Materials and Design 60 (2014) 532–539

Contents lists available at ScienceDirect

Materials and Design

journal homepage: www.elsevier.com/locate/matdes

Improvement of ternary recycled polymer blend reinforced with date palm fibre

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ARTICLE INFO

Article history:
Received 23 December 2013
Accepted 11 April 2014
Available online 23 April 2014

Keywords:
Natural date palm fibre
Polymer blend matrix
Recycling
Mechanical properties
Morphology

ABSTRACT

This paper investigates the study and preparation of date palm fibre reinforced recycled polymer blend composites. This is the first paper which describes the recycled polymer ternary blends of (1) recycled low density polyethylene (RLDPE), (2) recycled high density polyethylene (RHDPE) and (3) recycled polypropylene (RPP). The date palm fibre reinforced composites (C_{D00}) were prepared by maintaining constant weight% of fibre of 20 wt% without any fibre treatment. Maleic anhydride (MA) was used as the compatabilizer (1 and 2 wt%) and the effect of compatabilizer on the blend matrix composites was studied. The mechanical, thermal, morphological properties, water absorption and chemical resistance properties were evaluated for these composites and also studied for pure blend matrix (C_{00}). Date palm fibre improved the tensile strength and hardness of recycled polymer blend matrix. Further improvement was achieved with 1% MA (C_{D1}), which showed that 1% MA treated composites (C_{D1}) had higher tensile strength, modulus and hardness properties. Thermal stability and water absorption were improved by 1% MA. These improvements were demonstrated at the nanoscale level by the decrease in roughness appearing in Atomic Force Spectroscopic Microscopy analysis indicating that flow is better under this concentration. The SEM analysis also showed that the fibre matrix adhesion improved by adding 1 wt% (C_{D1}) of MA. The melting and crystallisation temperatures of the blends did not change with the addition of date palm fibre and MA, indicating that the additives did not influence the melting and crystallisation properties of the composites. The chemical resistance test results showed that these composites are resistance to all chemicals but more weight gain observed in solvents. 2 wt% of MA (C_{D2}) caused poor adhesion between the polymer chains and fibres as well as polymer chain scission.

1. Introduction

Recently natural fibres have attracted many researchers as biodegradable reinforcing materials replacing the synthetic fibres for new composites. Natural fibres are emerging as low cost, light weight and environmentally alternatives to glass fibres in composites. These renewable fibres are useful in both thermoplastics and thermosets [1–5]. Thermoplastics are used in many applications because of their desirable physical and mechanical properties. Natural fibres reinforced thermoplastic composites are capable of reducing environmental pollution through integration of biodegradable filler materials [6]. The production of natural fibre reinforced thermoplastic composites also has important economic potential with many applications in different fields [7]. Applications for these products include building and construction materials, such as door and window frames, decking, railings for parapet walls and furniture sections, as well as door panels, setbacks, headlines, package trays, dashboards and trunk liners in the automobile industry [8–10].

In the last decade, thermoplastic composite industry has shifted from the use of high performance advanced composites to cost effective engineering composites by using natural fibres [11,12]. Fillers are also used to modify the properties of plastics, including their modulus and strength.

Researchers around the world are now interested in recycled materials because of the increase in environmental pollution. Waste plastics are abundantly available as solid waste products, and polymers made from petroleum waste are easy to recycle with only the addition of energy. The properties of recycled waste plastics can be approximately the same of virgin materials [13].

Polymer blending is a convenient route for the preparing of new polymeric materials with excellent properties than single polymers

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http://dx.doi.org/10.1016/j.matdes.2014.04.033
0261-3069/

[14,15]. In plastics recycling, blending of different polymers is necessary because the separation of a single component can be difficult or expensive. Polyolefins like Polyethylene (PE) and Polypropylene (PP) are mostly encountered in urban and industrial plastics waste and are recycled after separating the polymers. Polyolefin blends, particularly HDPE (high density poly ethylene) and PP have attracted great deal of attention because these plastics account for a significant percentage of waste material in urban and industrial areas [16]. These waste plastics are recycled after separating the polymers. The heterogeneous recycling of two classes of thermoplastics can lead to obvious advantages [17], such as reducing the amount of energy and saving natural resources needed to create virgin plastic.

In this work, we used three types of recycled polymers as the matrix to reduce the cost and energy used for separation, also we used very cheap and available waste in the middle east which is date palm fibre as reinforcement for making the new composites. One of the major problem with natural fibre composites is the hydrophilic nature of the lingo cellulosic fibre that makes it difficult to achieve bonding with hydrophobic matrices. By performing chemical treatment, bonding properties can be improved [18,19].

There are many reports on chemical modification of natural fibres, including the use of chemical treatments [20,21] and grafted polymers [22]. Maleic anhydride (MA) grafting was developed during the last decade [23,24] to improve the bonding between the polymer and the natural fibre. Malaeated coupling agents are widely used to strengthen composites containing fillers and fibre reinforcements, which modifies the fibre's surface and the polymer (i.e. or PE matrix) to achieve better interfacial bonding and mechanical properties [18]. In this work, we are using maleic anhydride as a compatabilizing agent to improve the bonding between the natural fibre and the matrix. Many authors have analyzed the properties of blend composites with different fillers [25,26] and some literature described the effect of maleic anhydride on polymer blends [27]. Up to our knowledge no one has prepared ternary blend with the date palm fibre. Study on the ternary blend mixtures of pure polymers with different fillers were available in literature [28,29]. These literature used two or three types of pure polymers as matrix and used maleic anhydride grafted as compatabilizers. No reports are available on the properties of date palm fibre reinforced composites prepared from blends of three types of recycled polymers.

Among several existing natural cellulose fibres, we used the date palm fibre in the present work for making the composites, because it is available in the Middle East and North African countries as a natural waste. This tree is a member of the palm tree family (*phoenix dactylifera*) and it is a very important as natural agro crop. Each year, date palm trees are pruned to remove dead or broken leaves. These leaves are partially utilized to make crates, robes, baskets and mats. However, the bulk of the material is discarded as waste. Effective utilization of this natural resource would help to preserve the environment [30]. Several reviews indicated that date palm fibre waste can be used as a reinforcement material in composites with thermoset and thermoplastic matrices [31,32]. However, previous literature have mainly focused on the chemically treated date palm fibre composites with single fibre matrix.

No literature is available about the effect of MA with three types of recycled polymer blend composites with date palm fibre. This study investigates the mechanical, thermal and morphological properties of recycled low density polyethylene (RLDPE), recycled high density polyethylene (RHDPE) and recycled polypropylene (RPP) blend composites with different ratios of MA compatibilising agent and date palm leaf reinforcement fibres. The desired polymer matrix properties were achieved by adding date palm fibre and MA to obtain a cost effective hybrid composite. The use of recycled polymers and date palm fibre reduce the impact on the environmental as well as reducing the cost.

2. Experimental details

2.1. Materials

Female date palm leave fibre were gathered from a local farm in Qatar. Recycled LDPE (0.936 g/cm^3), recycled HDPE (0.957 g/cm^3) and recycled PP (0.937 g/cm^3) were obtained from Doha Plastics Company. Date palm leaf fibres were cut into 2 cm in length oven dried at 70 °C. The recycled polymers were also oven dried for 4 h at 80 °C. MA (98.06%) from BDH Chemical Ltd., England was used as a coupling agent.

2.2. Composite preparation

Composites of recycled polymers and date palm fibre were prepared by a Brabender twin screw extruder. 20 wt% of date palm fibre was used in the matrix of the three types of recycled polymers. The processing temperature ranged from 160 to 210 °C. Polymer composites with different percentages of RLDPE, RHDPE, RPP and date palm fibre were prepared (Table 1). Table 1 shows the codes of different composition of date palm fibre reinforced ternary composites with 1 and 2 wt% of MA. The mixtures were fed into the hopper of the extruder and cooled and granulated. PE5 injection molding machine was used for making the dog bone shape samples according to **ASTM: D638-10**.

2.3. Mechanical testing

2.3.1. Tensile properties

Tensile tests were performed to measure the force required to break a specimen and the extent to which the specimen elongated before the breaking point. The tensile properties of the matrices and the composites were measured using a Universal Testing Machine at a crosshead speed of 10 mm/min by using **ASTM: D638-10.** The standard dimension was 20 mm in length, 12.5 mm in width and 3 mm in thickness. Five samples were tested at the uniaxial load direction for each composition, and the average value was reported.

2.3.2. Hardness properties

Hardness tests were carried out using a HRF Rockwell Hardness Tester. Using an F-Scale 0.0016 mm ball penetrator, a 60 kg load was applied, and a total of 10 indentation were made on the surface of each sample. For this test, **ASTM: D785-08** methods were applied for measuring the hardness. Vertical download direction was applied on the anisotropic samples (five times), for each composite system.

2.4. Morphology analysis (Scanning Electron Microscope)

Morphological analysis was performed using a Philips EDX Scanning Electron Microscope (SEM). The SEM was used to study the cross section of the samples after tensile testing of the bonding between the fibre and the matrix of the composite. Images were taken at different magnifications and without coatings.

2.5. Surface morphology analysis (AFM (Atomic Force Microscopy))

Sample morphology was studied by an AFM equipped with a Nanoscope IIIa controller (Digital Instruments MFP3D Asylum research 6310 Hollister avenue Santa Barbara, CA 93117 USA). Results were obtained in tapping mode in air using a vertical engage scanner and Si probe. For tapping mode, the resonant frequency of the free-oscillating cantilever to the adjacent surface of the sample was set as the driving frequency.