Composite Materials Based on Wollastonite for Automobile Construction

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Abstract

The effect of reinforcing the unsaturated polyester resin with wollastonite on primary physical-mechanical and performance characteristics of the hardened composite material is investigated.

INTRODUCTION

Development of automobile industry requires the development of new polymeric materials with the prescribed combination of properties, first of all with increased strength, hardness, heat resistance, thermal and humidity resistance, as well as low cost. The required characteristics can be most easily achieved by making reinforced polymeric composite materials the components of which are able to cause synergism when working together [1]. It is profitable from the economical point of view to reinforce polyester resins with inorganic mineral additives, first of all natural ones (silicate materials, talc, carbon black, *etc.*). In this respect, wollastonite is very promising as a silicate widespread in Siberia. The needle-like shape of crystals allows one to use this material as strengthening filler, similarly to other short-fibre fillers, for example asbestos, but unlike the latter wollastonite is absolutely harmless.

In the present work we investigated the main physicochemical characteristics of wollastonite $CaO \cdot SiO_2$ from the Sinyukha deposit and its effect as filler on the deformation strength and performance characteristics of the composite materials (CM) based on it.

EXPERIMENTAL

In order to make the composition, we mixed the orthophthalic polyester resin of S280 grade (Neste company) with a weighed portion of the filler at a temperature of 20 °C for 15 min, then added the hardening agent: methyl ethyl ketone peroxide (concentration: 2 mass %). The main characteristics of the resin were: styrene content, 30 %; viscosity, 0.70 Pa s; temperature of thermal deformation, 60 °C.

The size of wollastonite particles was determined using the sedimentation procedure, specific surface was measured with the help of Klyachko–Gurvich method [2], and acid-base characteristics were obtained using a multi-purpose ion meter EV-74. Thermal analysis was carried out with the Q-1500 derivatograph within temperature range 20–700 °C in the air. Macro- and microstructures were studied with the help of electron scanning microscope SEM-130.

RESULTS AND DISCUSSION

Wollastonite rocks contain the following components (concentration, mass %): SiO_2 49.11, CaO 46.09, Al_2O_3 0.98, K_2O 0.17, Na_2O 0.17. The main physicochemical characteristics of wollastonite are: density, 2.85 g/cm^3; mass-

TABLE 1

Characteristics of the composite materials based on wollastonite and a polyester resin

Characteristics	Non-filled composition	Concentration of wollastonite, mass %		
		30	50	55
Initial viscosity, Pa·s	0.70	1.30	5.45	7.05
Initial density, g/cm^3	1.12	1.36	1.50	1.53
Bursting stress, MPa:				
for compression	101.1	109.2	115.2	111.3
for tension	30.3	381	34.3	29.1
for bending	71.2	60.3	65.8	63.1
Temperature of the start of decomposition, °C	125	145	175	180
Water absorption for 30 days, mass %	0.54	0.56	0.58	0.59
Volume shrinkage, %	8.1	5.6	4.0	3.5

average particle size, (14.90±4.1) μm; specific surface S_{sp} = 1.6 m^2/g (measurement error is 10 %); alkalinity of water suspension pH (9.81±0.02), Mohs hardness, 5.

To determine physical-mechanical and performance characteristics of the resulting composites, we manufactured the standard samples by means of gravity casting.

The characteristics of CM based on wollastonite and unsaturated polyester resin are shown in Table 1.

A substantial change in the characteristics of reinforced polymers, especially rheological and physical-mechanical parameters, is due to the effect of the filler on the structure and properties of the boundary polymer layer, and also due to the interaction of the filler particles with each other. One can see in Table 1 that an increase in the mass concentration of wollastonite (from 30 to 55 %) the compression strength of the CM is higher by 8–15 % than that of the non-filled resin. This is explained by the fact that under compression a part of the external load is taken up by the rigid filler particles, so solid fillers increase the strength, provided that the adhesion of the filler to the binder is equal to or higher than the cohesive strength of the matrix.

Composite materials based on wollastonite possess high tensile strength. For instance, with 30 % of wollastonite introduced into the resin, this value increases by 26 %; further filling causes a characteristic decrease in the bursting stress.

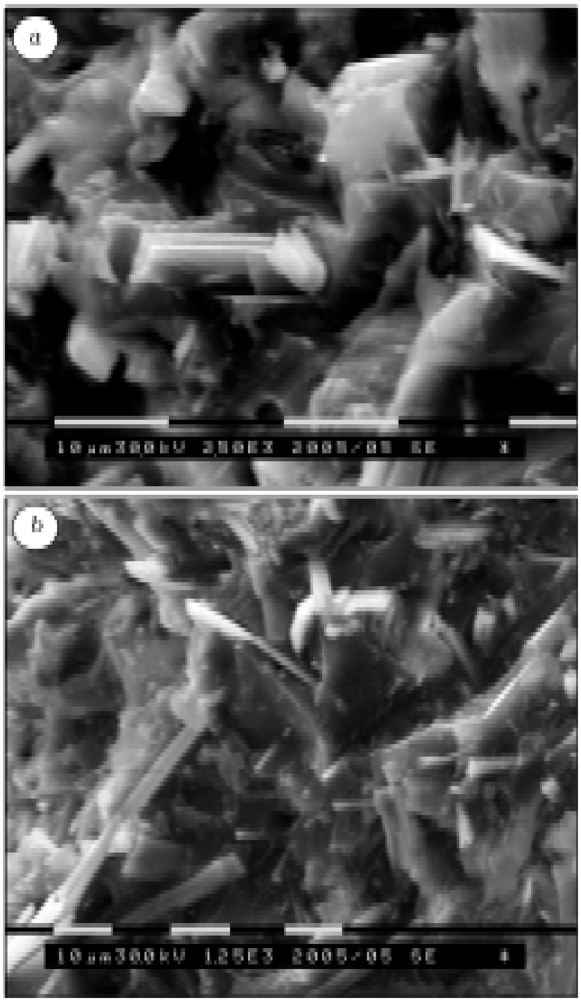

Fig. 1. Microstructure of composition materials based on wollastonite with the concentration of the filler 30 (*a*) and 50 mass % (*b*).

The authors of [4] explain the effect of increased strength of polymeric CM by the development of a coagulation grid-type structure formed as a result of cohesion of filler particles through thin adsorption-solvation polymer layers. With an increase in the filling extent of the composite, the fraction of adsorption-solvation polymer films increases until the polymer passes completely into the film state. Further filling causes the lack of polymer binder (its deficit in highly filled CM results in fragmentation of the film structure of the polymer) and intense pore formation, which is accompanied by a decrease in the strength of the composite [3].

According to the data of thermal analysis (see Table 1), the introduction of wollastonite decelerates destruction causing a shift of the initial CM decomposition temperature to higher values. An increase in the thermal stability of the filled polymers is likely to be due to the kinetic mobility of macromolecules due to their adsorption interaction with the filler surface.

Investigation of water absorption in the polyester resin and in the CM based on wollastonite showed that the sorption equilibrium is achieved after exposure for 24–30 days in distilled water. Water absorption in the samples containing wollastonite is insignificantly higher (by 0.02–0.05 %) than that in a non-filled sample.

The microstructure of the obtained materials is shown in Fig. 1. One can see that wollastonite conserves its structure in the composites; this allows one to obtain a twisted reinforcing structure composed of the crystals, which provides higher mechanical strength of the CM on this basis.

CONCLUSION

Thus, the introduction of wollastonite into the polyester resin allowed one to improve the strength characteristics of CM by 8–26 %, to elevate the temperature range of performance of this material to 180 °C, and to decrease shrinkage by 3–5 %; finally, taking into account low cost and large resources of wollastonite in Siberia, one may thus achieve a substantial decrease in the price of the final product. The designed materials can find application in automobile manufacturing when making parts, units and blocks operating under the simultaneous action of high temperature, tensile and compression stress, and increased humidity.

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