The Effect of Poly (vinyl chloride) and Filler on Technological Properties of Polyester Composites

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Abstract – The paper determines the influence of polymer modifier (poly (vinyl chloride)) and finely dispersed inorganic filler on the elastic-deformation and thermophysical properties of polyester materials. The research discovers the change of deformation modulus, elasticity modulus, high elasticity modulus, surface hardness, Vica heat resistance, and technological shrinkage of modified polyester composites filled with calcium carbonate and aluminum oxide.

Keywords – polyester, compositions, filler, modification, poly(vinyl chloride).

I. Introduction

Unsaturated polyester resins are technologically compatible with polymers and fillers different by nature. That enables them to provide a complex of essential properties. Among technologically and economically feasible methods of modification of polyester resins are physical methods based on the combination of polyester oligomers with oligomers of a different nature, and macromolecular compounds. Their application provides materials with the necessary complex of technological and operational properties.

Adding inorganic fine fillers, in particular, $CaCO_3$ and Al_2O_3 into polyester composition, along with the impact on technological and operational properties of the modified materials, will regulate the process of binder structuring through the formation of interfacial layers with different characteristics and formation of physical and chemical bonds between the filler surface and molecules of the polymer matrix [1].

II. Experimental

The unsaturated polyester resin (UPR) marked Estromal A023 was used for obtaining polyester composites. Unsaturated polyester resin curing was conducted in the presence of 1.5-2.0 pts.wt. initiator Metox-50 (methyl ethyl ketone peroxide solution in dimethyl phthalate) and 0.2-0.4 pts.wt. accelerator of cobalt naphthenate at room temperature.

Poly (vinyl chloride) (PVC) of brand Lacovyl PB1156 was used as polymer modifier. We also used the calcium carbonate ($CaCO_3$) and aluminum oxide (Al_2O_3) as fine disspersed inorganic fillers. Additionally, the composition was filled with diesterphtalate plasticizer of dibutyl phthalate (DBP) which is compatible with poly (vinyl chloride). It also functioned both as a solvent and plasticizer for the unsaturated polyester resin and polyvinyl chloride.

The research of elastic-deformation properties of modified polyester materials was carried out with the application of Hepler Consistometer at 293 K. The method is based on indentation of conical indenter under the load of 120 N and determination of characteristics by the modulus and deformation calculation according to the methodology.

Vica heat resistance of the investigated materials was determined in accordance with ISO 306:2013, the loading was 50 N.

The surface hardness of conical fluidity point was determined on Hepler Consistometer at 293 K by indentation of steel cone in the polymer sample with a sharpening angle of $58^{o}08'$ under the load of 50 N for 60 s. Shrinkage of polyester material was measured according to ISO 2577:2007, comparing the size of the obtained sample with the size of a form.

III. Results and Discussion

Unfilled unsaturated polyester resin is characterized by high values of deformational modulus and modulus of elasticity. Apparently, it is caused by structural features of cross-linked polymers, such as presence of chemical knots of the grid which practically are not destroyed under static loads. Herewith, high density of grid reduces the segmental mobility, as evidenced by the high values of High elasticity modulus.

Adding finely dispersed $CaCO_3$ filler in UPR increases the value of deformation modulus of composite that decreases its ability to deformation under static loads. The value of the equilibrium modulus, characterized by interatomic distances change in the chains of macromolecules, as well as bond angles deformation, significantly increases during the process of $CaCO_3$ adding. It is obviously caused by the decrease of mobility of structured polyester resin segments due to interphase interactions with the surface of finely dispersed filler. Along with this, there is a substantial increase of high elasticity modulus for polyester composites.

Adding PVC modifier to the polymer composition leads to increasing of elasticity and plasticity of the composite material. It is evidenced by the increasing of the elastic modulus and decreasing of the value of high elasticity modulus as in the case of unfilled and filled materials.

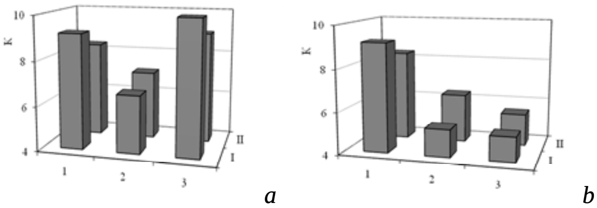
Adding plasticizer dibutyl phthalate in filled composition results in increased strength characteristics of the material (deformation modulus and elastic modulus are increased). These special features are caused by decrease defects of polyester grid owing to the interaction of plasticizer molecules with solid filler surface and change of interphase characteristics of the system polyester matrix – filler [2].

In the case of applying Al_2O_3 as a filler of unmodified polyester compositions, we could observe the similar to $CaCO_3$ effect on deformation modulus and high elasticity modulus (these values increase).

However, the deformation modulus decreases in the materials which except the filler contain 20 weight part of PVC. It shows that the modified composite is less rigid and hard compared to the unmodified one.

Influence of the filler nature and polymer modifier on structure coefficient K of the polyester materials are shown in Fig. 1.

Adding poly (vinyl chloride) in unfilled composition increases the coefficient of the composite structure, which apparently is a consequence of the formation of partly interpenetrated grid of structured polyester resin and PVC macromolecules.



a *b*

Fig. 1 Influence of filler nature and PVC polymer modifier on structure coefficient K of polyester composites:
a) UPR:$CaCO_3$:DBP, wt. p.: 1 – 100:0:0; 2 – 100:235:0; 3 – 100:235:3; PVC content, wt. p. I – 20, II – 0.
b) UPR:Al_2O_3:DBP wt. p.: 1 – 100:0:0; 2 – 100:150:0; 3 – 100:150:3; PVC content, wt. p.: I – 20, II – 0

It is found out that the addition of inorganic filler, irrespective of its nature, reduces the composite structure coefficient due to the influence of surface filler on the process of oligomers structuring in the studied systems. This may form a three-dimensional grid with less knots integrity. Adding poly (vinyl chloride) and inorganic finely disspersed fillers to the polyester compositions allows predetermining the process of structuring polyester binder through the formation of boundary layer on the border of filler-polymer matrix [3]. Therefore, it affects the thermal and physicomechanical properties of the obtained composite.

TABLE 1

THE IMPACT OF MODIFIER CONTENT AND NATURE FILLER ON TECHNOLOGICAL PROPERTIES OF POLYESTER MATERIALS

№	Composition content		Shrin-kage, %	Vica heat resistance K	Surface hard-ness, MPa
	Filler	PVC content, wt. p.			
1	-	-	8,64	582,3	30
2		20	7,82	522,2	26
3	$CaCO_3$	-	7,08	643,0	48
4		20	5,65	599,3	34
5*		20	6,87	589,5	36
6	Al_2O_3	-	7,45	638,9	44
7		20	5,82	579,4	33
8*		20	7,15	594,6	33

* In the presence of 3 wt. p. of DBP.

The impact of the polymer modifier and nature of finely dispersed inorganic filler on thermal and physico-mechanical properties of polyester materials is presented in Table.1.

It is determined that the modified polyester materials containing finely dispersed inorganic fillers, are characterized by various principles of change of the values of surface hardness and Vica heat resistance compared to the unfilled materials. Adding finely dispersed inorganic fillers, for instance $CaCO_3$ and Al_2O_3 in polyester matrix allows adjusting strength properties of the material. It is found out that adding finely dispersed inorganic fillers leads to higher values of surface hardness.

These features of polyester material could be explained by the different nature of interactions between polyester resin and filler. It leads to significant changes in the structure of supramolecular polyester matrix and to the change of properties of polyester composite.

Technological shrinkage of polyester material depends on the nature of the filler, modifier content, and also on the ratio of the reagents in the composition. It is found out that adding finely dispersed inorganic filler and poly (vinyl chloride) polymer modifier in the polyester matrix causes the reduction of technology shrinkage of the material by 30-35%.

Conclusion

The study discovers that the nature and content of finely dispersed inorganic filler calcium carbonate and aluminum oxide substantially affect the elastic-deformation, thermal and technological properties of modified poly (vinyl chloride) polyester materials.

Highly filled modified polyester composites are characterized by the increased values of Vica heat resistance, hardness, modulus of elasticity and reduced values of technological shrinkage.

Adding poly (vinyl chloride) leads to increases of highly elastic features of polyester composites. Evidently, it is due to the formation of partly interpenetrated grid involving structured polyesters and poly (vinyl chloride) macromolecules.

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