Investigation on short carbon fiber filled composites based on polyamide blend PA6 and PA6.6

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Necessity of enhancement of application field of short carbon fiber filled polyamides has stimulated resource of polyamide blends as matrix. It was revealed optimal ratio blend components and short carbon fiber filled composites based on them were prepared. Mechanical and friction comparison tests allowed ascertaining a number of preferences of blend composites. To explain the observed effects the composites structure was studied with differential scanning calorimetry and X-ray diffraction pattern. Correlation between material composition, its structure and friction behavior was ascertained.

Introduction

Since the middle of 20-th century polymer mixing has been one of widespread ways of producing of advanced materials [1]. It's particularly urgent in connection with the need for plastic's recycling . Polyamides are used for tribology application. Short carbon fibers (CF) loading in polyamides improves their strength, friction and heat-transfer properties, that allows them to rival with nonferrous metals[2]. To spread the application field of short carbon fiber filled (SCFF) polyamides the investigation of PA-6 and PA-6.6 blends as matrix was stimulated. Chemical and structure similarity of these polymers promotes their complete blending. Addition of PA-6.6 with more high melting temperature as compared with PA-6 should increase the heat resistance of matrix. We have supposed that increasing of heat resistance has to improve its friction behavior.

Experimental

The influence of polymeric matrix composition being the blend of PA-6 and PA-6.6 on friction of SCFF composites was investigated. High tensile carbon fiber UKN-12K (Production association "ChemVolokno" Balakovo, Russia) as a filler was used. Pure PA-6-210/310 pellets (Production association "ChemVolokno" Grodno, Belorussia) and PA-6.6 Zytel EFE 1147-010 (Du Pont Co.) were used as components for matrix. Mix matrices with different proportion of PA-6 and PA-6.6 and compositions based on them were prepared by double screw extrusion. The samples composites were molded into test bars on a Mannesmann- Demag moulding machine KD-100. The strength tests were performed at 23ºC and at a relative humidity 50% by Instron machine. Deformation heat resistance was determined with Automatic system for determination of flexure temperature under loading UGT-HV-2000-C6W by ISO 75-2. The end friction machine (Fig.1) was used for investigation of friction properties of composite samples. Test conditions subject to composition were following: for polymer blends -sliding velocity V=0.5m/s and constant load P= 0.05MPa; for SCFF plastics - V=1m/s and P=0.1MPa. Weight wear of sample was determined by weighting on analytical balance every hour. Measurement of friction temperature was taken at a distance 1mm from surface of the counter-body by a thermocouple. Thermal- physic investigations were performed by differential scanning microcalorimeter DCM-3A. Measurements were carried out within temperature range 50÷300ºC under heating rate 16°/min. X-ray diffraction patterns were made under reflection mode by diffractometer DRON-3 (CuK_α radiation).

Results and discussion

1. Results of mechanical tests and structure researches.

1. a. Polyamide blends

Table 1

Properties of polyamide blends

Composition and properties	Blending ratio (%)				
PA-6.6,%	30	70	45	0	100
PA-6,%	70	30	55	100	0
Density , kg/м^3	1,14	1,14	1,14	1,13	1,13
Bending strength , MPa	105	103	100	108	114
Module of elasticity, GPa	2,6	2,5	2,5	2,6	2,9
Tensile strength,, MPa	81	80	60	79	79
elongation,%	6,1	6,1	5÷40	6,0	4,9
Impact strength with notch J/м^2	9,0	9,4	7,9	8,1	9,5
Melting temperature (PA-6/PA-6.6), ◦C	228	215	225	226	272
	260	267	256		
Enthalpy (PA-6/PA-6.6), J/g	18	19	23	53	69
	81	70	67		

Tests of polyamide blends with different blending ratio has allowed to show optimal composition. Data of differential scanning calorimetry indicate of amorphization of PA-6 and changes of PA-6/6 crystallites (Fig.5,7). These conclusions are confirmed by X-ray investigations (Fig.2÷4). All reflections of both polyamides are discernible at diffraction patterns.

1. b. Polyamide blends with carbon fibers.

Presence of carbon fibers in polyamide blends changes diffraction pattern sufficiently: considerably intensity of amorphous halo increases and only reflections of PA-6.6 crystalline phase (under 2θ= 20.6-20.8-20.3(Fig.4) are visible. The date of differential scanning calorimetry has confirmed deep amorphization of PA-6 and partial disordering of PA-6.6 crystalline phase (Fig6,8). This change simultaneously crystallite morphology and formation of certain spatial structure of blend are evidently a factor determining mechanical properties (table 2).

Table 2

Composition and properties	Blending ratio of matrix and content of CF (%)					
PA-6	90	80	70	60	85	20
PA-6.6	10	20	30	40	-	80
UKN 12K	15					
Density , kg/м^3	1,21	1,21	1,22	1,22	1,21	1,22
Impact strength with notch J/м^2	13	13	18	10	12	11
Bending strength , MPa	171	170	215	166	177	175
Module of elasticity,GPa	11,3	10,8	13	11,9	11,6	12,1
Tensile strength,, MPa	115	121	142	123	120	133
elongation, %	2,5	2,7	3,0	2,5	2,6	2,7
Deflection temperature	191	197	203	206	196	230

2. Friction behavior of SCFF plastics based on polyamide blends.

Study of structure of polyamide blends and role of fiber filler allows finding out the influence of polymer amorphization on tribological properties. It is may be connected with partial compatibility of crystallites in melting and forming of structure similar “hard solution”.

The distinguishing feature of this friction study consists in high temperature of experiments. It’s been ranged at 70°C depending on composition and test duration. Under these conditions the friction coefficient SCFF composites was high 0.5÷0.7. The such test setting has been connected with investigation of influence of more heat-resistance PA-6.6 on wear of PA-6 under elevated temperatures.

The findings on wear of SCFF plastics for 6 hours by the end friction machine are shown in Fig.9 and table 2 and 3. We can see that SCFFPA-6.6 is more wear-resistant than SCFFPA-6. Perhaps it is stipulated by enhanced heat resistance of PA-6.6. Dependence of wear on blending ratio is not proportional (Fig.9). Adding of 10% PA-6.6 hasn’t improved wear-resistance of composite. Only 20% of PA-6.6 has resulted in jumping of composite wear-resistance. Then under the high content of PA-6 in blend the graceful growth of wear is observed. It notices the minimum wear coincide with maximum stress-strain properties of composites (Table 2).We can suppose essentially the physical-mechanical properties influence on wear, particularly on run-in stage. As follows from friction tests for 6 hours, the run-in stage comes to end for 5 hours, and just then the friction goes on run-in surface. Thereat besides data of 6-hours wear (Fig.14) we present dependence of wear on blending ratio within 6-th hour of test (Table 3).

Table 3

Composition and properties	Blending ratio of matrix and content of CF (%)						
PA-6	85	90	80	70	60	20	0
PA-6.6	0	10	20	30	40	80	85
UKN 12K	15						
Wear after run-in, $g \cdot 10^{-4}$	15	5	8	9	9	14	6

As we can see the dependence of wear after ran-in on blending ratio is similar to the same dependence of total wear. The wear of SCFF PA-6.6 is sufficiently less than wear of SCFF PA-6. But adding of 10÷30% PA 6.6 to SCFF PA-6 allows increasing their wear stability under high temperature. In turn it promotes to carry out the run-in more effectively. In contrast to positive effect of small additions of PA-6.6 to SCFF PA-6, introduction of small quantities of PA-6 to SCFF PA-6.6 did not improve run-in process (Table 3).

References

1.Thomas S. Ellis , Mixing relationships in aliphatic polyamide blends, Polymer, 1992, V.33, №7, p.1469-1476.

2. Krasnov, A.P., Rashkovan, I.A., Kazakov, M.Ye, el at., The Properties of Filled Thermoplastics Depended on the Carbon Fiber Antifriction Characteristics, Vestn. Mashinostroen. (Journal of Mechanical Engineering), 2002, no. 12, pp, 25-28.

Figures

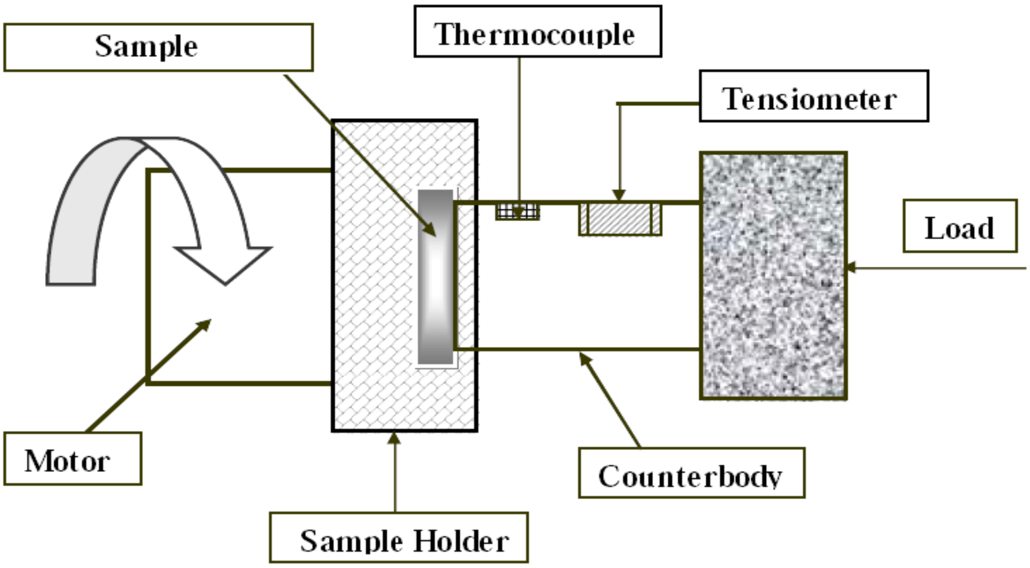

Fig.1.Scheme of friction tests.

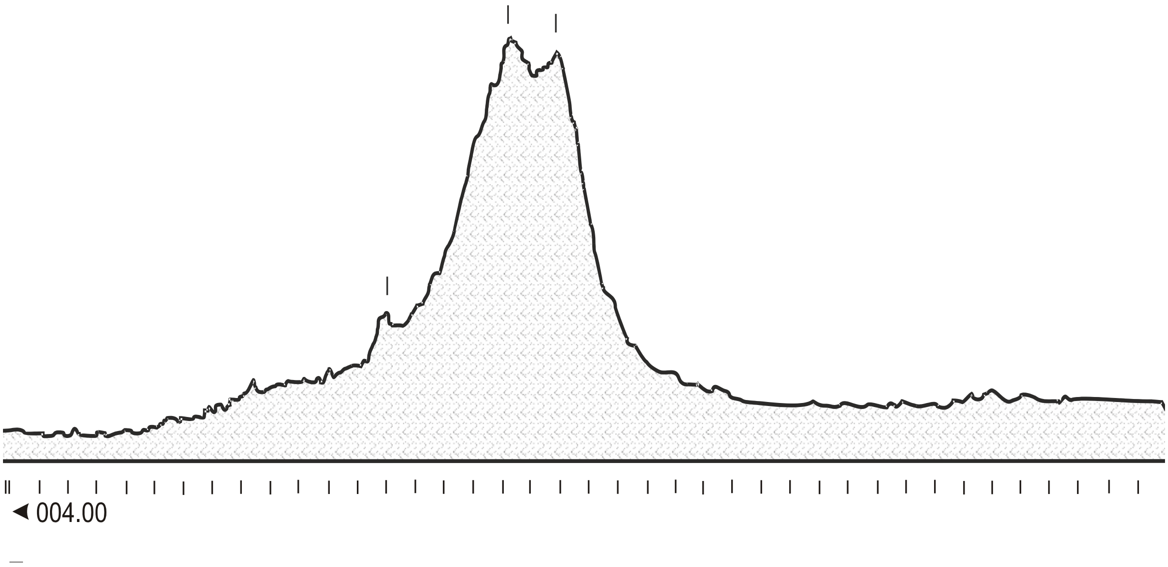

Fig.2. X-ray diffraction pattern PA-6

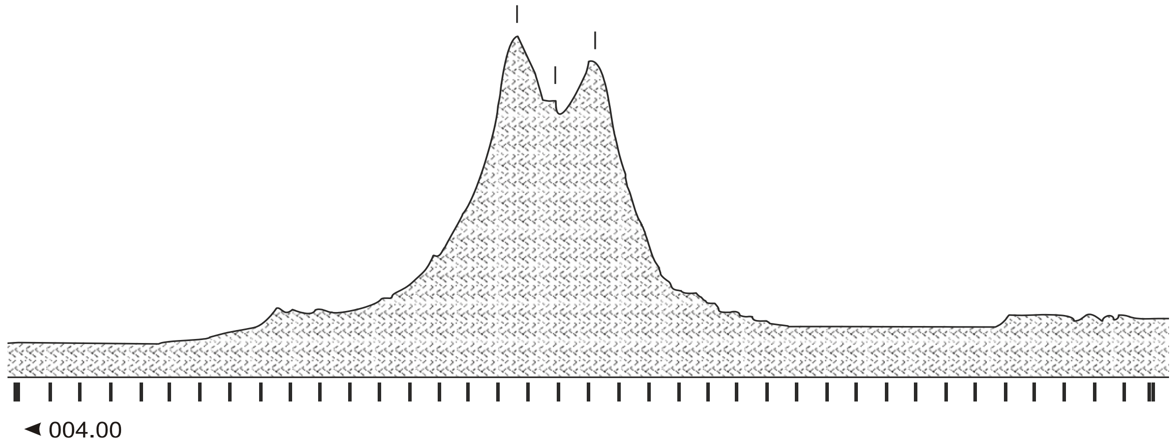

Fig.3. X-ray diffraction pattern PA-6.6

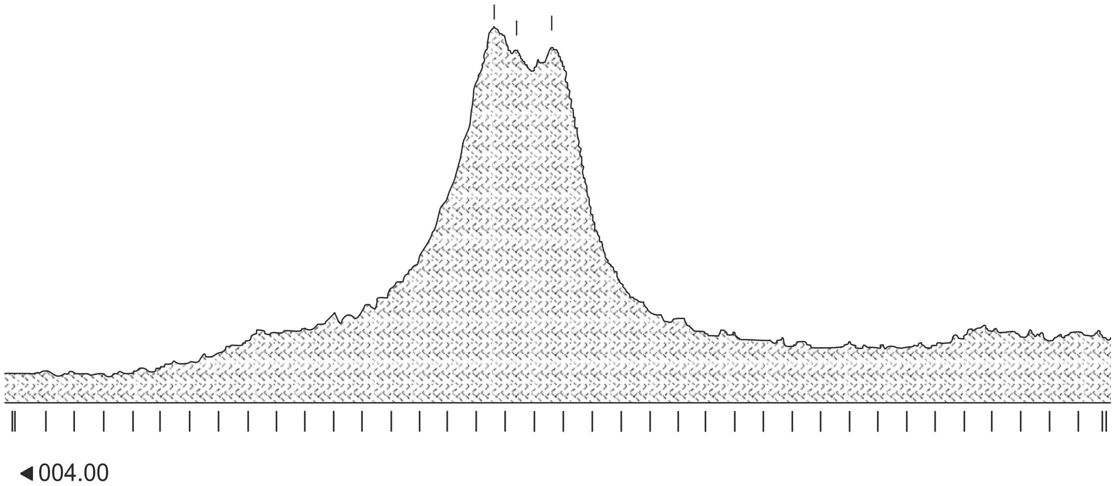

Fig.4. X-ray diffraction pattern 70%ПА-6:30%ПА6.6

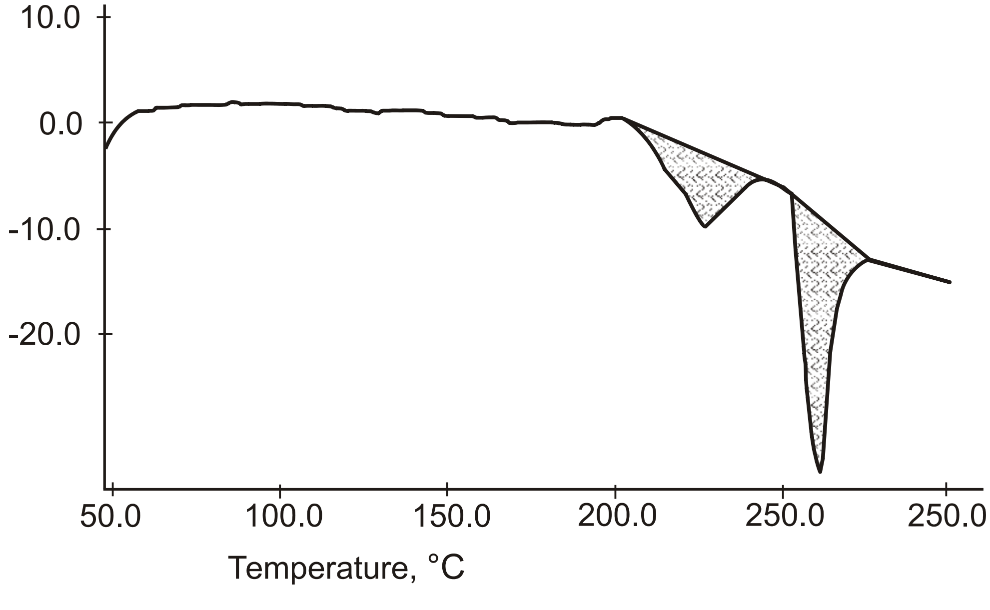

Fig.5. DSC-diagram PA 6:PA 6.6 (70:30)

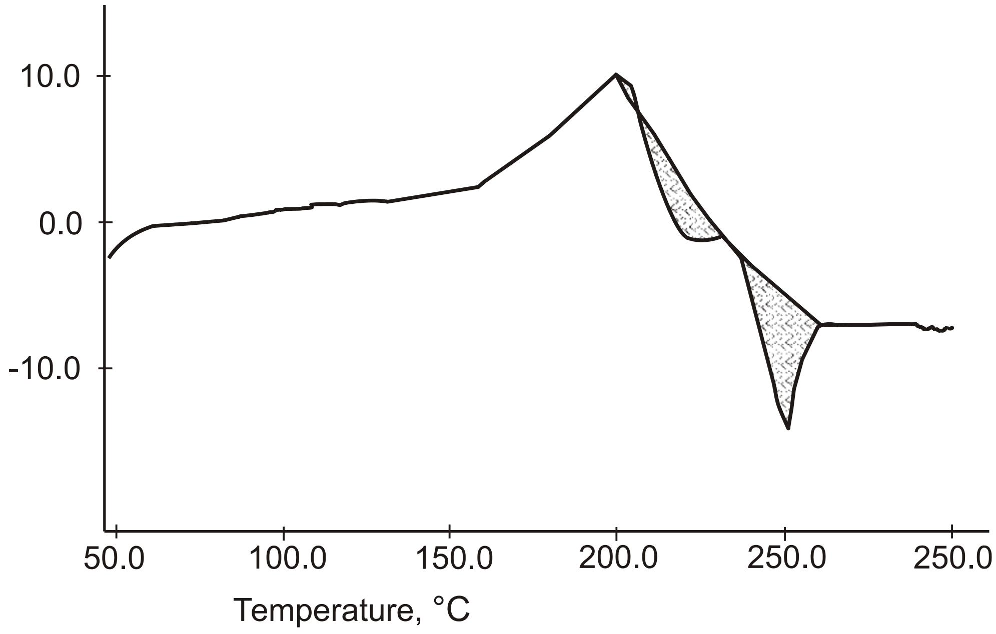

Fig. 6. DSC-diagram PA 6:PA 6.6 (70:30)+ 15% CF

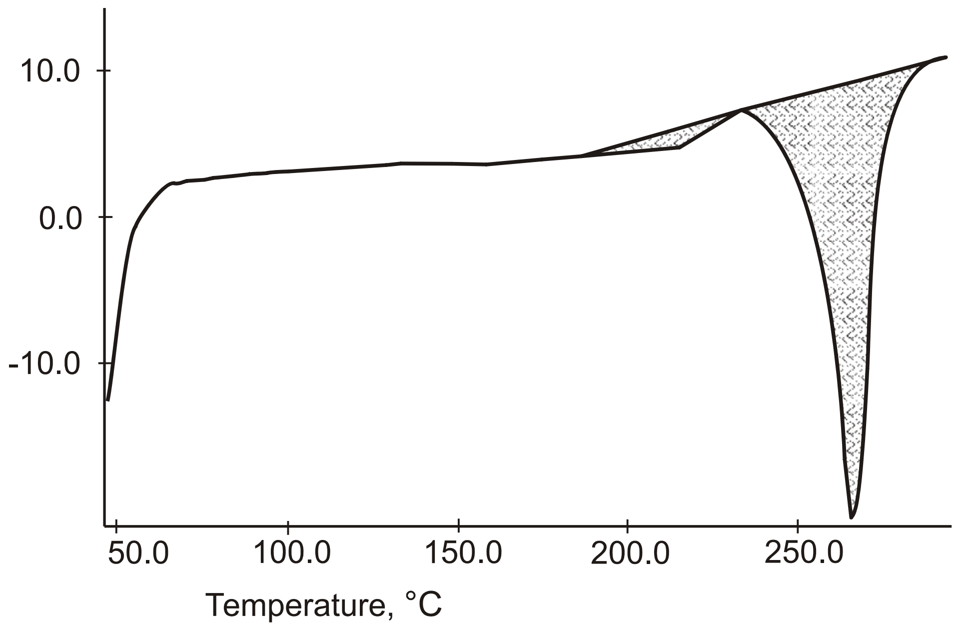

Fig.7. DSC-diagram PA 6:PA 6.6 (30:70)

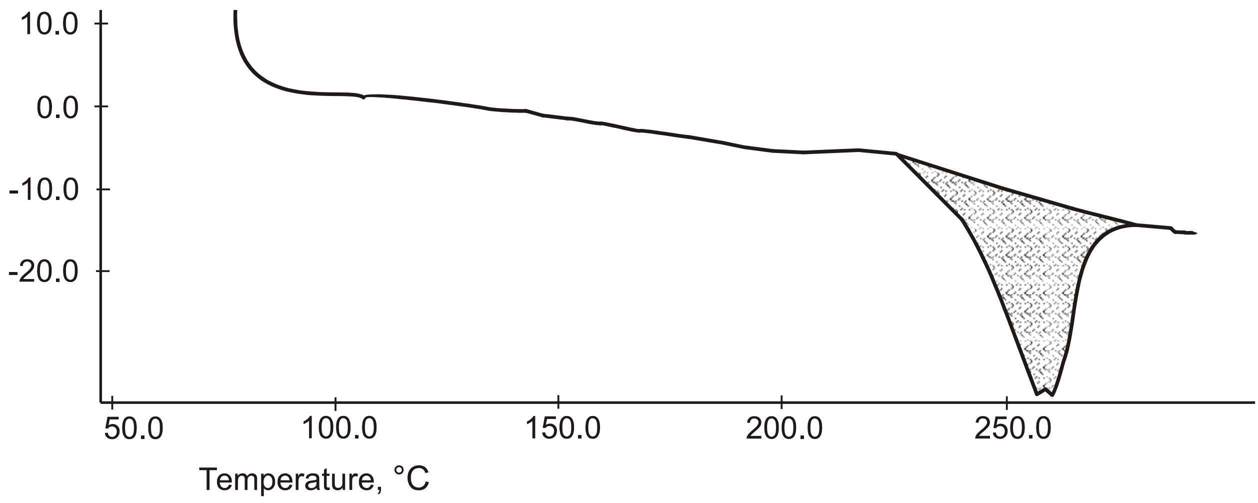

Fig.8. DSC-diagram PA 6: PA 6.6 (30:70) +15% CF

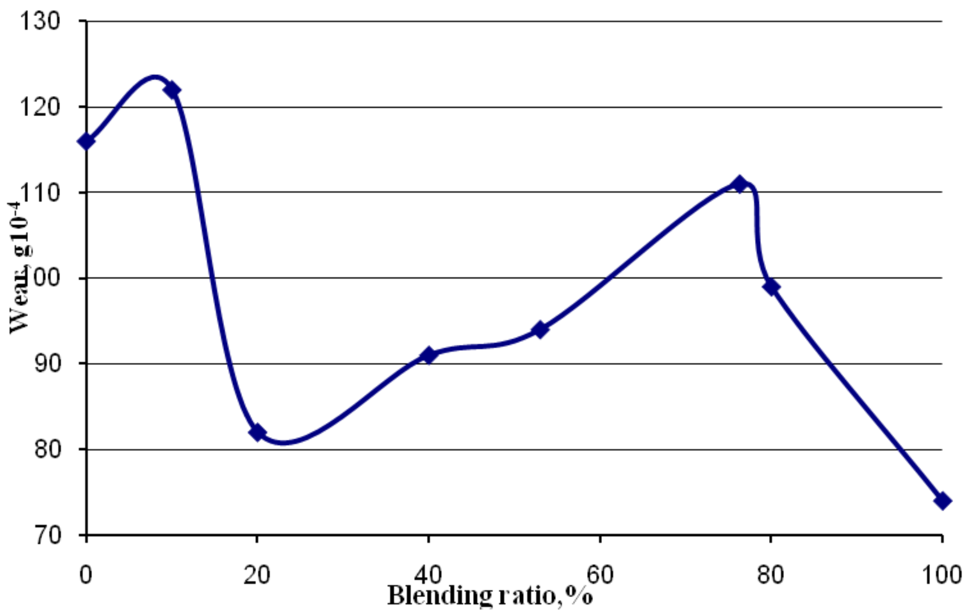

Fig.9. Influence of composition on wear under 6 hours of test