

№	Epoxy Compositions	Coating formation conditions			
		In the shadow (t=25 minutes)	In the sun (t, minutes)		
			5	15	25
1	ED–20 – 100 mass part., PEPA –8 mass part DBP – 10 mass part (HS–10 mass part)	7,22 8,21	6,24 7,23	11,63 11,94	12,42 12,64
2	ED–20– 100 mass part PEPA – 10 mass part DBP – 10 mass part (HS–10 mass part)	17,4 19,0	16,3 18,2	23,5 24,7	26,5 27,7
3	ED–20 –100 mass part., PEPA – 12 mass part., DBP–10 mass part., (HS –10 mass part)	21,7 22,1	19,8 21,1	50,5 52,8	52,5 54,5
4	ED–20 – 100 mass part., PEPA –14 mass part., DBP – 10 mass part., (HS –10 mass part)	22,3 25,6	20,3 23,5	51,8 54,4	53,8 56,1
5	ED–20–100 mass part., PEPA – 16 mass part., DBP – 10 mass part., (HS –10 mass part)	23,1 26,4	21,1 23,9	53,6 55,6	54,7 58,4
Note: in the denominator for glossy floor resin					

As can be seen from the presented results, the curing reaction of epoxy and furanoepoxy compositions after their treatment for 5 minutes is accelerated 1.7–2.4 times, depending on the content of the hardener; A high degree of curing at 5-minute processing is achieved when the ambient temperature is 42 ° C and the composition contains 12 PEPA for ED. This is due to the following circumstances:

- when exposed to solar energy, the viscosity of the composition is significantly reduced compared with compositions in the shade;

–Reduction of viscosity contributes to an increase in fluidity, and, consequently, a more uniform distribution of the hardener molecules and orientation of their functional groups.

Further increase of the hardener to 20 wt.h. does not lead to significant changes in the degree of curing of the coatings.

In order to establish the optimal ratios of plasticizing components and modes of processing solar radiation, the effect of ambient temperature on the microhardness of polymer coatings was studied (Table 2). For these purposes, selected epoxy composition containing 12 wt.h. Pep. The processing time of solar radiation was 1,800–36,000 seconds. The results show (Table 2) that, due to the effective influence of solar energy, not only initiation of the curing reaction of the polymer network, accompanied by an intensive increase in the degree of crosslinking, but also improves the hardness of epoxy coatings as a result of improving the structure of the PMC. Moreover, the greater the flow of solar energy (processing time on the sun), the greater the microhardness of the coating of one of the same composition.

Table 2:The effect of solar processing time on the microhardness of coatings at different ratios of HS to DBP

Sun processing time τ, s	Microhardness of coatings Nm, MPa at ratios HS: DBP, in mass.				
	20:0	15:5	10:10	5:15	0:20
1800	82	78	74	65	61
3600	132	126	122	107	104
18000	151	150	149	132	126
36000	192	182	176	164	158

The above results led to the conclusion that the treatment of the polymer composition with solar radiation is an effective way to control the curing reaction, saving energy in the preparation of highly viscous epoxy compositions using HS 10:10 (parts by weight) with DBP.

In order to establish the optimal treatment regimes for solar radiation, the effect of ambient temperature on microhardness and impact strength of polymer coatings has been studied (Table 3). For these purposes, selected epoxy composition containing 12 wt.h. PEPA, the processing time of solar radiation was 5 minutes, the post-hardening of the coating was performed in the shade (the air temperature in the room was 30 ° C), the samples were tested 24 hours after the coating was applied.

As can be seen from the table. 3 results, due to the effective effect of solar energy, not only initiation of the curing reaction of the polymer network, accompanied by an intensive increase in the degree of crosslinking, but also improves the mechanical properties of epoxy coatings as a result of improving the polymer structure. Moreover, the greater the flow of solar energy (or the temperature of the medium, processing), the greater the microhardness and impact strength of the coating of the same composition.

The above results led to the conclusion that the treatment of the polymer composition by solar radiation is an effective way to control the curing reaction, to save energy in the preparation of highly viscous epoxy compositions using gossypol resin 50:50 DBP, which is important for practical implementation in industry for technological equipment and products operating under conditions of corrosion – hydroabrasive wear.

Table 3:The dependence of the properties of epoxy coatings formed by solar processing on the ambient temperature

Mechanical properties of coatings	30 °C	35°C	40 °C	45 °C	47 °C	50 °C
1. Microhardness, MPa	75,3 (67,2)	78,4 (70,3)	87,3 (79,2)	103,0 (95,1)	117,2 (105,8)	120,8 (109,7)
2. Shock resistance, Nm	17,5 (19,2)	21,3 (24,6)	28,4 (31,5)	28,0 (32,7)	25,0 (29,5)	25,4 (30,1)
3. The degree of crosslinking polymer mesh,%	93,4 (95,6)	94,8 (96,5)	94,9 (96,9)	97,6 (98,8)	98,2 (99,4)	97,3 (99,4)
Note: in brackets for plasticized coatings HS						

Next, to test the formation modes of polymer coatings by treating them with solar radiation, we studied the properties of epoxy coatings depending on the duration of treatment (Table 4). The composition contains 12 wt.h. PEPA, 10 wt.h. DBP and 10 wt.h. HS and it is not processed by solar radiation in the preparation of compositions. Control coatings were formed in the shade, the test was carried out after 24 hours.

Table 4:Dependence of properties of epoxy unfilled coatings depending on the duration of treatment with solar radiation

Coating properties	Processing time, minutes.				
	Control	100	200	300	400
1. Adhesive strength, kgf / sm (peeling)	2,21	2,28	2,45	2,50	2,37
2. Strength at break, MPa	120,3	120,0	135,8	130,7	125,5
3. Shock resistance, Nm	21,0	27,0	30,0	22,3	23,0
4. Microhardness, MPa	120,0	120,5	123,3	125,0	128,0

As can be seen from the table 4 experimental data, physical and mechanical properties of epoxy and furanoepoxy coatings increase depending on the duration of treatment with solar radiation.

In particular, with an increase in the processing time up to 300 minutes, the adhesion strength of epoxy coatings increases from 2.21 kgf / sm (control) to 2.50 kgf / cm, that is, it increases by 13% compared to the untreated one. The tensile strength is 12%, the impact strength is 47%, and the micro hardness of the coating increases slightly and tends to stabilize with increasing processing time.

The improvement of physical and mechanical properties is explained by the fact that during the direct processing of a polymer coating on the sun, that is, during a chemical crosslinking reaction with a curing agent, the polymer mass and the substrate heat up. Reducing the viscosity of the composition increases the mobility of the macromolecular chains of the polymer and improves the orientation of the functional groups of the interacting components.

In tables 5 and 6 presents the results of the study of the type and content of the filler - Angren kaolin on operational properties: microhardness and impact strength for tearing, with the same content of 50 wt.h. and after processing in the sun for 10 hours. It can be seen that nanocomposite coatings filled with Angren kaolin brand AKT – 10 have the best performance properties, and the worst performance indicators are observed in the composite coating filled with AKF – 78.

Table 5: Influence of the type and content of fillers (Angren kaolin) on the microhardness of nanocomposite epoxy coatings

Type of filler	Operational properties $\sigma_{a.s}$ (MPa) of coatings with filler content, in mass.					
	10	20	30	40	50	60
AKF–78	161	161	143	132	112	–
AKS–30	172	162	152	138	125	–
AKT–10	164	172	178	175	161	144
AKO	148	158	161	154	139	138
Note: processing time is 30 hours						

Table 6. Influence of the type and content of fillers (Angren kaolin) on the impact strength of nanocomposite epoxy coatings

Type of filler	Operational properties $\sigma_{a.s}$ (MPa) of coatings with filler contents, by weight.					
	10	20	30	40	50	60
AKF–78	18	19	23	23	19	-
AKS–30	20	21	24	23	22	-
AKT–10	22	26	32	28	28	20
AKO	19	22	27	25	24	16
Note: processing time is 30 hours						

As can be seen from the analysis of the results obtained, fillers having the same natural properties have a different effect on the properties of the coatings depending on the dispersion. It should be noted that the greater the amount of nanosized filler particles (AKF – 78), the higher the operational properties of coatings at low (10–20 parts by weight) filler contents, and at high economically advantageous contents (30–50 parts by weight) .) there is a deterioration in the properties of coatings with a high content of nanoscale particles.

This can be explained on the basis of technological properties, namely the deterioration of the wettability of filler particles, which is observed with a sharp increase in the viscosity of the composition. When the content of 60 wt.h. and more the quality of coatings is deteriorating.

From the analysis of the research results presented in Table. 7, it can be noted that for casting materials, the content of the filler is 60 wt.h. not yet the limit. Since the increase in the content of the filler material density increases, however, with different intensity.

For example, the smaller the number of nanoscale particles of fillers (AKF – 78, AKS – 30), the less intensively the density of the material increases. This indicates the formation of micropores in the composition due to the deterioration of structure formation, due to the large specific surface of the filler.

Table 7:Influence of the type and content of fillers from Angren kaolin on the density of nanocomposite potting materials

Type of filler	Density of casting materials, (γ, g / cm3)					
	10	20	30	40	50	60
AKF–78	1,16	1,22	1,35	1,39	1,49	1,55
AKS–30	1,18	1,26	1,43	1,47	1,58	1,61
AKT–10	1,21	1,31	1,48	1,55	1,68	1,76
AKO	1,19	1,29	1,46	1,51	1,63	1,71

IV. CONCLUSION

An analysis of the results of the conducted research allows us to conclude that heterocomposite polymeric materials and coatings from them formed by the solar technology method can be successfully applied in

the details of various technological machines. Targeted properties of these materials using mineral kaolin fillers can be obtained by various methods of mechanochemical modification.

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