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Studies on Mechanical, Thermal & Electrical Properties and *Insitu* Compatibilization of Recycled Nylon 6 – Poly Propylene Blends

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Abstract: *Recycled Nylon-6 was melt blended with PP (Poly Propylene) in two formulations (75:25% and 50:50% (wt %), using a twin screw compounding extruder. In situ compatibilization based on Maleic anhydride with benzoyl peroxide was used to make the blends compatible. Injection molding technique was used for test specimen preparation. The testings were done as per ASTM standard. The results were compared with that of Recycled Nylon-6, PP, and Recycled nylon6-PP with and without compatibilizer (75:25%). The tensile strength, flexural strength, flexural modulus, HDT was increased. But, the impact strength was lowered because recycled Nylon-6 has lower impact strength than that of PP. The flammability and shrinkage were lowered. The water absorption was increased and the volume resistivity was little lowered. In other words, as PP content increases, the impact strength of Recycled Nylon6 Increases, the water absorption lowers very much, and the Tensile strength, flexural modulus and HDT lowers and are optimum.*

Due to the use of insitu / reactive compatibilizer the Mechanical properties and electrical properties were little higher than that of uncompatibilized one.

Key words*: Insitu Compatibilization, Poly Propylene, Recycled Nylon6, Mechanical, Thermal & Electrical Properties*

I. Introduction

PP is a commodity plastic having higher crystallinity and excellent chemical resistance (1) like Nylon-6 (2). Nylon-6 is an engineering plastics and so higher in cost than that of PP. But the Recycled nylon-6 is cheaper than Virgin Nylon-6. By the use of recycled nylon-6 the properties of PP can be improved particularly like Tensile strength, Flexural Strength & Modulus, and Heat deflection Temperature (HDT). But, the impact strength may be lowered. However, by the use of compatibilizer the compatibility of the PP-Nylon-6 blends can be improved and hence the impact strength also can be improved.

Nylon-6 is an engineering thermoplastic and so it is widely used in many engineering applications like gears, cams, rods, bearings, bushes like Poly acetals because of its toughness, rigidity, abrasion resistance, good chemical resistance and reasonable heat resistance (3). But, slightly lower electrical properties which may be improved by blending with plastics like PE and PP which are having excellent insulation characteristics. Polymer blends of Nylon-6 with ethylene copolymers improve the toughness of the HDPE containers. These containers are useful to make Transport containers and sports equipments (4).

PP is widely used as mouldings because of its good appearance, sterilizability, Environmental stress cracking resistance (ESCR), good heat resistance and excellent fatigue resistance. PP mouldings are widely useful like sterilizable syringes, hospital equipments (Trays), luggages, staking chairs, washing machines parts, various car parts such as dome lights, door frame parts (5). Also PP is useful as fibres, BOPP film bags, and wire coating (5).

So, the Recycled nylon-6 with PP Blends may be useful for some of the above mentioned applications mentioned for Nylon-6 as well as PP mouldings with lower cost that nylon-6 and optimum properties.

Recycling of Nylon-6 has been reported in the literature (6, 7). Recycling of Nylons for some application like brake lining cannot be tolerated even with minimum quantities of recyclate or regrind because of safety factors (7). Hence, recycled nylon6 may be blended with polyolefins.

In this present study, our interest is to blend the recycled Nylon-6 with PP along with an *in situ* compatibilizer by grafting Maleic anhydride onto PP polymer chains with help of benzoyl peroxide catalyst free radicals using a twin screw compounding extruder while compounding PP with recycled Nylon and to study the effect of recycled Nylon-6 on the Mechanical, thermal, electrical and physical properties of PP.

II. Experimental

2.1 Materials

PP (Inj Grade, Trade name Koyalene) having MF1 10 was used. It was obtained from Reliance petrochemicals, Mumbai. Nylon-6 was obtained from SRF Ltd., Manali, Chennai (Inj Grade, Trade name Tufnyl). Maleic Anhydride (MAn) and Benzoyl peroxide (BPO) were obtained from BDH Chemicals supplier, Chennai. The Nylon-6 was injection moulded into different test specimens. The test specimens, sprues, runners and gates were cut into small pieces using a scrap grinder and used in this study.

2.2 Methods

2.3 Twin Screw Compounding

The Recycled Nylon-6 with PP were thoroughly mixed in a High speed mixer and then further mixed with Maleic anhydride and benzoyl peroxide. The maleic anhydride will be grafting on the PP chains while compounding at high temperature in the twin screw extruder. Also, the maleic anhydride group will be reacting with the end amine (-R-NH_2) groups of Nylon-6; these reactions lead to the reactive compatibilization of PP with Nylon-6: The Extruder has two co-rotating screws (Berstorff, Germany) which blends the Nylon-6 with PP homogeneously. The Temperature range used for the melt blending is given below.

Zone	1	2	3	4	5	6	7	8	9	10 (Die)
Temp(ºC)	140	160	180	220	225	235	240	245	250	245

The extrudate was cooled through a water trough and then chopped into granules using a chopper cutter.

2.4 Injection Molding

The compounded granules were used again to make Test specimens by an injection molding machine (SP 130 *Klacknar Windsor*) as per ASTM standard. The samples were then conditioned and tested as per ASTM standards (8).

III. Results And Discussion

The blends of recycled Nylon-6 with PP were made in two formulations B and C (75:25 and 50:50 wt% of Recycled Nylon 6 and PP) using a twin screw extruder. *In situ* compatibilizer was used in these two formulations. For 75:25 composition one more formulation, without compatibilizer (formulation A) was also made. The properties of these blends were given in the Table I and II. Some of the properties are shown in the Figure 1-3. From the melting points study, one can easily identify the presence of PP and Nylon-6 in these polymer blends.

It is observed that the blends of Recycled Nylon 6-PP has higher values of Tensile Strength and lower elongation than that of PP but lower than that of Recycled Nylon6 (Fig 1). Similarly, the flexural strength and modulus were higher than that of PP since Nylon-6 has higher values than that of PP. The Impact strength values of these blends are also increasing as the PP percentage was increasing since PP has higher impact strength values than that of Recycled Nylon.(Fig 2) The hardness was decreasing since PP has lower Hardness than that of Recycled Nylon-6 (Table I).

The HDT (Heat Deflection Temperature) was increasing since Recycled Nylon-6 has higher HDT value than that of PP. The flammability (rate of burning) decreases since nylon is self-extinguishing while PP is flammable.

Table I Mechanical properties of Recycled Nylon 6 – PP blends

Property	Unit	Recycled Nylon-6	Formulation			PP
			A	B	C	
			75:25	75:25	50:50	
Tensile Strength	M Pa	55.8	36.5	40.2	27.6	17.8
Elongation At Break	%	66	92	128	130	252
Flexural Strength	M Pa	71.5	50.1	49.6	42.1	32.3
Flexural Modulus	M Pa	3678	2784	2864	2313	1364
Impact Strength Izod, notched	Kgcm/cm	7	7.84	8	13	16
Hardness, Rockwell	R Scale	100	92	84	87	79

Table II Thermal, Electrical and Physical properties of Recycled Nylon 6 – PP blends

Property	Unit	Recycled Nylon-6	Formulation			PP
			A	B	C	
Arc Resistance	Sec	152	132	123	166	274
Volume Resistivity	Ohm-cm	3.9 x10 12	3.0 x1012	1.1x1013	1.5 x 1013	3.3 x 1013
Flammability (Horizontal Burning)	cm/min	1.09	2.15	2.18	2.20	2.58
Heat deflection Temperature At 18.5 Mpa	C	67	66	65	61	59
Water absorption (for 24 hours at 23 C)	%	2.16	1.23	1.09	0.33	0.01

Formulation A: without compatibilizer 75:25 Re NY 6-PP Formulation B: 75:25 Re NY 6-PP with compatibilizer, & C: 50:50 Re Ny 6-PP with compatibilizer

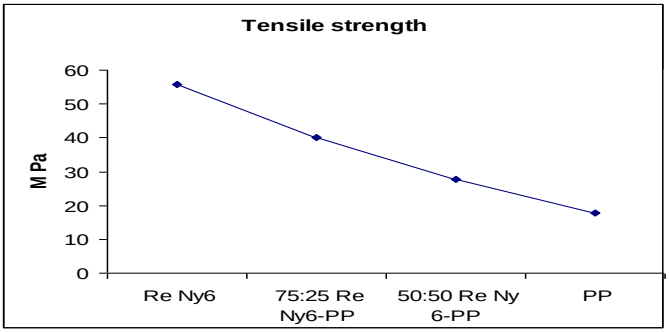

Fig1 Tensile Strength of Recycled Nylon6-PP blends in comparison with Recycled Nylon6 and PP

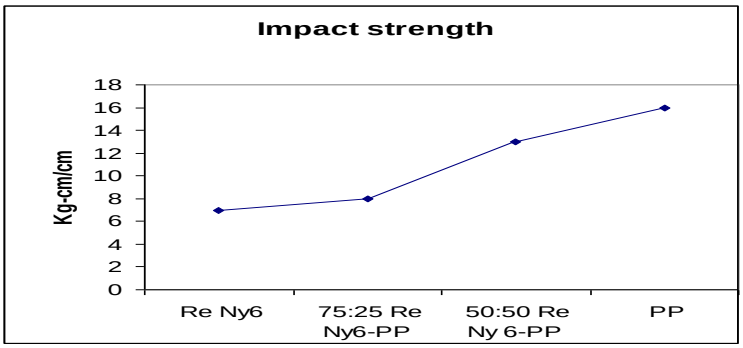

Fig 2 Izod Impact Strength of Recycled Nylon6-PP blends in comparison With Recycled Nylon6 and PP

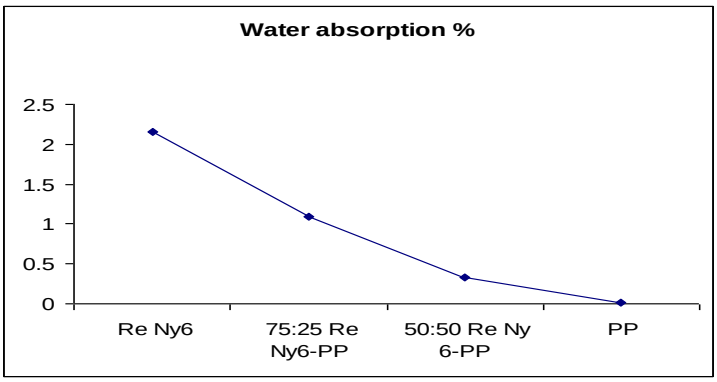

Fig 3 Water absorption of Recycled Nylon6-PP blends in comparison with Recycled Nylon6 and PP

Nylon-6 has higher moisture absorption and lower volume resistivity than that of PP. So, these properties are reflected in the blends. I.e. The blends have lower water absorption (Fig 3) and higher volume resistivity than that Recycled Nylon6. But, there is no regular trend in the arc resistance.

3.1 Effect of compatibilizer

When compatibilizer was used in the formulation 'B' the Tensile strength, Flexural modulus and Impact strength were little higher than that of the formulation 'A' which is not having compatibilizer materials (MAn monomer and BPO catalyst) for the compatibilizer formation on PP by Grafting of MAn. The Hardness is slightly lowered due the reactive compatibilizer which function as few cross-links leading to ladder like behaviour and thereby increasing the flexibility of the blends. Recycled Nylon-6 and PP may compatible due to the chemical cross linking through end amine and anhydride groups.

The volume resistivity is also higher and the water absorption was little lowered. However, the flame resistance and heat deflection temperature were similar for these two formulations A and B.

These blends may be useful like PP moulding with improved mechanical strength, modulus & thermal properties but with optimum impact strength & optimum cost.

IV. Conclusion

In the Recycled Nylon 6-PP blends, the recycled Nylon-6 increases the mechanical properties like Tensile strength, Flexural strength & modulus, but decreased the impact strength than that of PP. Also the HDT was increased. But, since the water absorption of nylon is higher than that of PP, the blends have higher water absorption and slightly lower volume resistivity. In other words, as PP content increases, the impact strength of Recycled Nylon-6 Increases, the water absorption lowers very much and electrical properties increases, but the Tensile strength, flexural modulus and HDT are lowers much and are optimum.

Due to the use of *insitu* / reactive compatibilizer the Mechanical properties and electrical properties were little higher than that of uncompatibilized one.

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