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PROBLEMS OF RESTORING THE BEDS OF MAIN BEARINGS AND STUDYING THE DEFORMATION-STRENGTH PROPERTIES OF POLYURETHANE ADHESIVES

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Abstract: the article deals with the problems of increasing the durability of main bearings and methods of restoration using polymeric materials. Deformation-strength properties (specific work, breaking stress and relative elongation) at rupture of a polyurethane adhesive were studied depending on the ratio of components, test temperature, curing temperature and curing time

Keywords: increasing the durability of fixed joints, main bearings, deformation and strength properties, polymeric materials, specific work, breaking stress, relative elongation, polyurethane adhesive, test temperature, curing temperature, curing time

Introduction: The need to restore the beds of the main bearings of the engine cylinder block, increase the durability of the fixed joints of the plain bearings and reduce the cost of maintaining them in working condition has led to the development of a significant number of methods for restoring the fixed joints. Promising ways to restore the beds of the main bearings of the cylinder block are methods of restoration using polymeric materials [1, 2, 3].
Polymeric materials make it possible to reduce the labor intensity of machine repair by 20–30% and the cost by 15–20%, while reducing the consumption of metals by 40–50% [3]. In repair enterprises, epoxy resins ED-16 and ED-20, as well as powder epoxy compositions PEP-177 and PEP-534 are used to restore the beds of main bearings of cylinder blocks. However, the use of epoxy compositions based on ED-16 and ED-20 resins in the restoration of beds of indigenous beds is associated with certain technological difficulties. Liquid epoxy compositions have insufficient viability. After preparing the composition, it is necessary to use it within 20 ... 25 minutes. At operating temperatures of engine bearing assemblies, epoxy compositions have low elasticity, which reduces the durability of restored fixed joints. Epoxy compounds are toxic, therefore, all operations for their preparation and use must be performed in special rooms with enhanced ventilation. To restore the beds of main bearings with powder compositions PEP-177 and PEP-534, their preliminary boring, heating of the block, the presence of an apparatus for electrostatic charging of polymeric material and mechanical processing after coating are required. The listed technological difficulties and the lack of the necessary equipment at repair enterprises hinder the widespread use of this method for restoring the main bearings of engine cylinder blocks.
Methods: In recent years, the country's chemical industry has mastered the production of polyurethane adhesives, which are two-component formulations. The components are easy to mix and do not contain highly toxic substances. They have good vibration, oil, petrol resistance, resistance to low temperatures and thermal shocks; differs in good adhesion to various substrates. The polyurethane adhesive can be cured at temperatures ranging from minus 10 to plus 120°C. However, at present, there are no scientifically based recommendations on the use of these materials, which hinders their widespread use in the repair industry [1].
The deformation-strength properties of the polyurethane adhesive Vilad-11 were studied on films with a thickness of 90–150 µm. Films were molded on fluoroplastic plates. The plate was set at an angle of 45° and watered with an adhesive solution, and then kept in air for 15–20 min at a temperature of 20°C. Three to five layers were applied in this way. Curing was carried out at temperatures of 20°C for 7 days and at 100°C for 3 hours, and then the films were separated from the fluoroplastic plates. Samples were cut from the films in the form of rectangular strips 35 mm long and 5 mm wide. The physicomechanical properties of the films at different test temperatures were determined according to the method of the Institute of Physical Chemistry [4]. Breaking stresses and relative elongations were studied on a laboratory vertical tensile testing machine equipped with a thermal cryochamber. Heating was carried out by an electric coil, and cooling was carried out with liquid nitrogen. The test was carried out in the temperature range from 40 to 100°C. The temperature was controlled by a chromel-copel thermocouple in the immediate vicinity of the test sample and maintained in a given mode with an accuracy of ±2°C. Tests at elevated and low temperatures were carried out after thermostating the samples for 15 m
Results: The results of studies of the deformation-strength properties of the polyurethane adhesive Vilad-11 show that they largely depend on the ratio of components A and B.

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The influence of the ratio of components on the breaking stress, relative elongation and specific work at break of the polyurethane adhesive Vilad-11 is shown in Fig.1.

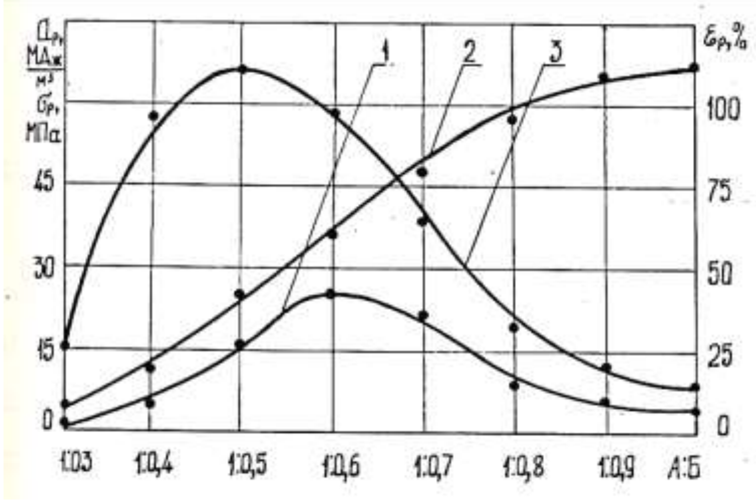

Fig.1. Dependences of the specific work at break αp (1), breaking stress (2) and relative elongation (3) on the ratio of components A and B of the polyurethane adhesive Vilad-11

The strength of the polyurethane adhesive, depending on the ratio of components, varies over a wide range of values. Thus, the breaking stress at a ratio of components of 1:0.3 is 3.0 MPa. With an increase in component B to 0.8, the strength increases sharply. A further increase in components B leads to a decrease in the rate of strength increase. With a ratio of components of 1:1, the strength reaches a maximum value of 68.7 MPa. Relative elongation with an increase in component B from 0.3 to 0.5 increases sharply and reaches a maximum value of 111.7%. A further increase in component B leads to a sharp decrease in relative elongation at a ratio of components of 1:1 relative elongation compared with the maximum decreases by 8.9 times.

Films with a component ratio of 1:0.6 have the maximum specific work at break, equal to 26.8 MJ/m3. With an increase or decrease in component B, a decrease in specific work is observed. With a ratio of components of 1:1, the specific work at break is reduced by 6.8 times, and with a ratio of components of 1:0.3, by 17 times. The density of the spatial network of the polymer, which is determined by the molecular weight and the ratio of components, has a significant effect on the strength and relative elongation of the films [5].

Increasing the degree of crosslinking by reducing the molecular weight of the hydroxide-containing oligomer generally results in an increase in strength and a decrease in tensile elongation. The properties of polyurethanes largely depend on the ratio of isocyanate hydroxide-containing groups in the initial compositions. With an increase in the proportion of the trifunctional isocyanate component, the concentration of urethane and urea, allophanate, and biurethane bonds changes, which leads to changes in the polymer structure [6

Thus, the physical and mechanical properties of polyurethane adhesives are determined mainly by the ratio of the initial components and the presence of chemical and physical bonds in the system.

The conditions for the formation of polyurethane coatings, in particular the temperature regime of curing, have a significant impact on their physical and mechanical properties. The deformation and strength properties of polyurethane adhesives cured at room temperature are inferior to those of polyurethane adhesives cured at elevated temperatures. This is due to the peculiarities of the formation of a polyurethane network at low temperatures, the presence of a significant amount of extractable substances in the polymer, the defectiveness of the physical structure, and insufficient removal of the solvent from the system [7].

The optimal heat treatment mode, in which the specific work at break reaches its maximum value, was determined by optimizing this parameter using the theory of planning a multifactorial experiment according to the optimal composition plan of type B2.

As a result of experimental data processing, a mathematical model of the dependence of the specific work at break on the heat treatment parameters was obtained, which adequately describes the optimum region.

The mathematical model has the form of a second-order polynomial:

Y \u003d 29.578-0.888X1-5.595X2-4.6776X1X2-2.7275X12-7.9075X22, (1)

where X1 is the heat treatment time;

X2 - heat treatment temperature.

The result of studies of the deformation-strength properties of films obtained from the polyurethane adhesive Vilad-11 shows that they largely depend on the heat treatment mode. The influence of the heat treatment mode on the specific work at break is shown in Fig.2.

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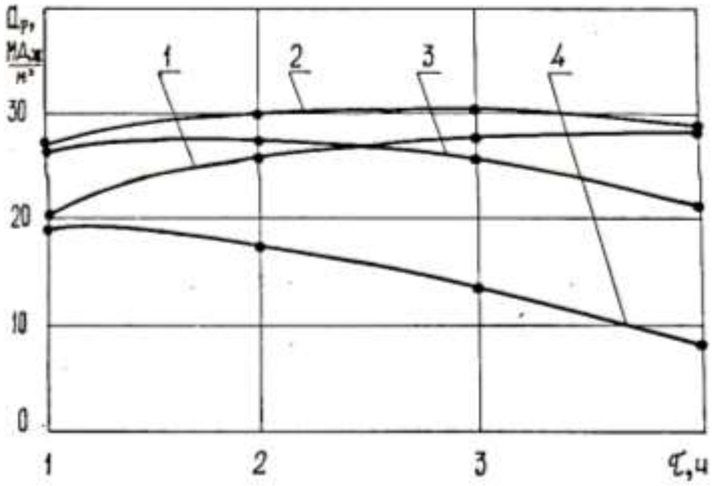

Fig.2. Dependences of the specific work at break αp on the time of heat treatment of the polyurethane adhesive Vilad-11 at different temperatures T: 1,2,3,4, respectively, at a heat treatment temperature of 60, 80, 100 and 1200C.

The maximum values of specific work 30, MJ/m3 have films heat-treated at 800C for 3 hours. The breaking stress in this case reaches 48.2 MPa, and the relative elongation is 98.4% (Fig. 3).

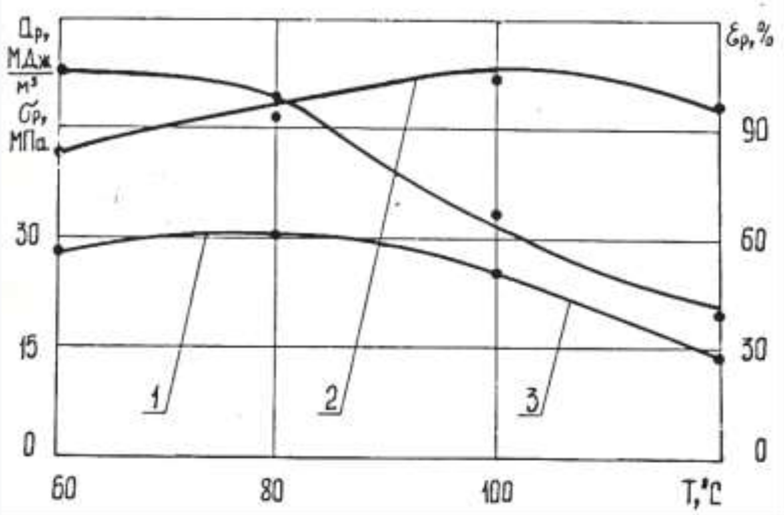

Fig.3. Dependences of the specific work at break αp (1), breaking stress (2) and relative elongation (3) on the heat treatment temperature of the polyurethane adhesive Vilad-11 for 3 hours.

The maximum strength reaches 52.3 MPa at a heat treatment temperature of 1000C, which is 1.5 times higher than the strength of films heat-treated at 600C (Fig. 3). Increasing the curing temperature to 1200C also leads to a decrease in strength. With an increase in the heat treatment temperature to 1200C for 3 hours, the specific work decreases to 14.0 MJ/m3 and within 4 hours to 8.1 MJ/m3.

The maximum relative elongation at break of 105% have films cured at 600C. With an increase in the heat treatment temperature, the relative elongations decrease and at a temperature of 1000C they amount to 66% (Fig. 3).

The response surface of the specific work on the heat treatment temperature is shown in Fig.4. After the canonical transformation of the model, a two-dimensional section of the response surface is constructed, which is shown in Fig.5.

The regression equation in canonical form is:

Y \u003d 30.6394-4.2047X12-6.4303X22. (2)

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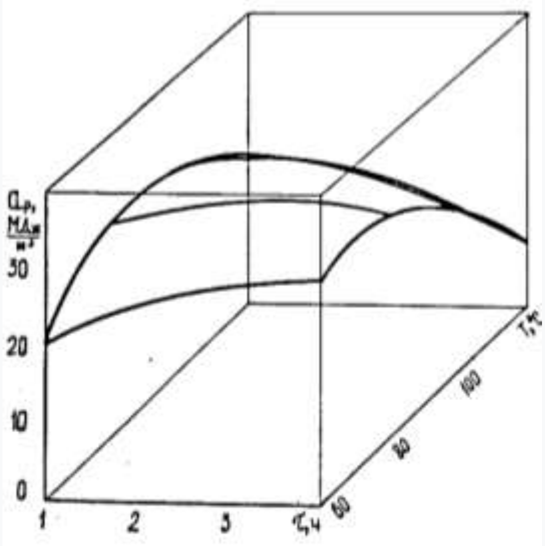

Fig.4. Dependence of specific work at break αp of Vilad-11 polyurethane adhesive on temperature T and heat treatment time

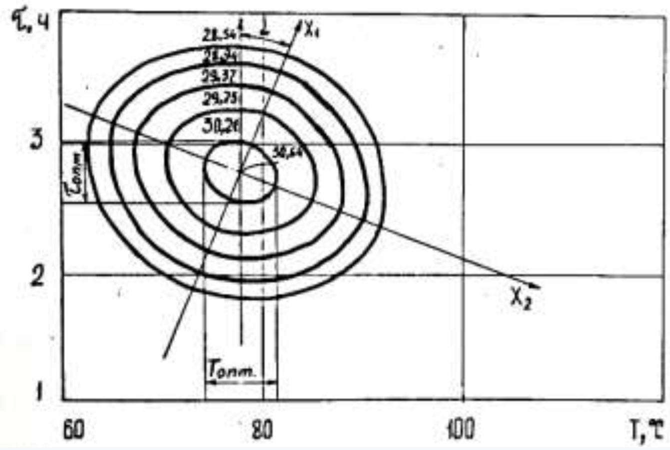

Fig. 5. Two-dimensional section of the response surface characterizing the specific work at break of heat-treated films of the polyurethane adhesive Vilad-11: Topt and τopt are the ranges of optimal values, respectively, of the temperature and time of heat treatment of the polyurethane adhesive

Based on its analysis, the area of the optimum of the optimization criterion was determined and the optimal mode of heat treatment of the polyurethane adhesive was selected: the heat treatment temperature was 800C and the heat treatment time was 3 hours.

The curing temperature regime has a significant effect on all deformation-strength properties of coatings. The nature of the dependence of the breaking stress and relative elongation on the curing temperature of the polyurethane adhesive Vilad-11 is due to the peculiarities of its structure and the ability to react structuring at elevated temperatures. Polyurethane adhesive heat-treated at temperatures below 100°C deforms significantly due to the unfolding of rolled long high molecular weight molecules. In this case, the total deformation consists of elastic, highly elastic deformation and flow deformation. Strength in this case is provided by a relatively weak intermolecular interaction. At curing temperatures above 1000C, cross chemical bonds are formed between the polymer molecules. Increasing the curing temperature to 200C leads to a decrease in the strength properties of the films due to the destruction of biurethane and alofanate bonds.

On fig. Figure 6 shows the dependence of the specific work at break, breaking stress and relative elongation of the Type-11 polyurethane adhesive, cured at a temperature of 200C for 36 hours, on the test temperature. Films have the greatest strength of 87.5-81.3 MPa in the temperature range of minus 40 - minus 200C. With an increase in the test temperature to 400C, the strength decreases sharply. With a further increase in temperature, the rate of strength decrease decreases. At 1000C, the strength of the films, compared with the maximum, decreases by 14.5 times.

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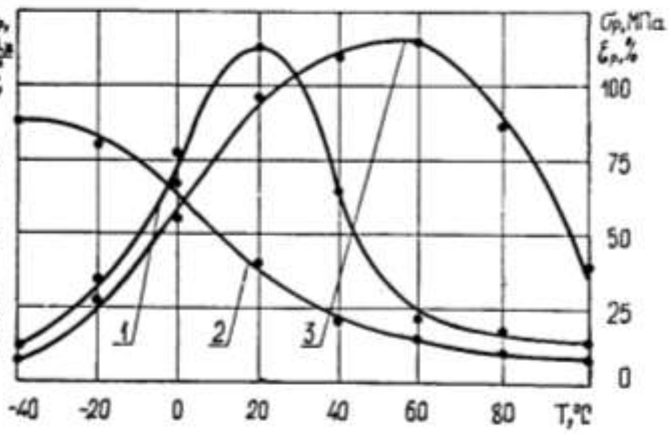

Fig.6. Dependences of the specific work at break αp (1), breaking stress (2) and relative elongation (3) on the test temperature of the polyurethane adhesive Vilad-11, cured at a temperature of 200C for 36 hours.

The relative elongation of the polyurethane adhesive Vilad-11 increases with an increase in the test temperature to 600C and reaches a maximum value of 113.7%. Further increase in temperature to 1000C elongation is reduced by 3 times.

Vilad-11 polyurethane adhesive has the maximum specific work at break equal to 26.8 MJ/m3 at a test temperature of 200C. With an increase in temperature to 1000C, it decreases by 8.9 times.

Figure 7 shows the dependences of the specific work, breaking stress and relative elongation at break of the polyurethane adhesive Vilad-11, heat-treated at a temperature of 800C for 3 hours, on the test temperature. The film has a maximum strength of 82.6 MPa at a test temperature of minus 400C. A sharp decrease in strength is observed in the temperature range of minus 20 - +400C. With a further increase in the test temperature, the rate of strength decrease decreases. At 1000C, it decreases by a factor of 6.6 compared to the maximum.

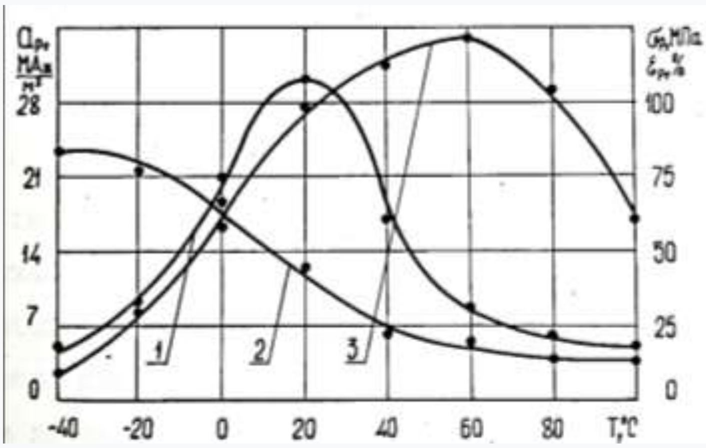

Fig.7. Dependences of the specific work at break αp (1), breaking stress (2) and relative elongation (3) on the test temperature of the polyurethane adhesive Vilad-11, cured at a temperature of 800C for 3 hours.

Discussion: With an increase in the test temperature from minus 40 to plus 600C, the relative elongation of the polyurethane adhesive Vilad-11 increases sharply and reaches 122.5%. At a temperature of 1000C, they decrease by 2.4 times.

With an increase in the test temperature to 200C, the specific work at break increases and reaches 29.8 MJ/m3, a further increase in temperature leads to a decrease in the specific work at break. At a test temperature of 1000C, the specific work is reduced by 5.7 times compared to the maximum.

The relatively low strength of the polyurethane adhesive cured at a temperature of 200C is explained by the fact that this adhesive has a low reactivity of the polyisocyanate during structuring. At a temperature of 200C, not all

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functional groups are involved in the formation of the network. Cured at elevated temperatures leads to an increase in the density of the adhesive network based on complex and silicon-containing oligoesters. An increase in the density of the adhesive network causes a monotonous increase in the hardness and strength of the coatings, while the relative elongation decreases [9].

The rate of increase in breaking stresses in tension with increasing temperature (Figs. 6 and 7) is the greater, the greater the tendency of oligoether chains to intermolecular interaction and the lower their kinematic mobility. In the temperature range of 40-500C, there is a change in strength properties with conformational transitions due to the breakdown of physical (hydrogen) bonds, and a characteristic increase in the mobility of hydrocarbon chains is observed.

The nature of the dependence of relative elongations on the test temperature is determined by intermolecular interaction. At a temperature close to the glass transition temperature, the development of highly elastic deformation is hampered by the existence of strong intermolecular bonds. With an increase in temperature, intermolecular bonds weaken [9].

Conclusions. Thus, the deformation-strength properties of polyurethane adhesives are determined mainly by the ratio of the initial components and the presence of chemical and physical bonds in the system

The deformation-strength properties of Vilad-11 polyurethane adhesives depend on the ratio of components and the heat treatment mode. They have maximum breaking stresses at break at a ratio of components A and B of 1:1, relative elongations at 1:0.5 (Vilad-11) and maximum specific work at break at 1:0.6. With an increase in the heat treatment temperature to 1000C, their strength increases, and relative elongations decrease.

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