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Preparation of Glass Fiber Reinforced Polyvinyl Chloride Composites by Aqueous Suspension Impregnation*

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Abstract An aqueous suspension impregnation technique has been developed and extended to prepare rigid polyvinyl chloride/glass fiber composites, and the effects of the interphase on properties were investigated.

Keywords aqueous suspension, GF/PVC composite, preparation technique, interphase
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Polyvinyl chloride (PVC) is one of the versatile thermoplastics, and its properties can be modified extensively through compounding or reinforcing. Recently, reports on the preparation and applications of glass fiber (GF) reinforced rigid PVC appear to increase dramatically[1]. GF reinforced PVC composites are normally prepared using melt-blending, solution impregnation or fluid-bed processes. While property enhancement can be achieved, problems associated with the methods have imposed. These include low fiber content and poor fiber dispersion due to the difficulties in PVC's flowability, environmental pollution due to the use of toxic organic solvents, and high cost due to the requirement of expensive equipment, etc.

In recent years, an aqueous suspension impregnation method has been developed and used to prepare continuous fiber reinforced high performance resin composites[2,3]. In this process aqueous resin particle suspension is used, eliminating environmental pollution. The manufacturing cost will be low because of the relatively simplified devices. Prepregs with various fiber fractions (20%~70%) can be readily prepared, and granulated fiber reinforced polymer composites with designed fiber length can also be obtained. In this work, we have extended and developed the aqueous suspension technique to prepare PVC/glass fiber composites and the effects of the interphase on properties were investigated.

1 Experimental

The main ingredients of the suspension include water, PVC powder and other additives. The PVC powder (PVC XS-5) used is a product of Guangzhou Chemicals Factory.

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All other chemicals and additives are CP grade reagents. The impregnation device is schemed in Figure 1, which consists of a set of tow guides, a suspension vat, a heating stove and a cutter. The glass fiber tows were impregnated, dried, and then compression or injection moulded.

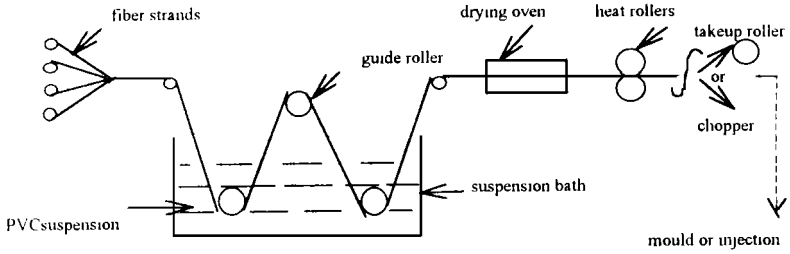

Fig. 1 Schematoc diagram of the aqueous suspension impregnation process

2 Results and Discussion

To take the advantage of the aqueous technique, systematic investigations on the suspension composition and additives, their effects on the stability of the suspension system and the properties, control of fiber dispersion and content, the design and control of interphase, as well as various of processing parameters have been carried out in the study.

It was shown that powdered PVC resin with rough surface obtained by suspension polymerization was suitable for the process. With addition of suitable surfactants and mechanical stirring, stable aqueous suspension system can be achieved. To stabilize the PVC resin upon heating, liquid organic tin compound can be used as an efficient thermo-stabilizer. It was evident that the resin content of the composite is controlled by the suspension concentration, and the particle size and distribution of the resin powders, with higher concentration, smaller size and narrower distribution being favorable to the higher resin content. Additionally, the impregnating mode and the passing speed of the fiber bundles through the suspension are also found to affect the resin content.

Based on the results of the formulation studies and the specified conditions, GF/PVC composites with fixed fiber fraction of w 30% were prepared with different suspension formulas. The typical data of mechanical and physical properties of the composites are compared with those prepared by other methods, as given in Table 1. It can be seen that the properties of the materials fabricated by the aqueous method are quite satisfactory. Meanwhile, it has also been found that further property improvement of the composite is possible with proper control of various factors.

It is well known that interphase in a polymer composite governs the loading transfer between the fibers and matrix and therefore affects the mechanical properties of the composites[4]. As can be expected, the interfacial issues are more complicated in the aqueous suspension system because both the liquid-solid and solid-solid interfaces present, and the existing additives such as surfactant(s) and polymeric binder may interact variously with other compositions and function on the interface and interphase. Among other factors, interaction and/or compatibility of the binder component with the PVC matrix and the fiber surface are found to be the most important factor in influencing the structure of interphase and the mechanical properties.

Tab. 1　Comparison of the properties of GF/PVC[1] composites prepared by suspension impregnation with other methods

Sample	I_F /MPa[2]	I_I /MPa[3]	θ_H /℃[4]	C_T /(m·℃$^{-1}$)[5]
Formula-1	210	96		
Formula-2	308	98	88.7	9.5590×10^{-5}
Formula-3	212	81		
Melt-blending chopped GF(w= 30%)	163	6.6 (Notched)	89.5	
Fluid-bed chopped GF(w= 30%)	160	35		
Net PVC XS-5	97	9.8	88.5	1.2732×10^{-4}

1) PVC resin used in this study is PVC XS-5 produced by The Chemical Factory of Guangzhou
2) I_F is flexural strength; 3) I_I is impact strength; 4) θ_H is heat distortion temperature; 5) C_T is thermal expansion coefficient

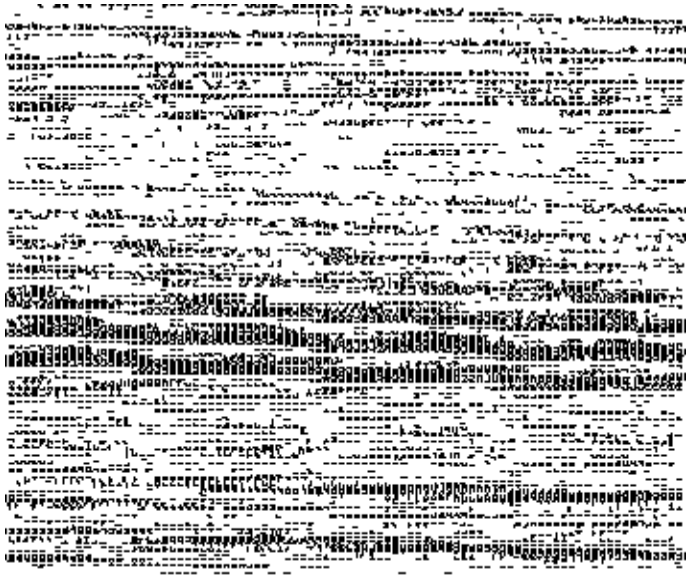

Fig. 2　SEM micrographs of fracture surface of the GF/PVC composites with different binders and surface treatment

To evaluate the effects of different binders on the microstructure of interphase as well as its effects on the properties, binders with different chemical natures, such as vinyl-acetic ester copolymers, acrylic ester copolymers and NBR latex, have been used in preparing the GF/PVC composites. Figure 2 shows the representative SEM morphologies of the impact fracture section of the corresponding composites. Poor interfacial adhesion can be seen (Fig. 2a) when the fibers were not treated with any coupling agent. Poor adhesion is also observed in the case of lacking compatibility between the binder and the matrix (Fig. 2b). On the other hand, good interfacial adhesion can be obtained for the systems in which the polymer binder is compatible with PVC and when the fibers were treated with suitable coupling agent (Fig. 2c). When the polymer binder used is not only compatible with the matrix, but can also react chemically with the coupling agent or fiber surface,

strong interfacial adhesion can be achieved (Fig. 2d). Therefore, the design and control of interphase for the aqueous suspension process depend mainly on the formulation of suspension, the nature of polymeric binder and the surface treatment of the glass fibers.

In summary, using the technique developed in this study, GF/PVC composite materials with satisfactory properties have been obtained. More detailed results and further development of this technique are to be described in our coming reports.

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水悬浮法制备玻璃纤维/聚氯乙烯复合材料的研究

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摘 要 阐述了水悬浮法制备纤维增强热塑性树脂基复合材料的主要优点, 着重研究了用水悬浮法制备玻璃纤维增强聚氯乙烯复合材料的工艺技术和工艺配方以及用该方法制备的复合材料的性能. 并研究了水悬浮法制备 GF/PVC复合材料的界面层设计及其对材料性能的影响.

关键词 水悬浮法, GF/PVC复合材料, 制备工艺, 界面层

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