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Antifriction and Deformation-Strength Properties of Epoxyurethane Polymer

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ABSTRACT: The tribotechnical indices of the epoxyurethane polymer are investigated. The values of the coefficient of sliding friction and Brinell hardness of samples of epoxyurethane polymeric materials were measured. The dependence of the sliding friction coefficient of an epoxyurethane polymer on the content of urethane oligomer in it was studied. The synthesis of oligomer which contains urethane groups is presented. The infrared spectrum of the epoxyurethane polymer is decoded. Thermomechanical indicators were determined. Comparative analyzes of indicators of epoxyurethane and epoxy polymer were made.

KEY WORDS: epoxyurethanes, oligourethanes, triboplasts, friction and antifriction polymers, coefficient of sliding friction, Brinell hardness, thermomechanics properties.

I.INTRODUCTION

One of the current areas of research in the field of mechanical engineering is the improvement of physical and mechanical properties, increasing the reliability of the materials from which machines and mechanisms are made for various industries. Not least important attention is required and the life of these machines. Epoxyurethane polymers are widely used as a binder for the production of high-strength composite materials used in various industries. Epoxyurethane polymers are characterized by a set of technical properties, among which, depending on the specific purpose of the polymer, there may be wear resistance, static and dynamic strength, chemical resistance, and increased deformation.

II. SIGNIFICANCE OF THE SYSTEM

The paper mainly focuses on how to synthase the oligomer containing urethane groups and preparation of epoxyurethane polymer based on epoxy resin and synthesized oligourethane OU-300. The study of the literature review is presented in section III, the methodology is explained in section IV, section V covers the experimental results of the study, and section VI discusses the future study and conclusion.

III. LITERATURE SURVEY

One of the important areas of science that studies the problems of corrosion under friction, the mechanisms of interaction of surfaces and the nature of friction, a consequence of the destruction of polymers or a lubricant under friction, is called tribology [1]. The emergence of new types of friction units, the ever-growing requirements for the operational characteristics of the parts of the mechanisms necessitate the development of new materials for tribotechnical purposes [2].

Undoubtedly, in modern mechanics, polymeric materials of different composition are demanded materials for units operating under friction conditions without a lubricant. Proper use of polymeric materials makes it possible to increase the life of machine parts, improve their performance and technical and economic indicators [2, 3]. The preparation of parts of mechanisms from polymeric materials is notable for easy performance, manufacturability, and also less labor and energy. The use of polymeric materials allows to reduce the cost of parts and allows you to abandon the scarce and, very often, insufficiently effective alloys of non-ferrous metals [2, 4].

All polymeric materials for tribotechnical purposes are divided into antifriction and friction, depending on their friction coefficient value. The great need for triboplasts shows that the creation of antifriction and friction polymers with wide

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ranges of predetermined deformation-strength and physicomechanical properties is still quite a lot of important task. The creation of such materials is possible only with a comprehensive study of the physics and chemistry of polymers and the processes of their friction and wear [3, 5].

IV. METHODOLOGY

Oligouretan OU-300 is synthesized by non-isocyanate method. The method eliminates the use of di - or polyisocyanates, which according to taxicometric parameters are evaluated by highly toxic substances. Work with isocyanates requires strict engineering controls and personal protective equipment [6]. Ethylene glycol, urea, sodium hydroxide solution with concentrations of 0.5N and formalin are used as starting materials for the preparation of an oligomer containing urethane groups. The reaction is carried out in a four-necked flask equipped with a dropping funnel, a thermometer, a stirrer and a reflux condenser.

Epoxy polymer is obtained by hot curing of epoxy resin with polyethylene polyamine [7]. To obtain an epoxyurethane polymer, the epoxy resin and the urethane oligomer are vigorously stirred until a homogeneous mass is formed and cured with polyethylenepolyamine. Table 1 shows the composition of the epoxy and epoxyurethane polymer.

Table 1. Composition of epoxy and epoxyurethane polymer.

Name	Raw materials		
	Oligouretan OU-300	epoxy resin ED-20	polyethylenepolyamine
	Mass fraction of raw materials,%		
Epoxy polymer	0	89	11
EU-10	10	85,7	4,3
EU-25	25	71,4	3,6
EU-40	40	57,0	3,0
EU-50	50	47,6	2,4
EU-60	60	38,1	1,9

EU-10 - epoxyurethane polymer. The mass fraction of OU-300 is 10% of the total mass of the polymer; EU-25 - epoxyurethane polymer. The mass fraction of OU-300 is 25% of the total mass of the polymer; EU-40 - epoxyurethane polymer. The mass fraction of OU-300 is 40% of the total mass of the polymer; EU-50 - epoxyurethane polymer. The mass fraction of OU-300 is 50% of the total mass of the polymer; EU-60 - epoxyurethane polymer. The mass fraction of OU-300 is 60% of the total mass of the polymer.

To study the tribotechnical characteristics of polymeric materials, a metal-plastic friction pair is considered expedient. Such pair of friction can be viewed as a set of hard metal microprotrusions embedded in the flat surface of a polymer body, on the grounds that the elastic modulus of plastics is hundreds of times smaller than that of a metal [8].

The magnitude of hardness, elasticity and plasticity of epoxy and epoxyurethane polymer according to Brinell has been established.

V. EXPERIMENTAL RESULTS

Figure 1 shows the IR spectrum of cured epoxyurethane. The IR spectrum contains absorption bands of stretching vibrations of the –CH3 bonds in the region of 2962.68–2870.08 cm^{-1} and the deformation vibrations of the dimethyl group of diphenylolpropane in the region of 1454.33–1382.96 cm^{-1}. The absorption bands in the region of 3319.49-3035.98 cm^{-1} explain the presence of the –CO-NH-group. The IR spectrum contains an absorption band in the region of 1506.41 cm^{-1}, corresponding to -NH-groups and absorption bands in the region of 879.54-827.46 cm^{-1}, corresponding

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to stretching vibrations of the C-N groups. The absorption band at 1737.86 cm^{-1} indicates the presence of a urethane group. Deformational vibrations of a vapor of a substituted aromatic ring can be seen on the absorption bands in the region of 827.46-763.81 cm^{-1}.

The results of IR spectroscopy show the absence of unreacted epoxy groups of ED-20 resin. This means that epoxy groups reacted not only with the amino groups of the hardener, but also with the amines of oligourethane OU-300, which are located on the edges of the oligomer.

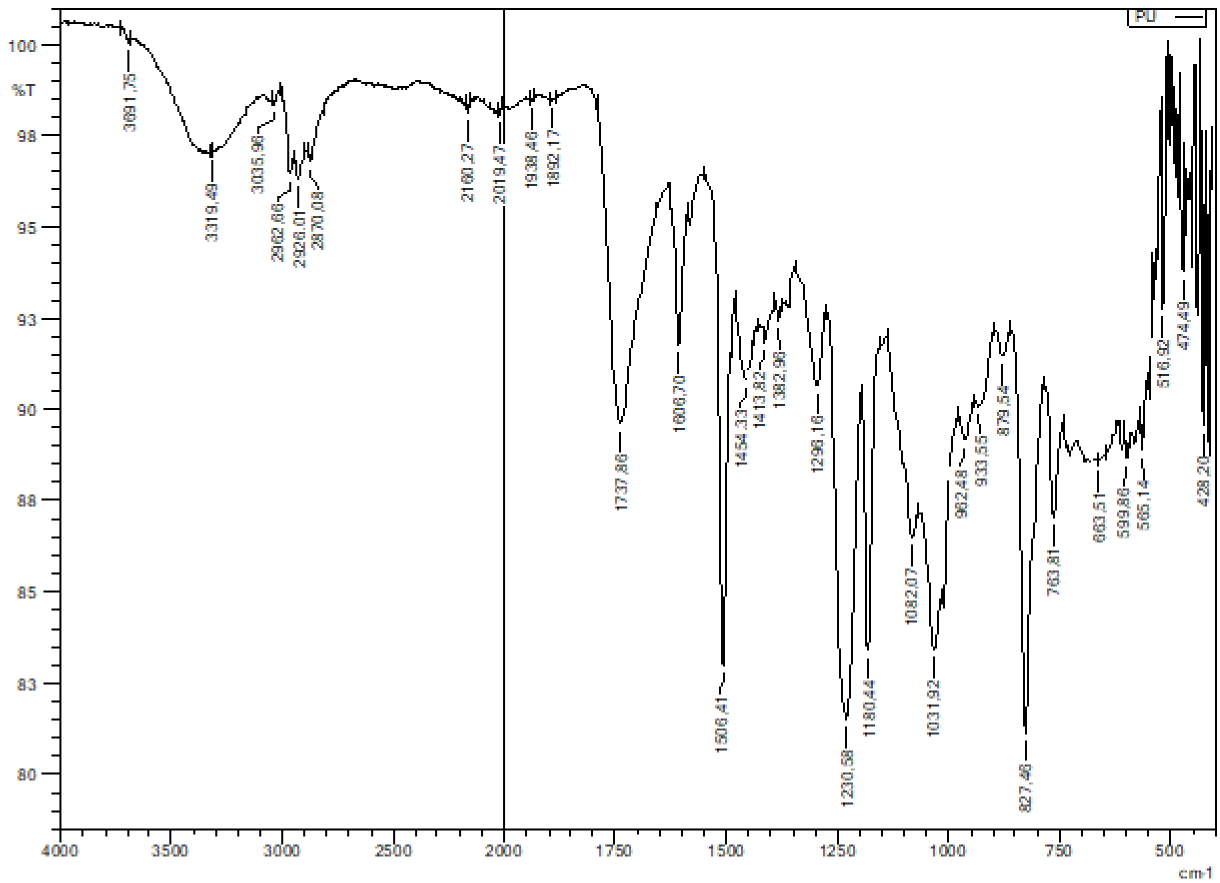

Fig 1. IR spectrum of cured epoxyurethane.

Table 2 shows the friction coefficients of epoxy and epoxyurethane polymer at various constant loads.

Table 2. The friction coefficients of epoxy and epoxyurethane polymer

Name	Constant load, P				
	20	30	50	70	100
	Slip friction coefficient				
Epoxy polymer	0,194	0,230	0,313	0,350	0,367
EU-10	0,192	0,212	0,281	0,342	0,354
EU-25	0,184	0,209	0,268	0,324	0,340

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EU-40	0,176	0,182	0,246	0,293	0,314
EU-50	0,172	0,171	0,241	0,276	0,302
EU-60	0,170	0,180	0,286	0,329	0,348

Figure 2 shows a diagram of the dependence of the friction coefficients of the samples of polymeric materials obtained from various constant loads. According to the diagram, it is possible to compare the friction coefficients of the obtained epoxyurethanes and epoxy polymer. An increase in the constant load leads to an increase in the friction coefficient of all samples. All epoxyurethane samples show a lower friction coefficient than epoxy polymer. With an increase in the mass fraction of OU-300 in the polymer up to 50%, a noticeable decrease in the friction coefficient occurs. But a further increase in the concentration of OU-300 leads to a decrease in the tribological and deformation-strength characteristics of the polymer material. The lowest coefficient of friction is for samples EU-50 and EU-40. The coefficient of friction of the EU-60 at low constant pressures is less than that of the other samples, but with increasing constant pressure, the sample deteriorates its physical and mechanical properties.

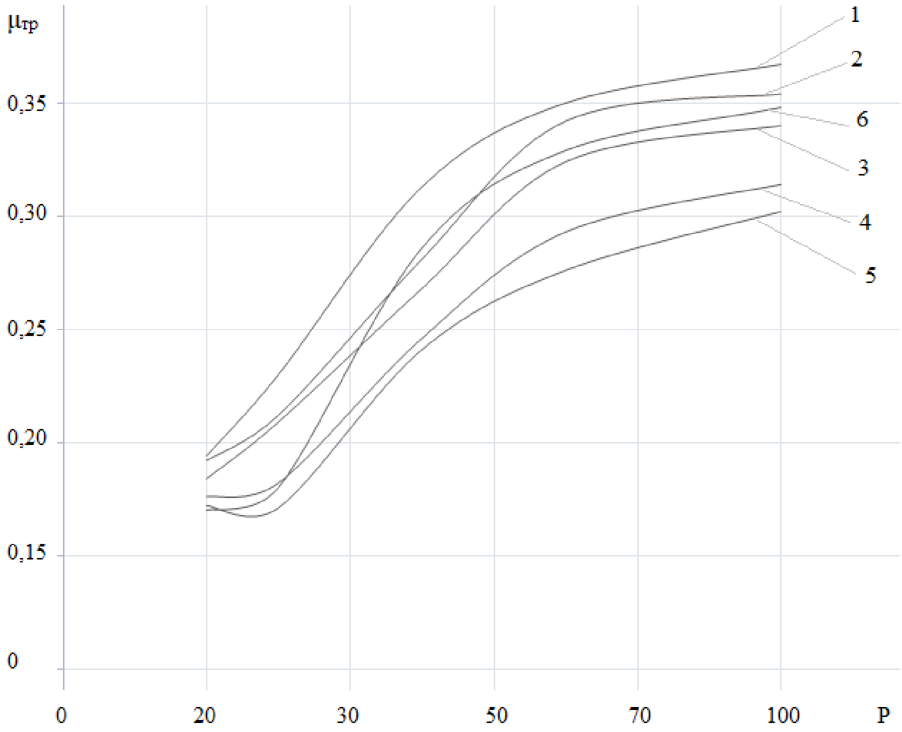

Figure 2. The dependence of the coefficient of sliding friction μ_{tp} epoxy and epoxyurethane polymer from the constant load P. 1 - epoxy polymer; 2 - EU-10; 3 - EU-25; 4 - EU-40; 5 - EU-50; 6 - EU-60.

A diagram of the dependence of the Brinell hardness of an epoxyurethane polymer on the mass fraction of OU-300 in it (Fig 3) has been compiled. The diagram shows that the hardness in all epoxyurethane polymer samples decreases with an increase in the mass fraction of oligourethane OU-300. There is a slight difference between the hardness indicators of epoxy polymer and EU-10. A sharp decrease in hardness is observed in the EU-60. The hardness of the EU-60 is almost two times less than the hardness of the epoxy polymer. Less significant reducing the hardness of the epoxyurethane polymer occurs with an increase in the mass fraction of EO-300 from 40% to 50%.

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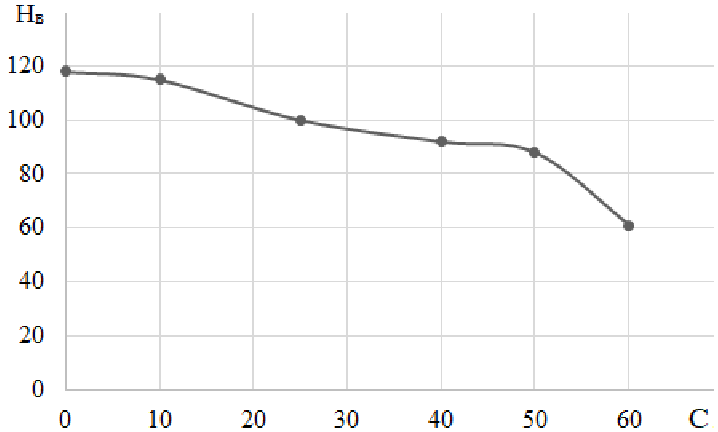

Fig 3. The dependence of Brinell hardness H_b (MPa) of epoxyurethane polymer on the mass fraction of OU-300 in it C (%).

To determine the elasticity and plasticity of epoxy and epoxyurethane polymer samples using the Brinell method, it is necessary to measure the indenter's insertion depth (h) at the set load and the insertion depth of the indenter (h_1) after removing the load. After removal of the load, the samples show elasticity by lifting the indenter. Below are the formulas for determining the elasticity E and plasticity P [9]. The results of the study are summarized in table 3.

$$E=\frac{h-h1}{h}100\ ,(\%) \qquad P=100-E,(\%)$$

Table 3. The elasticity and plasticity of epoxy and epoxyurethane polymer

Name	Elasticity, E (%)	Plasticity, P (%)
Epoxy polymer	89,28	10,72
ЭУ-10	89,02	10,98
ЭУ-25	88,24	11,76
ЭУ-40	87,96	12,04
ЭУ-50	87,94	12,06
ЭУ-60	84,91	15,09

According to the data from table 3, a decrease in the elasticity of epoxyurethane polymer samples is observed. The difference in elasticity between epoxy polymer and EU-50 is 1.34%. The magnitude of the elasticity of the sample EU-60 sharply reduced to 84.91%. The difference in the magnitude of elasticity between the EU-50 and EU-60 is 3.03%.

VI. CONCLUSION AND FUTURE WORK

Studies of the effect of oligourethane OU-300 on the coefficient of friction of an epoxy-polymeric polymer material have shown that with an increase in the constant load, the coefficient of friction in epoxy and epoxy-urethane polymer samples increases. Good antifriction properties showed a sample of epoxyurethane polymer EU-50, containing 50% of OU-300. A low coefficient of friction is also observed for the epoxyurethane polymer EU-60 with 60% of mass fraction of OU-300, but only at low constant loads. At high permanent loads, the sample of the EU-60 is experiencing a deterioration of the physic-mechanical and antifriction properties. The hardness of epoxyurethane samples decreases with an increase in the mass fraction of oligourethane OU-300. A noticeable decrease is found in sample EU-60.

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Further work involves the development of processing technology of the new polymeric materials to obtain details used in friction units.

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