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Assessment of Recycled Plastic Performance in The City of Zawia Libya

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Abstract: Plastic particles and other plastic pollutants exist in our environment and in the food chain and threaten human health. Inappropriate handling and disposal of plastic waste is a global problem and is still not resolved in many countries. When recycling companies need to deal with complex plastic, the problem becomes even more serious, which can prevent their recycling initiatives. The main purpose of this research is to determine whether recycled products can be used as post-consumer materials in various recycling ratios to produce new products without reducing quality. In the study, 0 percent, 20%, 50%, 70%, and 100 percent regrind ratios were used. Reduction, hardness, and solid density are the qualities studied. The results show that the properties did not change significantly.

Keywords: Recycling, plastic, polyethylene, molding

1. Introduction

Thermoplastics account for about 85% of all plastics consumed worldwide [1]. As a result, a growing number of plastic-based materials are being recycled. Several variables have influenced the development of plastic recycling initiatives in this setting. Rising raw material costs, greater consumer demands, and increased environmental consciousness are among these issues [2,3]. Several studies have investigated how molding processes can be used to recycle polymers. Elsheikhi et al. [4] used post-consumer materials or waste yard materials, whereas others used raw materials [5] and mixed materials [4,6]. The recycling of polymers using injection/blow molding has many economic and environmental benefits [2]. Indeed, this process is simple to carry out and does not necessitate various operations such as sorting, filtering, and cleaning, which are typically necessary with waste yard-derived products. On the other hand, it's critical not to skimp on the new product quality (i.e., the characteristics of the recycled material remain the same as the raw material). As a result, sprues, runners, and unused parts will be reused in this project. The regrind material is combined with the raw material in ratios ranging from 0 to 50 percent or more, depending on customer specifications [1]. Lewis and Buser [5] looked studied the impact of treating low density polyethylene "LDPE" by

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adding 25% recycled to the raw material with different melt histories on tensile characteristics within the same batch. Lewis and Buser [5] have demonstrated that adding 25% regrind to the LDPE process has no influence on the ability or tensile qualities of the material. Manufacturers can save money by using regrind to make parts without having to worry about its effects on tensile characteristics. Another study using high-density polyethylene "HDPE" with varied regrind ratios of 0%, 50%, and 100% indicated that there was no difference in melt temperatures between the raw material and the 100% regrind [7,8]. In this case, it can be shown that the modulus of elasticity is the same for the three regrind ratios considered: 0 percent, 50 percent, and 100 percent regrind.

Industry frequently uses reprocessing of recycled materials or resources reclaimed from post-consumer trash; nonetheless, maintaining product quality is a key barrier for recycling processes. Most published studies on the reprocessing and recycling of such materials focused on the influence of reprocessing on the physical and mechanical properties of a variety of polymers. Elsheikhi et al., [4], studied the possibility of the recycling process using the recycled refuse LDPE, HDPE, and PP. As a result, these three materials are among the most successfully recycled materials, based on the tensile strength of the process part as a reference. Other research has focused on the recycling processes in the cities of Benghazi and Misurata [6,8,9]. Their finding revealed the relative consistency of the moldability of HDPE material because of repeated reprocessing plans using 0, 20, 50, 80, and 100 % regrind. Due to the large number of daily-consumed plastic materials (e.g., bottles and bags) in the city of Zawia, Libya, recycling is extremely important. The main objective of this research is to find out whether recycling products are used as post-consumer materials at different processing ratios to produce new products without making significant changes. An assessment of the nature and behavior of the employed materials, a study of the process parameters, and an understanding of both the preprocessing and regrind effects are all undertaken to achieve the desired goal. More precisely, the impact of the reprocessing processes on key properties is investigated.

2. Limitations

2.1 Material Type

Most recycling methods have been performed on post-consumer materials, mixed landfill waste and items salvaged from yards. These materials were chosen for this investigation because they are easy to recognize and do not require any sorting or filtration. Furthermore, these materials were not exposed to adverse environmental conditions such as deterioration, UV rays, or corrosion.

2.2 The Conditions of Molding Process

Before implementing repeated recycling plans, it's helpful to examine the effective process settings (temperature, pressure, velocity, and so on) to avoid a dramatic drop in critical properties (mechanical properties, molecular weight, and so on). The commercial machine provided by a private company was employed in this study under regular operating conditions. As a result, changing the machine settings was impossible.

2.3 Related Properties

Several major product quality indicators and physical attributes are expected to change during the recycling process. An association between mechanical properties, molecular weight, thermal stability, and several other attributes should be developed to understand the theory behind what is happening throughout these alterations. Only the product shrinkage, hardness, and solid density were used in this investigation due to a lack of advanced equipment and machines available at the university's labs.

3. Procedure

3.1 Preparation: Material and Sample

The major uses and structure of HDPE material, which is commonly used for blow molding goods, were discussed in the literature review. This type of material is widely used in Zawia city to create everyday products such as detergent bottles. As a result, due to cost and environmental concerns, choosing such a material is a preferable option. The raw material utilized was RASCO High Density Polyethylene (HDPE) grade 5116. The blow molding machine used in this study was a CHIA MING, 100-tonne clamp force, model: CMH-1000B. This machine was offered from Al-Wafaa Plastic Factory. The products to be recycled was detergent bottle size 1 liter (without cover) as shown in Fig. 1.

3.2 Blow Molding Conditions

For the front zone, middle zone, and rear zone, the barrel temperature was set at 165°C, 155°C, and 146°C, respectively. The mold temperature was set to 14 °C (and the temperature was kept constant with the help of a water circulation controller). The screw rotational speed was set at 496 rpm, with 4 bar extruding pressure.

3.3 Plans for The Recycling Operation

The work was completed in five plans in this study. As illustrated in Fig.2, the scenario for each plan was created using different regrind ratios (0% for plan I, 20% for plan II, 40% for plan III, 50% for plan IV, 70% for plan V, and 100% for plan VI).

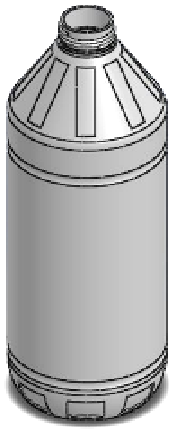

Fig. 1 - Used product

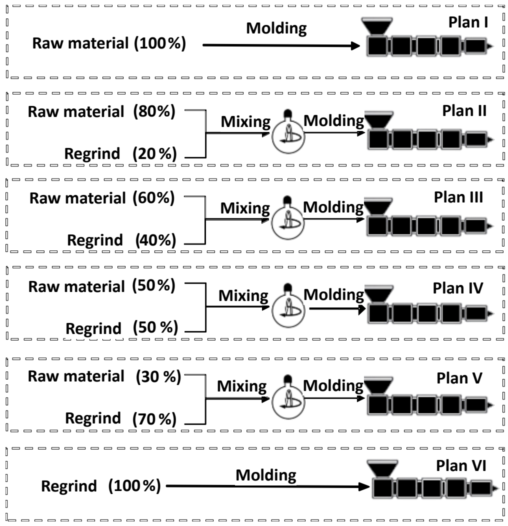

Fig. 2 - The Scenario of the process for each plan

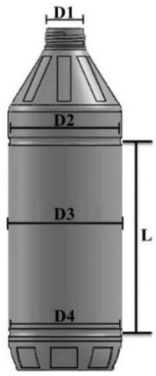

Fig. 3 - Positions of the shrinkage

3.4 Shrinkage Calculation

The behavior of shrinkage is critical to determine the ultimate dimensions of a part. The thermal contraction of the molten material during the cooling process, as well as the relaxing of stretched polymer chains, produce this phenomenon [10]. The shrinking phenomena is influenced by several causes. Material qualities, process parameters throughout the filling, packing, and cooling phases, and cooling system design are all factors to consider [11]. Shrinkage was measured at several positions on the product as shown in Fig. 3, and five samples were taken for each plan. The following calculation is used to compute the shrinkage as a percentage of the cavity dimension. [12]:

$$R = \left(1 - \frac{M}{M_0}\right) * 100 \tag{1}$$

where, R denotes shrinkage, M0 is the mold cavity dimension, and M denotes the actual product dimension. Figure 2 shows the geometry of the mold cavity and the measurement positions that were chosen.

3.5 Solid Density

Density, an important physical characteristic, is related to crystallinity. HDPE is also a semi-crystalline polymer that has both amorphous and crystalline parts. The relative volume fractions of the amorphous (low density) and crystalline (high density) phases determine the bulk material's density. Examining and comparing the densities of the molded products of all of the plans is beneficial. To achieve this test, the volume and mass measurement (mass in grams and volume in cm3) should be calculated by cutting off four samples so that they have the same position and dimensions (width, length, and thickness) and then measured using a digital calliper. These samples were weighed using a digital weighing scale.

3.6 Hardness Test

Hardness defines as the ability of a material's surface to resist the penetration of other particles into its surface or the metal's resistance to scratching. The hardness test is a process conducted on a test sample to determine its hardness property which; enables the material to maintain a coherent surface shape under the influence of loads. In general, hardness is defined as the resistance of a material to scratching or impact that would be attained under the same test conditions with a different material. Vickers is the method for testing the hardness in this study. The following formula is used to calculate the Vickers hardness:

$$\mathrm{HVN} = 1.854 * \frac{P}{D^2} \tag{2}$$

Where,

P: applied force
D: the average length of the diagonal left by the indenter.
Ray-Ran Vickers hardness device, model: STARA STD 226, is used in this study. This device is available in university laboratories. The test was performed according to ASTM D955-21.

4. Results and Discussion

4.1 Shrinkage

The shrinkage in all positions (D1, D2, D3, D4, and L) decrease over all plans as shown in Fig.4. The changing of the shrinkage levels may be linked to the augmenting levels of crystallinity [13-15]. The maximum shrinkage at diameter position D3 (across flow direction) is noted to be at plans 1 and 2 (3.7 %). The shrinkage (%) at position (D3) has decreased from 3.7 % to 2.0 %, from plan 1 to plan 6; approximately 46% lower. Similarly, position D2 has the lowest shrinkage (%), hitting 0.8% at plan1 and decreasing until it approaches 0.1% at plan6, resulting in an 87.5% reduction. Additionally, the relative consistency for error bars can be noted in Fig. 5. Based on ASTM D955-21, the shrinkage ranges of HDPE material related to the process is between 1.5 to 3%. According to the results observed in this work, it can be concluded that the parts produced from the reprocessing plans showed good stability for the dimensions.

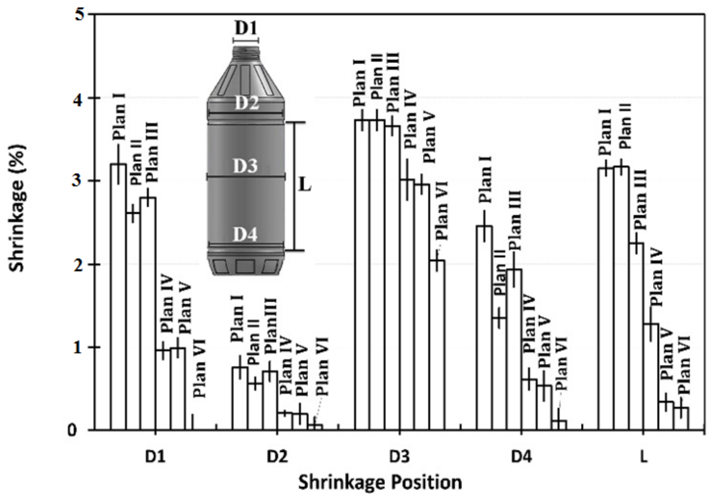

Fig. 4 - Measurements of shrinkage at all positions

4.2 Density

HDPE is made up of amorphous and crystalline regions as a semicrystalline material [10]. The relative volume fractions of the amorphous (low density) and crystalline (high density) phases determine the bulk material's density. As seen in Fig. 5, there is a decrease of roughly 8% in density with the designs from the initial plan 1 to the last plan V1. It's also worth noting that the error bars in Fig. 5 are all the same size. Elsheikhi [16,17] clarified density behaviour by enhancing crystallinity due to crystals that grew up employing free molecule segments. This effect could be explained by the polymeric chains' increased mobility due to their lower molecular weight as a result of degradation.

4.3 Hardness

Based on Fig. 6, the hardness is irregular between different regrind ratios, as the variation in values is noticeable from the regrind ratio of 0% (raw material 100%) to the regrind ratio of 40%, followed by the behaviour of the hardness values in a continuous decrease to the regrind ratio of 100% with a reduction of 15% of the hardness. It is also worth noting that the error bars are consistent.

5. Conclusion

The following conclusions can be made: (1) No significant changes in the consistency of the HDPE mold material were observed by using regrind ratios. A slight change in the key physical properties such as shrinkage, and density, and hardness was realized by using regrind ratios. This would allow many plastic manufacturers to produce products with acceptable quality levels. In terms of the impact of the recycling plans on product property, the following results have been found, (a) The product density was not significantly influenced by the regrind ratios, (b) Shrinkage: The molded parts produced from the recycling plans; using the ASTM D955-21 machine; showed good stability for the dimensions and (c) No significant change on the hardness of the final product was observed using the regrind ratios compare with original product with no regrind material.

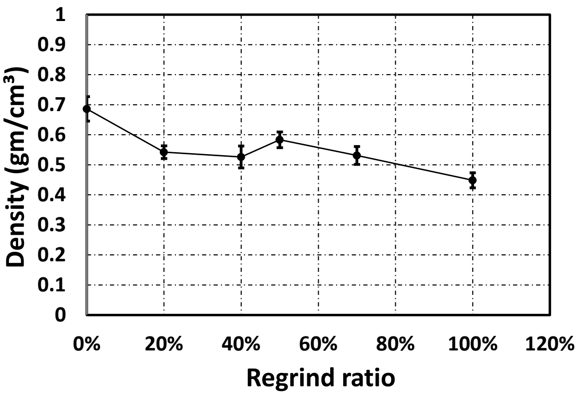

Fig. 5 - Density for different regrind ratios

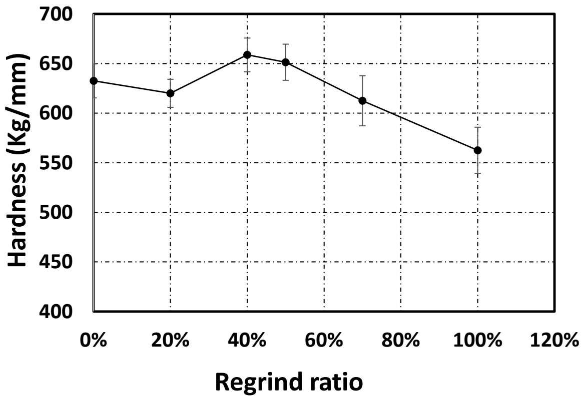

Fig. 6 - Hardness for different regrind ratios

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References

[1] Elsheikhi, S.A., & Benyounis, K.Y. (2014). Review of Recent Developments in Injection Molding Process for Polymeric Materials.

[2] La Mantia, F. (2002). Handbook of plastics recycling, iSmithers Repra Publishing.

[3] Elsheikhi, Salah & Benyounis, K. (2020). Plastics Recycling Processes and Public Attitudes, in Encyclopedia of Materials: Plastics and Polymers 10.1016/B978-0-12-820352-1.00024-9.

[4] lsheikhi, Salah & Mulvaney-Johnson, Leigh & Campean, Felician. (2014). Statistical Evaluation of the Reprocessing Conditions Through Injection Moulding Using Response Surface Methodology, in International Conference on Biobased Materials and Composites, ICBMC14, paper # 148. 2014.

[5] Elsheikhi, Salah. (2015). Reprocessing of Post-Consumer Material Through Blow Moulding in Benghazi/Libya. 10.13140/RG.2.2.25538.99528.

[6] Lewis, C. L. & Buser, M. A. (1997) Effect of reprocessing pre-consumer polyethylene in an injection molding environment, in 55th Annual technical conference, ANTEC 3162, (1997).

[7] S Elsheikhi, S. A. (2015). Reprocessing of Post-Consumer Material Through Blow Mouldingin Benghazi/Libya. The International Journal of Engineering and Information Technology. 2, 6-10.

[8] Andrzejewski, Jacek, Mateusz Barczewski & Marek Szostak. (2019). Injection Molding of Highly Filled Polypropylene-based Biocomposites. Buckwheat Husk and Wood Flour Filler: A Comparison of Agricultural and Wood Industry Waste Utilization. Polymers 11, no. 11: 1881. https://doi.org/10.3390/polym11111881

[9] Elsheikhi, S. A. & Eljaarani, M. A. (2017). Material reprocessing through blow moulding in Misurata – Libya. International Journal of Engineering and Information Technology. 3, 141-146.

[10] Elsheikhi, S. A., Mohamed, H. A. & Eldressi, K. A. (2018). Evaluation of multiple plastic recycling in Benghazi-Libya", Libyan Journal of Science & Technology, 7:1, 54-57.

[11] Gowariker, V.R., Viswanathan, NV. & Sreedhar, J. (1986). Polymer Science, John Wiley and Sons. Indianapolis.

[12] Mamat, A., Trochu, F. & Sanschagrin, B. (1994). Shrinkage analysis of injection molded polypropylene parts, ANTEC Conference Proceedings, 11, 513-517.

[13] Fischer, J. (2003). Handbook of molded part shrinkage and warpage. William Andrew.

[14] Lozano-González, M., Rodriguez-Hernandez, M. & Villalpando Olmos, J., 2000. Physical–mechanical properties and morphological study on nylon-6 recycling by injection molding. Journal of applied polymer science, 76, 851-858.

[15] Pontes, A.J., Neves, N.M., Velosa, J.C., Faria, A.R. & Pouzada, A.S. (2002). Glass fibre contents of PP plates and their properties: Part I: Shrinkage and changes in time. In Key Engineering Materials (Vol. 230, pp. 48-51). Trans Tech Publications.

[16] Elsheikhi, S. A., Hamzah A. Mohamed, & Eldressi K. A. (2020). Estimating the Quantity of Consumed Plastic Products and their Economic Returns in the City of Benghazi. Libyan Journal of Science & Technology 11:1, 28-32.

[17] Elsheikhi, S. A. (2011). A holistic approach to injection moulding optimisation for product quality and cost through the characterization of reprocessed polymeric materials and process monitoring," Ph.D. thesis, University of Bradford UK.