International Journal of Synergy in Engineering and Technology IJSET

Effects of mechanical properties on blend loading ratio for recycled High Impact Polystyrene and Acrylonytrile-Butadiene-Styrene

Alias Mohd[1]*, Siti Noor Arfahtin Latif

[1]University College TATI, Jalan Panchor, Telok Kalong, 24000 Kemaman, MALAYSIA
*Corresponding author: aliasmohd@tatiuc.edu.my

KEYWORDS

Injection moulding
Mechanical properties
RSM
Recycled HIPS
ABS

ABSTRACT

In this work, the blend loading ratio of recycled HIPS/ABS will be conducted using twin screw extrusion machine. It is used extensively for mixing compounding, or reacting polymeric materials. The flexibility of twin screw extrusion equipment allows this operation to be designed specifically for the formulation being processed. The polymer blend will be injected using injection moulding machine according to ASTM D638. To investigate the mechanical properties; RSM approach will be used to setup the experimental work according to the machine parameter and levels used. A binary blend (45%ABS–50%HIPS wt) was conducted on a conventional injection moulding machine, at 190 – 195 – 200 – 210 °C melting temperature respectively. Finally, ternary blends were prepared by varying the SEBS content, from 0% to 30 % (wt %), at the same conditions of ABS-HIPS blends. It was found that the tensile strength (125.44 MPa) for recyled HIPS/ABS is maximum when the value of melting temperature (200˚C) and injection pressure (90 MPa) for the value of the injection moulding parameters setting.

1.0 INTRODUCTION

The study of mixtures of polymer materials has been the subject of a great deal of intense research in the last few decades. However, in spite of this study, there are still many problems associated with production of these materials which need to be studied and analysed in order to find solution (Peydro Rasero et al, 2013).

For the past few years, the difficulties to manage the waste plastic disposable problem around the world are increasing drastically. The volume of waste increased and triggered a problem in waste management system. The plastic waste are difficult to be disposed because of these materials are not easily decomposed and a number of the abundant waste. Plastics, for example, pose a risk to the environment when disposed of in landfills due to their long-term degradation process and to the presence of flame retardants. Additionally, plastics occupy a lot of space in landfills and thus could be made better use of or recycled before being discarded. In 2015, the world production of thermoplastic resins was 260 million. Latin America represents 5%

Received 20 October 2020; received in revised form 20 November 2020; accepted 25 November 2020.

of this production, with Brazil accounting for almost half of this value (Mendes Campolina et al., 2017).

Hence, this research is carried out to determine the optimum amount of recycled HIPS/ABS at the correct loading ratio to be injected and tested. The mechanical properties will be analyzed to obtain the optimum result. In addition, the blend polymers can be used for household product or office product. At the same time, it will help to solve the environment issue by recycling the waste plastic products and the new composite will be produced from recycled HIPS and ABS based on their blending ratio that will breed new material in moulding industry.

High impact polystyrene (HIPS)

High impact polystyrene (HIPS) is widely used in packaging, toys, bottles, house wares, electronic appliances, and light-duty industrial components because of its good rigidity and ease of coloring and processing. Therefore, it is a common practice to toughen polymer/filler hybrid composites by incorporating elastomer micro-particles, e.g., by physical blending of HIPS, $Mg(OH)_2$ with elastomer (Balani, 2015). An addition of fillers in such high amounts adversely affect mechanical properties of the plastics, including reducing elongation at break, sacrificing impact strength, and increasing melt viscosity (Focke, W. W. et. al., 2009). Therefore, it is a common practice to toughen polymer/fillers hybrid composites by incorporating elastomer micro-particles, e.g., by physical blending of HIPS, $Mg(OH)_2$ with elastomer (Balani, 2015).

Polystyrene is highly amorphous, glassy and brittle due to replacement of hydrogen by benzene ring with no steric order. It has T_g of 100 °C with high transparency, rigidity and easy workability as shown in figure 1. PS can be of various grades depending upon the mode of production such as, general purpose grade (GP) without any modification, high-impact poly-styrene (HIPS), expandable polystyrene (EPS) and modified polystyrene for improved flow (Thakur, S. et. al., 2018)

Acrylonitrile – Butadiene – Styrene (ABS)

ABS is a common thermoplastic used to make polymeric wood composites, has good physical properties in comparison with other commodity plastics and is cheap in comparison with other engineering plastics (Goutham, R et. al., 2018). The advantage of ABS is that this material combines the strength and rigidity of the acrylonitrile and styrene polymers with the toughness of the polybutadiene rubber. The most amazing mechanical properties of ABS are resistance and toughness (Alias et. al., 2016). Acrylonitrile gives chemical resistance and heat stability, butadiene gives toughness and impact strength and the styrene gives rigidity and easiness of process ability, whereas neat ABS as well as other polymers has its limitation in tribology due to high friction coefficient and wear rate (Sudeepan et al., 2014).

.

Styrene-Ethylene-Butylene-Styrene (SEBS)

HIPS and ABS are compatible with SEBS, then there are the strong probability that SEBS acts as an agent of compatibility between ABS and HIPS. The elastic character of SEBS must bring improved ductile properties to the ABS-HIPS system. One of the first effects that can be observed in the mechanical properties (Peydro Rasero et al., 2013). Chemical structures and mechanical properties of SBS and SEBS were shown in figure 1 and table 1 below (Direksilp & Threepopnatkul, 2014).

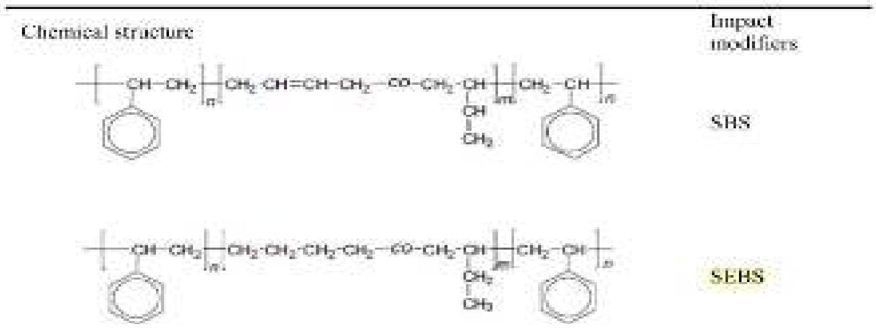

Figure 1: Chemical Structures of SBS and SEBS (Direksilp & Threepopnatkul, 2014)

Table 1: Mechanical Properties of SBS and SEBS(Direksilp & Threepopnatkul, 2014)

Mechanical properties	SBS	SEBS
Tensile strength (MPa)	32	>28
300% Modulus (MPa)	2.8	-
% Elongation at break	880	>800

Injection moulding

From the previous study, a binary blend Acrylonitrile-Butadiene-Styrene and High Impact Polystyrene (ABS-HIPS 50% wt) was prepared on a twin-screw extruder at 190-210 °C. The different mechanical properties were then analyzed for each experiment conducted. The tonnage capacity of the injection moulding machine used is 50 ton (TOYO Ti-Gx50).

There are over 200 different parameters that must be established and controlled to achieve proper injection molding of a plastic part. These parameters fall within four major areas: pressure, temperature, time, and distance as shown in table 2 (Koffi et al., 2016).

Table 2: Melt and Mold Temperatures For Specific Materials (Koffi et al., 2016).

Material	**Abbreviation**	**Melt Temp °c**	**Mould Temp °c**
Acrylonitrile Butadiene	Styrene ABS	240-280	50-80
Low Density Polyethylene	LDPE	170-240	10-40
Polypropylene	PP	200-270	10-40
High Density Polyethylene	HDPE	180-270	10-40
Polystyrene	PS	180-260	10-40

2.0 EXPERIMENTAL PROCEDURE

Materials and equipment

A commercial HIPS with MFI of 97 g/ 10 min (200 °C, 5 kg) and specific weight of 1.04 g/cm^3 together with ABS with MFI of 95 g/ 10 min (270 °C, 5 kg) and specific weight of 1.03 g/cm^3 are used as the polymeric material in present study. TOYO Ti-50GX injection moulding and crusher machine are used for injecting the specimen according to ASTM D638 type 1 as shown in figure 2. The Toyolac 700 314 Grade ABS and Idemitsu PS HT50 Grade Hips is being used and mixed accordingly. Three parameters are considered in the injection moulding machine are melting temperature, injection pressure and cooling time. INSTRON 3382 tensile test machine was used for performing tensile test.

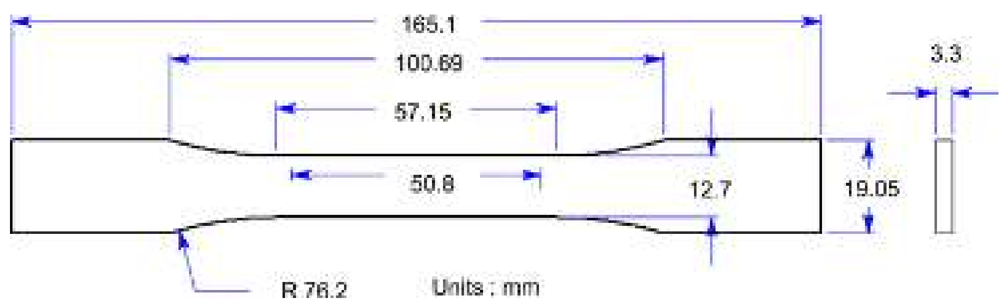

Figure 2: specification of specimen (ASTM D638 Type I)

Experiment works

A binary blend (50%ABS – 50%HIPS wt) was conducted on a conventional twin-screw extrusion machine, at 190 – 195 – 200 – 210 °C extrusion temperatures. Finally, ternary blends were prepared by varying the SEBS content, from 0% to 30 % (wt %), at the same conditions of ABS-HIPS blends (Peydro Rasero et al., 2013). This research is using 50% recycled HIPS, 45% ABS and 5% SEBS. SEBS is act as coupling agent for these two polymeric materials.

For ABS polymer, the moulding machine should be set up to deliver a melt temperature between 210 to 240°C, with an aim of 230°C for processing the polymer. The optimum temperature profile depends on many variables such as the ratio of machine capacity to shot size, screw design, mould and part design, and cycle time. The mould temperature range recommended for ABS materials is 40 to 60°C. Cooling time is important for part performance and cycle time optimization. Table 3 shows the selected parameters and their levels to conduct the experimentation works. The results obtained as shown in table 4 were analyzed using a Central Composite Design (CCD) in RSM.

A CCD is an experimental design, useful in response surface methodology, for building a second order (quadratic) model for the response variable without needing to use a complete three-level factorial experiment. CCDs are very efficient, providing much information on experiment variable effects and overall experimental error in a minimum number of required runs. CCDs are very flexible (Carley, K. M et. al., 2004). The availability of several varieties of CCDs enables their use under different experimental regions of interest and operability. A Central Composite Design (CCD) is an experimental design, useful in response surface methodology, for building a second order (quadratic) model for the response variable without needing to use a complete three-level factorial experiment

Table 3: Injection Parameter for Experiment

Moulding Parameter	Level
Melting Temperature (°c)	200-220
Injection Pressure (MPa)	90-110
Cooling Time (s)	16-20

Table 4 : Tensile and modulus strength results

Std	Run	Melt Temperature °C	Injection Pressure (Mpa)	Cooling Time (s)	Tensile Strength (MPa)	Modulus Strength (Mpa)
9	1	210	100	20	113.98	4256.89
10	2	220	100	18	121.49	4241.15
8	3	210	110	18	114.67	4350.02
18	4	220	110	16	112.62	4070.33
7	5	210	100	18	114.63	4113.33
20	6	220	90	16	116.07	4228.16
4	7	200	110	16	113.65	4394.52
11	8	210	100	18	112.69	4348.06
14	9	210	90	18	111.25	4204.82
6	10	210	100	18	109.29	4256.63
1	11	210	100	16	108.87[b]	4266.38
2	12	220	90	20	115.54	4528.78
12	13	210	100	18	116.33	4511.77
15	14	200	100	18	120.27	4465.9
3	15	210	100	18	116.41	4429.28
16	16	200	90	16	120.89	4530.77
13	17	200	110	20	121.46	4653.67
19	18	220	110	20	113.2	4291.1
17	19	210	100	18	116.39	4441.88
5	20	200	90	20	125.44[a]	4455.65

[a] = The highest value of tensile strength
[b] = The lowest value of tensile strength

3.0 RESULTS AND DISCUSSION

It can be observed after performing the tensile test, the results were analyzed to study the effect and correlation of recycled HIPS/ABS using CDD method at the different loading ratio.

Figure 3 shows the 3D graph representation of recycled HIPS/ABS tensile strength (125.44 MPa) interaction between melting temperature and injection pressure the maximum value of the setting injection moulding parameters. It was found that the tensile strength (125.44 MPa) for recycled HIPS/ABS is maximum when the value of melting temperature (200˚C) and injection pressure (90 MPa) the value of the setting injection moulding parameters. Change cooling time has not significant role in the change of tensile strength but with change in the inejction pressure, there is a significant change in the tensile strength. Tensile strength is minimum when melting temperature and injection pressure is maximum. The melting temperature and injection pressure had more effect on tensile strength than its cooling time. It is observed that melting temperature and injection pressure have positive influence on the tensile strength. This study shows that recycled HIPS/ABS at melting temperature of (210˚C) and injection pressure of (100 MPa) of injection moulding parameters were decrease in response to the cooling time.

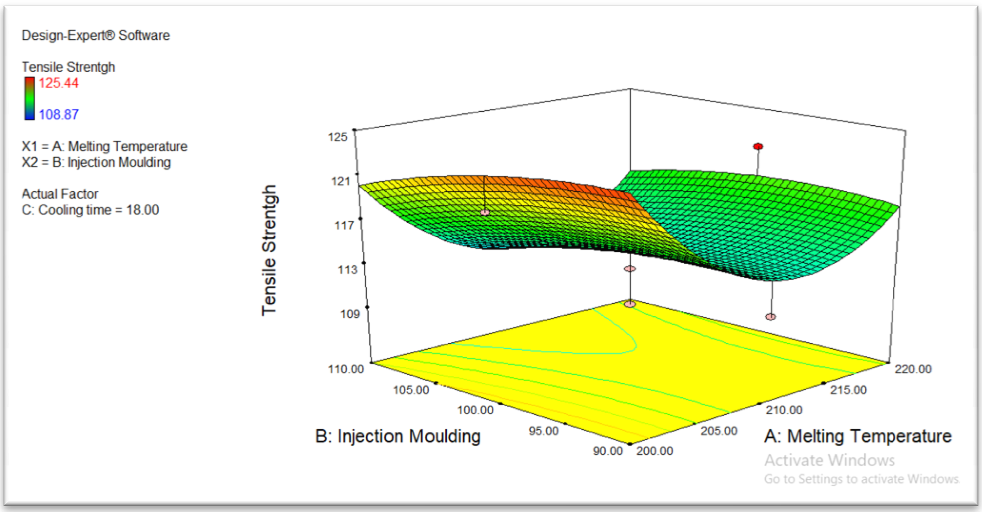

Figure 3: 3D plot effect tensile strength of interaction between melting temperature and injection pressure for recycled HIPS/ABS

Table 5: ANOVA analysis of tensile strength for recycled HIPS/ABS

Source	Sum of Squares	df	Mean Square	F Value	p-Value Prob>F	
Model	265.31	9	29.48	3.36	0.0364	significant
A	51.94	1	51.94	5.91	0.0353	
B	18.47	1	18.47	2.1	0.1776	
C	30.7	1	30.7	3.5	0.0911	
A^2	128.63	1	128.63	14.65	0.0033	
B^2	0.84	1	0.84	2.24	0.1566	
Residual	87.82	10	8.78			
Lack of fit	46.78	5	9.36	1.07	0.4446	not significant
Pure Error	41.06	5	8.21			
Cor Total	353.13	19				

Tensile strength= +114.18-2.28*A-1.36*B+1.75*C=0.68*A*B-1.54+0.55*B*C+6.84*A2-1.08*B2-2.62*c2 (1)

Table 5 has indicates that the analysis of variance (ANOVA) for mechanical properties of recycled HIPS/ABS in term of tensile strength. Statistically, the quadratic model F-value of 3.36 implies the model was significant. The p-value is less than 0.05, indicates that the model is significant. It can be seen that term A, A2 of the model were significant. The p-value for the term A, A2 was significant factor of 0.0353 and 0.0033. For terms A, C and A2 there were no significant factor. The lack of fit F-value of 1.07 implies the lack of fit is that it is not significantly relative to the pure error. From Equation (1), the quadratic model of tensile strength for recycled HIPS/ABS in terms of coded factors is given above.

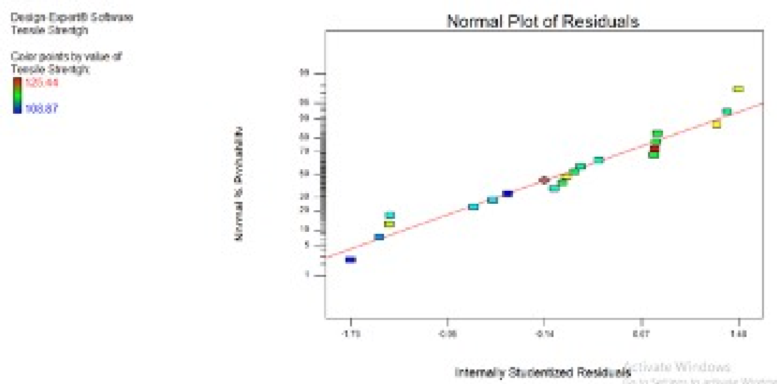

Figure 4: Normal plot of residuals.

Figure 4 shows that the normal plot of residuals also called the normal probability plot. The normal probability plot is a graphical technique for assessing wether or not a data set is approximately normally distributed. The data are plotted against a theoretical normal distribution in such a way that the points should form an approximate straight line. Depatures from this straight line indicate depatures from normality. In addition, a straight line can be fitted to the points and added as a reference line. The further the points vary from this line, the greater the indication of departures from normality. Probability plots are used to assess the assumption of a fixed distribution. In particular, most statistical models are of the form:

$$\text{Response} = \text{deterministic} + \text{random} \qquad (1)$$

Where the deterministic part is the fit and the random part is error. This error component in most common statistical models is specifically assumed to be normally distributed with fixed location and scale. This is the most frequent application of normal probability plots. That is, a model is fit and a normal probability plot is generated for the residuals from the fitted model.

4.0 CONCLUSION

From the experiment, it can conclude that the research works confirmed that, the optimum formulation was achieved with composition of 50% recycled HIPS,45% ABS, and 5% SEBS-g-MA to produced recycled HIPS/ABS blends. The temperature of 200˚C (low) was found to give the highest tensile strength (125.44 MPa) for recycled HIPS/ABS. Meanwhile the medium melting temperature (210˚C) of recycled HIPS/ABS resulted the lowest tensile strength (108.87 MPa).

It was found that the cooling time has no significant effect on mechanical properties. It can be observed that the melting temperature is the most significant factor affecting the tensile strength. A part of that, recycled HIPS and ABS are compatible with SEBS and establishing good bonding between these two polymeric materials which resulted the optimum tensile strength is obtained.

Also for this study, the experimental works are designed based on the Design of Experiment (DOE) together with the variable and the parameter selected which resulting the major and minor error such as random error can be minimize and avoided. Hence, the data and result that obtained from experiment is reliable and trusted and can be used by recycling the plastic for downgrade applications. Also, the recycled material can reduce the cost by reusing it again and again.

REFERENCES

Alias Mohd , Ainul Ayunie Roslan, Nor Bahiyah Baba (2016). Effect of Injection Molding Parameters on Recycled ABS (r-ABS) Mechanical Properties. Indian Journal of Science and Technology, Vol 9(9), DOI: 10.17485/ijst/2016/v9i9/88733, March 2016,

Balani, K. (2015). Physical and Mechanical properties of Polymers. Biosurfaces: A Materials Science and Engineering Perspective, 329–344. https://doi.org/10.1002/9781118950623.app1

Carley, K. M., Kamneva, N. Y., & Reminga, J. (2004). Response Surface Methodology 1 CASOS Technical Report School of Computer Science, (October).

Direksilp, C., & Threepopnatkul, P. (2014). Performance improvement of PS From Expanded Polystyrene off-grade. Energy Procedia, 56(C), 135–141. https://doi.org/10.1016/j.egypro.2014.07.141

Focke, W. W., Joseph, S., Grimbeek, J., Summers, G. J., & Kretzschmar, B. (2009). Mechanical properties of ternary blends of ABS + HIPS + PETG. Polymer - Plastics Technology and Engineering, 48(8), 814–820. https://doi.org/10.1080/03602550902994862

Goutham, R., Veena, T. R., Babagowda, & Prasad, K. R. S. (2018). Study on mechanical properties of recycled Acrylonitrile Butadiene Styrene (ABS) Blended With Virgin Acrylonitrile Butadiene Styrene (ABS) Using Taguchi Method. Materials Today: Proceedings, 5(11), 24836–24845. doi:10.1016/j.matpr.2018.10.282

Koffi, A., Koffi, D., & Toubal, L. (2016). Injection Molding Parameters Influence on PE Composites Parts, 12(10), 29–39.

Mendes Campolina, J., São Leandro Sigrist, C., Faulstich de Paiva, J. M., Oliveira Nunes, A., & da Silva Moris, V. A. (2017). A study on the environmental aspects of WEEE plastic recycling in a Brazilian company. International Journal of Life Cycle Assessment, (March), 1–12. https://doi.org/10.1007/s11367-017-1282-2

Peydro Rasero, M. a., Juarez, D., Sanchez Caballero, S., & Parres, F. (2013). Study of the Mechanical Properties of Acrylonitrile Butadiene Styrene – High Impact Polystyrene Blends With Styrene. Annals of the Oradea University, Fascicle of Management and Technological Engineering, (1), 269–272. https://doi.org/10.1.1.407.6723

Sudeepan, J., Kumar, K., Barman, T. K., & Sahoo, P. (2014). Study of Friction and Wear of ABS/Zno Polymer Composite Using Taguchi Technique. Procedia Materials Science, 6(Icmpc), 391–400. https://doi.org/10.1016/j.mspro.2014.07.050

Thakur, S., Verma, A., Sharma, B., Chaudhary, J., Tamulevicius, S., & Thakur, V. K. (2018). Recent developments in recycling of polystyrene based plastics. Current Opinion in Green and Sustainable Chemistry, 13, 32–38. doi:10.1016/j.cogsc.2018.03.011