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Effect of Fluid Media on Abrasive Polymeric Composite Products with Various Elasticity

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Abstract. The fluid media influence studies established that only water substantially affects epoxy-based rigid composites; the effect of kerosene and oil on products modified with acetur and, particularly, polyethylsiloxane is insignificant. Besides, bending strength and hardness change approximately in proportion to the level of saturation. As for elastic composites, the level of saturation depends on the fluid type and laprolate rubber component in the bond; the water effect is substantially higher as compared to other fluids. The more laprolate, the higher the effect of fluids is. Due to low viscosity, water enters pores easily, dissolves unpolymerized material areas, breaks adhesive bond, and deteriorates composite quality. Thus it is necessary to foresee use of fluid media according to the particular parameters of the composites and fluids, as well as service life.

1 Introduction

Some industrial composite products, including tools, are made of abrasive polymeric mixtures. Such products are operated with various fluid media, among them are different operating, lubricating-cooling, and other fluids [1, 2]. It is common knowledge that the polymers contained in composites are subject to fluid saturation, which changes their properties. Besides, the structure of such compound materials features openings and pores due to the interface between the polymer and abrasive filler [3, 4].

For this reason, the degree of impact of various fluids on the variation of the physical and mechanical properties of the abrasive polymeric composite material with various elasticity (rigid and elastic) was studied.

2 Study methodology

The study comprised two sets of composites with different elasticity degrees. Rigid composites were studied, using samples of abrasive epoxy composites made according to various formulations: non-modified, modified with polyacetalurethane rubber (acetur) or silicone fluid polyethylsiloxane with elasticity modulus E_0 = 1800–3000 MPa. Composites

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include nearly 50–60 % of abrasive fillers; the rest is polymer base. In addition to epoxy resin and modifiers, it comprised the curing agent polyethylenepolyamine up to 12 % of the resin weight [5, 6]. Elastic composites — for hydroxyurethane-bond samples of abrasive polymeric composites, with elasticity modulus E_0 = 100, 500, 1000 MPa [5]. These values correspond approximately to 70, 60, and 50 % content of the rubber urethane component laprolate [7] in the bond against epoxy resin. The content of abrasives is around 50–60 % as well. Chemical nature of such composites consists in using epoxy resin and a urethane rubber polymer with joint curing by polyethylenepolyamine [8].

Kerosene, oil Industrialnoe 20, OSM-1, and water were used as fluid media. The material samples in the form of blocks were held in those fluids up to 150 days. The relative variation (Δ) of the material mass indicating the degree of material saturation with the fluid was determined by weighing on analytical balance VLA-200g-M accurate within 0.0001 g at specific time intervals and comparing the obtained data with those initial. Test repeatability n = 10, the result of each replicate test is the average value of three measurements.

Relative variations of the main physical and mechanical parameters were also determined: bending strength and specific impact viscosity ($\Delta\sigma, \Delta a_n$), hardness (Δh) and elasticity modulus (ΔE_0) [5, 9–10]. The following general formula was used to calculate the variation values:

$$\varepsilon = \left[\left(P_2 - P_1\right)/P_1\right]\cdot 100\% \tag{1}$$

wherein P_1 and P_2 are the parameter values before and after holding in fluids.

3 Study results

The obtained correlations (Fig. 1) make it clear that the mass of all composite samples increased after holding in fluids. The saturation intensity was obtained for the impact of water, kerosene, OSM-1, and oil Industrialnoe 20 (in the order of decreasing) on the material. The viscosity values of the fluids feature, as is well known, nearly the same order of increasing.

Introduction of modifiers into the test material significantly decreased its saturation with the fluids. It is first of all caused by increased structural density and hardness of the modified material. The composite modified with polyethylsiloxane features the highest saturation resistivity (the value of Δ is more than 2 times as low as that of the initial composite). It apparently results from certain excess of this polymer in the cured material that serves as a liquid filling lubricant filling all the pores and looseness and restricting fluid penetration inside the structure.

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The correlation between the fluid saturation and relative variation of the compound physical and mechanical properties (ε) was studied, using formula (1). The selected holding time of 30 days is related to the approximate maximum service life of gear hones, 90 — to reaching full saturation. The results are given in Table 1. The 'minus' sign of the obtained values of $\Delta\sigma$ and the 'plus' sign of Δh means decreased bending strength and hardness of the material, correspondingly.

No significant influence of fluid media on the elasticity modulus variation of the tested compounds was discovered. Saturation with fluids did not result in decrease of the material's specific impact viscosity; on the contrary, it even increased slightly (by 2.5–12.0 %). It is presumably caused by the increased plasticity of the sample surface layers. The fluids, especially water, adversely affected the material's bending strength and hardness (Fig. 2); the decrease of these parameters was approximately proportional to the degree of saturation (Δ) [5].

This can be explained both by the decreased strength of the polymer bond and its disbonding from the abrasive material's grain surface within the sample layer saturated with the fluid. Thus, water influence on the non-modified material of the gear-hones decreased the values of $\Delta\sigma$ and Δh by 33 % and 40 %, correspondingly, during 90 days. Decrease of such parameters of the acetur-modified compound is 1.5–1.8 times as low as that of the non-modified compound; as for polyethylsiloxane-modified compounds, it is 2.5–3.3 times as low.

Influence of water and oil on the elastic hydroxyurethane-bond compound material with elasticity modulus E_0 = 100, 500, 1000 MPa (70, 60, and 50 % laprolate content in the bond) was studied. Correlation between the fluid saturation degree of the samples and the holding time is shown in Fig. 3.

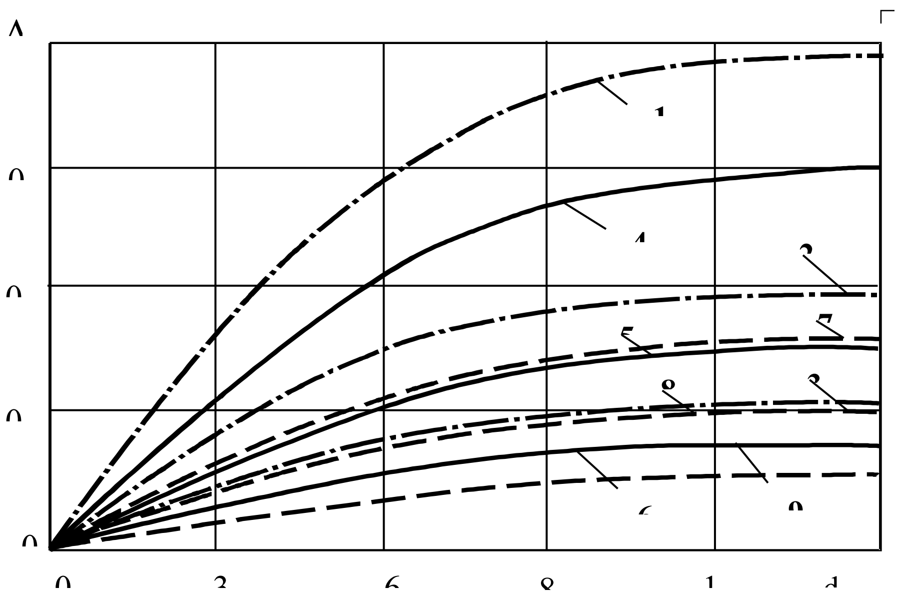

Fig. 1. Saturation degree Δ of non-modified abrasive epoxy compound samples (1, 2, 3) and those modified with acetur (4, 5, 6) and polyethylsiloxane (7, 8, 9) in oil Industrialnoe 20 (3, 6, 9), kerosene, oil OSM-1 (2, 5, 8), water (1, 4, 7) vs. holding time (days).

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Table 1. Influence of fluid saturation on physical and mechanical parameters of compound materials with various modifiers.

Modifier type	**Medium type**	**Holding time, days**	**Variation of physical and mechanical parameters**			
			Δ, %	$\Delta\sigma$, %	Δa_n	Δh, %
1	2	3	4	5	6	7
Acetur	Kerosene	30	0.15	-5.0	7.5	9.0
		90	0.28	-10.0	9.0	16.0
	Oil Industrialnoe 20	30	0.08	-3.0	4.0	5.5
		90	0.15	-5.0	7.0	9.0
	OSM-1	30	0.14	-5.0	7.5	8.5
		90	0.25	-8.5	8.5	15.0
	Water	30	0.28	-9.0	10.0	15.5
		90	0.55	-18.0	12.0	28.0
Polyethylsil oxane	Kerosene	30	0.11	-3.5	5.0	6.0
		90	0.20	-6.0	7.5	10.5
	Oil Industrialnoe 20	30	0.5	-2.0	2.5	4.0
		90	0.10	-3.0	4.5	6.0
	OSM-1	30	0.11	-3.5	5.0	6.0
		90	0.20	-6.0	8.0	10.5
	Water	30	0.15	-5.0	7.5	9.0
		90	0.35	-10.0	9.5	16.0
Without modifiers	Kerosene	30	0.21	-7.0	8.0	11.0
		90	0.35	-11.0	11.0	19.0
	Oil Industrialnoe 20	30	0.11	-3.5	5.0	6.0
		90	0.20	-6.0	7.5	10.5
	OSM-1	30	0.21	-7.5	8.0	11.0
		90	0.35	-10.5	11.0	19.0
	Water	30	0.37	-12.5	11.0	20.0
		90	0.75	-33.0	12.0	40.0

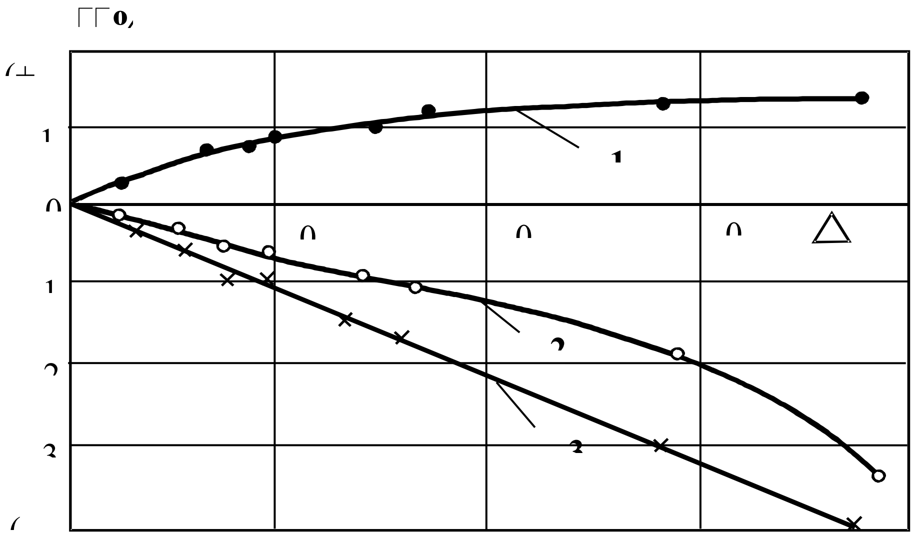

Fig. 2. Relative variation value ε of specific impact viscosity Δa_n (1), bending strength $\Delta\sigma$ (2), and hardness Δh (3) of the abrasive epoxy compound samples after holding in fluids vs. saturation degree Δ

Saturation intensity decreases as the holding time increases, the saturation degree depends on the fluid type and laprolate amount in the bond. Water had the maximum impact on this material — the saturation degree is an order of magnitude higher as compared to other media. The influence-degree order of the fluids is as follows: water, oil, OSM-1 and kerosene, oil Industrialnoe 20. In case of static tests, saturation with the last three fluids is insignificant even within 150 days — less than 0.1–0.5 %. The less laprolate in the bond, the lower the saturation degree.

Variation of physical and mechanical parameters of elastic materials ($\Delta\sigma, \Delta a_n$ Δh, E_0) saturated with water and oil OSM-1 was determined for a period of 30 days (the maximum approximate service life).

Higher laprolate content in the bond resulted in more intensive decrease of all the material parameters affected by fluids (Fig. 4).

The value of specific impact viscosity Δa_n featured the least variation, which can be attributed to certain compensation of the fluids influence due to increased plasticity and resistance to impact loads in the material surface layers. Whilst the influence of OSM-1 within the range of the material's E_0 values was not critical ($\varepsilon < 18$ %), the water impact resulted in significant decrease of the hydroxyurethane-bond material properties: at E_0 = 100 MPa, the value of ε for σ, h, and E_0 reaches 75–95 %.

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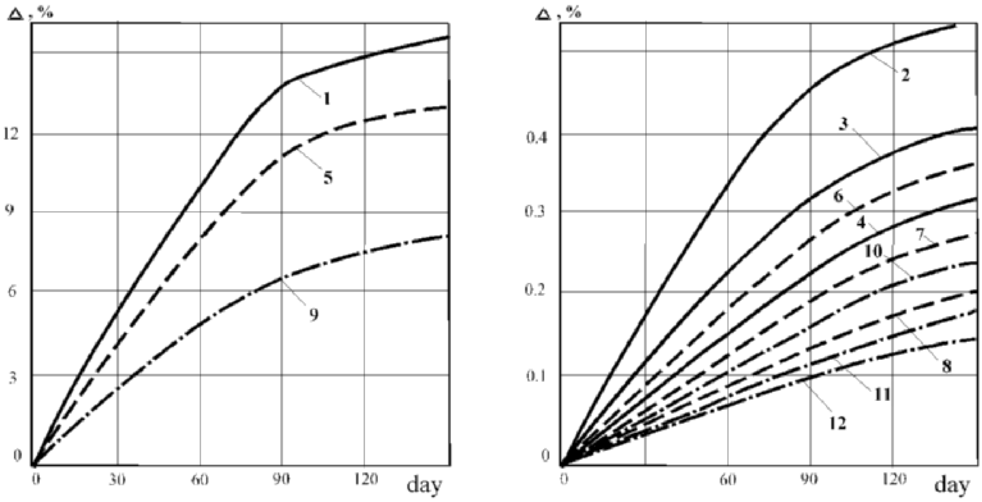
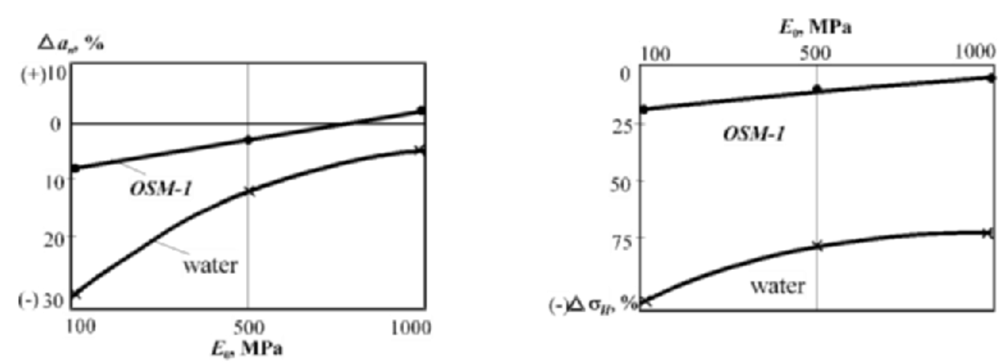


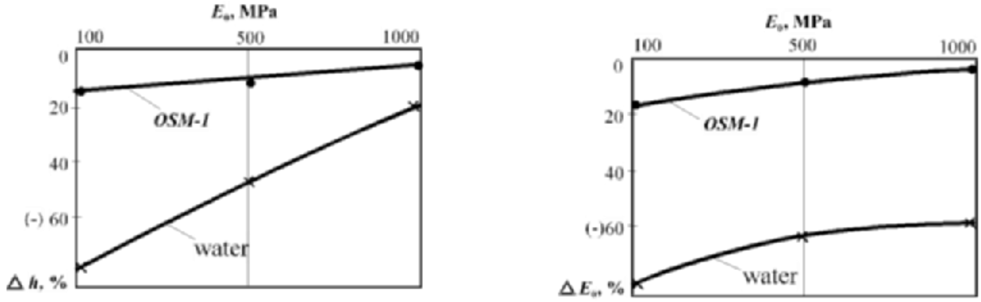
a *b*

Fig. 3. Saturation degree Δ of elastic hydroxyurethane-bond compound samples at laprolate amount in bond of 70 % (1–4), 60 % (5–8), 50 % (9–12), in oil Industrialnoe 20 (4, 8, 12), kerosene (3, 7, 11), oil OSM-1 (2, 6, 10), and water (1, 5, 9) vs. holding time

Water features low viscosity, penetrates pores easily, dissolves and washes away unpolymerized material areas, has a wedging effect, breaks adhesive bonds with abrasive grains. Saturation with water causes material volume increase, promotes formation of subsurface locations and cracks. As a result, rigidity and strength of the elastic material structure decrease substantially. Such material condition makes products unfit for operation.



a *b*



c *d*

Fig. 4. Variation of parameters Δa_n (*a*), $\Delta\sigma$ (*b*), Δh (*c*), and ΔE_0 (d) of hydroxyurethane-bond compound samples after holding in OSM-1 and water vs. initial values of material elasticity modulus E_0 .

4 Conclusion

In general, the studies demonstrated that only water significantly affects rigid composites in practice; the influence of kerosene and oil during the service life of products made of acetur-modified, and particularly hydroxyurethane-modified, materials is insignificant. It is primarily attributed to the fluid viscosity level and degree of penetration to composite pores. Bending strength and hardness change nearly in proportion to the saturation degree. Introduction of modifiers into the hard material being tested significantly decreased its saturation with the fluids.

As for elastic composites, intensity of saturation with fluids decreases as the holding time increases; the saturation degree depends on the fluid type and laprolate amount in the bond; the water saturation degree is an order of magnitude higher as compared to other media. Due to low viscosity, water enters pores easily, dissolves unpolymerized material areas, breaks the adhesion bonds in composites, and increase the composite volume and cracks. As a result, rigidity and strength of the elastic material structure decrease substantially.

Therefore, the established influence of fluids on abrasive polymeric composites and corresponding decrease of certain parameters should be considered for use of such composites, as well as the peculiar parameters of composites and fluids and service life.

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