Revue des Sciences et Sciences de l'ingénieur
Journal of sciences and engineering sciences
ISSN 2170-0737/EISSN: 2600-7029
https://www.asjp.cerist.dz/en/PresentationRevue/303

Tensile behavior of high density polyethylene composites with organic and inorganic fillers

***El-Miloudi Khaled, Bentouta Karima and Hamadouche Khadidja**

Laboratoire de physique théorique et physique des matériaux, Université Hassiba Benbouali de Chlef, Algérie

Article history
Submitted date: 2018-02-04
Acceptance date: 2018-09-06

Abstract

This contribution deals with the influence of the nature of the filler on the mechanical properties of a polymer matrix. Composites of high density polyethylene and different fillers such as clay, fiberglass, wood sawdust and paraffin were prepared at various concentrations and their tensile behavior was studied. The compatibility between the polymer matrix and the filler is shown to be the key factor to the enhancement of the mechanical behavior.
Keywords: *High density polyethylene, tensile behavior, filler type.*

Résumé

Cette contribution porte sur l'influence de la nature de la charge sur les propriétés mécaniques d'une matrice polymère. Des composites de polyéthylène haute densité et différentes charges telles que l'argile, la fibre de verre, la sciure de bois et la paraffine ont été préparés à diverses concentrations et leur comportement en traction a été étudié. La compatibilité entre la matrice polymère et la charge s'avère être le facteur clé de l'amélioration du comportement mécanique.
Mots-clés : *Polyéthylène haute densité, comportement en traction, type de charge.*

1. Introduction

Nowadays, both industry and academia are interested in the development of innovative materials based on polymer/filler composites. High density polyethylene (HDPE) is a worldwide commonly used thermoplastic in many fields such as piping and packaging. The improvement of its mechanical properties by incorporating different fillers is an interesting route especially for recycled HDPE. Recently, Khalaf (1) demonstrated that it is possible to make eco-friendly composites of HDPE and lignocellulosic filler from food industry wastes. The composite shows better mechanical behavior than pure HDPE.

In this study, tensile tests are made on composites of HDPE and four fillers of different chemical nature and physical morphology: wood sawdust, paraffin, clay and fiberglass. We aim to investigate the influence of the filler type on the mechanical behavior of HDPE composites.

2. Experimental

Materials:

PEHD, paraffin and short strand fiber glass were gratefully supplied by SOTUPLAST, a local plastics company. The clay used in this study was gratefully supplied by ECDE, a local cement company of the Chlef region, Algeria. The wood floor was collected from local carpentry workshops as sawdust. All materials were used as received without further purification.

Preparation method:

About 90 g of a mixture of polymer+filler in appropriate percentages were introduced in a mold and heated at 250°C during 25 min to ensure total fusion of the mixture. After cooling of the obtained plates, dog bone specimens for tensile testing were shaped according to ASTM D638 as a standard testing method for thermoplastic materials. The overall specimen dimensions were 165, 19 and 3 to 4 mm for length, width and thickness, respectively. The specimens were finished to be free from cracks or necks to avoid false facts during testing.

Mechanical properties:

The tensile tests were conducted on a universal Gunt brand type WP 310 (50 kN) machine.(2) The loading rates were set to be 10 mm/min. The specimens were placed between the extensometer grips and the slipping was avoided as much as possible. The load, extension, stress and strain were collected as numerical values output via a computer connection. At least 5 specimens were tested and averaged for each sample.

3. Results and discussion

Tensile tests of pure PEHD and its composites are presented in this section and discussed on Young's modulus basis

3.1 Tensile behaviour of pure PEHD

Melted pure PEHD specimens were cooled to room temperature by quenching in an ice bath or slowly in air. The thermal history had a huge influence on the tensile behaviour of the under study specimens. Figure 1 shows the stress-strain curves of air cooled or quenched PEHD.
The different thermal treatment resulted in two different performances. The air cooled PEHD has a linear elastic solid profile. However, the quenched one shows both elastic and plastic regions. This is due to the different chain conformation depending on the thermal treatment.

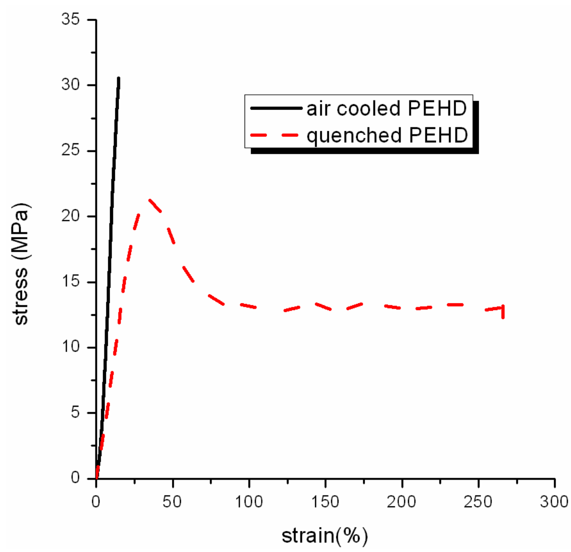

Fig. 1: tensile test of air cooled and quenched PEHD

On the melted state, the polymer chains conformation distribution is stochastic under thermal agitation. The subsequent quenching freezes the polymer chains in a totally disordered configuration. The resulting material is totally amorphous with a ductile/plastic behaviour.

On the other hand, air cooling gives a sufficient time to the polymer chains to rearrange in a more ordered conformation. The polymer became semi-crystalline with amorphous and crystalline regions resulting in a brittle/elastic material.

As the tensile behaviour of the ductile material was unpredictable and non-reproducible, we choose to cool the composites specimens in open air to determine conveniently the Young's modulus.

3.2 Tensile behaviour of PEHD composites

The choice of the fillers used in this study is not justified only by their availability and ease of use but because of the interesting applications of their composites with a polymeric matrix.

So, it was shown that PEHD/Paraffin wax composites could be used as phase change materials (3). PCMs are able to store and release large amounts of energy upon melting and solidifying and hence are used as energy storage materials. PEHD matrix has the role to keep the paraffin in confined area and prevent its leakage upon melting.

PEHD/wood sawdust composites find their uses as engineering materials for house-wares, automotive industries and various construction applications (4).

Fiberglass strands are reinforcing agents and are incorporated in a polymer matrix to give a strong and stiff low density material (5).

Clays are nano-layered materials with interesting properties. The intercalation or exfoliation of the nanolayers in a polymer matrix results in a material with good gas barrier suitable for gas storage or pipelines welding protection (6-7).

Table 1: Young's modulus of PEHD composites

Composite	Filler load (wt %)	Young's modulus (GPa)
Pure PEHD	---	0.197
PEHD/Clay	2	0.159
	4	0.170
PEHD/Fiber glass	2.5	0.150
	5	0.194
	7.5	0.133
PEHD/Wood sawdust	2.5	0.128
	3	0.146
	4	0.175
PEHD/Paraffin	4.5	0.129
	8.4	0.134
	13.5	0.104

It was reported that the composites properties depend on the size and the distribution of the filler particles and their surface compatibility with the matrix (8-9). So, the compounding to be effective, the filler surface must be treated with a coupling agent to augment the adherence to the polymer and guarantee better dispersibility.

Accordingly, tensile tests were conducted in order to explore mechanical properties of PEHD composites with aforementionned fillers. The Young's modulus of the composite specimen was averaged from at least 5 stress-strain curves. Table 1 gathers the data according to the type of the composite and the filler load.

As can be seen from Table 1, no improvement of the stiffness of PEHD was performed by incorporating the different fillers at different loads unless flexibility is needed for a special application. This is due to the compounding methodology or to the thermal treatment of the composites.

Comparing the results of tensile tests, fiber glass had the best performance in the enhancement of PEHD stiffness especially the 5 wt % composite. The fiber glass absorbs and distributes the stress transmitted by the polymer matrix resulting in a stiffer material. However, the reinforcing action of the fibers disappears at higher concentration because of the agglomeration of fiber glass and lack of adherence with the polymer matrix.

Also, the thermal treatment could induce phase separation due to differences between the filler and the polymer in terms of heat conductivity and volume changing rate. Thus, the filler became a structure defects rather than a reinforcing agent. So, the monitoring of the thermal treatment is primordial to develop a composite material with good mechanical properties.

4. conclusion

Tensile tests were conducted on high density polyethylene with four fillers: clay, fibre glass, wood sawdust and paraffin. The results show a great influence of the thermal treatment on the tensile behaviour of pure HDPE.

However, no enhancement of the stiffness of this polymer was noticed by incorporating any of the studied fillers. The lack of interfacial adherence and the incompatibility between the polymer and the fillers is responsible for the degradation of the mechanical properties of HDPE.

The influence of the size and the dispersibility of the filler particles are an important issue to the formulation of new composite materials.

References

[1] Moayad N. Khalaf, M.N., Mechanical properties of filled high density polyethylene, Journal of Saudi Chemical Society, Volume 19, Issue 1, January 2015, Pages 88–91

[2] Bentouta, K., Hamadouche, K. and El-Miloudi K., Comparative Study of the Mechanical Performances of Polyethylene Composites, FRACT'2, Chlef, Algeria 2013

[3] Sotomayor, M.E. et al. Thermal and mechanical characterization of injection moulded high density polyethylene/paraffin wax blends as phase change materials, Renewable Energy, Volume 68, August 2014, Pages 140-145

[4] Behzad, H.M., et al. Impacts of wood preservative treatments on some physico-mechanical properties of wood flour/high density polyethylene composites, Construction and Building Materials, Volume 35, October 2012, Pages 246-250

[5] Masuelli, M.A. (2013). Introduction of Fibre-Reinforced Polymers – Polymers and Composites: Concepts, Properties and Processes, Fiber Reinforced Polymers - The Technology Applied for Concrete Repair, Dr. Martin Masuelli (Ed.), ISBN: 978-953-51-0938-9, InTech

[6] Kotal, M., Anil K. Bhowmick, A.K., Polymer nanocomposites from modified clays: Recent advances and challenges, Progress in Polymer

Science, Volume 51, December 2015, Pages 127-187

[7] Jeremy J. D. et al, Polyethylene-based nanocomposites containing organoclay: A new approach to enhance gas barrier via multilayer coextrusion and interdiffusion, Polymer, Volume 61, 20 March 2015, Pages 42-54

[8] E. Eichner, S. Heinrich, G.A. Schneider, Influence of particle shape and size on mechanical properties in copper-polymer composites, Powder Technology, 2018, *in press*.

[9] Cindy S. Barrera, Katrina Cornish, Processing and mechanical properties of natural rubber/waste-derived nano filler composites compared to macro and micro filler composites, Industrial Crops and Products, Volume 107, 2017, Pages 217-231.