Journal of Industrial Technology 4 (2), 1994, 27-35

PROPERTIES OF ANNEALED POLYPROPYLENE, NYLON 6 AND LINEAR LOW DENSITY POLYETHYLENE BLENDS

C.Y. Yap, S.L. Lee, K.C. Nyew and T.T. Tee*

Faculty of Engineering
University of Malaya
59100 Kuala Lumpur
Malaysia

RINGKASAN: *Tujuan pengajian ini adalah untuk menguatkan sifat-sifat polipropilena (PP) pada suhu 120°C ke 140°C melalui pengadunan dengan Nilon 6 (PA6). Titik lebur PP adalah 163°C dan Nilon 6 adalah 224°C. Pengadunan dijalankan dengan menggunakan mesin pengacuanan suntikan dan beberapa sampel dibuat untuk ujian mekanik. Polietilena ketumpatan rendah linear (LLDPE) juga ditambahkan untuk pengajian ini. Pembajaan atas adunan dibuat pada 160°C dan sifat mekanik adunan-adunan diuji pada suhu bilik.*

ABSTRACT: The purpose of this study was to strengthen the properties of polypropylene (PP) at temperatures of 120°C to 140°C by blending with Nylon 6 (PA6). The melting point of PP is 163°C and that of Nylon 6 is 224°C. The blendings were done in an injection moulding machine and samples were made for mechanical testings. Linear low density polyethylene (LLDPE) was also added for the study. Annealing on blends at 160°C was carried out and the mechanical properties were measured at room temperature.

KEYWORDS: Polymer blends, polypropylene, nylon 6, composite, compounding, annealing on polymer blends.

* To whom all correspondence should be addressed.

INTRODUCTION

Blends of dissimilar polymers provide materials that are tailored to specific application requirements, with performance that could not be duplicated by an existing single polymer. Benefits from blending include improvements in mechanical, electrical and thermal properties, ease of processing, and reduced cost. A miscible polymer blend exhibits strong attraction between its polymer constituents, generally arising from interaction between functional groups of the polymers. This miscible blend has a single phase and a single glass transition temperature (Tg). This type of blend provides synergistic properties both in processing and end-use.

Partially miscible blends display some miscibility and may even be totally miscible if one polymer is present at low concentration. Phase separation tends to be more pronounced as the mixtures approach a 50/50 blend. Partially miscible blends have two distinct Tgs, both of which are between the Tgs of the constituent polymers. Immisicible blends exhibit limited attraction between polymer constituents. The component polymers exist as two phases, with the polymer present in a higher concentration generally forming the continuous phase. The immisicible blends of two polymers show two distinct Tgs which are similar to those of the pure polymers.

Theoretical studies of the compatability and many other aspects of various polymer systems are available (Paul and Newman, 1978; Utracki, 1989 and 1991).

A substantial amount of work has been done on PP/PE blends (Dumoulin et al., 1987 and 1988; Lovinger, and Williams, 1980; Noel and Carley, 1973; Paul and Newman, 1978; Utracki, 1989, and 1991). In this study Nylon 6 (PA6) and linear low density polyethylene (LLDPE) with PA6 were blended with polypropylene (PP). The melting point of PP is about 163°C and PA6 is about 224°C. Samples of the pure PP and PP blends were annealed at 160°C. Mechanical properties were measured and compared for unannealed and annealed PP blends.

MATERIALS AND METHODS

Polymers used in work were : polypropylene with melt flow index MFI of 8g/10 min and density of 0.899 g/cc manufactured by Hercules Canada Limited; Nylon 6 with density of 1.14 g/cc manufactured by Bayer; linear low density polyethylene film grade with MFI of 1 g/10 min and density of 0.918 g/cc; and LLDPE injection grade with MFI of 20 g/10 min and density of 0.924 g/cc, both manufactured by Union Carbide Chemicals and Plastics Company Inc. respectively. Nylon 6 was dried in an oven for 4 hours at 100°C before blending with polypropylene and LLDPE. The polymer pellets were premixed by tumbling.

The melt blending of polymers were done by a single screw injection moulding machine. The processing conditions, the number of runs and codes are shown in Table 1.

Table 1. Processing conditions for the production of different blends of polymers

F= FILM GRADE *I = INJECTION GRADE*

RUN	1	2	3	4	5	6	7	8	9	10
CODE	230PP	230N20	250N20	270N20	PPN5	PPN10	PPN30	PPN40	PPN51E5	PPN5FE5
% Wt of PP	100	80	80	80	95	90	70	60	90	90
% Wt of PA6	0	20	20	20	5	10	30	40	5	5
% Wt of PE	0	0	0	0	0	0	0	0	5(1)	5(F)
INJ. TEMP (°C)	230	230	250	270	230	230	230	230	230	230
INJ. PRES (kg/cm2)	1300	1300	1300	1300	1300	1300	1300	1300	1300	1300
HOLDING5 TIME (s)	5	5	5	5	5	5	5	5	5	5
COOLING TIME (s)	20	20	20	20	20	20	20	20	20	20
MOULD TEMP (°C)	80	80	80	80	80	80	80	80	80	80
DRYING TEMP (°C)		100	100	100	100	100	100	100	100	100

Since PP and PA6 have different melting points, an optimum processing temperature was determined by using 20% PA in the blends. Three temperatures were used, i.e. 230, 250 and 270°C. The tensile strength obtained for the 20% PA blends at 230, 250 and 270°C are 31.2, 30.4 and 27.5 MPa respectively. As the tensile strength was highest at the processing temperature of 230°C, it was decided to process all the blends from 5% to 40% PA at 230°C. The composition of the two components blends PA6/PP used were in the ratios of 5/95, 10/90. 20/80, 30/70 and 40/60 by weight. The composition of the three components blend LLDPE/PA6/PP was 5/5/90 by weight.

The tensile testing strength were obtained by injecting the blended melt into a tensile test mould which was designed according to ASTM D638. The tensile strengths and elongations were determined by the Instron Universal Testing Machine. At least five samples were used in each test and the average value was taken. The tests were conducted at 25°C ± 0.2°C with a crosshead speed of 20 mm/min. Differential scanning calorimetry (DSC) was performed with a Mettler 20 calorimeter. Granulated materials of weights from 7 to 9 mg were heated from 25 to 260°C at a rate of 10°C/min in air under atmospheric conditions. Annealing of samples was done in an oven at 160°C for 30 minutes.

RESULTS AND DISCUSSION

Unannealed Blends

For the unannealed blends, the tensile strength at yield and percentage elongation at break are shown in Table 2. The tensile strengths for pure PP is 32.3 MPa and for 5, 10, 20, 30 and 40% PA6 blends are 32.4, 32.1, 31.2, 28.7 and 29.1 MPa respectively. Figures 1 and 2 show the tensile strength and percentage elongation versus weight percentage of PA6 respectively. From these data, it can be seen the addition of 5 and 10% PA6 had no effect on PP. At 20% PA6, there was a 2.8% decrease in tensile strength. However, at 30 and 40% PA6, the decrease in tensile strength were about 11% showing phase separation had occured in the blends.

Table 2. Tensile strength and percentage elongation of various blends
(Note: A = After Annealing)

Code	Tensile Strength at Yield (MPa)	Percentage Elongation at Break (%)
230PP	32.3	41.5
230N20	31.2	22.8
250N20	30.4	24.6
270N20	27.5	29.2
PPN5	32.4	31.5
PPN10	32.1	27.3
PPN30	28.7	22.2
PPN40	29.1	21.3
PPN5A	32.2	25.2
PPN10A	32.0	20.3
PPN20A	30.6	12.8
PPN5IE5	29.3	39.8
PPN5FE5	30.4	32.3
PPN5FE5A	29.1	38.5
PPN5IE5A	29.3	40.6

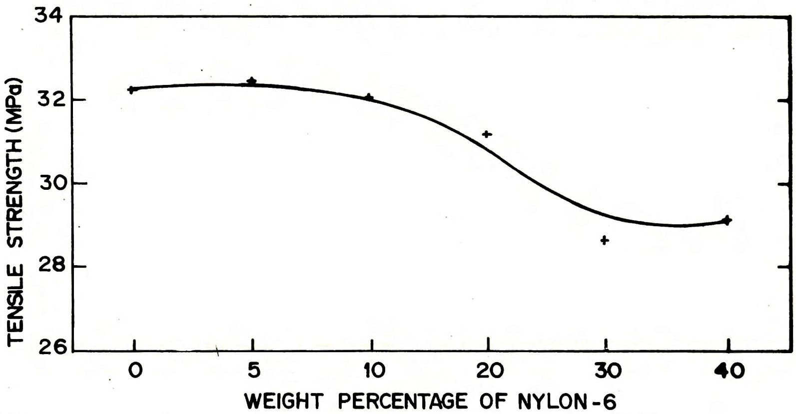

Figure 1. *Tensile strength at yield vs. weight percentage of Nylon 6*

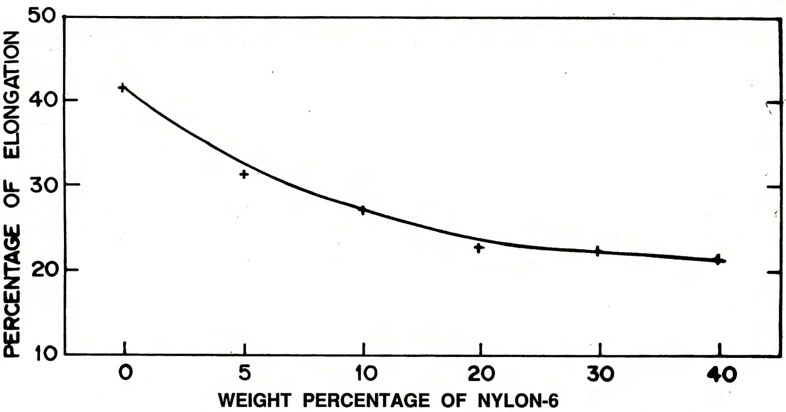

Figure 2. *Percentage of elongation vs. weight percentage of Nylon 6*

The addition of PA6 into PP had a greater effect on the elongation properties. The elongations for pure PP was 41.5% which decreased to 31.5, 27.3, 22.8, 22.2 and 21.3 for the 5,10,20,30 and 40% PA6 blends. Hence the elongation decreased by 25%, 45% for the 5% and 20% PA6 blend. The 30%, 40% PA6 blend showed about the same degree of decrease in elongation as the 20% PA6 blend. The decrease in elongation for the blends is due to the relatively lower elongation of PA6.

Annealed Blends

The tensile strengths and elongations of the annealed blends are shown in Figures 3 to 6. Figure 3 compares the tensile strength of unannealed and annealed blends. The annealing process was done at 160°C for 30 minutes. The mechanical properties were determined after the samples were cooled and conditioned at 25°C. It was found that pure PP could not withstand the heat process and melted while the blends remained in solid condition. Hence, the tensile strength value could not be obtained for pure PP since the samples melted after heating. However, the tensile strengths for 5, 10 and 20% annealed PA6 blends were very close to the unannealed blends as shown in Figure 3.

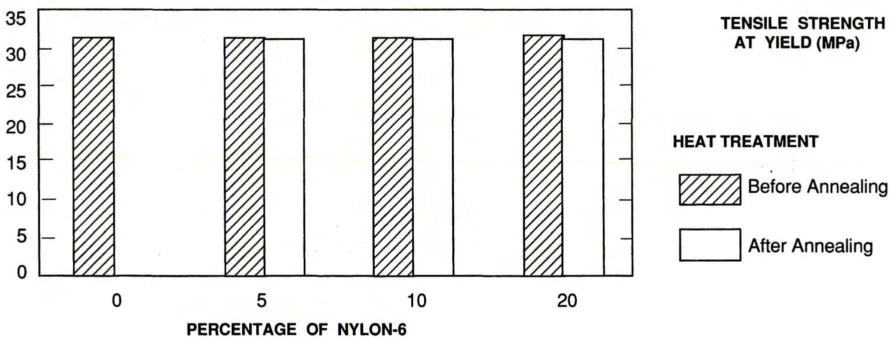

Figure 3. *Tensile strength at yield vs. weight percentage of nylon 6 after annealing*

A comparison of the elongations for unannealed and annealed samples are shown in Figure 4. The percentage elongations were greatly affected by annealing. The decrease in elongation was 20%, 26% and 44% for the 5,10 and 20% PA6 blends. The decrease in elongation after annealing is probably due to the increase of crystallinity of the blends.

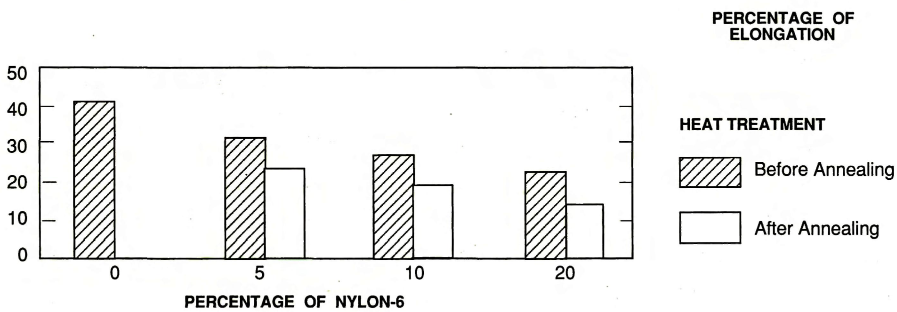

Figure 4. *Percentage of elongation vs. weight percentage of nylon 6 after annealing*

Three Component Blends

Two types of LLDPE were added to PA6/PP blends. The first type was the injection moulding grade LLDPE and the second type was the film grade LLDPE. The effects of adding LLDPE to the 5% PA6 blends are shown in Figures 5 and 6. There was a small decrease in tensile strength when LLDPE was added to the 5% PA6 blends.

As shown in Figure 5, the decrease in tensile strength for the unannealed samples is10% with the addition of 5% injection grade LLDPE and 6% for the film grade. There was nearly no change of tensile strength after annealing.

There were some increases in elongation when 5% of LLDPE was added. The blend containing 5% injection grade LLDPE showed an elongation that was 26% higher before annealing, and 61% higher after annealing. The increase in elongation is due to the higher elongation of LLDPE.

The addition of the film grade LLDPE showed no change in the elongation before annealing, but increased by 21% after annealing.

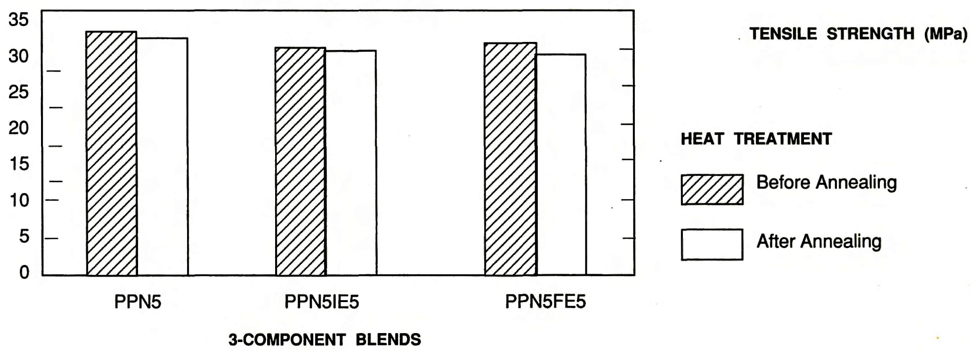

***Figure 5.** Tensile strength at yield for 3-component blends*

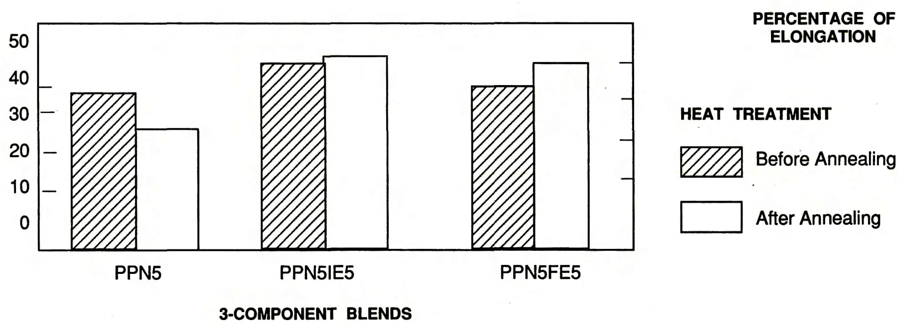

***Figure 6.** Percentage of elongation for 3-component blends*

DSC Thermograms

The compatibility of the blends could be deduced from the peak temperatures shown in the DSC thermograms. Figure 7 shows the thermogram obtained from a Mettler 20 Differential Scanning Calorimeter for 20/80 PA6/PP blend. The two peaks at 163°C and another at 224°C correspond to the melting points of PP and PA6 respectively. Hence it can be deduced that PP and PA6 form an immiscible blend.

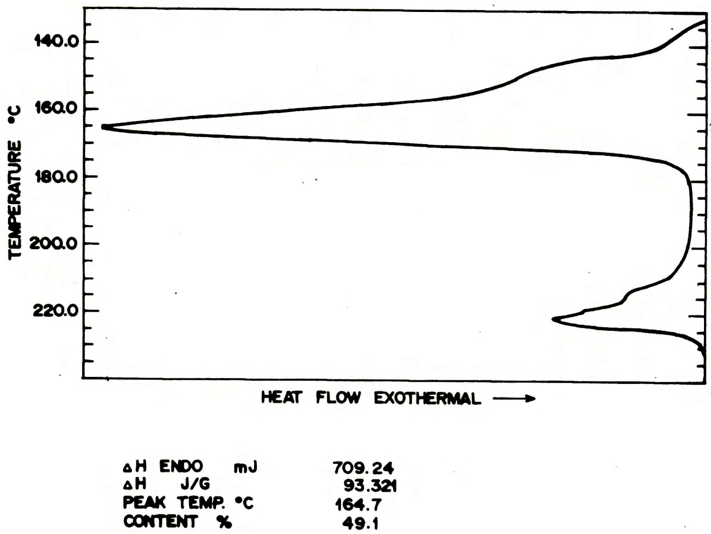

Figure 7. *Thermogram for the 20/80 PA6/PP blend*

CONCLUSIONS

The experimental results showed that pure PP could not withstand the annealing temperature of 160°C for 30 minutes and melted. However, by adding 5% and more of PA6 to PP, the test samples maintained its original shape and dimensions after annealing. This showed that the melting temperature of the blend had been elevated, thus indicating the possible application of such blended plastics at higher temperatures from 120 to 140°C. The addition of 5% LLDPE to the 5% PA6 blend in the ratio of 5/5/90 for LLDPE/PA6/PP further improved the elongation of the blend. The DSC thermograms for the PA6/PP blend showed two peaks which were identical to the melting points of PP and PA6 and confirmed that the blends are immiscible.

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