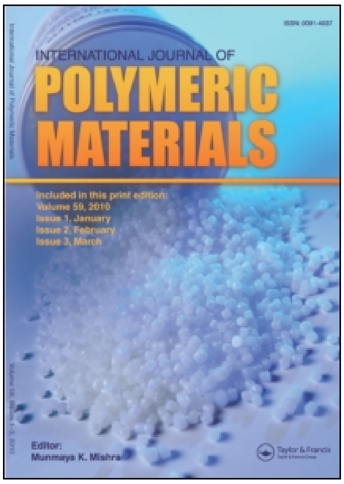

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New Aspects of Reducing Flammability of Polymeric Composite Materials Reinforced with Organic Fibers

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New Aspects of Reducing Flammability of Polymeric Composite Materials Reinforced with Organic Fibers

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New approaches to reduce flammability of polymeric composites are reviewed.

KEY WORDS Flammability, polymeric composites, organic fibers.

INTRODUCTION

Chemical technology is faced with a large increase in the production of polymeric composite materials (PCM) and consequent pressure for cost reductions. This problem may be solved by application of cheap reinforcing fiber materials such as commercially available chemical fibers: viscous (VF), polyester (PE), polycaproamide (PCA), poly(vinyl chloride) (PVC), and others. A few years ago these materials were not considered to be effective reinforcing fillers because of their low modulus, insufficient strength, and high flammability. But investigations conducted during the last few years indicate that it is possible to produce PCM with the desired properties using the method of modification.[2–7] Now we can produce flame-resistant PCM with physical and mechanical properties suitable for different branches of industry.[8–12]

The present work is a review of investigations directed toward development of flame-resistant PCMs based on industrial chemical fibers.

1. INFLUENCE OF THE COMPOSITION OF REINFORCING FIBERS ON PCM THERMAL DESTRUCTION AND BURNING

Some authors[13–18] have shown a relationship between the thermal stability and flammability of nonfilled polymers and their chemical composition and burning conditions.

In Reference 11 it is shown that thermodestructive and burning characteristics of PCMs reinforced with chemical fibers depend mainly on the thermophysical and thermochemical properties of fibers. Therefore, the temperature of PCM destruction is directly related to the thermal stability of reinforcing fibers.

Taking into account thermal stability, all reinforcing fibers containing acrylonitrile and epoxide PCMs may be arranged as follows: PAN > mechanical mixture PAN/PVC > copolymer of acrylonitrile and vinyl chloride AN/VC > PVC.

The introduction of fibers makes a nonadditive contribution to the change in the thermolysis mass rate ($\dot{m}/m$, and $\dot{m} = dm/dt$, where m is the sample current mass, t is time. It was shown that the thermolysis rate of the epoxide resin is four times higher than that of phenolic resin, but the pyrolysis rate of CMs based on these resins differs by only 20–50% with the same trend (Table I).

The temperature in the flame area depends to a great extent on gas consumption of the pyrolysis of the reinforcing fibers, which in turn depends on the chemical nature of the fibers. Introduction of PCM fibers increases the flame temperature of epoxide PCM by 30° due to the evolution of HCN (Table II). The flame temperature of PCMs reinforced with chlorine-containing fibers depends on the quantity of chlorine in a given material. During burning of PCMs reinforced with the copolymeric fiber AN/VC (chlorine constitutes 13% of the mass) temperatures reach 1453 K; this is 40 K higher than the flame temperature of materials based on a mixture of polyacrylonitrile/poly(vinyl chloride) (PAN/PVC) fibers containing 9% chlorine.[11] This is caused by a considerable evolution of combustible HCN

TABLE I

Mass rates of PCM pyrolysis,[11] c^{-1}

Reinforcing fiber	Temperature, K 673	773	873	973	1073
		Epoxide			
ED-20 without fiber	0,4	2,5	2,8	3,35	3,9
PAN	0,64	0,98	1,54	1,96	2,44
PVC	0,5	0,94	1,26	1,8	2,22
PAN/PVC mixture	0,4	0,9	1,4	1,9	2,35
AN/VC copolymer	0,65	1,15	1,75	2,4	3,0
		Phenolic			
CF-342A without fiber	0,08	0,2	0,4	0,8	1,0
PAN	0,45	0,78	1,1	1,4	1,6
PVC	0,35	0,65	0,98	1,3	1,5
PAN/PVC mixture	0,4	0,7	1,0	1,3	1,6
AN/VC copolymer	0,35	0,8	1,3	1,8	2,3

TABLE II

Burning characteristics of epoxide PCMs

Reinforcing fiber	Chlorine quantity, % of mass	Flame temperature, K	Flame retarding time, s
PAN	–	1493	1,0
PVC	24,0	1313	2,6
PAN/PVC mixture	9,6	1413	1,8
AN/VC copolymer	13,3	1453	2,6
ED-20 without fiber	–	1463	1,3

from a copolymeric fiber that is six times higher than the evolution from PAN/PVC fibers, while the quantity of acrylonitrile in them remains the same (60% of the mass).[19] It is evident that the flammability of PCMs depends not only on their chemical composition but also on the macromolecular structure of their reinforcing fibers.

2. WAYS OF REDUCING THE FLAMMABILITY OF REINFORCED PCMs

It is possible to reduce PCM flammability by reinforcing chemical resins with flame retarding fibrous fillers (e.g., glass, boric acid, asbestos, carbonic acid, polyamides). But in this case almost all of the combustible polymeric matrix burns away and the mass loss corresponds to the materials binder contents.[21]

A more efficient way of reducing PCM flammability may be by introducing reinforcing fibers or binders in combination with compounds containing nitrogen, halogens, or phosphorus (antipyrens) which partially or fully surpress burning. Modification of chemical fibers with antipyrens may be carried out by introduction of antipyrens into the fiber forming polymer during synthesis: before fiber forming, by chemical modification, by surface treatment of already formed fibers and other means which are discussed in many works.[22-40]

Antipyrens may be introduced into the binder at the oligomer synthesis stage or just before combination with fillers.[41-49]

Some works give examples of the high efficiency of PCM burning inhibition by introduction of antipyrens with fibers.[11,21,50-52] This may be explained by the fact that during PCM formation it is easier for the antipyren to diffuse from the fiber into the amorphous polymeric matrix then from the binder into the dense structure of the fiber. As a result, we obtain simultaneous inhibition of fiber and polymeric matrix burning. Such a mechanism was proved experimentally on samples of epoxide binder ED-20 filled with fireproof chemical fibers.[50]

The study of PCMs by differential scanning electron microscopy in combination with microprobe analysis on "superprobe" defined some phosphorus in a boundary layer of polymeric matrix adjacent to a fiber at a distance exceeding maximal thickness (5 mm) of binder layer in PCM produced by compression pressing (Figure 1).

Application of antipyren-containing resins that are reinforced with flammable

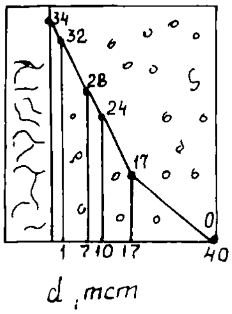

FIGURE 1 Number of pulses for phosphorus—distance from the fiber surface.

fibers is less effective because it requires a large quantity of antipyren and deteriorates the physical and mechanical properties of the PCM.[52] For example, dibrompropylphosphate (DBPP) introduced with PAN fibers into phenolic resin SP-342 A reduces mass loss two times, retards the rate of flame spreading, increases flame temperature by 20°, and oxygen index (O.I.) from 28 to 34% of the volume as compared to PCMs containing the same quantity of DBPP but in combination with a binder.

The synergic system of bromine and phosphorus is more effective in burning inhibition than chlorine. But introduced together with DBPP into phenolic resin (16% of the mass) reinforced with nonfireproof PAN fiber, it reduces flammability less (mass loss is about 35%) than chlorine introduced in the same quantity but into material with a reinforcing mixture of PAN and chlorine-containing PAN fibers (mass loss is about 9%).[52]

The method of introducing an antipyren into composition defines the coke structure formed during burning of materials in open air.[55] In PCMs without an antipyren the coke has porous uniform structure which cannot be split without destruction.

If we introduce an antipyren with a reinforcing fiber, we obtain coke on the surface of which appears a layer of highly porous coked cellular material with low density, which reduces the coke thermal conductivity and material flammability. The fiber textile structure remains in the coke volume. In materials containing an antipyren with a binder, the macroporousness of the coke is reduced and the fiber textile structure under the coke surface layer deteriorates considerably.

The considerations above concerning effective influence of modified fibers on PCM burning have been taken as a basis for the development of a large class of flame-retarding PCMs. The following reinforcing systems were used:

- Fibers of the same chemical nature, modified with similar and different antipyrens;
- Mixtures of fibers different in chemical nature and protected by both similar and different inhibiting compounds.

3. PCMS BASED ON VISCOUS FIBERS

Modification of viscous fibers has been carried out by antipyrens containing nitrogen and phosphorus and by compounds containing phosphorus and chlorine such as ammonia polyphosphate (PPA), the phosphorus acid salt of polyethylene-polyamin (PASPEP), diaminomethylphosphonate (DAMP), trioxymethylphosphine (TMP), trichlorethylphosphate (TCEP), and others.

The high flammability of viscous fibers is the result of a depolymerization process going on at high temperatures and competing with a dehydration process and accompanied by formation of flammable levoglucosan.[35]

It was shown that almost all indicated antipyrens initiate the basic stage of fiber thermal destruction. As a result the initiating temperature, maximal mass loss rate, and thermolysis completion shift into the zone of lower temperatures (by 20–30°). Destruction of modified (fire-protected) fibers goes with low rates and is accom-

TABLE III

Results of TGA of viscous fibers and PCMs based on them

Material	$k\Gamma$ %/temperature, K					
	373	473	573	673	773	873
Fibers						
1. VV original	94,5	91,2	47,1	24,5	13,6	5,0
2. VV + DAMP	100	89,0	46,0	39,0	31,0	26,0
3. VV + TOMF	98,6	98,0	53,5	46,8	43,0	36,4
4. VV + TCEP	95,8	88,5	40,0	26,5	17,5	18,0
Epoxide composite materials (fiber/binder ratio 50:50)						
1. VV original	97,5	95,9	71,2	41,3	35,5	23,5
2. VV + DAMP	97,5	94,0	63,0	55,3	48,7	28,5
3. VV + TOMP	98,5	95,0	70,5	50,0	41,0	29,5
4. VV + TCEP	97,3	92,5	66,1	52,0	42,0	30,0

TABLE IV

Results of fibers SPGC and PCMs

Material	H_2O generation		CO_2 generation		CO generation	
	Mg/mg	T_{max}, K	Mg/mg	T_{max}, K	Mg/mg	T_{max}, K
Fibers						
Original VV	151,3	553	128,6	556	57,7	553
VV + PFA	214,9	479	145,8	473	7,4	–
VV + 35% mass FC PEPA	191,3	483	59,4	483	15,0	–
VV + 25% mass FC PEPA	215,1	496	72,8	498	18,0	–
VV + DAMP	228,0	453	62,8	453	2,8	–
Epoxide composite materials (fiber/binder ratio 50:50)						
Original VV + ED-20	203,0	563	69,3	563	85,7	–
(VV + 25% FC PEPA) + ED-20	211,6	518	72,2	528	89,3	–
(VV + 35% FC PEPA) + ED-20	207,4	513	70,7	513	87,5	513
(VV + DAMP) + ED-20	209,0	448	71,0	–	88,0	–

panied by increased evolution of coke residue after completion of the basic stage of thermolysis (Table III).

Rate of Volatile Products Destruction and Coke Residue Changes

The coke residue quantity is reduced and the share of noncombustible H_2O and CO_2 in volatile products increases. This may be proved by the results of the stepwise pyrolysis gas chromatography (SPGC) (Table IV).[54]

Table V shows that water generation is defined by the chemical nature of the antipyren. Its increased quantity in a fiber, for example from 25% to 35% of mass in PC PEPA modification, can reduce the effect of the antipyren from +42 to

TABLE V

Antipyren influence in % to nonmodified viscous fibers

Material	Antipyren gain of mass, %	H_2O		CO_2		CO		O.I.
		ΔY	ΔT	ΔY	ΔT	ΔY	ΔT	Δ
Fibers								
VV + PPA	+44,5	+42,4	−26,6	+13,4	−29,3	−86,6	–	+102,0
VV + PC PEPA	+25,0	+42,0	−20,9	−43,7	−20,5	−70,0	–	+78,2
VV + PC PEPA	+35,0	+27,0	−25,6	−54,8	−25,2	−73,8	–	+115,2
VV + DAMP	+36,1	+51,1	−36,2	−51,6	−36,5	−94,8	–	+147,8
Epoxide composite materials (fiber/binder ratio 50:50)								
VV + 25% PC PEPA	–	+4,2	−15,5	+8,0	−12,0	+4,2	–	+29,5
VV + 35% PC PEPA	–	+2,2	−17,2	+4,0	+17,2	+2,2	–	+50,0
VV + DAMP	–	+2,9	−7,3	+2,4	–	+3,0	–	+16,4

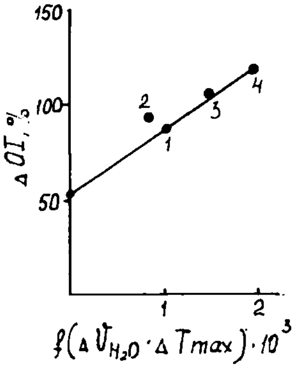

FIGURE 2 Interrelation of the oxygen index and the dehydration stage. (1) VF + 25% mass PC PEPA; (2) VF + 35% mass PC PEPA; (3) VF + PPA; 4 – VF + DAMP.

+27. At the same time, the dehydration temperature goes from 496 K to 483 K. There is a correlation between the oxygen index, H_2O generation, and the dehydration temperature (Figure 2).

The behavior of antipyrens in a system of epoxide (ED-20), melaminephormaldehydic (MP-100 C) and anilinephenolphormaldehydic (AP-342 A) materials was studied.

The efficiency of modified fibers in compositions with binder decreases (Tables IV and V). At the same time the dehydration reaction temperature decreases as compared with PCMs based on original viscous fibers (Table IV). This shows that the decomposition mechanism of fire-protected fibers is still active. In the presence of antipyrens the generation of coke residue grows (Table III) and its structure changes, thus substantially reducing PCM flammability. Flammability depends on the quantity of the antipyren in a compound (Figure 3) and on PCM composition (Figure 4). Antipyrens are quite effective in reducing the linear rate of flame spreading on the surface of PCMs (Figure 5). Introduction of a nonfire-protected viscous fiber even more combustible (0,1–19% of volume) than epoxide resin (0,1–21,5% of volume) results in the reduction of the flame-spreading rate. This is

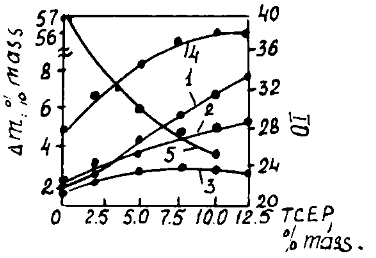

FIGURE 3 Dependence of flammability on the quantity of the antipyren and the method of its introduction into composition. (1) O.I. for VF + TCEP; (2) O.I. for (VF + TCEP) + ED-20; (3) O.I. for VF + (ED-20 + TCEP); (4) O.I. for (VF + TCEP) + CP-342 A; (5) PCM mass loss (VF + TCEP) + CF-342 A.

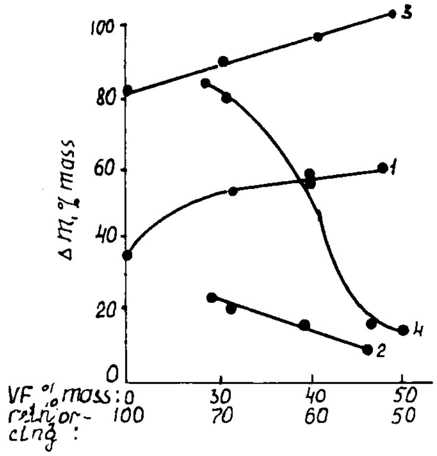

FIGURE 4 Influence of PCM composition on mass loss during burning. (1) VF original + MCP-100 C; (2) (PP + DAMP) + MCP-100 C; (3) VF original + ED-20; (4) (VF + DAMP) + ED-20.

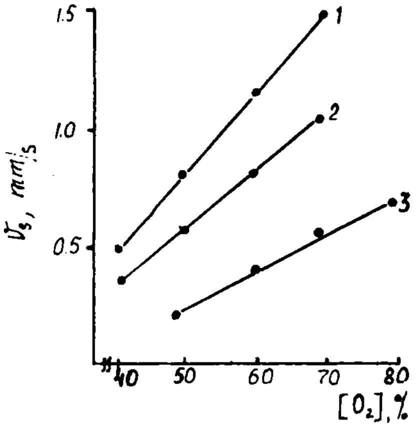

FIGURE 5 Flame-spreading time on the surface. (1) ED-2; (2) VF original + ED-20; (3) (VF + DAMP) + ED-20.

related to the thermal-physical properties of a fiber, which has higher thermal capacity and lower thermal conductivity than the epoxide matrix. We can see an even sharper reduction of this characteristic after the introduction of a modified fiber.[54]

These data indicate that antipyrens reduce the flammability of PCMs based on viscous fibers, mainly due to the change of reaction mechanism in a condensed phase.

The physical and mechanical properties of PCMs depend on the chemical nature of the fiber, binder, and antipyren and on the quantity of the reinforcing filler having definite correlation with its textile structure.

Taking into account the physical and mechanical properties of materials and the cost of reinforcing systems (fabric is about three times expensive), it is reasonable to use canvas for reinforcing.[53]

The polymeric matrix type depends on the range of the PCMs application. To produce composite material with perfect physical–chemical and physical–mechanical properties, and neglecting appearance and toxicity, it is possible to use CF-342 A resin. Aminoplasts have several advantages over phenoplasts: they are odorless, they dye easily—in all colors from light to dark, and they have sufficiently high physical–mechanical properties reinforced with viscous canvas. Application of epoxide resin is reasonable for production of items with increased bending strength.

4. PCMS BASED ON POLYETHER FIBERS

Low water adsorption, stability to atmospheric effects, sufficient thermal stability, and comparatively high mechanical properties make polyether fibers very good prospects for use as reinforcing materials.

Fire protection of lavsan was ensured by tricresyl phosphate (TCP) and decarbromdiphenyloxide (DBDO). Antipyrens were introduced into the fibers at the stage of fiber forming synthesis after the process of polycondensation. The maximum possible quantity of antipyren in phosphorus constitutes 1,5% of the mass, and in bromide, 18%. A further increase in quantity is impossible because of the loss of fiber forming properties of polymers.[55]

When epoxide resins are reinforced with PE fiber fire-protected by TCF (OZL-T), the flame-spreading rate on the surface decreases, mass loss decreases from 90 to 54%, the oxygen index (O.I.) increases up to 26,5% as compared to materials reinforced with nonmodified PE fibers. An insufficient content of phosphorus does not allow us to reduce flammability notably.

Reinforcement of epoxide resin with PE fiber protected by DBDO (OZL-D) ensures further reduction of flame-spreading time and mass loss during burning (up to 14%) without independent burning (Table VI).

If we compare coke generation in PCMs reinforced with OZL-T and OZL-D (Figure 6), it is evident that phosphorus-containing antipyrens influence chemical reactions mainly during the condensation phase, because coke generation in the temperature zone of maximal decomposition rate (623–673 K) is four times higher

TABLE VI

Flammability of epoxide materials (fiber binder ratio 1:1)

	Antipyren		Inflammability characteristics		
Material composition, weight %	Type	Quantity %	Mass loss %	Time of independent burning, m	O.I.
PETP-fiber nonmodified:ED-20 = 50:50	–	–	80–90	4	21,0
PETP-fiber nonmodified:ED-20 modified TCP = 50:50	P	0,75	75	3	22,5
OZL-T:ED-20 = 50:50	P	0,75	54,0	2,5	26,5
OZL-D:ED-20 = 50:50	Br	9	13,85	0	
OZL-T:OZL-D:ED-20 = 40:10:50	P + Br	0,6 + 1,8	2,9/46,0	0	
OZL-T:OZL-D:ED-20 = 25:25:50	P + Br	0,4 + 4,5	10,5/55,9	0	
OZL-T:OZL-D:ED-20 = 10:40:50	P + Br	0,15 + 7,2	3,8/21,5	0	

Numerator: actual mass loss; denominator: estimated by additive scheme; O.I. for Br or Br + P containing materials, because materials with DBDO burn forming a drop and this drop sliding on the surface of the material deforms the values 0.

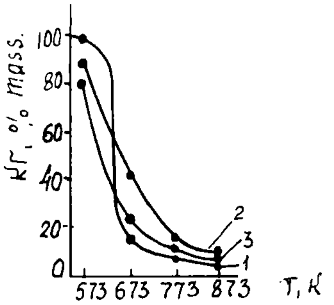

FIGURE 6 Coke generation for different materials with 50% ED-20. (1) Lavsan original; (2) OZL-T; (3) OZL-D.

than that of material not modified with PE fibers. In addition, the decomposition rate decreases, heat evolution also decreases, and the initial temperature of thermal destruction increases by 20 K.

Electron scanning microscopy in combination with microprobe analyses define some phosphory in coke rather uniformly distributed on its surface. Perhaps, the role of bromine may be explained by burning inhibition at the gas phase, because DBDO has almost no influence on coke generation (Figure 6). So, introduction of OZL-D into epoxide composition allows us to produce materials with increased fire resistance. However, such materials have lower (15–30%) tensile strength Gp, bending strength Gu, and impact strength *A* (Table VII). As for the application of OZL-T, it ensures conservation and in some cases even improves material properties as the result of the plasticization effect of TCP on the polymeric matrix.[56]

It is possible to maintain the fire protective effect of bromine without worsening the physical and mechanical properties of PCMs. This may be achieved by reinforcing the epoxide resin with a mixture of fire-protected OZL-T and OZL-D fibers in ratios of 20:80, 50:50, and 80:20. Such combinations of fibers exhibit the synergism of the bromine and phosphorus action, which results in a considerable

TABLE VII

Physical and mechanical properties of PCMs

	MPa		
Material composition weight %	Gp	Gu	A, kJ/m^2
PETP-fiber nonmodified: ED-20. = 50:50	120–140	190–200	74–80
OZL-T:ED-20 = 50:50	118–140	173–190	88–95
OZL-D:ED-20 = 50:50	103–120	155–160	63–70
OZL-T:OZL-D:ED-20 = 10:40:50	120–140	206–220	100–110
OZL-T:OZL-D:ED-20 = 25:25:50	135–140	220–240	110–115
OZL-T:OZL-D:ED-20 = 40:10:50	140–146	240–246	115–122
PAN fiber nonmodified:CF-342 = 50:50	80–95	75–90	10–12
(PAN fiber + DBPF):CF-342 A = 50:50	75–90	70–85	14–16

reduction (4–15 times lower than additive values) of mass loss when burning (Table VI).

PCMs based on fiber mixtures have better strength characteristics (Table VII).

5. PCMS BASED ON FIBERS

PAN fibers have good water and chemical resistance, and high thermal and noise-insulating characteristics[57] and are therefore acceptable as reinforcing systems.

To reduce flammability, the phenolic resin was reinforced with PAN fiber fire-protected by DBPF. Introduction of fire-protected fibers reduces flame-spreading time from 1,2 to 0,7 mm/sec (60% O_2), increases the oxygen index from 27% to 34%, and increases the volume and the temperature of flammability from 1383 K to 1437 K. The results of TGA show that in compositions with modified fibers the generation of coke does not increase, but the quantity of water increases and the quantity of toxicity and combustible HCN decreases. This means that there are some changes in reaction at the condensed phase. In addition, DBPF reduces flame temperature from 1533 K to 1483 K, decreasing the quantity of evolved heat, and thus reducing the reaction rate at the gas phase. So, it is defined that DBPF influences the process of burning both at the condensed and gas phases.[20]

Especially effective for reducing the flammability of PCMs is the reinforcement of the resin with a mixture of PAN fibers protected by DBPF and chlorine-containing PAN fibers. Under these conditions the flame-spreading time decreases and mass loss decreases from 10% to 3% (with total contents of antipyren at 15%) as compared to PCMs containing only DBPF.[52]

When reinforcing resins with PAN fibers, it is necessary to think not only about reduction of flammability but also about the problem of toxicity of the pyrolysis gases. This may be solved by application of PAN fibers fire-protected with DBPF for reinforcing. In addition, the quantity of HCN decreases six times when reinforcing phenolic resin with mechanical mixture of PAN (60%) and PVC (40%) fibers. This may be explained by the catalytic effect of PVC pyrolysis gases on

PAN cyclization and by interaction of pyrolysis gases evolving during decomposition of mixture components.[19]

6. HYBRID POLYMER COMPOSITE MATERIALS

Several works deal with ways of obtaining desired properties of PCMs by combining chemically different fibers modified by similar or different antipyrens in one material.[2,11,21,58,59]

In section 4 we mentioned the hybrid effect of improving strength and reducing flammability of PCMs with application of a mixture of chemically similar fibers (polyether), but modified by different antipyrens (TCF and DBPO).

Of great importance is the reduction of pyrolysis gas toxicity (six times by HCN) if we use PAN and PVC fiber mixtures for reinforcement (section 5).

PCMs filled with a mixture of synthetic fibers (polyether, polycaproamide, polyacrylonitrile) and viscous fibers show mutual inhibiting and initiating influences of fibers on thermolysis and burning of the mixture. Therefore, it is impossible to predict the flammability of mixed materials based on information about the flammability of separate fibers. Nevertheless, there are some features that are characteristic for all mixtures under discussion:

1. The maximum effect of flame inhibition is reached in compositions containing some quantity (20%) of another fiber (Figure 7). If the quantities of different fibers are equal, then during burning mass loss is approximately the additive value.
2. Considerable reduction of flammability may be achieved by application of uniform fiber mixture. If fibers are arranged in layers their inhibiting effect is reduced. If the amounts of components in a mixture are equal, then flammability exceeds the calculated values (Figure 7).
3. Mass loss (Δm); 2:2:4–burning duration; 1.2–arrangement of fiber layers; 3.4–uniform mixture of fibers; 1.2–calculated values.

The hybrid effect results in a change of quantity of pyrolysis combustion products, an increase of coke residue generation, change of the material's composition and structure, partially because of quick coking or complete prevention of the fusion of thermoplastic fibers.

Consequently, the hybridization of reinforcing systems makes it possible to control the processes of thermolysis and combustion by changing reinforcing methods and quantitative composition.

7. DEVELOPMENT OF NEW TECHNOLOGIES

We developed the combined way of producing pressed materials and called this method "polycondensation." The method suggests synthesis and polycondensation of binder in the structure of filler and allows us to produce PCMs which differ in structural characteristics from materials produced by traditional methods.[53] Deep

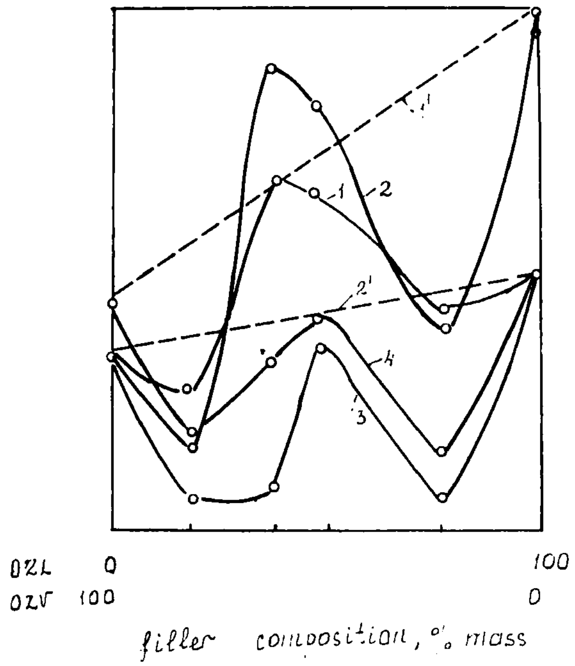

FIGURE 7 Influence of filler composition and the reinforcing method of burning of epoxide composite materials.

TABLE VIII

Fire-resistance of PCMs based on canvas made of viscous fibers

Method	PCM	%	O.I.,%
Traditional	Canvas + PPO	57,0	26,5
Polycondensation	Canvas + PPO	11,6	27,5
	Canvas + FFC with 5% PP	11,0	27,5
	PPB + canvas with 5% PP	3,3	28,5
	PPB + canvas with 10% PP	2,5	34,5
	PPB + canvas with 20% PP	1,9	36,5
	PPB + canvas with 30% PP	1,8	39,5

PPB—phenolphormaldehide binder made of monomers and catalyst.
PPO—phenolphormaldehide oligomer.

diffusion of monomeric molecules into the structure of fibers and readiness of the filler's functional groups for interaction with groups of synthesized binder lead to formation of material structure that is resistant to burning in open air. Mass loss of such materials is about 12% (Table VI) as compared with 56% of the same composition produced by traditional methods. In addition, these materials have better physical and mechanical properties.

Application of modified fibers, for instance by polyphosphate, further improves the fire resistance of the materials. Mass loss decreases approximately six times and the oxygen index increases from 27,5 to 35,5 (Table VIII).

In these compositions polyphosphate acts as a filler at the same time, thus reducing the quantity of combustible components in the material (by 20–30%) along with production costs.

The considerations above show that there exists the possibility of increasing resistance by application of chemical fibers modified by antipyrens.

Such PCMs may be recommended as structural materials in different branches of industry.

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