Mechanical and Thermal Properties of ABS and Leather Waste Composites

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ABSTRACT: To determine the possibility of using leather waste as reinforcing filler in the thermoplastic polymer composite, acrylonitrile–butadiene–styrene (ABS) as the matrix and leather buffing powder as reinforcing filler were used to prepare a particulate reinforced composite to determine testing data for the physical, mechanical, and thermal properties of the composites, according to the filler loading in respect to thermoplastic polymer. The ABS and leather powder composites were prepared by the extrusion of ABS with 2.5, 5, 7.5, 10, 12.5, and 15 wt % of leather powder in corotating twin screw extruder. The extruded strands were cut into pellets and injection molded to make specimens. These specimens were tested for physicomechanical properties like tensile and flexural strengths, tensile and flexural modulus, Izod and charpy impact strength, abrasion resistance, Rockwell hardness, density, Heat deflection temperature (HDT) and Vicat softening point (VSP), water absorption, and thermal degradation analysis. The incorporation of leather waste powder does not affect the tensile, flexural strengths, Izod impact strength, abrasion resistance, Rockwell hardness, density, HDT and VSP values drastically. However, the tensile modulus, tensile elongation, and charpy impact strength values are reduced significantly. © 2006 Wiley Periodicals, Inc. J Appl Polym Sci 101: 3062–3066, 2006

Key words: composite; ABS; leather powder; mechanical; thermal properties

INTRODUCTION

Studies are ongoing to find ways to use natural fillers in place of inorganic fillers and synthetic fibers.[1–7] These natural fillers are especially being sought since the production of composites using natural substances is not only inexpensive but also minimizes the environmental pollution caused by characteristic biodegradability,[8] enabling these composites to play an important role in resolving future environmental problems. Further advantages are their low density in comparison to inorganic fillers, moreover the natural fibers are less abrasive, and do not cause the wear of barrels and screws during processing. They can be used to produce products with various physical properties and effective functions. Fillers modify the existing physicochemical characteristics but also invariably reduce cost, improve workability during processing, and develop new properties not present in the original resin. These natural fillers provide much higher strength[9–11] per unit mass than most of inorganic fillers such as calcium carbonate, talc, zinc oxide, and carbon black. There is a keen interest in utilizing these natural resources in material applications because of their positive environmental attributes. The leather buffing powder from leather industry is one of the natural resource not utilized for any useful purpose. The finished animal skin, called leather, composed of two layers with distinctly different structure. The upper layer, which includes the entire length of hair follicles, is called grain layer. The second inner layer, composed of mostly thick bundles of collagen fibers, is called corium. These bundles are interwoven in a random, three dimensional fashion. During the leather products manufacturing process, the inner-collagen layer of the finished leather is buffed to get a smooth and fine finish. This process gives a fine powder of collagen fibrils in large quantities in leather industries, which is a polymer of significant importance. Compared to studies on natural fibers such as jute, sisal, coir, pineapple, and bamboo, less effort has been focused on this type of leather waste. As these waste fibers are found in large quantity, there is a great interest in finding new applications by mixing it with synthetic thermoplastics. Among the synthetic thermoplastics materials, ABS is a popular plastics in industrial as well as commodity applications and being used in many fields like defense, aerospace, automobile, electrical, computer, telecommunications, and appliance applications. ABS is a hard and tough thermoplastic terpolymer with good impact strength and surface gloss. However, it is not an environment friendly

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TABLE I
Properties of Leather Waste Powder

S. no.	Properties	Values
1	Apparent Density (g/cc)	0.374
2	Charring temperature (°C)	300–500
3	Colour	Grayish
4	Particle size (mesh)	1040
5	pH of aqueous slurry	7.0
6	Solubility in water, ethanol, acetone, *n*-hexane, and dilute HCl	insoluble

material, resistant to environmental degradation after its use, and becomes a critical problem to the plastics industries.

As a part of our continuing research aimed at the preparation and evaluation of hydrophilic/biodegradable polymers,[12–16] the present study reports the preparation of ABS/leather powder composites. The thermoplastic polymer–ABS was used as the matrix and leather buffing powder material as the filler to prepare a particulate reinforced composite to examine the possibility of using leather waste as reinforcing filler and to test for the physical, mechanical and thermal properties of the composites according to the reinforcing filler content with respect to thermoplastic polymer. In today's environment-focused society, the demand for cost effective, environmental friendly materials continues to increase. The driving forces behind the use of the leather waste are cost, annually renewable resource utilization, and environmental benefits.

EXPERIMENTAL

Materials

The thermoplastic polymer ABS, supplied by Bayer ABS Ltd. (ABSOLAC ABS, 300FR), in the form of pellets with density of 1.033 g/cc and melt flow index of 35 g/10 min (220°C/10 kg) and the leather buffing powder obtained from local leather industry were used in this study for preparation of composites.

Filler preparation

The reinforcing filler in the composite was leather buffing powder waste. The leather buffing powder waste was obtained from a local leather factory. The soft powder was cleaned and dried in sunlight carefully, then sieved before using. This powder was washed with water to neutralize and dried again in an oven with air circulation for 16 h at 50°C to adjust it to a moisture content of 1–2% and stored over desiccant in sealed polyethylene covers and utilized in this work.

Characterization of fillers

Apparent density was measured according to ASTM D 1895B. Color was evaluated visually. Solubility performance of the sample was examined in water, acetone, *n*-hexane, and dilute HCl. The surface chemistry of the filler was examined by pH technique. The pH of the aqueous slurry made by stirring 1 g of sample in 10 mL of boiled distilled water was obtained. The mixture was cooled before readings were taken. Charring temperature was determined by visual notation of the changes in color of the sample subjected to a heating program and the results are reported in Table I. The composition[17] of powder is mostly collagen with little ash.

Compounding and specimen preparation

The ABS granules and powder were premixed in a high speed mixer (Henschel, Germany, Model FM 10 LB). The mixed material was extruded in a twin screw extruder (Berstorff, Germany) with L/D ratio of 33 with temperature profile of 175–215°C. The extruded strand was pelletized and stored in sealed packs containing desiccant. Six levels of filler loading (2.5, 5, 7.5, 10, 12.5, and 15 wt %) were designed in sample preparation (Table II). Tensile, flexural, Izod, charpy, Heat distortion temperature(HDT), Vicat softening point(VSP), and water absorption specimens were prepared using an R.H. WINSOR INDIA, SP-130 automatic injection molding machine with 100 ton clamping pressure at 200°C and an injection pressure of 1200 psi. After molding, the test specimens were conditioned before testing according to ASTM D 618.

Testing methods

Tensile strength, modulus, and elongation tests were carried out as per ASTM D 638 at a cross head speed of 50 mm/min and flexural strength, modulus tests were carried out as per ASTM D 790 on Universal testing machine (Lloyd, LR 100 K). Izod and Charpy

TABLE II
The Composition of ABS and Leather Powder Composites

S. no.	Sample code	Composition in weight percentage	
		ABS	Leather powder
1	A	100.0	–
2	B	97.5	2.5
3	C	95.0	5.0
4	D	92.5	7.5
5	E	90.0	10.0
6	F	87.5	12.5
7	G	85.0	15.0

TABLE III
Tensile and Flexural Properties of ABS/Leather Powder Composites

S. no.	Sample code	Tensile strength (MPa)	Tensile modulus (MPa)	Percentage of elongation (%)	Flexural strength (MPa)	Flexural modulus (MPa)
1	A	38.73	2828	16.6	61.43	2450
2	B	37.99	2060	5.5	60.20	2628
3	C	36.85	2055	5.3	59.60	2819
4	D	35.25	1981	4.8	57.90	2863
5	E	34.90	1844	4.1	56.53	2883
6	F	33.71	1696	3.8	55.50	2903
7	G	32.67	1447	3.3	54.33	2917

impact strength tests were carried out in Izod–charpy digital impact tester (ATS FAAR, Italy) as per ASTM D 256 A and B standards respectively, in the standard laboratory atmosphere. Abrasion resistance was measured for 100 mm diameter discs using CS-10 wheels as per ASTM D 1044. Rockwell hardness was measured as per ASTM D 785 using 50 mm diameter discs. Density was measured for extrudate material as per ASTM D 792 standard. Heat deflection temperature test and Vicat softening point tests were carried out as per ASTM 648 and ASTM D 1525 respectively, in HDT–VICAT Tester (ATS FAAR Italy, model MP/3). Thermogravimetric analysis (TGA) was carried out in Dupont 910 series thermal analyzer system at the rate of 20°C/min from ambient to 800°C in nitrogen atmosphere. Water absorption was measured for 50 mm diameter disc specimens as per ASTM D 570 standard test method.

RESULTS AND DISCUSSIONS

Mechanical properties of the ABS/leather powder composites

The tensile and flexural results of the composites made of leather waste powder and ABS matrix at different filler loadings are shown in Table III. From the table, it is clear that there is a small reduction in the tensile strength of the composites from 38.73 to 32.67 MPa and flexural strength from 61.43 to 54.133 MPa respectively, with increase in filler loading from 2.5 to 15 wt %. Further the tensile elongation decreased from 16.6 to 3.3%. The reduction may be due to difference in polarities between the ABS resin and the leather (collagen) powder, which leads to poor interfacial bonding and incompatibility. The poor interfacial bonding causes partially separated microspaces between filler and matrix polymer, which obstructs stress propagation while tensile stress is loaded and induce increased brittleness. The reduction in mechanical strength is a general phenomena in case of thermoplastics filled with natural fillers,[18–20] as the filler loading increased, thereby increasing the interfacial area, the worsening interfacial bonding between the filler (hydrophilic) and the matrix polymer. In the case of modulus (Table III), tensile modulus decreased from 2828 to 1447 MPa, while the flexural modulus increased from 2450 to 2917 MPa. This contrasting behavior may be due to the orientation of the leather (collagen) fiber, In the case of tensile modulus test, the force applied is parallel to the direction of the fiber orientation, while in the case of flexural modulus, the force applied is perpendicular to the fiber orientation.

The izod and charpy impact strengths of composites at different filler contents are shown Table IV. The izod impact strength decreased from 29.75 to 26.22 Kg cm/cm and charpy impact strength decreased from

TABLE IV
Physicomechanical Properties of ABS/Leather Powder Composite

S. no.	Sample code	Izod impact strength (Kg cm/cm)	Charpy impact strength (Kg cm/cm^2)	Abrasion weight loss (mgms) (1000 cycles)	Rockwell hardness (R scale)	Density (g/cm^3)
1	A	29.75	47.9	64	85.2	1.033
2	B	28.00	19.4	65	85.0	1.051
3	C	28.66	16.4	66	85.0	1.060
	D	28.61	15.8	66	84.75	1.060
4	E	28.01	15.2	67	84.75	1.059
	F	27.50	14.7	69	83.1	1.059
5	G	26.22	14.5	72	82.25	1.060

TABLE V
Thermal Properties of ABS/Leather Powder Composite

S. no	Sample code	Heat deflection temperature (°C)	Vicat softening Point (°C)
1	A	82.0	107.5
2	B	78.0	103.0
3	C	76.0	101.5
4	D	75.0	100.0
5	E	74.0	97.5
6	F	73.5	97.0
7	G	73.0	96.0

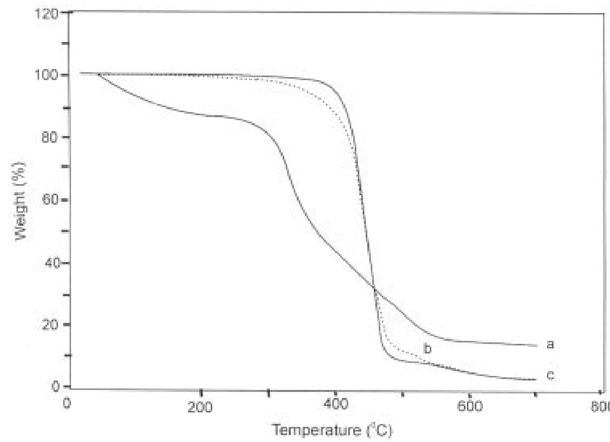

Figure 1 TGA thermograms of (a) leather powder, (b) ABS resin with 7.5% leather powder, and (c) ABS resin.

47.9 to 16.5 Kg cm/cm^2 respectively, with increase in filler loading from 2 to 15 wt %. The decrease in impact strength may be due to poor interfacial bonding between the polymer matrix and the filler, which induces microspaces between the filler and the matrix polymer, and that causes numerous microcracks when impact occurs, which induce crack propagation easily and decreases the impact strength of the composites. Especially the charpy impact strength of the ABS decreased from significantly higher value, the variation in impact strength between izod and charpy were due to difference in fracture processes. The lack of interfacial adhesion due to opposite polarities between the ABS resin and leather powder is responsible for this poor impact strength. The incorporation of leather powder into ABS brings brittleness. The abrasion resistance, Rockwell hardness, and density results of ABS/leather powder composites are shown in Table IV. From the table, it is clear that the filler loading does not affect the abrasion resistance, Rockwell hardness, and density of ABS matrix significantly.

Thermal properties of the ABS/leather powder composites

Many factors are considered when selecting a material for a high temperature application. In this regard, HDT and VSP are the two important factors. The HDT and VSP values of ABS and leather powder composites are shown in the Table V, which indicates marginal decrease in HDT as well as VSP values with the incorporation of leather powder as in the case of mechanical properties. Again this may due to poor interfacial bonding which at elevated temperature deforms more easily and reduces the HDT and VSP results.

Figure 1 shows the TGA thermograms of leather waste, ABS resin (Sample A), and 7.5 wt % filler ABS resin (Sample D). From figure, it is clear that the leather sample exhibits two mass loss steps. The initial mass loss below 100°C is due to gradual evaporation of absorbed moisture. The second mass loss step is from 300 to 600°C because of the decomposition of collagen. In ABS resin, the mass loss occurs in a single step process, which started at 400°C and completed at 600°C. The thermal degradation of ABS can take place through random chain scission and a radical chain mechanism. However the major sources of degradation in leather powder is collagen. Figure 1 further shows that effect of mixing leather powder with ABS resin was to improve the thermal stability of composites in comparison with that of leather powder. Leather powder and its blends show more ash content than the ABS matrix. In the final stages of degradation process from 500 to 600°C, ABS shows more weight loss than the collagen fibers. This may be because the collagen shows more ash content.

The water absorption results of the ABS/leather composites as per ASTM D 570 are shown in Table VI, which indicates only a marginal increase in water absorption and not in proportion to the filler (hydrophilic) loading. This may be due to the fact that the natural (collagen) filler is encapsulated by ABS matrix, which retards the collagen fibers to absorb more water molecules, hence, the filler material is not properly exposed to the surface to have higher water absorption. However, when the temperature is increased, the

TABLE VI
Effect of Filler Loading on Water Absorption of ABS Resin

		Percentage of water absorption		
S. no	Sample code	24 h at 30°C	30 min at 100°C	2 h at 100°C
1	A	0.27	0.25	0.49
2	B	0.32	0.31	0.64
3	C	0.41	0.41	0.92
4	D	0.49	0.45	0.95
5	E	0.54	0.47	0.99
6	F	0.58	0.50	1.25
7	G	0.64	0.66	1.50

water absorption increased, this may be because with increase in temperature, the matrix expands its volume and the water molecules penetrates the matrix and shows weight gain.

CONCLUSIONS

Acrylonitrile–butadiene–styrene (ABS) composites were prepared with leather powder waste at different compositions. These specimens were tested for mechanical and thermal properties. The test results indicate that the incorporation of leather waste powder does not affect the tensile, flexural strengths, Izod impact strength, abrasion resistance, Rockwell hardness, density, and HDT and VSP values drastically. However, the tensile modulus, tensile elongation, and charpy impact strength values are reduced significantly. These results are generally observed phenomena in noncompatible polymer blends. However, the main purpose of this work is to study the effect of leather waste on the mechanical and thermal properties of the ABS resin to reduce the cost, resource utilization, and get environmental benefits.

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