

## FIBER COMPOSITE MATERIALS

### EFFECT OF POLYACRYLONITRILE FIBERS MODIFIED BY VARIOUS CHEMICAL FINISHES ON THE HARDENING KINETICS AND PROPERTIES OF AN EPOXIDE COMPOSITE BASED ON THEM

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*The effect of treatment with various chemical modifiers on the physicochemical properties of polyacrylonitrile (PAN) fibers was studied. The structures of the finished reinforcing systems were analyzed. The hardening kinetics of an epoxide binder in the presence of the modified fibrous systems were studied. It was found that modification of PAN filament improved the mechanical properties of epoxide composites based on it.*

Modification of reinforcing fillers that improves the boundary adhesion of a fibrous system to a polymer matrix is given special attention when designing polymer-matrix composites based on chemical fibers. Such modification strengthens and optimizes the mechanical and other functional properties of the composites, which enables their areas of application to be expanded [1, 2].

The goal of the present work was to study the effect of polyacrylonitrile (PAN) fibers treated with various chemical modifiers on the hardening kinetics and properties of epoxide composites based on them.

The modifiers were a mixture of fatty acid glycol esters (Dyron OS 3151) and 3-aminopropyltriethoxysilane (AGM-9). PAN technical filament (PAN-TF) was modified by finishing additives at solution concentrations of 2, 5, and 10% and treatment time 60 s. Modified fibers were dried in two steps at 50°C in the first and 100°C in the second.

The effect of the conditions for treating PAN-TF with the modifiers on its physicochemical properties showed that its strength characteristics improved by 40 and 49% as a result of modification of the fibrous filler by AGM-9 and Dyron OS 3151 solutions (5%) (Table 1).

The tendency of the strength properties of the PAN precursor modified by solutions of the used finishers to increase was related to the formation on the fiber surface of a film coating that "cured" PAN-TF microcracks and defects. This was confirmed by optical microscopy (Fig. 1).

IR spectra of finished reinforced systems were studied in order to characterize the interaction of PAN-TF with the modifiers. Spectra were interpreted using literature data [4, 5].

An analysis of the IR spectra (Fig. 2) confirmed that bands at 800-850 cm<sup>-1</sup> for SiOCH<sub>3</sub> (curve 2) and at 1300 cm<sup>-1</sup> for COO (curve 3) that were characteristic of the modifiers appeared in the spectrum of the PAN-TF fibrous filler modified by the finishing compositions. The spectrum of fibrous filler modified by Dyron OS 3151 solution (curve 3) changed significantly because it was a non-binding modifier that could be adsorbed on the polar surfaces of the filler to form a monolayer [2]. The spectrum of fiber treated with AGM-9 (curve 2) was characteristic of a Si-containing group

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Table 1. Mechanical Properties of PAN Filament as a Function of Bath Modifier Content

Bath modifier content, %	Relative tensile strength (cN/tex) after modification		Relative strain (%) after modification	
	AGM-9	OS 3151	AGM-9	OS 3151
2	47	54	17	20
5	60	64	16	23
10	50	59	18	23
Starting PAN filament	43	43	16	43

Note. Treatment time 60 s

Table 2. Hardening Parameters of Epoxide Composites Based on Modified PAN

Material	Time, min		Maximum hardening temperature, °C	Hardening degree, %
	gel formation	hardening		
ED-20	60	71	119	93
ED-20+PAN-TF	30	40	62	98
ED-20+PAN-TF+AGM-9	35	45	63	97
ED-20+PAN-TF+Dyron	25	46	43	99

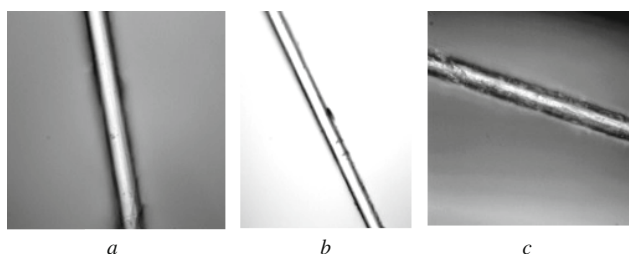


Fig. 1. Photomicrographs of samples ( $n = 1200$ ): PAN-TF (a), PAN-TF + AGM-9 (5%) (b), PAN-TF + Dyron OS 3151 (5%) (c).

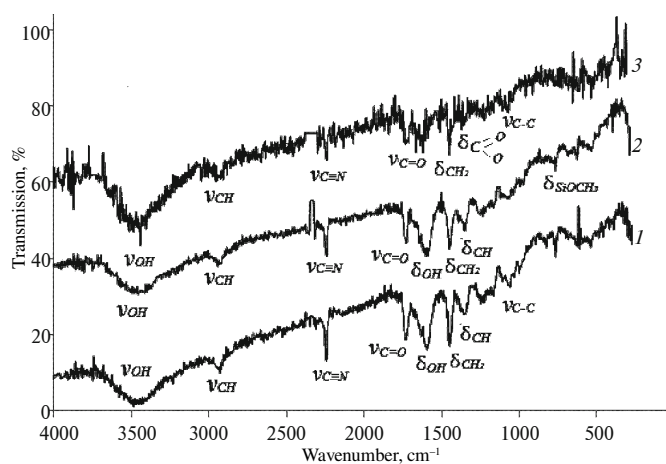


Fig. 2. IR spectra: PAN-TF (1), PAN-TF + AGM-9 (5%) (2), PAN-TF + Dyron OS 3151v (5%) (3).

and had a weaker peak for  $-CN$  in the region of  $2240\text{ cm}^{-1}$  than the spectrum of unmodified PAN-TF. This also indicated that the modifier might have reacted chemically with the reinforcing system.

The change in the chemical composition of the fibrous filler surface necessitated an assessment of the effect of the finished PAN fibers on the epoxide-resin hardening process (Fig. 3, Table 2).

The study of the hardening kinetics of the epoxide binder in the presence of the studied fibrous systems showed that unmodified (curve 2) and modified PAN-TF (curves 3 and 4) had analogous effects on the hardening of the epoxide

Table 3. Comparison of Strengths of Composites Based on Modified PAN-TF

Filler	Tensile strength, MPa		Brinell hardness, MPa
	stretching	bending	
ED-20unfilled	20	70	50
PAN-TF	74	105	118
PAN-TF+AGM-9	87	130	185
PAN-TF+Dyron OS 3151	90	124	277

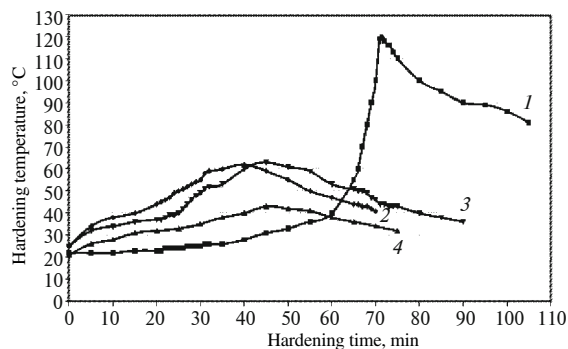


Fig. 3. Hardening kinetics: unfilled ED-20 resin (1), ED-20 + PAN-TF (2), ED-20 + PAN-TF + AGM-9 (3), ED-20 + PAN-TF + Dyron OS 3151 (4).

binder (curve 1). The gel-formation time decreased by 2-2.2 times; hardening time, by 1.6-1.8 times. The maximum hardening temperature dropped by 57-76°C with a simultaneous increase of the degree of hardening to 97-99%.

However, an analysis of the hardening kinetics of the epoxide binder in the presence of the modified fibrous systems showed that they had a more pronounced effect on structure formation in the polymer matrix that was obviously due to the introduction of the new functional groups. As a result, the physicochemical compatibility of the epoxide-binder—modified-reinforcing-filler system improved. This increased the strength properties of the polymer-matrix composite (Table 3).

Thus, modification of PAN-TF altered the surface chemical composition of the fibrous filler. This enhanced its effect on structure formation in the polymer matrix and increased the mechanical properties of epoxide composites based on the modified PAN fiber.

## REFERENCES

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