TENSILE PROPERTIES OF TERNARY BLENDS FOR HDPE/PP/RECYCLE HDPE IN BLOW MOULDING PROCESS

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ABSTRACT: Increasing the environmental concern among peoples have increased the recycling activities, especially for high-density polyethylene (HDPE) bottles. Therefore, recycled HDPE needs to be mixed with other plastic materials to improve their mechanical properties. In this study, recycled HDPE was mixed with virgin HDPE and polypropylene (PP). The ratio of virgin HDPE and PP were set at 10/90, 30/70 and 50/50, meanwhile recycled HDPE was set at 20%, 35% and 50%. The blended materials were extruded into the parison and was blown using extruded blow-moulding machine to produce a 5-litre bottle. The tensile strength and elongation at break of the blended materials were measured using universal testing machine (UTM). Miscibility of the blended materials was also evaluated using differential scanning calorimetry (DSC). The result shows that decreasing the recycled HDPE in the blended materials increases the tensile strength. Meanwhile, increasing the recycled HDPE content in the blended materials increases the elongation at break of the blended materials. DSC curve shows that blended materials are immiscible.

KEYWORDS: *Ternary Blend; HDPE/PP/Recycled HDPE; Extruded Blow-Moulding Machine*

1.0 INTRODUCTION

Increasing environmental awareness and resin price gives the positive impact of recycling activities, especially to HDPE bottle recycling. For example, in United State, HDPE bottle collection rate for recycling rose to 31.6% in 2012 compared to 29.9% in 2011. Export of collecting HDPE bottle rose to 201 million pounds and import of postconsumer HDPE decreased by 35% to 33.1%. As shown in Table 1, Nickolas and Charles had reported on the issue of recycling and disposal of plastics between 2008 and 2011 [1]. They found that the recycling rate of plastics increased by 21% to 2.66 million tons due to higher recovery of polyethylene terephthalate (PET) and high-density polyethylene (HDPE) bottles, as compare to other HDPE and polypropylene (PP) of rigid plastics and HDPE and low-density polyethylene (LDPE) of films, bags and wraps. The issue of using recycled plastic materials for producing plastic product was the low performance of mechanical properties [2]. Therefore, some effort to increase mechanical properties have been done by mixing of recycled plastic materials with virgin materials having reinforcing agents such as adding natural fibers, ceramic, metal and polymer itself in the blends [3-4].

Table 1: Estimation of generation, recycling and disposal of plastics from 2008 to 2011 in US [1]

In 1000's of tons	Generated, 2008	Recycled, 2008	Landfilled plus WTE 2008	Generated, 2011	Recycled, 2011	Landfilled plus WTE 2011
Total durable goods	10,520	390	10,130	11,420	740	10,680
Cups/plates	780	Negligible	780	1,030	Negligible	1,030
Trash/bags	930	Negligible	930	1,010	Negligible	1,010
Other non-durables	4,810	Negligible	4,810	4,480	110	4.370
Total non-durable	6,520	0	6,520	6,520	110	6,410
Bottles/jar, PET	2,680	730	1,950	2,740	803	1,937
Bottles/jar, HDPE	750	220	530	770	230	562
Other containers	1,900	280	1,620	1,870	290	1,767
Bags, sacks, wraps	3,960	390	3,570	3,880	430	3,683
Other packaging	3,720	110	3,610	4,640	60	3,460
Total containers/packages	13,010	1,730	11,280	13,900	1,813	11,497
Total plastics	30,050	2,120	27,930	31,840	2,663	29,177
Total plastics (in %)	100%	7.1%	93%	100%	8.4%	91.6%

As is known that the mechanical properties of recycled HDPE decreased compare to virgin HDPE, therefore, the recycled HDPE need to blend with virgin HDPE or others plastic materials such as PP to compensate the reduction of mechanical properties of recycled HDPE [5-6]. Blending with an appropriate approach of polymers blend gives the significant approach to develop good performance materials with a potential for more extensive applications [7-8]. The performance of

these polymer blends depends on the properties, contents and morphology of polymers involved. HDPE has an excellent chemical resistant to acids, bases or salts, fairly strong characteristics, low cost, easy process ability and excellent electrical insulation properties. Containers produced from HDPE normally opaque and have a dull surface appearance. PP is quite similar to HDPE but has better chemical and heat resistance. PP containers also similar to HDPE containers, but have much shiner surface. Recycled HDPE has lower melt temperature and viscosity than virgin HDPE resulting from a long chain breaking process into smaller chain of heat applied in former processing history. Therefore, this study focuses the blending these two virgin materials with recycled HDPE. Further, this study investigates to find right mixture ratio of HDPE/PP and recycled HDPE blend in order to obtain optimum mechanical properties of tensile strength and elongation at break.

1.1 Experimental

Plastic materials used for this study were virgin ETILINAS high-density polyethylene (HDPE) produced by Polyethylene Malaysia Sdn. Bhd., virgin TITANPRO polypropylene (PP) (produced by Titan Petchem (M) Sdn. Bhd.) and recycled HDPE (flash and rejected bottles). The recycled HDPE was prepared by crushing the flash and rejected bottles in crusher machine and changing it into small pieces. In order to ensure the validity of the results obtained, only the first cycle recycled HDPE (through only first thermal history) used in this study. Figure 1 shows the process of collecting recycle HDPE bottle. HDPE Bottle was extruded using an extruding machine. Then, the HDPE bottle were crushed in crushing machine. Then the recycled HDPE bottle was mixed with virgin HDPE and PP with three combinations of ratio as shown in Table 2. Three repetitions have been done for every experimental run. Thus, the total samples prepared were 27 specimens.

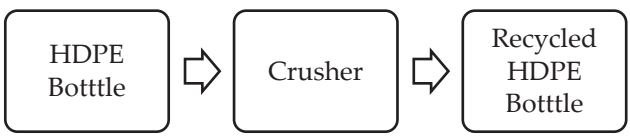
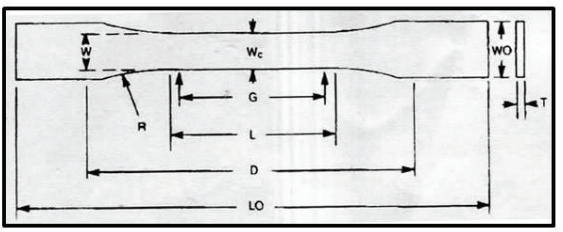


Figure 1: Process of collected recycle bottle HDPE

Table 2: Blending ratios matrix of virgin HDPE/Virgin PP/ Recycle HDPE

HDPE/PP (Ratio)	Recycle HDPE (%)
10/90	20
30/70	35
50/50	50

For evaluation of the tensile strength and elongation at break, ASTM D-638 standard Type 1 was used. Instron 50kN universal testing machine (UTM) made from USA was used to examine the tensile strength and elongation at break. The dimension of samples for tensile testing is shown in Figure 2. A crosshead speed was set at 50 mm/min.



W—Width of narrow section[E,F]	13 [0.50]
L—Length of narrow section	57 [2.25]
WO—Width overall, min[G]	19 [0.75]
WO—Width overall, min[G]	...
LO—Length overall, min[H]	165 [6.5]
G—Gage length[I]	50 [2.00]
G—Gage length[I]	...
D—Distance between grips	115 [4.5]
R—Radius of fillet	76 [3.00]

Figure 2: Dimensions of type I samples for tensile testing [2]

2.0 RESULTS AND DISCUSSION

2.1 Tensile Strength

Table 3 shows the experimental result of tensile strength for virgin HDPE, virgin PP and recycled HDPE. From Table 3, virgin PP has the highest tensile strength compared to virgin HDPE and recycled HDPE. The tensile strength of recycled HDPE decreases only 2.52% compared to virgin HDPE [9]. This indicates that virgin HDPE can be replaced with recycled HDPE in order to increase HDPE bottles recycling activities hence reduces the landfill of waste materials. Reduction in tensile strength of recycled HDPE can be explained by a long polymer chain of HDPE has been cut to shorter polymer chain by heat thus reducing the strength of the chain.

Table 3: Blending ratios matrix of virgin HDPE/Virgin PP/ Recycle HDPE

Materials	Tensile Strength
100% Virgin HDPE	21.03
100% Virgin PP	29.67
100% Recycled HDPE	20.50

Analysis of variance (ANOVA) for tensile strength shows that combination factor of HDPE/PP has a significant effect on tensile strength of HDPE/PP/ recycled HDPE blends as shown in Figure 3. The main effect plot for tensile strength as shown in Figure 4 indicates that HDPE/PP: 10/90 ratio of the blends gives higher tensile strength to HDPE/PP/recycled HDPE blends compared to 30/70 and 50/50 ratios. That 20% of recycled HDPE content contributes higher tensile strength to HDPE/PP/recycled HDPE blends compared to 35% and 50% of the recycled HDPE content. This shows that the ratio of HDPE/PP/ recycled HDPE: 10/90/20 has the highest value of tensile strength compared to other ratios of blends as shown in Figure 5.

Analysis of Variance for Tensile (coded units)

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Main Effects	2	40.764	40.764	20.3822	15.36	0.000
HDPE/PP	1	37.556	37.556	37.5556	28.29	0.000
Recycled HDPE	1	3.209	3.209	3.2089	2.42	0.134
2-Way Interactions	1	2.253	2.253	2.2533	1.70	0.205
HDPE/PP*Recycled HDPE	1	2.253	2.253	2.2533	1.70	0.205
Residual Error	23	30.530	30.530	1.3274		
Lack of Fit	5	19.630	19.630	3.9259	6.48	0.001
Pure Error	18	10.900	10.900	0.6056		
Total	26	73.547				

Figure 3: Analysis of variance (ANOVA) for tensile strength

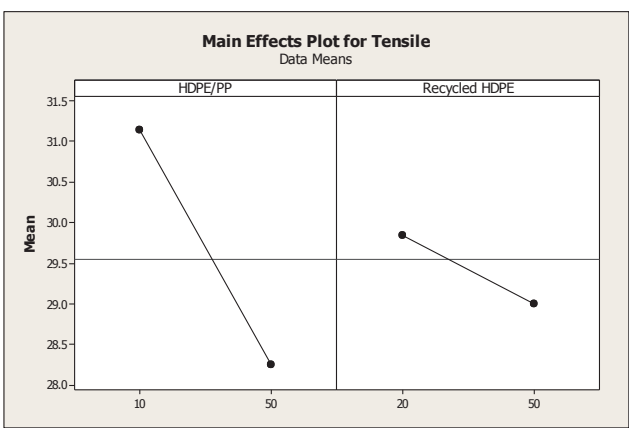


Figure 4: Main effects plot for tensile strength

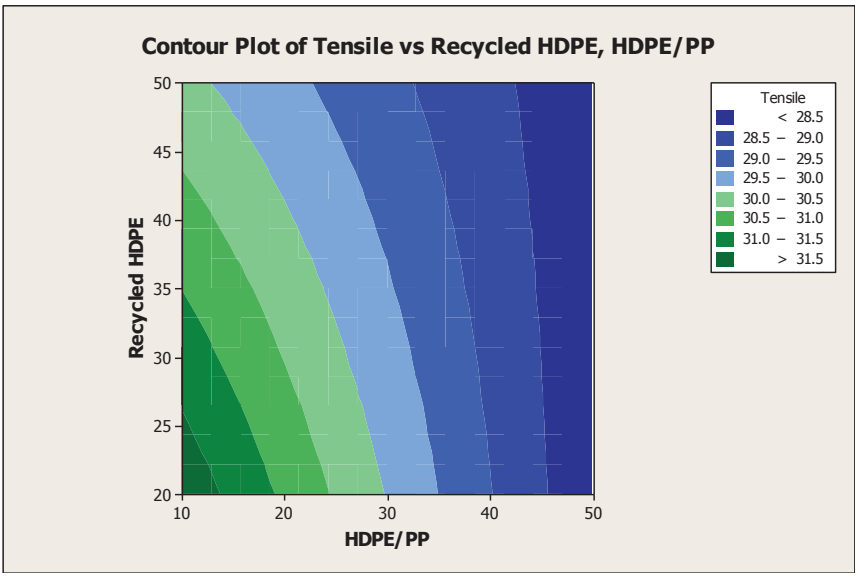


Figure 5: Contour plot of tensile strength

This can be explained that by the presence of a high percentage of virgin PP and the low percentage of recycled HDPE. Virgin PP has the highest tensile strength and recycled HDPE has the lowest tensile strength between these three studied materials. This result support by Mariam et al. which the tensile strength of recycled PP/recycled HDPE blends decreased with increasing recycled HDPE content [10]. They concluded that the addition of recycled HDPE influenced the tensile strength of the blends. The tensile strength increased with increasing virgin PP content. This because of PP has a rigid short methyl group that attached to every second carbon atom of the polymer chain. The restriction of the chain rotation produces a stronger but less flexible material.

2.2 Elongation at Break

Table 4 shows the experimental result of elongation at break of virgin HDPE, virgin PP and recycled HDPE that used in this study as reference.

Table 4: Elongation at break of virgin HDPE, virgin PP and recycled HDPE

Material	Elongation at Break (%)
100% Virgin HDPE	42.87
100% Virgin PP	9.24
100% Recycled HDPE	49.57

From Table 4, recycled HDPE has the highest elongation at break compared to virgin HDPE and virgin PP. Virgin PP has the lowest elongation at break among these three materials. Elongation at break of recycled HDPE increases about 15.63% compared to virgin HDPE. This indicates that recycled HDPE can be used as an alternative to virgin HDPE. Long polymer chain reduces the flexibility of virgin HDPE. Heat applied to material has cut the long polymer chain with a shorter polymer chain. This increases the flexibility of polymer chain, thus increases elongation at break of recycled HDPE.

Analysis of variance (ANOVA) for elongation at break shows that interaction between HDPE/PP/recycled HDPE has a significant effect on elongation at break of HDPE/PP/recycled HDPE blends as shown in Figure 6. The main effect plot for elongation at break as shown in Figure 7 indicates that HDPE/PP: 50/50 ratio of the blends gives higher elongation at break to HDPE/PP/recycled HDPE blends compared to 10/90 and 30/70 ratios. That 50% of recycled HDPE content contributes higher elongation at break to HDPE/PP/recycled HDPE blends compared to 20% and 35% of the recycled HDPE content. This shows that the ratio of HDPE/PP/recycled HDPE: 50/50/50 has the highest value of elongation at break compared to other ratios of blends as shown in Figure 8.

Analysis of Variance for Elongation (coded units)

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Main Effects	2	22.35	22.35	11.176	1.85	0.180
HDPE/PP	1	11.94	11.94	11.940	1.98	0.173
Recycled HDPE	1	10.41	10.41	10.412	1.72	0.202
2-Way Interactions	1	49.05	49.05	49.046	8.12	0.009
HDPE/PP*Recycled HDPE	1	49.05	49.05	49.046	8.12	0.009
Residual Error	23	138.89	138.89	6.038		
Lack of Fit	5	68.86	68.86	13.771	3.54	0.021
Pure Error	18	70.03	70.03	3.891		
Total	26	210.28				

Figure 6: Analysis of variance (ANOVA) for elongation at break

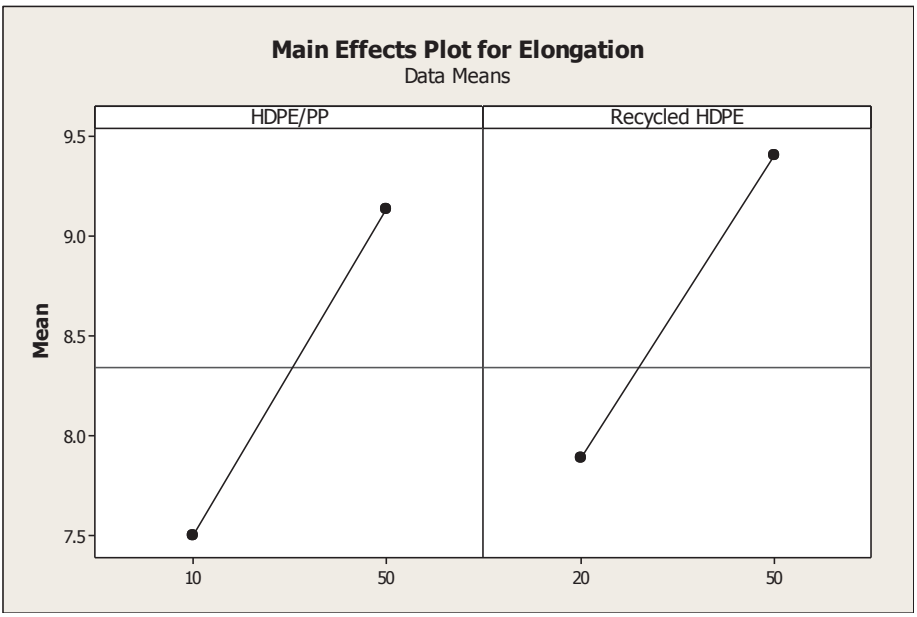


Figure 7: Main effects plot for elongation at break

This can be explained that by the presence of a high percentage of recycled HDPE and the low percentage of PP due to recycled HDPE has a higher elongation at break compared to virgin PP. Similar result reported by Abo and Ali which mentioned that the elongation at break of blends increased with the increasing of recycled HDPE content [11].

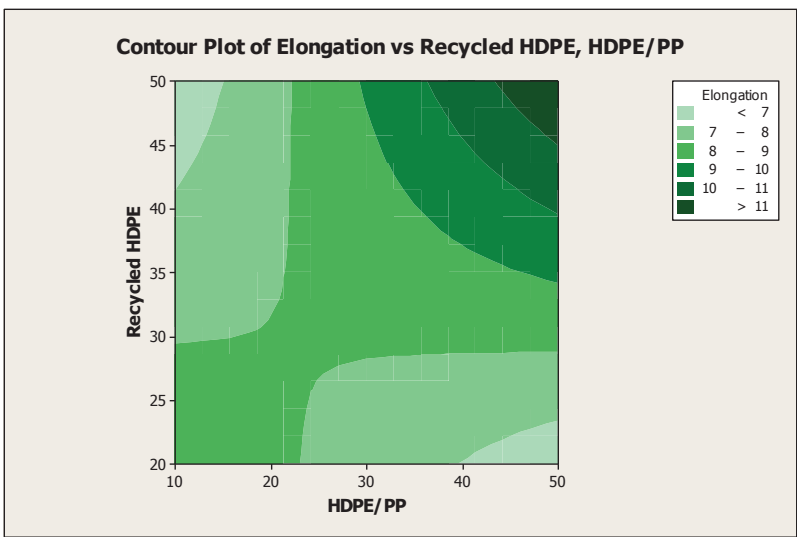


Figure 8: Contour plot of elongation at break

2.3 Miscibility of Polymer Blends

Thermal analysis done on HDPE/PP/recycled HDPE blends by using Differential Scanning Calorimetry (DSC) shows that there are two peaks of melting point in the total heat flow curve for all blend ratios as shown in thermograms in Figure 9, lower temperature peak for virgin HDPE / recycled HDPE and higher temperature peak for virgin PP. Madi found similar result where HDPE/PP/recycled HDPE blends were immiscible [6]. Figure 9 shows the single peak of melting point in the total heat flow curve for 100% virgin HDPE, 100% virgin PP and 100% recycled HDPE.

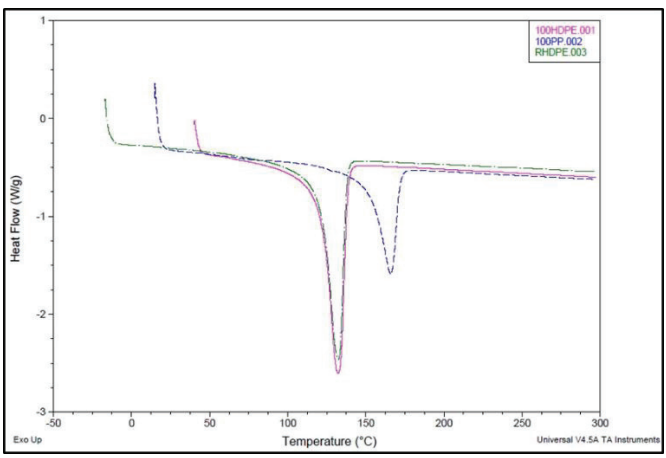


Figure 9: DSC Thermograms of virgin HDPE, virgin PP and recycled HDPE

3.0 CONCLUSION

It can be concluded that tensile strength of the blended materials increases with combination lower percentage of recycled and virgin HDPE. Meanwhile, combination high percentage of virgin PP and recycled HDPE increases the elongation at break for the blend.

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