Mechanical properties of short-fiber polymer matrix composites

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Abstract The influence of fiber content and aspect ratio L/D on the compression strength of high-density polyethylene- short glass fibers composite was investigated. Composite was produced by hot isostatic compression. Glass fibers reinforced polymer, but for the higher content of fibers, the premix is needed. The influence of fiber dimensions was defined as aspect ratio; the higher aspect ratio L/D, the higher compression strength.

Introduction

High demands on materials for better overall performance has led to extensive research and development efforts in the composites fields. These materials have low specific gravity that make their properties particularly superior in strength and modulus to many traditional engineering materials such as metals. Composite materials that exist today can be categorized into five major classes, which include ceramic matrix composites (CMCs), metal matrix composites (MMCs), intermetallic matrix composites (IMCs), carbon-carbon composites (CCCs) and polymer matrix composites (PMCs). In this discussion, considerable attention is paid to the latter class of materials (PMCs) [1,2].. There are two important types of polymer matrix composites, short-fiber and continuous-fiber composites. The choice of polymer matrix for such composites can be either a thermoset or a thermoplastic [3,4].

Short-fiber composites on the other hand are primarily reinforced with chopped fibers such as glass, graphite and cellulose fibers. These types of composites are very common and well established in many applications that require low strength and stiffness such as automotive and appliance applications. Compared to continuous-fiber composites, short-fiber composites can be easily processed in a similar manner to the matrix. In the case of thermoplastics, methods such as molding can be adopted to allow mass production of molded products with complex shape.

The properties of a composite material are strongly influenced by the properties of its constituents and their distribution and also the quality of interactions among them. The most important of all the composite properties are usually the mechanical properties, since whatever may be the reason for the choice of a particular composite for some application, it must have certain characteristics of shape, rigidity and strength.

The mechanical properties of continuous-fiber composites, such as stiffness, can be predicted using several prediction schemes such as the “Rule of Mixtures” and the Halpin-Tsai equations [3]. In contrast, in the case of short-fiber composites, these properties are difficult to predict. This is due to the various factors that influence the properties. Such factors include (i) the fiber dispersion, (ii) the orientation and geometry (aspect ratio- length divided by effective diameter, L/D) of the fibers within the composites, (iii) the fiber

volume fraction, and (iv) the quality of the interface between the reinforcing fiber and polymeric matrix phase. These parameters are often difficult to control particularly during processing [5-8].

Experimental

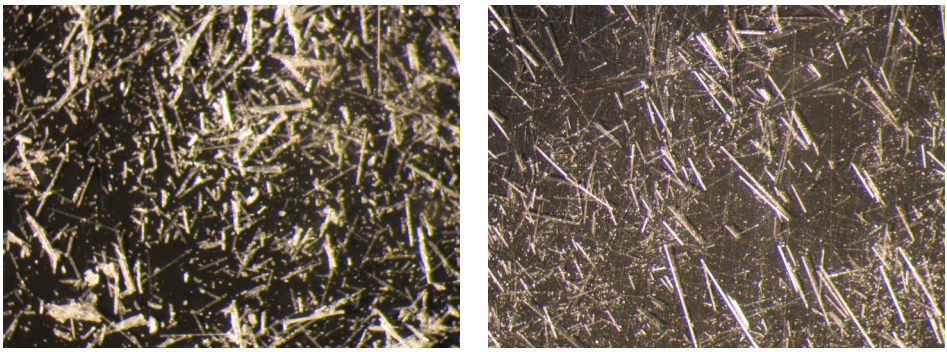
In this paper, the investigation of processing of the composite material high density polyethylene- short glass fiber was reported. The started material for reinforcement short fibers was a wasted glass mat – a felt made of randomly oriented short fibers cuts to shape called preforms, which are impregnate with urea-formaldechide. Glass mat was chopped to obtain short glass fibers. The particles selected by dimension and then mixed with bonding polymer. The samples were processed by hot isostatic compression (pressure 41.38 MPa, temperature 160-170ºC, time 26 min).

The referent sample from pure polyethylene and three Series of composite samples (in respect of L/D) were processed (Table 1). The aspect ratio L/D for the series was obtained by image analyzing of glass fibers (figures 1-3). The short glass fibers were annealed for better images and measuring of fibers dimensions.

The fourth series of composite samples was processed with annealed mat, in the aim to investigate the role of urea-formaldechide in the quality of interface between fibers and polymer.

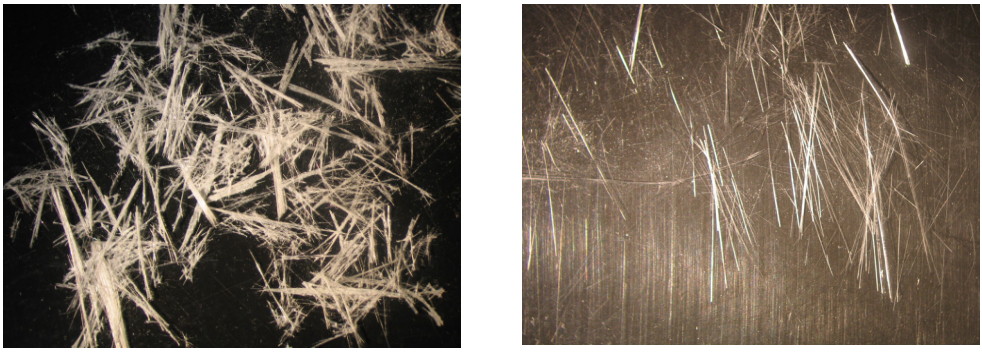
Table 1. *The composition of samples series*

Series	L/D	Fiber contents (mass.%)
I	16.71	30
		40
		50
II	173.72	30
		40
		50
III	258.92	30
		50
IV	225.79	30
		40
		50



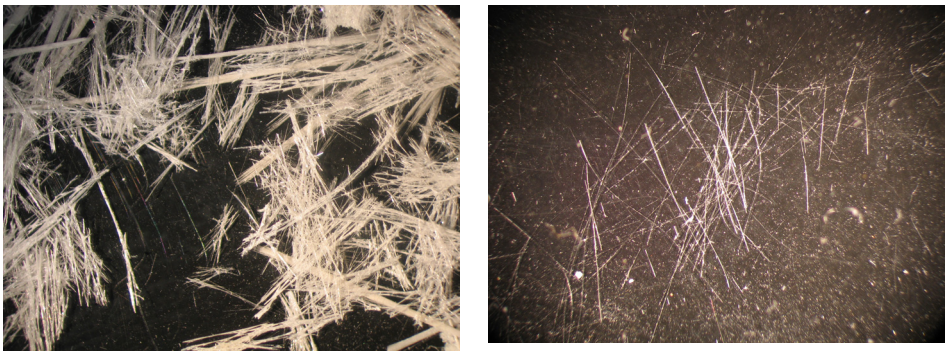
a) b)

Fig 1. *Short glass fibers of Series I: a) chopped mat (40 ×), b) annealed fibers (10 ×)*



a) b)

Fig 2. *Short glass fibers of Series II: a) chopped mat (31 ×), b) annealed fibers (1.65×)*



a) b)

Fig. 3. *Short glass fibers of Series III: a) chopped mat (27 ×), b) annealed fibers (1.65×)*

Results and discussion

The effect of the fiber content and fiber length (aspect ratio) on the compression strength of composites was investigated. The compression tests of samples normal to direction of processing compression were performed. Because of cylindrical shape of samples the compression strength were expressed as the force when first crack obtained (Table 2. and fig. 4).

Table 2. *Results of compression tests*

L/D	Fiber contents (mass.%)	Compression strenght (kN)
-	0	1.766
16.71	30	4.905
	40	3.237
	50	2.354
173.72	30	5.101
	40	4.120
	50	3.728
258.92	30	5.886
	50	3.139
225.79	30	3.139
	40	3.041
	50	2.747

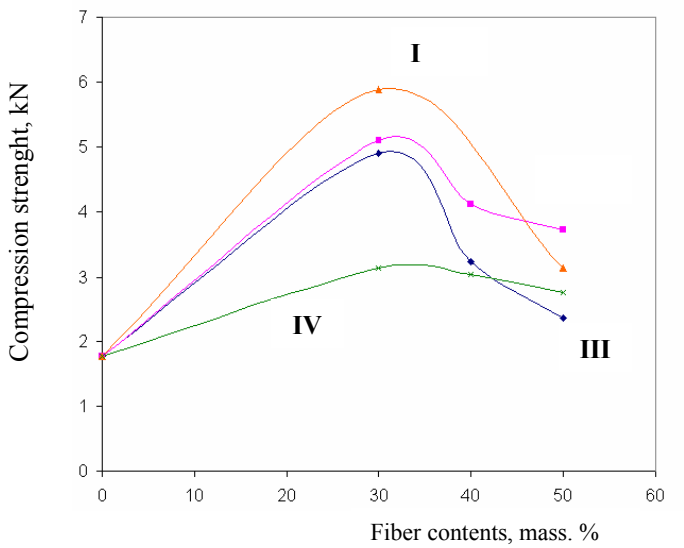


Fig. 4. *Results of compression tests*

Conclusion

In this paper, the influence of composition of polymer matrix composites and aspect ratio of reinforcement fibers was investigated. In this aim the several series of samples with different content of fibers and different aspect ratio L/D was processed by hot isostatic compression. The compression test of samples was undertaken.

It is obvious that glass fibers reinforce polymer; the higher aspect ratio L/D, the higher compression strength. The falling of compression strength values with increasing of fiber content pointed out to limitation of this method of processing. It is need to make a premix for higher fiber contents for this process of hot isostatic compression. The lowest values for the compression strength were showed series IV with annealed mat. This result pointed out to influence of urea-formaldechide on the better quality of the interface between the glass fiber and polymeric matrix phase.

References

[1].K. H. G Ashbee, fundamentals Principles of Fiber Reinforced Composites, 2nd edition, Technomic Publishing Company, Inc., Lancaster, PA, 1993.

[2]. M.J. Folkes, Short Fiber Reinforced Thermoplastics, John Wiley& Sons, New York, 1982

[3] G. M. Newaz, " Polymer-Matrix Composites ", in Materials Science and Technology – Vol, 13, T. W. Chou (ed.), VCH, NewYork, 1993.

[4] T. W. Clyne, and D. Hull, in An Introduction to Composite Materials, 2 nd ed.,Cambridge University Press, Cambridge, 1996, pg. 1-3.117

[5] J. R. White and S. K. De, " Survey of Short Fiber-Polymer Composites ", Short Fiber-Polymer Composites, J. R. White and S. K. De (eds.), Woodhead Publishing, Cambridge, 1996.

[6] M. G. Brader and A. R. Hill, " Short-Fiber Composites ", *Materials Science andTechnology* – Vol. 13, T. W. Chou (ed.), VCH, New York, 1993.

[7] G. B. Nando and B. R. Gupta, " Short Fiber-Thermoplastic Elastomer Composites ", in Short Fiber-Polymer Composites, J. R. White and S. K. De (eds.), Woodhead Publishing, Cambridge, 1996.
[8] D. N. S. Han and S. T. Sean, " Composites from Newsprint Fiber and Polyolefin : Their Processability and Properties", in Wood Fiber/Polymer Composites: Fundamental Concepts, Process, and Material Options, Forest Product Society, Madison, 1993.
[9] S. M. Shaler," Mechanics of the Interface in Discontinuous Wood Fiber Composites", in Wood Fiber/Polymer Composites: Fundamental Concepts, Process, and Material Options, Forest Product Society, Madison, 1993.