# Material Reprocessing Through Blow Molding in Misurata - Libya

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*Abstract* _ **The major aim of this study is to ascertain the feasibility of using recycled products in the form of post-consumer material using different regrind ratios to produce new products without a significant reduction in product quality. Five regrind ratios were used in this study: 0%, 20%, 50%, 80% and 100%. The used products were collected from different public places in Misurata city-Libya. The properties under investigation are mass, shrinkage, color, and solid density. The results indicated to no remarkable change in the concerned properties.**

*Index Terms:* **Blow molding, High-density polyethylene, regrind, reprocessing.**

## I. INTRODUCTION

Thermoplastics constitute 85% of consumed plastics in the world [1]. Therefore, the reprocessing of the thermoplastics and the usability of the reprocessed materials are gaining significance. Rising raw material costs, linked to increasing oil prices, increased consumer demand and increased environmental awareness have led to the development of plastic reprocessing programs [2].

Polymer reprocessing can be performed with many different technologies: this work concentrates on injection molding which is one of the most versatile and important technologies that widely used to process and reprocess different type of polymers [3].

Many researchers have conducted studies in the area of polymer reprocessing through the injection molding technology. These studies concerned the entirely recycled material in the form of post-consumer materials/ material reclaimed from scrap yards [1], entirely virgin material [4], and entirely mixed materials [5].

For many manufacturers, it is common practice to introduce reground sprues, scrapped parts, and runner systems into the injection molding process.
This process advantageous for economic and environmental reasons [2] and easy to implement because it doesn't require any sorting, filtering or cleaning operations usually required with material coming from landfill sites or post-consumer or rubbish yards.

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However, it is important to ensure that part quality is not affected; i.e. the properties of the reprocessed material remain the same with virgin material. Therefore, the process set up products in forms of sprues, runners, and unused parts were reground and used in this work.

Common industrial practice is to mix regrind material with the virgin material in ratios from 0-50% or higher depending on the customer specifications [3]. The authors in [4] have investigated the effect of processing low-density polyethylene "LDPE" on tensile properties by adding 25% of regrind to the virgin material with differential melt histories within the same batch. Their result showed that LDPE with 25% of regrind could be added to the process without affecting either the processability or the tensile properties. This allows manufacturers to save money producing parts with regrind without being concerned with the effects it may have on the tensile properties. Another study based on high-density polyethylene "HDPE" with different regrind ratios of 0%, 50%, and 100% found that the melt temperatures didn't change between virgin to 100% regrind [6][7]. In this context, Young's modulus was found to be the same between the three regrind ratios(virgin, virgin +50% regrind and 100% regrind).

Reprocessing of recycled materials or reclaimed from post-consumer waste material feedstock is widely used in industry; however, the product quality is an important challenge against the reprocessing operations. Therefore, the most published studies of such recycling/reprocessing of such material have dealt with the effect of reprocessing on the physical and mechanical properties of a range of polymers. The possibility of recycling and using recycled refuse LDPE, HDPE and polypropylene "PP" were investigated [1], and it was found that these materials which can be most successfully recycled based on the tensile strength of the processed part.

In Misurata city-Libya, the recycling operation is considerably needed; especially with enormous increasing of consumed plastic products during the daily life (bags, bottles, etc.). The major aim of this study is trying to manufacturing molded products using a different amount of recycled material within acceptable product quality level.

This aim can be achieved by studying the type and behavior of the material used; related process parameters; reprocessing effects and the regrind effects. Specifically, the aim of this study is to examine how some key properties are influenced by reprocessing operations.

## II. LIMITATIONS

### *A. Material Type*

The majority of the recycling works focused on post-consumer materials, landfill material; material reclaimed from yards or mixed material.

In this study, post-consumer materials were used; due to ease to recognize this type of material and hence, no need to sorting and filtration operations. Also; to avoid dealing with material that may be subjected to harsh conditions. These conditions may be corrosion, ultraviolet or possible types of degradations.

### *B. Blow Molding Conditions*

Before the multiple recycling plans; it may be useful to examine the effective process settings (temperature, pressure, velocity, etc.) to reduce the possible sharp reduction in the key properties (mechanical properties, molecular weight ..., etc.).

In this study, the commercial machine offered by the private company was used with the normal operating conditions. For this reason, it was impossible to change the machine setting.

### *C. Key Properties*

During the multiple recycling, key product characteristics and material properties may be expected to change through shear and thermal history. To understand what happened; this may need to make possible links between these properties such as molecular weight; crystallinity; thermal stability; and mechanical properties.

In this study, the key properties considered are mass, product geometry and shrinkage, product color, and density. The limitation of the properties considered due to unavailable facilities within the University's labs. Also, these facilities were not available in some research centers (plastic research center and petroleum research center) in Tripoli city.

## III. PROCEDURE

### *A. Material and Sample Preparation*

The literature review has outlined the key uses and structure of HDPE material, which is widely used for blow molding products. This type of material is widely used – in Misurata city – to manufacture daily consumed products such as the detergent gallons. This makes the selection of such material is a better choice; due to cost and environment issue. The raw material used was High-density polyethylene (HDPE); grade F00952 supplied by SABIC Inc.

The blow molding machine used in this study was a 100-tonne clamp force, model: KAI MEI. This machine was offered from Alghowail Plastic Factory. The products to be recycled was detergent gallon size 5 liters (without cover) as shown in Fig. 1. These products were collected from Al-Giran scrap yard, hospitals, houses and public utilities. Following the material collection; necessary steps were carried out to prepare the material and to make it ready for recycling process such like watching; drying; granulating then manufacturing.

Figure 1. The Selected Product in this Study

### *B. Blow molding conditions*

The barrel temperature was set to 165 °C, 155 °C and 146 °C for front zone, middle and rear zone respectively. The mold temperature was set to 14 °C (the temperature was maintained by using water circulation controller). The screw rotational speed was set up to 496 rpm, and the extruding pressure was 4 bars.

### *C. Plan of the Current Study*

In this study, the work was achieved in five plans. The scenario for each plan was developed to utilize different regrind ratios (0% for the plan I, 20% for plan II, 50% for plan III, 80% for plan IV and 100% for plan V) as shown in Fig.2. These plans can be illustrated as follows:

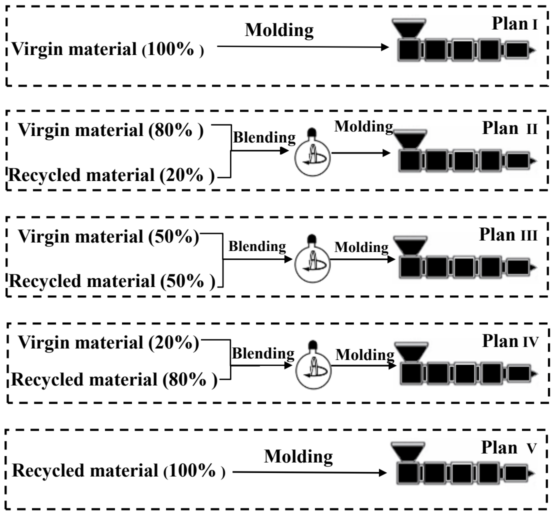



Figure 2. The Scenario of the Process for Each Plan

#### *1) Plan I*

In this plan, the recycling operations started by introducing 100% raw material (raw material) as shown in Figure.1. It was found that the machine to be stable after ten cycles. This could be noted easily when the stability of cycle time is observed (22 sec). The amount of raw material (10 kg) was found enough to achieve 30 cycles (30 products). The last five samples were collected for off- line testing.

*2) Plan II*

The scenario here is to use 20% of regrind material (using the post-consumer material) which blended with 80% of raw material as seen in Figure.1. This plan is aiming to ascertain the feasibility of using a raw material with the previously processed material (20%) to produce new products without a significant reduction in product quality. Five samples were collected to carry out the related tests.

*3) Plan III*

This plan is aiming to ascertain the feasibility of using 50% raw material with 50% of regrind from post-consumer material to produce new products as shown in Figure.1. Five samples were collected to carry out the related tests.

*4) Plan IV*

Here, the mixture was 80% regrind from post-consumer material and 20% raw material. This scenario is shown in Figure.1. Five samples were collected to carry out the related tests.

*5) Plan V*

The scenario here is to use 100% of regrind material (using the post-consumer material) as shown in Figure.1. This plan is aiming to ascertain the feasibility of using 100% regrind of previously processed material (from post-consumer materials) to produce new products without a significant reduction in product quality. Five samples were collected to carry out the related tests.

## IV. PART QUALITY

### *A. Specimen Mass*

The mass of a product is commonly used as a "part quality" indicator and changes of specimen mass can often be linked to changes in dimensions, and hence the stability in the specimen mass could indicate to the stability of the part dimension. The specimen mass is obtained by measuring the test sample including the runner and sprue on a standing mass balance for every reprocessing plan after that the average specimen mass was calculated.

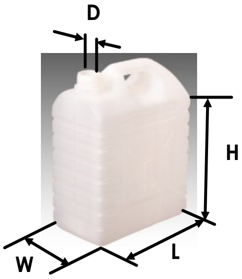
### *B. In-Plane Shrinkage*

Shrinkage behavior of a molded plastic part plays a principle role in determining final dimensions of the part. Shrinkage occurs due to the thermal contraction of the molten material during cooling and the relaxation of stretched polymer chains [8]. This phenomenon is affected by many factors including process parameters at filling, packing and cooling phases, cooling system design, and material properties [9].

In-plane shrinkage was measured in several locations on the specimen. Five samples were selected for each stage to measure the shrinkage. Equation (1) [10] was used to determine the in-plane shrinkage in as a percentage of the cavity dimension.

$$R = (1 - M/M_0), \quad (1)$$

where, R is the shrinkage, $M_0$ is the mold cavity dimension, and M is the same dimension measured on the specimen. The mold cavity shape and the selected measurement positions are shown in Figure.2.




| Shrinkage position | mm |
|---|---|
| D | 3.8 |
| H | 26 |
| L | 20 |
| W | 12 |

Figure 3. Shrinkage Positions

### *C. Product Colour*

The color of the samples is an important quality issue where the change of the product color may be aesthetically detrimental in the first instance and may indicate possible material degradation; there may also be an associated change in mechanical performance and material processability. Digital photo was taken by using Samsung digital camera model DV100. Images were obtained without flash, and all samples (from the plans I to V) included within the same frame for direct comparison under the same light conditions. This avoided the need to build a light controlled environment, but allows for a reasonable comparison of color change. Adobe Photoshop CS 2 version 9 was used to analyze the yellow color for the selected images (for every plan). Image mode CYMK (C: cyan, Y: yellow, M: magenta and K: black) and yellow channel were selected to determine the yellow color percentage.

## V. PHYSICAL PROPERTY DENSITY

Density is an important physical material property and is linked to crystallinity. Also, HDPE is a semi-crystalline material consisting of amorphous and crystalline regions. The density of the bulk material is dependent upon the relative volume fractions of the amorphous (low density) and crystalline (high density) phases. However, it could be useful to examine and compare the densities of molded specimens of all the plans. Due to unavailability of any device to measure solid density in Engineering Faculty labs; however; the test was carried out in a simple way by determining the volume and measuring the mass. Then the density - by definition - can be calculated as mass (in grams)/volume (in $cm^3$). Five samples for each plan were prepared to calculate the solid density.

## VI. RESULTS AND DISCUSSION

### A. Specimen Mass

In this study, the specimen mass is consistent at any given reprocessing plan, but mass slightly increases over the five plans by 2%; as shown in Figure. 3. The reduction in viscosity may explain the observed increase in mass since pressure gradients through the melt during the phase of extraditing is likely to be reduced, allow more material to be compressed into the cavity. This change of mass could be as a result of a reduction in viscosity, due to the possible effects of recycling. From Figure.3, it could be noticed, also, that the error bars (which represent the standard deviation) are consistent.

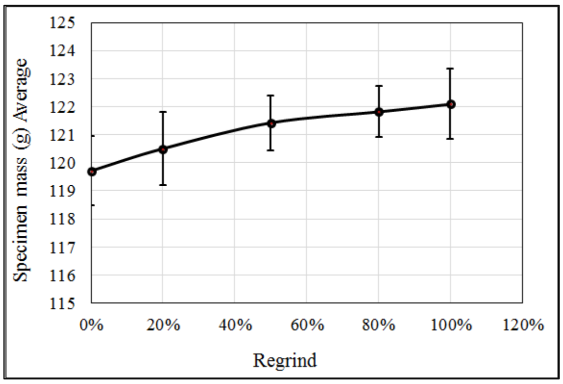



Figure 4. Mass Over Five Plans

### B. In-Plane Shrinkage

It can be noted from Figure.4, that the shrinkage through (D, W, and L) increases along the flow path. Similarly, the shrinkage through height (H) decreases along the flow path, which is along the flow direction. This could be justified as the shrinkage in the across direction of flow is higher than in the direction of flow. Also, increasing of shrinkage may be linked with increasing levels of crystallinity [11-13].

The shrinkage at "H" position has decreased from 0.0055 % to 0.003 %, from the plan I to plan5. With regards to across flow direction (D, W, and L); the maximum shrinkage is noted to be at the location of D (0.022 %). This may be explained by the fact that the position of D is very close to the source of flow, and hence it may take more time to solidify compared to the positions of W and L. Figure.4 shows, also, the relative consistency for error bars.

According to ASTM D955, the shrinkage range of High-Density Polyethylene material related to molding process between 1.5 to 3%. Based on the results observed in this study, it can be stated that the molded parts produced from the reprocessing plans show good dimensional stability.

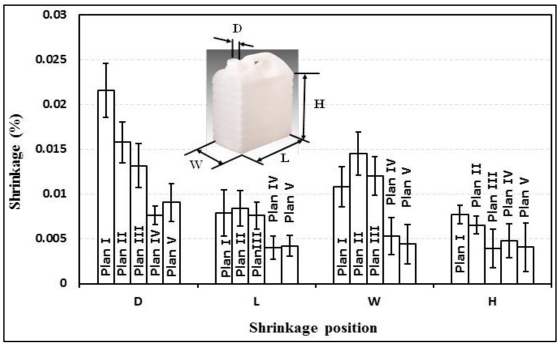



Figure 5. Shrinkage Measurements

### C. Colour

The aesthetics of a polymeric material may be an important quality feature, depending upon the end use of the product. The color change has been assessed by the percentage of yellow within the color spectrum. The color analysis indicated that the yellowness had not appeared gradually from plan Ito plan IV as shown in Figure.5. The relative change in yellowness (25 %) from 0% regrind to 100% regrind is low. In addition, From Figure.5, it could be noticed that the error bars are consistent. In industry, to accept or refuse the relative change in the product's color is absolutely depending upon the type of application, and the customer's specifications/requirements. However, this problem can be solved, if no severe or sharp drop in other properties such as the mechanical properties, by adding pigments or artificial colors.

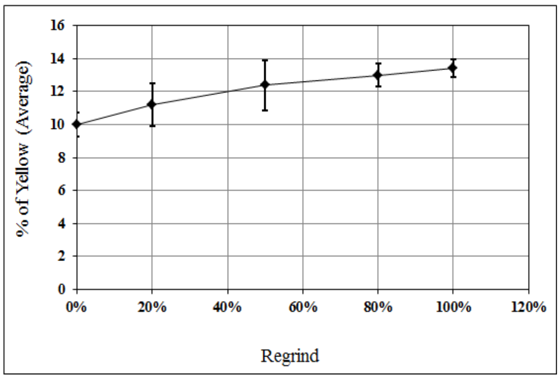



Figure 6. % of Yellow Over 5 Plans

### D. Density

High-Density Polyethylene is a semi-crystalline material consisting of amorphous and crystalline regions [8]. The density of the bulk material is dependent upon the relative volume fractions of the amorphous (low density) and crystalline (high density) phases. As shown in Figure.6, the density increases slightly (by 0.13 %) with reprocessing plans from the plan I to plan V reprocessed material. It could be noticed from Figure. 6; also; the error bars are consistent.

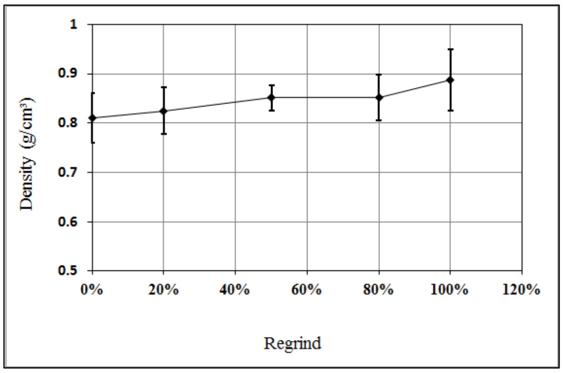



Figure 7. Density Over Five Plans

Some investigators [14] explained the behavior of density by increasing of crystallinity due to that the crystals which grown using molecule segments released. This could be explained by greater mobility of the polymeric chains due to lower molecular weight as a consequence of the degradation.

## VII. CONCLUSION

The following points can be concluded:

1. The moldability of HDPE material through successive reprocessing plans using 0, 20, 50, 80, and 100 % regrind is relatively consistent.
2. Examining the key product and physical properties (mass, color, shrinkage, and density) help to manufacture a product with a small loss of these properties at different regrind ratios.
3. Based on the results of selected properties in this study, it could be stated the following:
   - Mass: No remarkable change in the product mass over five planes; it could be stated that the regrind ratios have no considerable effects on product mass.
   - Colour: using the recycled material (in the form of post-consumer material) with different ratios (0, 20, 50, 80, and 100%), have no effect on final product color. This could make the using of this type of material more attractive to the costumers.
   - Shrinkage: Based on the ASTM D955, it can be stated that the molded parts produced from the reprocessing plans show good dimensional stability.
   - Density: No remarkable change in the product mass over five plans; it could be stated that the regrind ratios have no considerable effects on solid density.

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