

Effect of Particle Size on Tensile Strength Characteristics of Recycled HDPE Plastic

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ABSTRACT

This study aims to compare the tensile strength characteristics of pure HDPE materials with recycled HDPE by performing tensile tests on test specimens. The stages in this research were carried out by printing pure HDPE specimens and recycled HDPE with mesh sizes of 4 mm, 8 mm, and 12 mm for the test specimen weight of 184 grams and printing using a particle board press machine with a pressure of 40 kgf and a temperature of 40 kgf. used 1000 C for 5 minutes then carried out a tensile test using a tensile testing machine ASTM D638. Stepping to determine whether the specimen is feasible or not are carried out by comparing the results of the data on the HM specimen (as a reference) with the HDU4, HDU8, and HDU12 specimens.

Keywords: Particle Size, Tensile Strength, Recycled Plastic

1. INTRODUCTION

Nowadays, plastic waste in Indonesia is increasingly piling up, because many people still litter and do not know the process of recycling plastic waste, so that the accumulation of plastic waste in Indonesia reaches 5.4 million tons per year. Plastic waste can be divided into several types. These include PET or PET (Polyethylene Terephthalate), HDPE (High Density Polyethylene), PVC (Polyvinyl Chloride), LDPE (Low Density Polyethylene), PP (Polypropylene), PS (Polystyrene), and other plastic materials (BPA, Polycarbonate, LEXAN).). Of these kinds of plastic, there are some that are easy and difficult to recycle.

Plastic waste is a serious global problem that needs special attention. From several international studies and developments that have been carried out by national researchers in dealing with plastic waste, it has received serious attention, seen from the exposure of several researchers to date. Nelles et al., 2016 put forward the management of waste processing in Germany which is grouped into the right part in recycling processing, starting from ordinary waste to containing commodity value.[1]. Then also stated by John N Hahladakis et al, 2018, regarding the quality of these its grouping by packaging products and types of plastic ranging from PET,

HDPE, PVC, LDPE, PP to PS with the value of the commodity and method of processing plastic waste in the right "closing loop packaging materials". target[2]. Then explained further by Vollmer et al, 2020 stated in their article about "Beyond Mechanical Recycling: Giving new life to Plastic Waste", where plastic products go through 5 stages before being declared expired. Starting from monomer, polymer, product, waste sorting, and finally decision is the end of life time of plastic itself. And the methods range from conventional mechanical systems for recycling to modern processes that predict the development of plastic waste that can be processed until 2030.[3]. Furthermore, developments carried out at the national level as a solution to the problems of the Indonesian state in dealing with plastic waste include the habits of housewives in managing plastic waste, then the processing of commodity plastic waste to form plastic waste into useful items such as buildings, etc.[4-6].

Judging from previous research, plastic waste that is commonly used as the basic material for recycled plastic is HDPE, PP and PVC plastic waste. Recycling of plastic waste is very necessary in order to reduce the accumulation of plastic waste in Indonesia. One of the wastes that we often encounter in and is one of the plastic waste found in workshops and landfills is plastic waste used for vehicle oil bottles and bottles used for drinking

water, plastic waste used for oil bottles and drinking containers mostly accumulate in workshops and in landfills. So we need a solution so that the plastic waste has a selling value after the waste is recycled, so that in addition to reducing waste used for oil and drinking places, the waste also has a selling value. One of the trends in Indonesian society is abstract decorations attached to walls, these decorations come from the arrangement of particle boards that are arranged into a single unit to have a high abstract value. In order for the plastic waste to be sold freely, the plastic waste must have a high material strength. The strength of the material is something that is very important. Where the strength of the material is to ability of the material to withstand tensile loads up to fracture point, which is also the area under the stress-strain curve and also the density of material affects the brittleness of tested specimen.

Therefore, the authors conducted this research, in addition to reducing waste used for oil and used bottles, the waste can also have a selling value. The research will be carried out by the author by making a material (specimen) weighing 184 grams, the composition of the material is 50% used oil bottle caps and 50% drink bottle caps, then a hot pressing process is carried out using a particle board press machine with a size of particle board 20 x 10 cm, the temperature used is, and the size variations (mesh) are 4 mm, 8 mm, and 12 mm with a pressing time of 5 minutes. After the specimen has been completed, then the specimen is tested for material, the material test in this study is a tensile strength test. Where serves test is to determine the stress and the strain of specimen. 100°C, comparison of the strength of pure HDPE with recycled HDPE using different mesh sizes on the results of the tensile strength test of the specimen. And size variations (mesh) of 4 mm, 8 mm, and 12 mm with a pressing time of 5 minutes. After the specimen has been completed, then the specimen is tested for material, the material test in this study is a tensile strength test. Where the test serves is to determine the stress and strain of the specimen. So that in this study, the author determines the title of the study on the comparison of the strength of pure HDPE with recycled HDPE using different mesh sizes on the results of the tensile strength test of the specimen.

2. METHODS

The method in this research is the method experiment. Experiment by definition is a trial or special observation with the aim of proving exactly each condition, so that doubtful conditions can be found repaired or resolved. The stages in this research are preparing materials and tools that support the research process. First collect the material, namely recycled HDPE obtained from the workshop, after getting the material then wash the

bottle cap so that the bottle cap is clean from the remnants of oil, after washing the next step is to chop or crush the oil bottle cap. The oil is dried in the sun so that to ensure that there is no water content attached, the next step is to filter the chopped oil cap according to the specified desire. after that, mix the used oil bottle caps as much as 50% and 50% bottled beverage bottle caps, followed by filtering recycled HDPE with 4 mm, 8 mm, and 12 mm mesh variations. then the hot press process is carried out using a particle board hot press machine, it aims to form a test specimen. In the hot press process using a particle board hot press machine. After the particle board specimen has been completed, the tensile test specimen is formed according to the ASTM D-638 machine into the tensile test process.

The experiment contained in this study is to conduct an experiment by making several types of specimens with different mesh sizes. Then the test specimen is tested for tensile strength, the testing process aims to determine the strength of the stress, strain and modulus of elasticity in the test specimen. The test was carried out at the Mechanical Engineering Laboratory of the State University of Jakarta to determine the tensile strength of the specimens made.

Table 1. Mixed Composition Variations

| No | Specimen | Weight (grams) | Oil bottle cap (%) | Packaging bottle caps (%) |
|----|----------|----------------|--------------------|---------------------------|
| 1 | HM | 184 | 50 | 50 |
| 2 | HDU 4 | 184 | 50 | 50 |
| 3 | HDU 8 | 184 | 50 | 50 |
| 4 | HDU 12 | 184 | 50 | 50 |

The steps for making Pure HDPE and Recycled HDPE particle board specimens are as follows: The collection of materials in this study by grouping materials according to the type of material to be tested.



Figure 1. Used bottle caps

Pure HDPE and recycled HDPE materials are chopped (cut) using scissors (chopping tools) this is done so that the material can be measured easily.



Figure 2. HDPE Plastic Shredder

Screening of recycled HDPE materials is carried out according to the mesh size of each test sample. Weighing of pure HDPE and recycled HDPE materials is carried out so that the weight of the specimen is the same as 184 grams per one specimen. This makes it easier for researchers to proceed to the next stage.

Mixing recycled HDPE materials is done by mixing 50% of used oil bottle caps and 50% of bottled beverage caps.



Figure 3. Material Mixing Process

Pure HDPE and recycled HDPE materials that have been weighed then enter the material pressing stage. Material pressing (hot press), hot press means the material is done by hot pressing method, hot pressing in this study uses a particle board press machine, this is done because the sample (specimen) in this study is in the form of particle board. The stages in hot pressing are: preparing the material weighing 184 grams, turning on the machine and putting the material into the press machine mold, set-

ting the machine temperature at 1000C, setting the pressing time, setting the pressing time on this tool for 5 minutes, and pressing the mold, by pressing weight of 40 kg.



Figure 4. Plastic particle board press machine

As for testing on samples that have been made are: tensile testing with the method ASTM D638, hardness test using the Vickers method, and macro-structure analysis of the specimen.

3. RESULTS AND DISCUSSION

The results of the tensile test of the specimen are obtained by performing a tensile test on the specimen that has been made. From the tests that have been carried out by the researchers, the results obtained from pure HDPE and HDPE specimens with different mesh size variations.

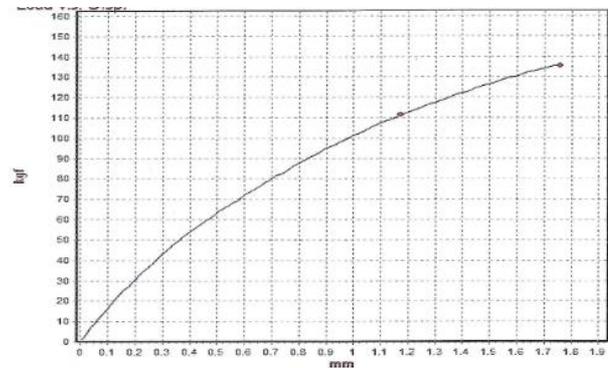


Figure 5. Tensile test results on HM Specimen

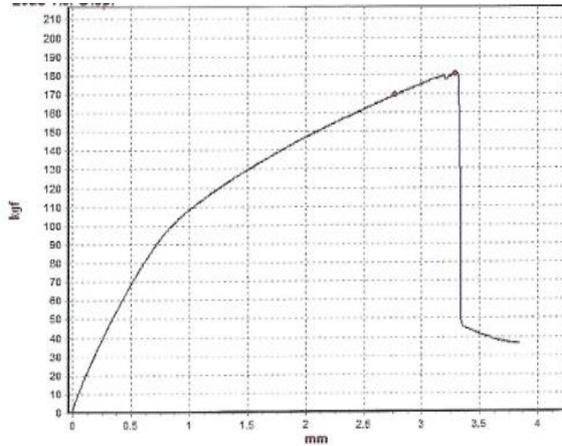


Figure 6. Tensile test results on HDU 4 . Specimen

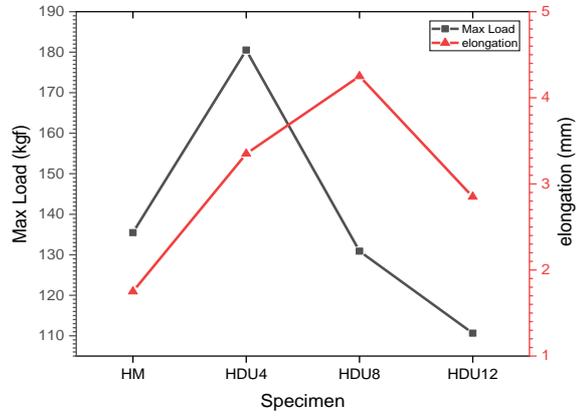


Figure 8. Tensile test results on HDU 12 Specimen

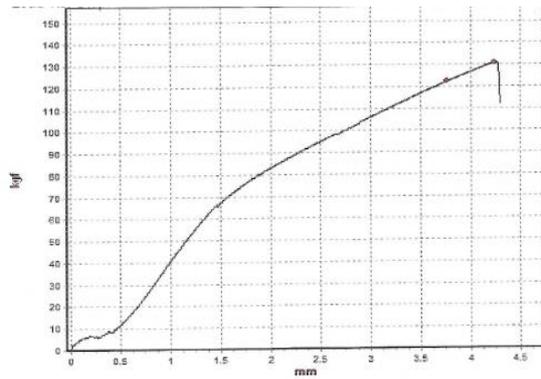


Figure 7. Tensile test results on HDU 8 Specimen

In the Figure 9 shows the order of the highest maximum load to the lowest obtained by specimens HDU4, HM, HDU8, and HDU12.

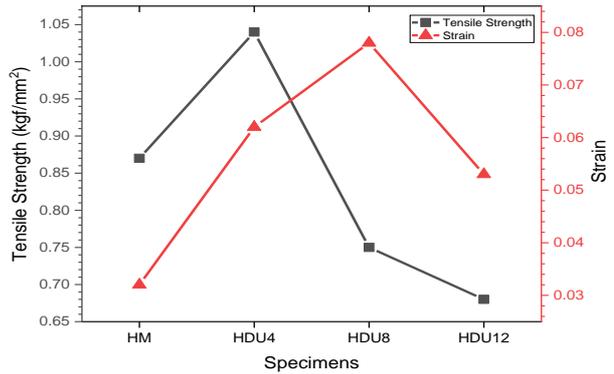


Figure 10. Tensile test result stress

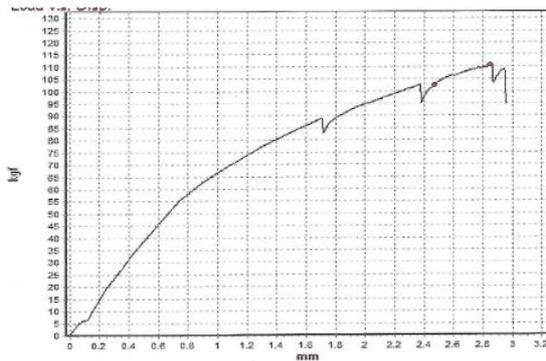


Figure 8. Tensile test results on HDU 12

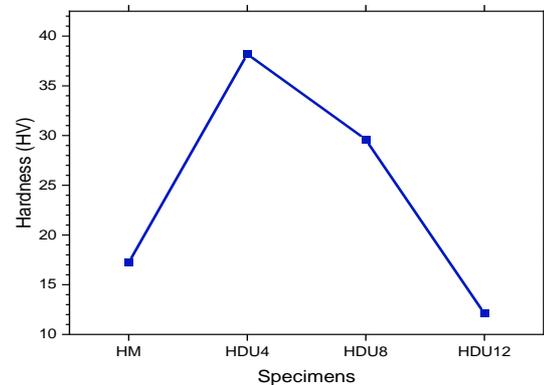


Figure 11. Vickers hardness test results

Based on Figure 11, the hardness value on Pure HDPE specimens has a hardness value of 17.2 VHN, recycled HDPE mesh 4 has a hardness value of 38.2 VHN. HDPE recycled mesh 8 has a hardness value of 29.6 VHN and recycled HDPE mesh 12 has a hardness value of 12.1 VHN. From the data above, it can be concluded that the highest specimen hardness was obtained by recycled HDPE specimens with mesh 4 and the specimens with the lowest values obtained from recycled HDPE specimens with mesh 12.

Observation of macro structure photos aims to analyze the structure contained in the test object or specimen, where in this study the object is the density of the specimen. So from the results of the observation of this macro-structure photo, it can be seen the difference of each characteristic of the test object, following the observation of the macro-photo with 8x magnification.



a. HM



b. HDU 4



c. HDU 8



d. HDU 12

Figure 12. Macro photos with 8x magnification

From the image of the macro structure 12.a. it can be seen that there are no pores or holes that are less dense, it indicates that the macro structure of the pure HDPE specimen is very good. From the macro structure image 12.b, it can be seen that there are a few gaps or holes that result in the specimen not being tight, or there is a hole that indicates that the level of material chopped is not perfect. From the macro structure image 12.c it can be seen that there are quite a lot of gaps or holes. which resulted in the specimen not meeting, it indicates that the level of the glass or mesh affects the density of the specimen. From the macro structure image 14.d we can see that there are a lot of gaps or holes in the specimen, this indicates that the greater the level of mesh or shredding, the more holes in the specimen. From the results of the macro photo observations above, it can be seen that the density level of the specimen from the most dense to the less dense is starting from the specimen.

From the discussion above, it can be concluded that HDU4 specimens are specimens whose count is smaller than other recycled HDPE specimens, so HDU4 specimens are suitable as material in the manufacture of particleboard which will later be used as interiors of house walls when viewed from the tensile test value obtained from the specimen HDU4.

4. CONCLUSION

Based on the research objectives, analysis and calculations of the data obtained from the test results regarding the comparison of the strength of pure HDPE material with recycled HDPE using different mesh sizes on the tensile test results of the specimen, so we can get conclusions for the first is reduction of HDPE plastic waste can be overcome by recycling HDPE plastic waste by mixing 50% used oil bottle caps and used bottle caps for packaged drinks, then chopping the used bottle caps with a mesh size of 4mm, then hot pressing with a temperature of 1000C for 5 minutes with a pressure of 40 kg. Then after tensile testing, it turned out that the largest elongation results were found in HDU 8 specimens and the lowest elongation was obtained in HM specimens.

After testing, it turns out that the highest yield point and max load are found in HDU 4 specimens and the lowest yield point is found in HDU 12 specimens. The smaller the mesh level or the chopped size, the better the specimen density results, as evidenced by the presence of gaps or holes in each specimen after macro testing. The stages in the Vickers test begin with preparing the part of the test object that will be given a load by giving bunches. Then press the on button on the Vickers tester and place the tip of the indenter in the position to be pressed. Then carry out the process of giving a load of 1

kg on the test object by bringing it closer to the test object, then releasing the handle so that the indenter in the form of a diamond pyramid presses the surface of the test object. This process is carried out for 10-20 seconds. The last step in the Vickers test is to look at the numbers listed on the Vickers hardness tester. The results of the Vickers hardness test showed that the highest specimen hardness was obtained by recycled HDPE mesh 4 specimens, while the specimens with the lowest hardness values were obtained by recycled HDPE mesh 12 specimens.

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REFERENCES

- [1] M. Nelles, J. Grünes, and G. Morscheck, "Waste Management in Germany – Development to a Sustainable Circular Economy?," *Procedia Environmental Sciences*, vol. 35, pp. 6-14, 2016.
- [2] JN Hahladakis and E. Iacovidou, "Closing the loop on plastic packaging materials: What is quality and how does it affect their circularity?," *Science of The Total Environment*, vol. 630, pp. 1394-1400, 2018.
- [3] MJFJ Ina Vollmer, Mark CP Roelands, Robin J. White, Toon van Harmelen, Paul de Wild, Gerard P. van der Laan, Florian Meirer, JosT.F. Keurentjes, and Bert M. Weckhuysen*, "Beyond Mechanical Recycling: Giving NewLife to Plastic Waste," *Angew.Chem. int. Ed. 2020*, 59.15402 –15423, vol. 59, p. 11, 2020.
- [4] SAM Ririn Setyowati, "The Level of Housewife's Knowledge and Behavior in Managing Plastic Waste," *Faculty of Public Health, Ahmad Dahlan University, Yogyakarta*, 2020.
- [5] AI Fahmi Hazman*, Ganesha Antarnusa, "Eco-Brick: Sturdy Building Materials as a Solution to Reduce Plastic Waste in Indonesia," *Proceedings of the National Seminar on Physics Education Untirta*, vol. Vol. 3, No. 1, November 2020, p. 277-282, p. 5, 2020.
- [6] MIU d. DEAF Ningrum2, "Plastic Waste Processing at UD Nialdho Plastics, Madiun City," *Indonesian Journal of Conservation*, vol. 9(2), pp. 89-95, 2020.