Archives of Materials Science and Engineering

Volume 35
Issue 1
January 2009
Pages 29-32

International Scientific Journal published monthly by the World Academy of Materials and Manufacturing Engineering

Mechanical and morphological properties of basalt filled polymer matrix composites

A. Akinci*

Department of Metallurgical and Materials Engineering, Engineering Faculty, Sakarya University, Esentepe Campus, 54187, Adapazari, Turkey

* Corresponding author: E-mail address: akinci@sakarya.edu.tr

Received 14.11.2008; published in revised form 01.01.2009

ABSTRACT

Purpose: The aim of this work is to study the effect of basalt on physical, mechanical and morphological of the injection molded LDPE.

Design/methodology/approach: In this study, the effect of basalt was investigated as a filler material in polymer matrix composite (PMC) and low density polyethylene (LDPE) was chosen as a matrix material.

Findings: A variety of mechanical tests were performed on the resultant composites which has appropriate compositions. Tensile, flexural, density and hardness tests have been carried out and, the relationship between the basalt content and properties were examined. XRD and SEM facilities were applied on polished and fractured surfaces after flexural tests respectively.

Research limitations/implications: In present study, it was found that, the content of basalt filler affected structural integrity and mechanical properties of composites. With increasing the amount of the basalt addition to the LDPE results in a decrease in elongation at break values.

Originality/value: It is thought that the nucleating effect of the basalt leads to an increased rate in orientation of the polymer. The crystallization was increased by increasing the basalt content. Basalt addition was observed to be an alternative additive to the LDPE. If suitable coupling agents could be added to basalt and LDPE mixtures, the mechanical properties can possibly be increased.

Keywords: LDPE; Basalt; Fracture surface; Mechanical properties

Reference to this paper should be given in the following way:

A. Akinci, Mechanical and morphological properties of basalt filled polymer matrix composites, Archives of Materials Science and Engineering 35/1 (2009) 29-32.

PROPERTIES

1. Introduction

Recently, polymer-inorganic particle composites have received considerable interest in the materials field because of their potential for large gains in mechanical and morphological properties. Thermoplastic polymers and especially polyolefins are produced and consumed today in vast quantities. However, they are seldom used as pure polymers and are usually combined with mineral fillers. Fillers find application in the polymer industry almost exclusively, e.g. to improve mechanical, thermal, electrical properties and dimensional-stability. LDPE composites are used in various applications as decks and docks, packaging film, pipes, tubes, window frames or, in the last years, also as materials in the automobile industry [1-6].

Basalt is a grey to black, fine-grained volcanic rock which is the major constituent of ocean islands and common component of the continental masses as well. Volcanic basalt rocks are widely available in various regions of Turkey. Basalt finds wide application in industry as abrasion, wear and chemical resistant materials. It can also be used as filler material for production of the PMC. They can be used wherever the transport of material causes mechanical or chemical abrasion as well as mineral wool for heat, noise and fire insulation [7-9].

The morphological features of semi-crystalline polymers such as crystalline level, crystal thickness, etc. are mainly governed by the nature of the polymer. Crystalline morphology is also strongly sensitive to thermo-mechanical treatment and processing. The five major methods of determining crystallization are based on specific volume, X-ray diffraction, thermal analysis, nuclear magnetic resonance, and infrared spectroscopy [10-13].

In the present work, test materials have been prepared a series of filled LDPE composites with basalt filler loading (10–70 wt. %), to study the effect of the filler content. The aim of this work is to study the effect of basalt on physical, mechanical and morphological of the injection molded LDPE.

2. Experimental

In this study, in order to characterize the polymer/basalt composites that produced tensile testing, three-point flexural testing, hardness, density, XRD and SEM were utilized. A series of filled LDPE composites with basalt filler loading (10-70 wt. %) was prepared to study the effect of the filler content. Four different weight percentage of basalt was introduced to LDPE to investigate the relationships between LDPE and basalt combinations. The polymer matrix material that used in this study is a commercial grade LDPE supplied by Turkish Petkim Polymer Industry. Natural basalt volcanic rocks obtained from the Middle Anatolia region of Turkey were used in PMC. Basalt rocks were obtained as a chunk and crashing was carried out in a jaw and conic crushers. The resultant powder was then ground using ring grinder and sieved to the particle size of under 90 μm for PMC production.

For tests the samples were manufactured in the form of rectangle plates. For production of basalt filled polymers an injection apparatus was used which has five different heating stages of 165, 175, 180 °C. Injection and molding pressure were chosen as 5 MPa and 9 MPa respectively. The mould temperature was fixed at 30 °C and the pressure was applied for 30 sec.

Tensile and three point flexural tests were carried out on an Instron 3367 universal test machine. The procedures were defined by the ASTM D 638 and ASTM D 790 standards respectively. The hardness tests were performed on Durotech, analogue shore scale hardness tester. ASTM D 792 standard was used for the density tests. Rigaku D/MAX/2200/PC model XRD analysis was done on PMC that prepared metallographically by polishing with 1000 grid emery paper. The SEM studies of the basalt filled polymers were obtained by using Jeol JSM-6060LV Scanning Electron Microscopy. Before the SEM studies, the gold coating was applied on the samples surface for the conductivity of the samples.

3. Results and discussions

The basalt used in this study are inorganic in nature whereas LDPE is an organic material. Processing conditions were chosen same for all the composites, the interaction between inorganic and organic materials is very slight. The addition of basalt the higher the flexural strength, the elastic modulus, the density, the hardness while the lower the tensile strain to fracture, the toughness and fracture energy as expected. The reduction of elongation at break values with increasing basalt content is indirect evidence that implies the bonding strength is poor. The polymer chains have enough time and amorphous regions with applied load. After immediately orientation of chains during tests the crystallinity start formation and this causes increase in elastic modulus of composite [4, 14]. Also, the filler added to polymer matrix restriction the motion of polymer chains and thus lowers tensile strain to fracture sharply. It was found that the hardness of test materials increased with the basalt content. The addition of basalt no remarkable affect on tensile strength to fracture of composite. Results showed that almost there is a linear relationship between mechanical properties and basalt weight percent. It is clear from the experiments that tensile, flexural and elongation at break values are influenced mainly by the ratio of basalt fillers. Physical and mechanical properties of basalt filled LDPE are given in Table 1.

XRD pattern of the basalt is given in Figure 1, it is seen that in Figure 1 the basalt is in the form of Augite (Ca(Mg0.85Al0.15)((Si1.70Al0.30)O6), Augite aluminian ($Ca(Mg,Fe,Al)(Si,Al)_2O_6$), Anorthite ($(Ca,Na)(Si,Al)_2Si_2O_8$), Albite ($NaAlSi_3O_8$) and Diopside ($CaMgSi_2O_6$). In Figure 1, two different crystal planes of the LDPE $(C_2H_4)_n$ material are shown with 1 and 2 peaks. XRD analysis is also used for determining the orientation relationships in the filled LDPE. The diffraction peaks were observed in 2 theta angles of 21.30 and 23.60 for planes corresponding to 1 and 2 respectively [1,15]. The intensity ratios of these two peaks are identified as crystallization degree or the orientation of the crystal paleness for LDPE [11,12,13]. The X-ray diffraction analysis proved that introducing of basalt particles resulted in an increase of crystallization degree of LDPE. In this study, it is expected that the plates of basalt particles lie parallel to the surface of the mold, and this orientation can induce a preferential orientation in the morphology of LDPE crystals placed near the filler. As shown in Table 2 the crystal orientation ratio of the (I_2/I_1) planes produced a value of 0.25. The more addition of basalt increase the orientation ratio. The relationship between the orientation ratio and the basalt content is given in Figure 2. As shown in Figure 2 (I_2/I_1), the more the basalt content the higher orientation ratio.

Table 1.
Physical and mechanical properties of basalt filled LDPE

Basalt content (wt. %)	Tensile strength to fracture (MPa)	Tensile strain to fracture (%)	Flexural strength (MPa)	Elastic modulus (MPa)	Toughness (MPa)	Fracture energy (MPa)	Hardness (Shore D)	Density (g/cm^3)
0	7.29	266.53	6.44	138.68	18.96	81.91	45.50	0.94
10	6.96	132.33	6.88	206.77	8.85	35.97	48.00	1.01
30	7.08	43.49	8.71	290.08	2.86	11.62	49.70	1.17
50	5.87	14.80	10.88	458.94	0.78	3.43	55.30	1.42
70	6.87	4.17	12.57	1438.66	0.03	1.10	68.70	1.81

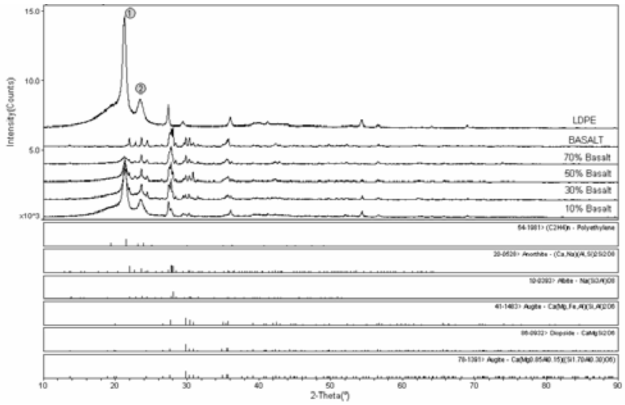

Fig. 1. XRD patterns of the pure LDPE, basalt and including 10–70 wt. % basalt LDPE matrix composites

As it can be seen in Figure 1, intensities of peaks of polymer decreases with increased the amount of basalt content. The basalt peaks have been dominant with increasing basalt content of composite. It is possible to claim that this affect mechanical and physical properties of composite.

Table 2.
The peak Intensity (%) of the (1) and (2) planes and crystal orientation ratio I_2/I_1 for LDPE composites

Basalt content (wt. %)	Intensity (%)		I_2/I_1
	I_1	I_2	
0	100	25	0.25
10	81	27	0.33
30	43	25	0.58
50	28	19	0.68
70	12	15	1.25

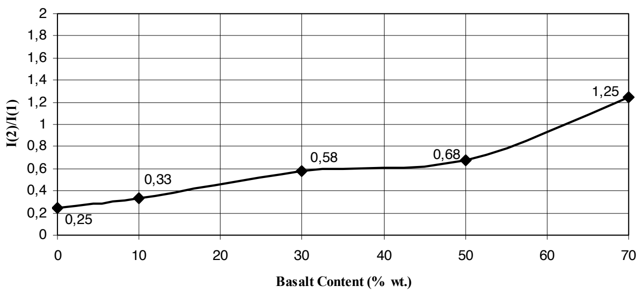

Fig. 2. Dependence of the reflection intensity (I_2/I_1) ratio on filler content

Fractured surfaces of PMC materials, including 10%, 30 %, 50% and 70% of basalt compositions, attained as a result of flexural strength test are analyzed by SEM method (Figure 3). The white areas reflect basalts and the gray areas show LDPE. In Figure 3 a and Figure 3 b, LDPE deforms in shape of fibrous nature are due to a high proportion of LDPE ingredient like 90% and 70% respectively. It can be observed that the numbers of basalt particles are enormous due to the composition of 50% and 70% basalt (Figure 3 c and Figure 3 d), the particle is not removed from surface. These can be attributed to existence of the bond between particle and matrix.

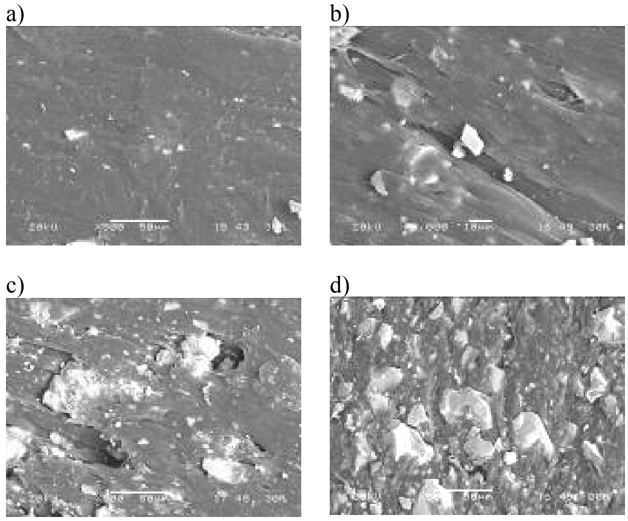

Fig. 3. The microstructure of the fractured surfaces of the composite X500, a) 10 wt. % basalt, b) 30wt. % basalt, c) 50 wt. % basalt, d) 70 wt. % basalt

4. Conclusions

In present study, it was found that, the content of basalt filler affected structural integrity and mechanical properties of composites. Basalt can be added to the polymers up to 30-70 wt. % to increase the hardness, flexural strength, elastic modulus and density. With increasing the amount of the basalt addition to the LDPE results in a decrease in elongation at break values. The Shore hardness value of the basalt filled LDPE was measured and it was seen that the basalt weight percent increases the hardness. XRD investigations showed that the crystallization ratio changes in the LDPE composites. It is thought that the nucleating effect of the basalt leads to an increased rate in orientation of the polymer. The crystallization was increased by increasing the basalt content. Basalt addition was observed to be an alternative additive to the LDPE. If suitable coupling agents could be added to basalt and LDPE mixtures, the mechanical properties can possibly be increased.

References

[1] A.S. Luyt, V.G. Geethamma, Effect of oxidized paraffin wax on the thermal and mechanical properties of linear low-density polyethylene–layered silicate nanocomposites, Polymer Testing 26/4 (2007) 461-470.

[2] P. Mareri, S. Bastide, N. Binda, A. Crespy, Mechanical behaviour of polypropylene composites containing fine mineral filler: Effect of filler surface treatment, Composites Science and Technology 58/5 (1998) 747-752.

[3] B. Pukanszky, G. Voros, Stress distribution around inclusions, interaction, and mechanical properties of particulate-filled composites, Polymer Composites 17/3 (1996) 384-392.

[4] M. Micusik, M. Omastova, Z. Nogellova, P. Fedorko, K. Olejnikova, M. Trchova, I. Chodak, Effect of crosslinking on the properties of composites based on LDPE and conducting organic filler, European Polymer Journal 42/10 (2006) 2379-2388.

[5] A.O. Maged, A. Ayman, W.S. Ulrich, Influence of excessive filler coating on the tensile properties of LDPE–calcium carbonate composites, Polymer 45/4 (2004) 1177-1183.

[6] J. Jancar, Advances in polymer science. Mineral fillers in thermoplastics I, vol. 139, Springer, Berlin/Heidelberg, 1999.

[7] G.H. Beall, H.L. Rittler, Basalt glass-ceramics, American Ceramic Society Bulletin 55/6 (1976) 579-582.

[8] S. Yilmaz, O.T. Ozkan, V. Gunay, Crystallization kinetics of basalt glass, Ceramics International 22/6 (1996) 477-481.

[9] V. Znidarsic-Pongrac, D. Kolar, The crystallization of diabase glass, Journal of Materials Science 26/9 (1991) 2490-2494.

[10] T. Labour, C. Gauthier, R. Seguela, G. Vigier, Y. Bomal, G. Orange, Influence of the β crystalline phase on the mechanical properties of unfilled and $CaCO_3$-filled polypropylene. I. Structural and Mechanical Characterisation, Polymer 42/16 (2001) 7127-7135.

[11] J.I. Velasco, C. Morhain, A.B. Martinez, M.A. Rodriguez-Perez, J.A. de Saja, The effect of filler type, morphology and coating on the anisotropy and microstructure heterogeneity of injection-moulded discs of polypropylene filled with aluminium and magnesium hydroxides. Part 1. A wide-angle X-ray diffraction study, Polymer 43/25 (2002) 6805-6811.

[12] M. Alonso, J.I. Velasco, J.A. de Saja, Constrained crystallization and activity of filler in surface modified talc polypropylene composites, European Polymer Journal 33/3 (1997) 255-262.

[13] F.W. Billmeyer, Textbook of Polymer Science, John Wiley and Sons, 1984.

[14] A.S. Luyt, J.A. Molefi, H. Krump, Thermal, mechanical and electrical properties of copper powder filled low-density and linear low-density polyethylene composites, Polymer Degradation and Stability 91/7 (2006) 1629-1636.

[15] J. Maity, C. Jacob, C.K. Das, S. Alam, R.P. Singh, Homocomposites of chopped fluorinated polyethylene fiber with low-density polyethylene matrix, Materials Science and Engineering A 479/1-2 (2008) 125-135.