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Studies on effect of coconut pith on reclaimed EPDM/recycled PP composites

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ABSTRACT

The concern for environment and sustainable growth has created more awareness among the researchers to develop composites based on recycled materials and materials from nature. Reuse and recycling extends the useful life of the raw material resources in instances where a market exists for the recycled products, and it is economical to carry out collection and reprocessing. Recycling and reuse of materials have been getting more interest now days. EPDM / Polypropylene thermoplastic vulcanizates are most commonly used ones. In the current study reclaim EPDM and recycled polypropylene thermoplastic vulcanizates were prepared by melt blending method. Reclaim EPDM and Recycled PP has been melt blended in a Brabender plasticorder in different ratios and the blend with optimized results was selected for preparation of composite. MA-g-EPDM has been added as a compatibilizer in reclaim EPDM/recycled Polypropylene blends. Coconut pith in different ratios was added into Reclaim EPDM/Recycled Polypropylene blends along with MA-g-EPDM and other additives. Physico- mechanical and thermal properties of the coconut pith Reclaim EPDM / Recycled PP composite has been carried out. The dispersion of coconuut pith in the matrix had been carried out by SEM analysis.

KEYWORDS

Reclaim EPDM;
Recycled PP;
Coconut pith;
Compatibilizer;
Melt blending.

INTRODUCTION

Recently, the importance of recycling waste has been increasing for all industries worldwide. For rubber products, the automotive and transportation industries are the biggest consumers of raw rubber[1]. Recycling of engineering materials will contribute to the sustainability and sustainable development of industrial processes. Nowadays, metals, glass, thermoplastics and many other engineering materials are recycled to a great extent. Growing environmental awareness has led to the new material development based on recycled materials and materials from natural origin[2]. TPE's based on EPDM and Polypropylene are most commonly used ones. The wastages from EPDM are mainly from roofing and automobile parts, source for Polypropylene wastes were mainly from plastic carry bags, plastic bottles etc. So the necessity of recycling and reuse of EPDM and Polypropylene based materials are important[3]. Coconut pith is naturally occurring filler obtained from coconut husks. It has high lignin content, as a result coconut pith takes decades to decompose. Most of the works were done to utilize the naturally occurring material in the polymer matrix for the cost reduction and property enhancement purposes[4,5]. During the recycling process the material undergoes various operations that bring out several modifications in the molecular structure. As a matter of fact, the mechanical properties of the recycled products and their structural organization are quite different compared to those composed of virgin material[6]. Polypropylene (PP) has good mechanical properties but lacks low temperature impact properties. Studies have been carried out on blends of PP and low modulus rubbers to obtain good low temperature properties and impact resistance. Among PP rubber blends the PP/EPDM blends has acquired commercial success and finds application in various industrial fields because the composition dependent properties of blends can meet the diverse requirements of industrial application[7-9]. On basis of literature survey carried out by me, no work has been reported using reclaimed and recycled materials (reclaim EPDM rubber and recycled Polypropylene) as the matrix phase and coconut pith as reinforcing phase in preparation of composite. Coconut pith and fiber are used along with Rubber thermoset and thermoplastics resins to make composites. EPDM itself is not compatible with polypropylene, the EPDM phase exist as separate particles in the polypropylene matrix due to stratification, segregation and phase inversion. To improve the compatibility of the EPDM /Polypropylene blends various compatibilizer were added. Interfacial compatibilization in polymer blends is achieved through reactive compatibilization of virgin EPDM and Maleic anhydride, wherein the block or graft compatibilizer is generated at the interface of the recycled Polypropylene and reclaimed EPDM rubber[10-12]. Thermoplastic elastomers (TPE's) combine the elastic and mechanical properties of thermoset cross linked rubbers with the melt processability of thermoplastics. Today, TPEs comprise the fastest growing rubber market. TPE's can be processed by a variety of techniques such as melt blending, extrusion, blow molding, injection molding, vacuum forming and calendaring[13,14]. The EPDM phase can be crosslinked under dynamic shear while maintaining the thermo plasticity of the blends, which opens up numerous advantages as a thermoplastic vulcanizates (TPV). Morphologically TPV's are characterized by the presence of finely dispersed crosslinked particles distributed in the continuous thermoplastic matrix. Crosslinking systems commonly used are of resin and peroxide[15,16].

EXPERIMENTAL

Materials

Recycled Polypropylene was obtained from Chethan Plastics Mumbai. Reclaim EPDM with 30% Rubber Hydrocarbon (RHC) for mixing was obtained from Gujarat Reclaim and Rubber Products Limited. Paraffinic oil was procured from Neelam Lubricants. Coconut pith was obtained from Rubber Park; Ernakulum. Dicumyl Peroxide 40 (DCP 40) for dynamic vulcanization was obtained from BP chemicals.

Method to prepare blend and composites

(a) Preparation of the blend

Blends were prepared by using Brabender plasticorder PL 2500 mixer with a temperature of 180°C, rotor speed of 20 rpm for 10 minutes. Blends in variable ratios of recycled PP: reclaimed EPDM – 100:0, 90:10, 80:20, 70:30 and 60:40 were prepared in Brabender. After melt mixing the materials were passed through the two roll mill and sheeted to about 2 mm thick. The sheet was then cut and press molded for 10 minutes in a compression molding machine hydraulic press at 180°C, under specified pressure. Silicone wax paper was placed between the sheet and the press plates to avoid adhesion to mold. The sheet was then cooled down to room temperature still under pressure. The test specimens were die-cut from the compression molded sheet and used for measuring mechanical properties after 24 hours of conditioning at room temperature. On the basis of results obtained by flexing test, impact test and abrasion resistance of different blend ratios an graph was plotted against the blend ratios and the obtained values and optimum value of the blending polymers were determined and 65 : 35 (recycled PP : reclaimed EPDM) was finalized for the preparation of composites.

(b) Preparation of composites

After the optimization study, composite with 65:35 (reclaimed EPDM: recycled PP) were prepared at different coconut pith content (0, 10, 20 and 30phr). Paraffinic oil was used as processing oil and MA-g-EPDM was used as compatibilizer. DCP40 was used for dynamic vulcanization. Compression molding under specified pressure, preparation of test specimen were carried out in a similar manner as described in preparation of blends. TABLE 1 gives the recipe for the preparation of composites -

TABLE 1 : 65:35 Blend and composite recipe

INGREDIENTS	PEC0	PECM0	PECM1	PECM2	PECM3
Recycled PP	65	65	65	65	65
Reclaim EPDM	35	35	35	35	35
MA-g-EPDM	0	10	10	10	10
Coconut Pith	0	0	10	20	30
Paraffinic Oil	10	10	10	10	10
DCP 40	1.2	1.2	1.2	1.2	1.2

Characterization

(a) Physico mechanical properties

1. **Tensile strength:-** Tensile strength properties were done on Instron1185 tensile tester according to ASTM D 638 at a cross head speed of 50mm/min.
2. **Tear strength:-** Tear strength of the sample was carried out according to ASTM D 624. This test method measures the resistance to tearing action.
3. **Hardness:-** Hardness testing was carried out by using Shore A durometer according to ASTM D 2240. Specimen should be of 6mm thickness.
4. **Flexing cycles:-** The no. of flexing cycles for failure was measured using Ross flex tester according to ASTM D 1052. The test specimens shall be 2mm in width, a minimum of 152 mm in length, and 6.35 mm (0.25 6 0.01 in.) in thickness, and shall be cut from a vulcanized sheet of 6.35 mm thickness
5. **Impact strength:-** The impact strength of the sample was carried out using Izod impact strength tester according to ASTM D 256.
6. **Weight loss:-** Weight loss of the sample was carried out using Taber Abraser according to ASTM D 4060. The specimen consists of 100mm diameter disc with both side's plane and parallel, also a 1/2in. diameter hole is drilled in the center.
7. **Wear index:-** 1000 times the loss in weight in milligrams per cycle. The sample used is same as for weight loss.

$$\textbf{Wear Index (I)} = \frac{\textbf{(A - B)1000}}{\textbf{C}}$$

A= Weight of test specimen before abrasion, mg; B = Weight of test specimen after abrasion, mg; C = Number of cycles of abrasion recorded

(b) Thermal analysis (TGA)

Thermo gravimetric analyses of the composites were carried out using TGA Q50 of TA instrument, USA. The samples were tested in N_2 atmosphere from 25°C to 600°C at a heating rate of 20°C/min.

(c) Morphological analysis

Phase morphology of the various blends was investigated by a JEOL JSM 5800 Digital Scanning Electron Microscope (SEM). The images were obtained at a tilt angle of 0° with an operating voltage of 20 kV.

RESULTS AND DISCUSSION

Mechanical properties

The tensile strength values decreases as there is an increase in coconut pith loading. Decrease in tensile values are susceptible due to presence of large interphase voids between the blending polymers, the large voids are due to the filler in the reclaimed rubber, and herein

TABLE 2 : Mechanical properties of composites

PROPERTIES	PEC0	PECM0	PECM1	PECM2	PECM3
Tensile Strength (Kg/cm^2)	32	32	27	29	28
Tear Strength (Kg/cm)	15	15	15	16	16
Hardness (Shore A)	67	70	75	80	85
Flexing Cycles (no. of cycles)	90	100	119	130	125
Impact Strength (J/m)	160	165	165	170	150
Abrasion Resistance (Weight Loss) (mg)	0.04	0.07	0.08	0.07	0.09
Wear Index (mg/cycles)	4×10^{-5}	7×10^{-5}	8×10^{-5}	7×10^{-5}	9×10^{-5}

we are again adding coconut pith as a cheap filler between the blending polymers and thereby increasing the voids to a large dimensions, and hence addition of coconut pith decreases the tensile values. As the coconut pith content increases there is an increase in tear strength values, which is advantageous for footwear application. Hardness of the composite increases with increasing coconut pith content. Flexing cycle's increases as the coconut pith content increases up to 20phr but at 30 phr loading there is a fall in counts of flexing cycle, due to low dispersion of coconut pith in to the polymer blend matrix. Impact values are optimum till 20phr of loading, but excess loading of coconut pith i.e. 30phr causes a detrimental effect on the impact property. As the loading of coconut pith increases there is an increase in the weight loss and hence abrasion resistance decreases. Wear index values are also in consent with the abrasion resistance. The decrease in the mechanical properties of the composites may be due to the fact that excess loading of coir pith does not leads to proper incorporation and dispersion of coconut pith in the polymer blend which further leads to low interfacial interaction between the blend matrices and coconut pith, therefore instead of providing reinforcing characteristics to the composites, coconut pith acts as an diluents which decreases the properties. Hence 20phr loading of coconut pith proves optimum for cheap sole application in foot wears and rubber mats.

Thermo gravimetric analysis

In order to investigate the influence on thermal stability of reclaimed EPDM / recycled Polypropylene / coconut pith composites, TGA study was carried out. Figure 1a, 1b, 1c and 1d shows the TGA thermographs of reclaimed EPDM/ recycled Polypropylene/ coconut pith composites with variable dosage of coir pith. Thermographs reveal that the onset of degradation of the composites shifts towards a higher temperature on increasing coconut pith concentration in the blend indicating higher thermal stability.

Morphological analysis

The SEM images of fractured coconut pith composites samples based on reclaimed EPDM / recycled Polypropylene / coconut pith are shown in Figure 2a, 2b, 2c and 2d. It is visible that the rubber particles are dispersed throughout the polypropylene matrix in the form of aggregates and the size of rubber particles is less than 2 μm in the unfilled thermoplastic elastomer sample as shown in Figure 2a, because the size of the dispersed rubber phase in unfilled reclaimed EPDM / recycled Polypropylene blends depends on the interfacial interactions between two phases. It should also be noted that the crosslinked rubber particles are covered by a layer of polypropylene Figure 2b shows that the size of rubber particles has been increased to 10 μm by the introduction of the coconut pith. Initially, the coconut pith cannot penetrate into the rubber phase, but after adding curing agent DCP40, the rubber phase become more polar. Therefore, it is possible that some coconut pith goes to reclaimed EPDM phase before the curing cycle ends. Hence there is change in the viscosity ratio between the two phases, and consequently, the size of the rubber phase increases.

TABLE 3 : Onset of degradation and residual weight

Sample	Ti (°C)	Residual weight (%)
PECM0	274.37	4.3
PECM1	277.93	7.8
PECM2	280.21	9.4
PECM3	313.33	10.6

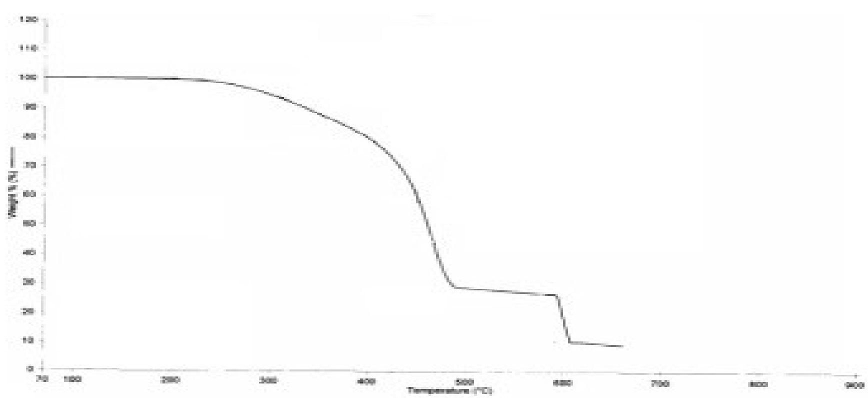

Figure 1a : 0phr loading of coconut pith

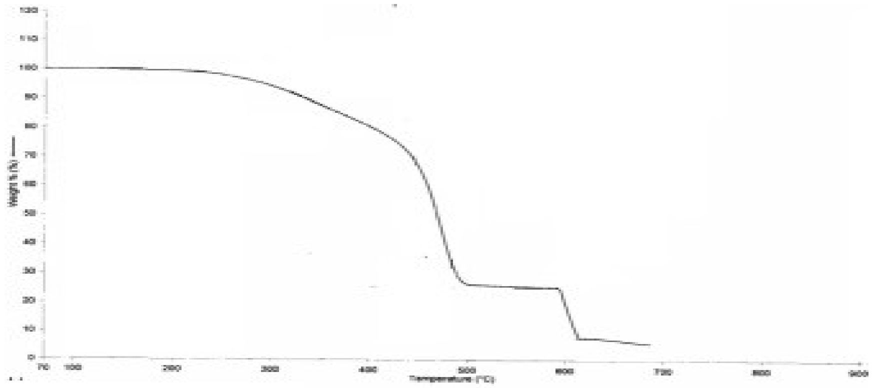

Figure 1b : 10phr loading of coconut pith

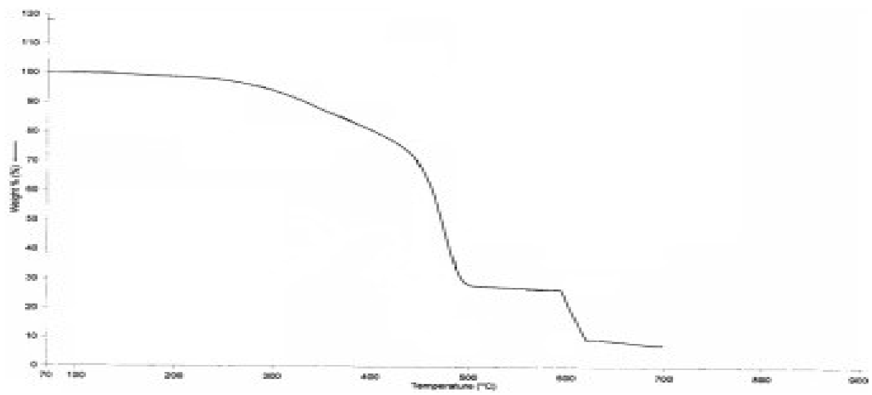

Figure 1c : 20phr loading of coconut pith

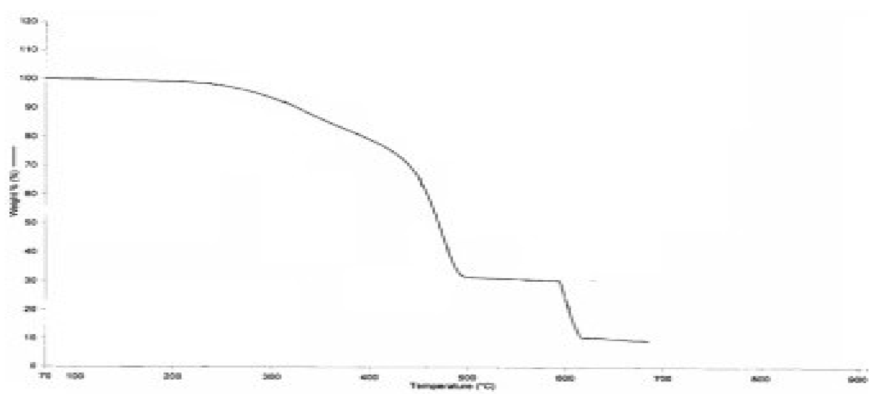

Figure 1d : 30phr loading of coconut pith

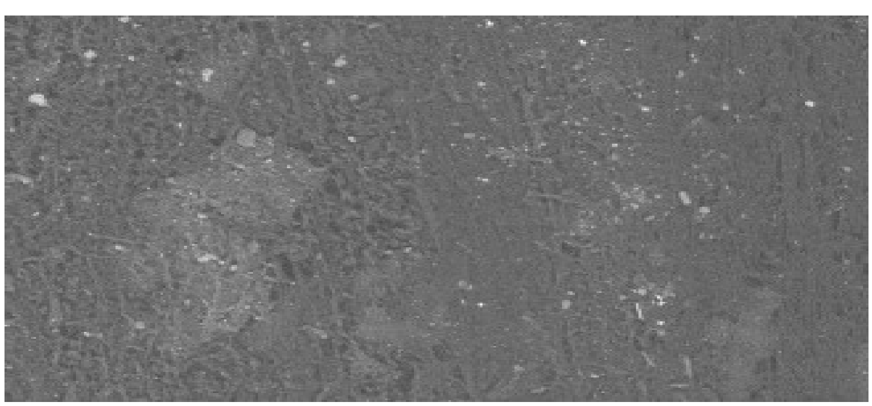

Figure 2a : 0phr loading of coconut pith

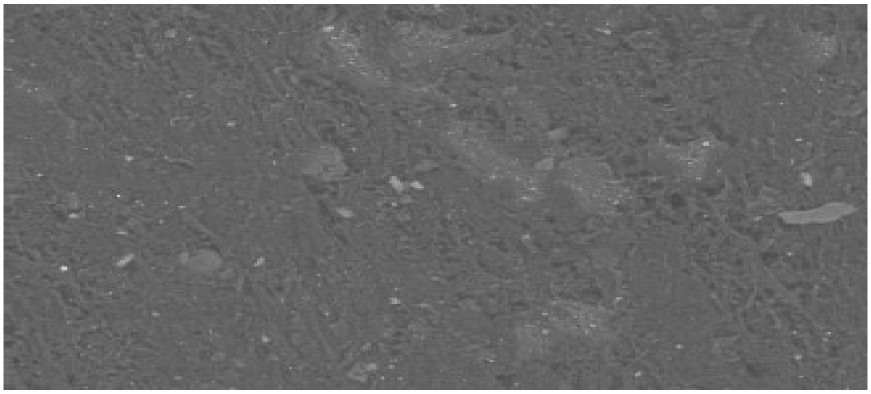

Figure 2b : 10phr loading of coconut pith

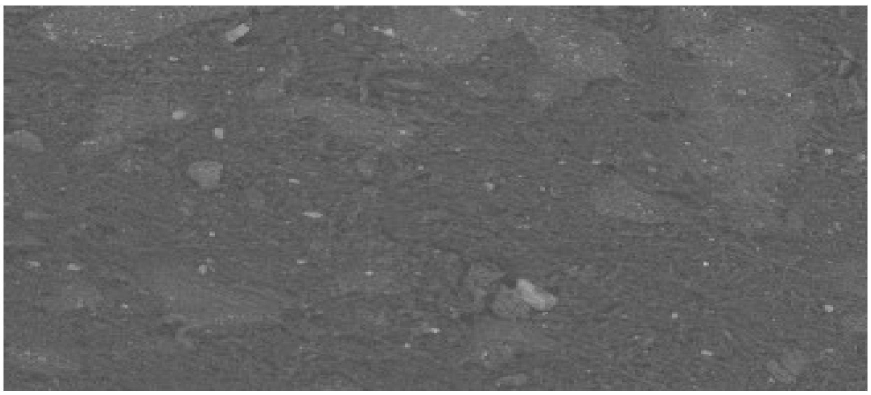

Figure 2c : 20phr loading of coconut pith

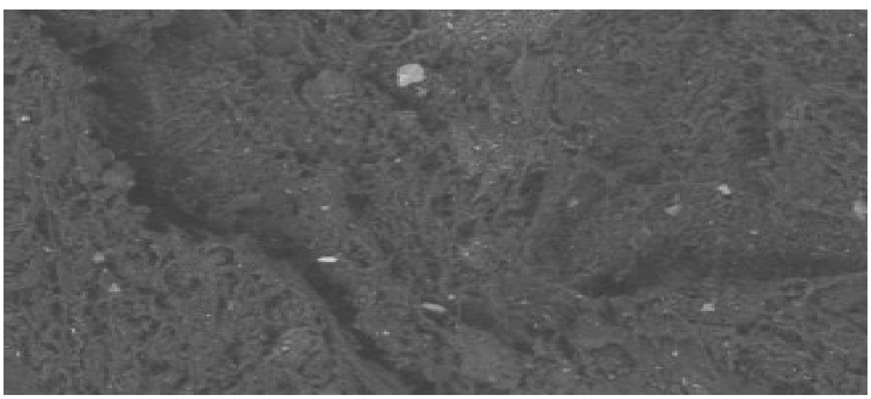

Figure 2d : 30phr loading of coconut pith

CONCLUSIONS

The study was conducted to determine the Recycled PP /Reclaim EPDM / Coconut Pith Composites for footwear and rubber mat applications, and 65:35 (recycled PP: reclaimed EPDM) blend ratio was optimized. Later the effect of coconut pith loading on 65:35 (recycled PP: reclaimed EPDM) was determined and observed that hardness, flexing cycles, impact strength increases up to 20 phr of coconut pith loading thereafter decreases due to agglomeration of coconut pith in the matrix as well as due to the low interfacial interaction. Abrasion resistance decreases as coconut pith loading increases but the values obtained at 20phr of coconut pith are comparable with the blend where no coconut pith is added (PECM0). Presence of coconut pith and maleic anhydride in recycled PP/reclaim EPDM/coconut pith composites improves the properties which are applicable to low cost footwear (sole) and rubber mat application. With the understanding that MA-g-EPDM takes part in interphase compatibilization between blending polymers and coconut pith acts a nucleating agent for polypropylene crystallization, coconut pith also forms physical interlocking between recycled PP /reclaimed EPDM which serves the function of compatibilization along with MA-g-EPDM. Morphological analysis shows that large agglomeration occurs when coconut pith at 30 phr loading is carried in reclaimed EPDM /recycled PP composites, leading to deterioration in properties, hence 20phr loading of coconut find its place in mechanical, thermal and also morphological properties of composites.

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