Investigation of the Mechanical Properties and Applicability of HDPE Recycled Plastic Bags

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Abstract

Plastics have been one of the most used materials in manufacturing products. Disposal of plastic wastes have led to a major problem to surrounding environment. Implementation of plastic recycling is important to the current era where disposed plastic is more than recycled or reused plastics. In this research, optimum heating conditions will investigate for the manufacturing of plastic boards from recycled HDPE plastic bags. Other possible applications are also further researched with comparison to products available in the market. Multiple specimens are produced and undergone microscopic observation, hardness, and compression test. HDPE plastic bag specimens are recycled using a normal home oven and its thermal insulation has been used to prevent heat loss. Various temperatures and duration in oven are tested in this research. The HDPE plastic bags are shredded, placed in a metallic pan, and melted in the oven with controlled heating temperatures and duration. The fully melted material is then poured in a mold and well compressed to produce planks or bars for the required mechanical tests. The experiments have shown that higher temperatures have produced better hardness results. The duration shown influence on the materials in terms of homogeneous bond. A heating temperature of 230˚C and 60 minutes duration in the oven give the better mechanical properties. Solid plastic boards for tables and chairs beside shopping trolley wheels are the suitable applications recommended for the recycled HDPE plastics.

Keywords: HDPE; Plastic Bags Recycling; Plastic Waste.

1. Introduction

In today's sustainable society, plastic is a substance that is frequently utilized and has ingrained itself into our way of life. Global plastic production has gradually increased through the years due to its low cost, versatility, high physical and chemical stability, and simple manufacturing and processing procedures [1]. Common commercial used thermoplastics are polyethylene terephthalate (PETE), high-density polyethylene (HDPE), polyvinyl chloride (PVC), low-density polyethylene (LDPE), polypropylene (PP), and polystyrene (PS), which can be identified with labels found on the products. Due to chemical properties of plastics, it takes decades to degrade. Due to their widespread commercial use, the present amount of trash from them poses a serious environmental risk if improperly disposed of. Common household used plastics are contributing to that factor as most plastic wastes are discarded without being recycled [2]. Plastic recycling process starts with sorting based on shape, size, density, colour, and chemical composition [3].

A astounding 322 million tonnes of plastics were produced globally in2015, an increase of 3.5% from the previous year. Plastic waste generated in Europe annually is 25 million tonnes on average. 29.7% was effectively recycled, 39.5% was used for energy recovery, and remaining of 30.8% was landfill [4]. E-waste has generated an estimated volume of 44.7 million tonnes in year 2016 and with annual growth rate of 3~4%, expectation will be 52.2 million tonnes in year 2021. Despite having a staggering volume in millions, overall

global e-waste recycling rate is only 15% [1]. Recycling rates in the United States, China, and Europe are 9%, 25%, and 30%, respectively, and global recycling rate are only at an average of 18% [5].

Plastic wastes have generated about 6300 million metric tons till the year 2015, 79% are discarded, 12% are incinerated, and only 9% are being recycled. Most plastic wastes end up in landfill or incinerated causing more pollution's while recycled plastics can be used to make a variety of things depending on properties of the recycled plastics [2]. Consumption of plastics will gradually increase and several methods of recycling to recover plastics are required which include mechanical recycling, chemical recycling, pyrolysis, and gasification. The most widely practiced recycling method are mechanical and chemical recycling [5].

One of the mechanical recycling methods is primary recycling also known as re-extrusion or closed loop process [6],[7]. Wood plastic composites made from different mixture, poses different strength, also, good combination of recycled plastics will provide better composition properties [8]. Plastic bags are the most popular item to pollute and destroy natural environment according to [9]. Solvents has been also used to dissolve the polymers in plastic recycling [10].

2. Experimental Setup

Simple recycling techniques for plastic bags are suggested to encourage regular people to choose the recycling industry due to its inexpensive startup and processing costs. The proposed procedures are an implementation of mechanical plastic recycling processes to produce plastic boards using compression molding. The procedure is separated into few stages, identification and separation, sorting, cleaning, shredding, heating and molding. Materials are first identified and separated by type according to recycling code, where HDPE plastic bags are chosen.

The following steps are followed for the recycling:

1. Classification and shredding of HDPE plastics.
2. Heating the shredded HDPE plastics in a normal domestic oven.
3. Decide the heating duration inside the oven for better melting.
4. Pouring the melted HDPE plastics into a prepared metal cast.
5. Applying sufficient pressure on the cast to get the homogeneous shapes.
6. Natural cooling at room temperature.
7. Conducting the mechanical testing on the samples.

HDPE plastic bags are chosen for this research as the raw material. The properties of HDPE are stiffness, strength, chemicals and moisture resistant, permeability to gas, ease to process and ease to form. Some product applications of HDPE are bottles, milk jugs, chemical bottles, dish and laundry detergent bottles, trash, and retail bags.

The equipment and apparatus utilized in this research to conduct the experiments are:

i. Plastics shredder
ii. House use thermal insulated oven. 1380W and 19L capacity. Temperature setting of the oven ranges from 0℃ to 250℃.
iii. Baking paper and metal trays
iv. Metal cylindrical mold for compression test samples.
v. Press with G-clamps
vi. Hardness testing machine – Shore A Durometer, Teclock Durometer GS-706G with ASTM D2240 standards.
vii. Compression machine – KENCO E-series Analog Compression Machine.
viii. Microscope – Olympus CX31

In this experiment, the temperature ranges from 210℃ to 230℃ with different duration inside the oven are implemented to produce the different recycled specimens. Each temperature is conducted with variation of 40, 50 and 60 minutes. Duration of 30 minutes or less are shown unsuccessful for complete melting of the HDPE flakes.

Figure 1 and Figure 2 shown sample specimens of recycled HDPE plastic and compression test, respectively.

Fig. 1 HDPE plastic specimen

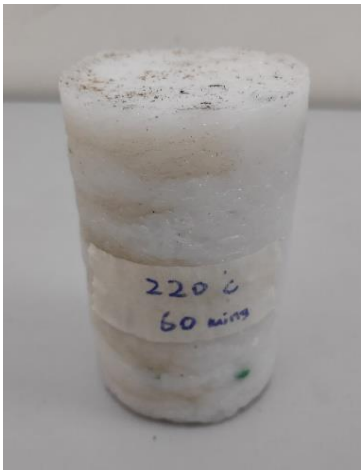

Fig. 2 HDPE plastic compression specimen

3. Result & Analysis

3.1. *Shore Hardness Test*

The hardness test is conducted on specimens according to ASTM D2240 standards, each reading is 12mm from the edges and 6mm in between each point. All data is recorded and tabulated according to time and temperature. Figure 3 is showing the hardness results at the different temperatures and different oven heating duration. It can be observed from the graph that the hardness value is increases with increasing temperature. At every duration, higher temperature results in higher hardness value. Highest hardness value of HDPE specimens at 210℃ is 91.1 while highest hardness value at 230℃ is 95.8. The behaviour of the specimen finally observed that the temperature has an impact on the specimen's hardness, however the highest hardness value was recorded after 60 minutes.

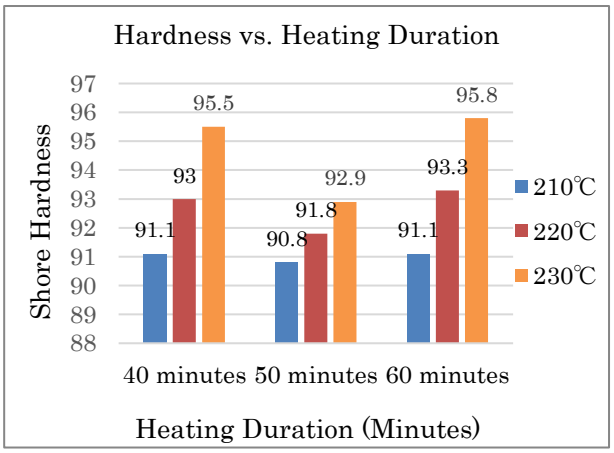

Fig. 3 Hardness comparison at different temperatures and oven heating duration

3.2. *Microscopic Surface Structure*

All specimens from the different recycling conditions have been magnified and observed under a microscope to compare each surface structure. Observation from human naked eye shows smooth surface compared to microscopic magnification which revealed grooves on each surface. Magnification power used to observe for each specimen is 10X. Observation results of surface structure of HDPE plastics when heating at 230^0C at different durations are shown from Figure 4 to 6.

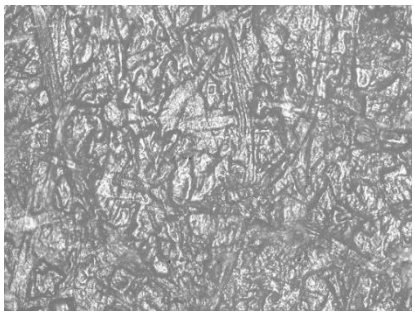

Fig. 4 Specimen at heating duration 40 minutes

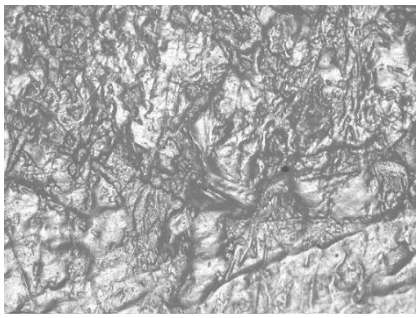

Fig. 5 Specimen at heating duration 50 minutes

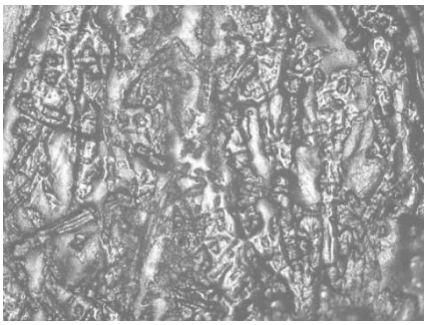

Fig. 6 Specimen at heating duration 60 minutes

3.3. *Compression Test*

Cylindrical specimens have been prepared and tested, using Kenco E-Series Analog compression test machine. After compressing the specimens, HDPE plastics exhibited ductile characteristics as specimens shows barreling from the sides. Cracks occurred on HDPE at certain amount of load and experiment was stopped.

Compressive strength can be calculated with data obtained from compression test. Value obtained from the equipment is Newton, a specific formula will be used to calculate and find the compressive strength value.

$$\text{CS} = \frac{Force\ (N)}{Cross\ sectional\ Area\ of\ Specimen\ (mm)}$$

*CS = Compression Strength

Table 1 Compression Strength of HDPE Plastic

Temperature (℃)	**210**	**220**	**230**
Compressive strength (MPa)	21.04	21.89	20.2

Table 1 shows the values of compressive strength of the recycled HDPE plastics at heating duration 60 minutes. It can be observed that at 220℃, the recycled HDPE is having the strongest compressive strength of 21.89MPa. At higher recycling temperatures, there is no apparent increase in compression strength.

4. Conclusion

In this paper, we have found that the recycling heating temperature and the time duration inside the oven are the dominant factors in the recycling of HDPE plastic bags. A specified temperature should be set for better recycling. Also, the duration inside the oven have shown an effect on the recycled HDPE quality. A heating temperature of 230°C with duration of 60 minutes have shown the best mechanical properties for HDPE recycling. It was noticed that if the recycling temperature was exceeded, the material could burn. Some burnt marks are visible to naked eye, but some can only be revealed through microscopic observation.

When compared to other materials, the recycled HDPE's mechanical qualities show that it can meet all the criteria needed for flat boards to be utilized as table and chair tops. Additionally, it can be utilized to replace the idler rollers and the die pads used for metal forming. Conveyor belts may be supported by idler rolls. Furthermore, recycled HDPE is suggested for the wheels on shopping carts.

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