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The Hardness and Microstructure of a Mixture of Used Plastic Waste HDPE, PET and Iron Filings

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Abstract. *Plastic an important role in human life, because plastic is one of the materials that is often used in everyday life as a place for food, drink bottles, etc. Plastics are often used because they are light, flexible, and malleable. But in today's era, plastic is now a new problem because it causes plastic waste to take a long time to decompose. In addition, waste is not only related to plastic, but metal can also become waste, such as iron dust generated during cutting and drilling of iron material. And the solution offered is to utilize all existing waste to be made into new materials in the form of a mixture of plastic and iron powder by pressing methods using heat/temperature, the types of plastic used in this research are high density polyethylene (HDPE), polyethylene terephthalate (PET) and iron powder, then composition in the range of HDPE 30% 50%, PET 30% 50% and iron powder 10% 20% Made. The percentage result is used as a guide for making samples, which are then tested for hardness and microstructure. After testing the highest hardness value is 2.63 Kgf/mm², and the lowest hardness value is 1.93 Kgf/mm². The microstructure test shows that in the material with the highest and lowest values, there are differences in the air trapped and the density of the material.*

Keywords - *Plastic waste composite, iron powder, desain of experiment, hardness test, microstructure*

INTRODUCTION

Plastic has a very big role in our lives because plastic is one of the materials that is often used as a packaging material for products such as food, beverages, and many other items. Plastics are often used as raw materials because they are plastic, light and easy to shape.

Plastic, or polymer, is a type of macromolecule that is formed through polymerization tricks. Polymerization is the process of combining several simple molecules (monomers) through chemical tricks into large molecules (macromolecules) or polymers [1].

Some types of plastic can be recycled, but there are types that cannot be recycled. The types of plastics available are PETE/PET (polyethylene terephthalate), HDPE (high density polyethylene), LDPE (low density polyethylene), PP (polypropylene), PVC (polyvinyl chloride), PS (polystyrene) and others [2].

This type of iron filing is produced from flakes resulting from cutting iron or also from grinding. This iron waste is usually thrown away and, not infrequently, also sold to collectors to be smelted into iron again. The process of processing plastic waste that we often encounter so far is 3R (Reuse, Reduce, Recycle). Reuse means to reuse many times so that plastic can be used. Reduce means to reduce the use of plastic in everyday life and reduce the use of single-use plastics. Recycle means to recycle plastic items [3].

Tests that are often carried out are usually carried out are mechanical tests, including hardness, tensile, impact and others. This study uses 2 types, namely hardness testing and microstructure testing.

Plastics according to [4]There are two main types of plastics:

1. Thermoplastic
   A type of plastic that is easy to soften and melt repeatedly so that it can be shaped into new products according to molds. Examples include polyethylene, polystyrene, and polyvinyl chloride.
2. Thermosetting
   A type of plastic that can be melted and formed only once and cannot be heated repeatedly, so after solidification it will become solid, such as urea formaldehyde and phenol formaldehyde.
   All materials used in this study were used materials, including:
   - HDPE (High Density Polyethylene).
     This type of thermoplastic consists of carbon and hydrogen atoms bonded together to form high molecular weight products.
   - PET stands for Polyethylene Terephthalate.
     This type is made from glycol (EG) and terephthalic acid (TPA)/dimethyl ester/terephthalic acid (DMT). and has properties like polyester.

- Powdered Iron.
  The elemental content of iron has an atomic number of 26 and an atomic weight of 55.85 g/mol, a melting point of 1.535 °C and boils at a temperature of 3.000 °C [5]. The iron powder used in this study is a type of hollow iron powder

METHODS

Research Materials and Tools

The materials used in this study were HDPE (High Density Polyrthilene) plastic, which was obtained from used oil bottles; PET (Polyethylene Terephthalate), which was obtained from used mineral water bottles; iron powder, obtained from grinding at a welding workshop in the writer's village; and the toolkit. The items used in this study include stoves, thermocouples, smelting media, and presses with loads.

Research Stages

1. Mould Creation
   The pattern for making specimens refers to the hardness test standard according to ASTM D6272 with dimensions of 127mm x 12.7mm x 3.2mm [6].

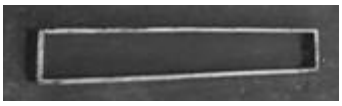

Figure1. Mould Specimen

2. Creating Comparison Data
   Before entering the specimen melting stage, first determine the mixture of materials that will be used as a reference for making specimens. To make the percentage of the mixture, the author uses DOE (Design of Experiment) software. According to [7], [8], DOE is a planned approach method to determine the cause and effect relationship. It can be applied to any process with measurable input and output.
3. Smelting Method
   The material to be melted first is HDPE. After it has melted, put in PET and finally iron powder, and stirred until it is mixed to a temperature of 220 C within 5–20 minutes. Then, before being poured, it is allowed to stand until the temperature is 200 C, then poured into the mold, waiting until the temperature of 150 C, then pressing with pressure according to size.

Figure 2. Sample of Specimen

RESULTS AND DISCUSSION

The results of hardness testing and microstructure testing of specimens from a mixture of HDPE, PET, and iron powder are shown in table 1. From the data in table 1, it is found that the highest average indentation diameter is at a value of 3.70 mm. This occurs because of the composition of the mixture and a good level of stirring, while the lowest average indentation diameter is at a value of 3.35 mm. This occurs because of the temperature at the time of pouring, which is too high. And the average diameter value of the test is 3.53 mm. Then the data above will be processed again to find the BHN (Brinell Hardness Number).

Table 1 also shows that the lowest data occurs because the average indentation is small so that the hardness value of the material increases. On the other hand, if the average yield is high, the hardness is low. From the data above, then do it again using the hardness formula [9] to find the BHN (Brinnel Hardness Number) value as follows:

$$BHN = \frac{2F}{\pi D(D-\sqrt{D^2-d^2})} \qquad (1)$$

Then the values are obtained as in table 2.

Table 1. Result of Experiment for Hardness Test

No	Force (Kgf)	d diameter of indentasi (mm)					d average
1	30	3,66	3,42	3,52	3,86	3,47	3,58
2	30	3,00	3,42	3,53	3,54	3,48	3,39
3	30	3,74	3,58	3,70	3,43	3,68	3,62
4	30	3,40	3,79	3,53	3,50	3,46	3,54
5	30	3,46	3,57	3,41	3,61	3,53	3,51
6	30	3,30	3,48	3,10	3,38	3,51	3,35
7	30	3,59	3,57	3,53	3,53	3,71	3,58
8	30	3,99	3,51	3,46	3,42	3,36	3,54
9	30	3,42	3,69	3,71	3,54	3,57	3,58
10	30	3,66	3,70	3,99	3,61	3,53	3,70
11	30	3,65	3,57	3,60	3,63	3,62	3,61
12	30	3,43	3,48	3,55	3,72	3,45	3,52
13	30	3,40	3,42	3,24	3,31	3,40	3,35

Table 2. Result Brinell hardness test

std	force (Kgf)	d diameter of indentasi (mm)					d average	BHN (kgf/mm²)
1	30	3,66	3,42	3,52	3,86	3,47	3,58	2,15
2	30	3,00	3,42	3,53	3,54	3,48	3,39	2,54
3	30	3,74	3,58	3,70	3,43	3,68	3,62	2,07
4	30	3,40	3,79	3,53	3,50	3,46	3,54	2,24
5	30	3,46	3,57	3,41	3,61	3,53	3,51	2,29
6	30	3,30	3,48	3,10	3,38	3,51	3,35	2,63
7	30	3,59	3,57	3,53	3,53	3,71	3,58	2,15
8	30	3,99	3,51	3,46	3,42	3,36	3,54	2,23
9	30	3,42	3,69	3,71	3,54	3,57	3,58	2,15
10	30	3,66	3,70	3,99	3,61	3,53	3,70	1,93
11	30	3,65	3,57	3,60	3,63	3,62	3,61	2,09
12	30	3,43	3,48	3,55	3,72	3,45	3,52	2,27
13	30	3,40	3,42	3,24	3,31	3,40	3,35	2,63
Average							3,53	2,26

Table 2, it can be concluded that the highest hardness value of the standard specimen is between Std. 6 and Std. 13, with a BHN value of 2.63 Kgf/mm2. As for the lowest hardness value of the standard specimen, 10, with a BHN value of 1.93 Kgf/mm2. For the lowest hardness value on the standard specimen, this happens because of the temperature factor when melting is too high and the stirring process is not mixed properly. From the data above, it can be concluded that the comparison graph between the average indentation diameter and the BHN value is as follows:

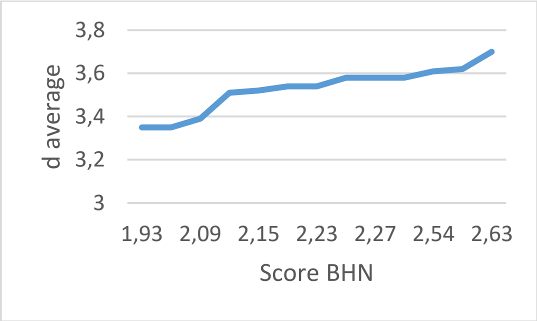

Figure 3. Graph Comparison of the average (d) with the BHN value

Figure 3 graph it can be concluded that the higher the diameter of the indentation, the lower the BHN value will be. On the other hand, if the diameter is lower, the BHN value will be higher. This is because the compressive strength of the soft material will be greater and vice versa.

According to [10], one of the problems with the brinell test is that the BHN depends on the load P for the same indentation. Generally, BHN decreases as the load decreases. The ASTM standard provides detailed specifications for the brine test. The brinell test is not affected by scratches and surface roughness. However, large brinell traces can affect and hinder the use of the test for small specimens or on parts that are critical to stress, where the indentation that occurs can cause failure in the test.

The data obtained from the tests in table 2 above is then entered into the DOE software. After that, the data will be analyzed to produce a graph in the form of a 3D graph shaped like a net. For data that has been entered into DOE, as shown in table 3 below:

Table 3. DOE (*Design of Experiment*) Data

Std	Run	HDPE (gram)	PET/PETE (gram)	Iron powder (gram)	Hardness test kgf/mm²
1	3	60,0	30,0	10,0	2,15
2	7	40,0	50,0	10,0	2,54
3	10	50,0	30,0	20,0	2,07
4	4	30,0	50,0	20,0	2,24
5	13	59,0	25,9	15,0	2,29
6	5	31,0	54,1	15,0	2,63
7	6	52,0	40,0	7,9	2,15
8	11	38,0	40,0	22,1	2,23
9	12	45,0	40,0	15,0	2,15
10	8	45,0	40,0	15,0	1,93
11	1	45,0	40,0	15,0	2,09
12	9	45,0	40,0	15,0	2,27
13	2	45,0	40,0	15,0	2,63

From the results of table 3. above, it can be concluded that the highest hardness value is in standards 6 and 13 with a value of 2.63 kgf/mm2 and the lowest hardness value is in standard 10 with a value of 1.93 kgf/mm2. Then it is processed again in DOE software to look for the graph.

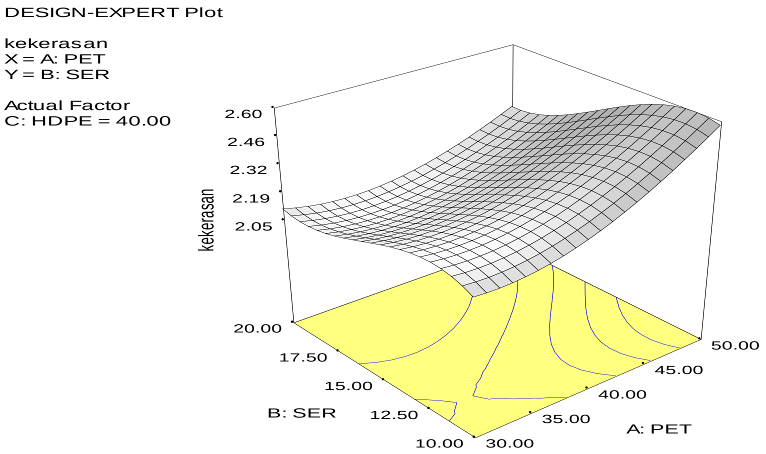

Figure 4. Graph from DOE Softwares like as data

Figure 4 graph it can be concluded that the highest hardness value requires a mixture of low iron powder. If the iron powder used is too high, then the specimen will become more brittle or break easily. The image of the test results can be seen in Figure 5 below:

Figure 5. Sample After Experiment

Microstructure Test

In observing the microstructure, the test was carried out on the fracture of the specimen resulting from the hardness test. This test aims to see if there are changes in the microstructure that occur in the specimen due to the hardness test treatment. The specimens were smoothed using 1000 grit sandpaper until the surface was shiny without scratches. The specimens were then observed with an optical microscope with a magnification of 100 times and photographed using an optilab connected to a computer. The results of the microstructure photos are stored in the form of images.

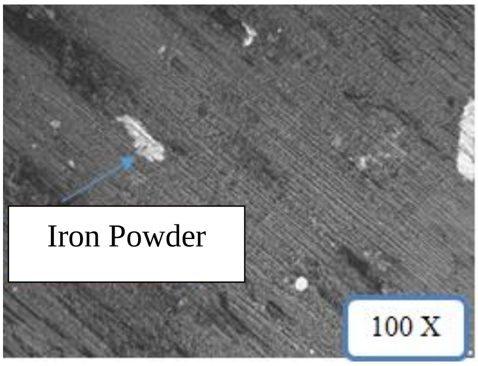

Figure 6. Iron Powder Microstructure std.6

Figure 6 can be seen that the density level is good with few air bubbles, thus making this specimen have a high level of hardness. This is because the diameter of the indentation after the hardness test results in a small average diameter so that the results of the hardness test are high. And because of the high PET mixture, the hardness level is also high.

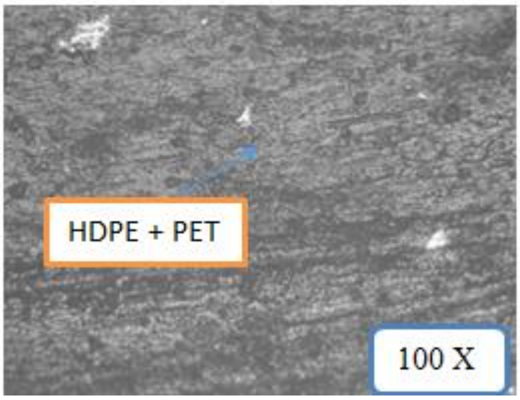

Figure 7. HDPE and PET combine Microstructure std.4

In Figure 7, the structure tends to be tight between HDPE and PET plastics, but there are air bubbles that make the hardness value of this specimen not high. This is because the indenter pressing process produces a moderate average value of 3.54 mm and produces a BHN value that is close to the average of 2.24 Kgf/mm2. and because the mixture of iron powder is higher than the mixture in Figure 2 above.

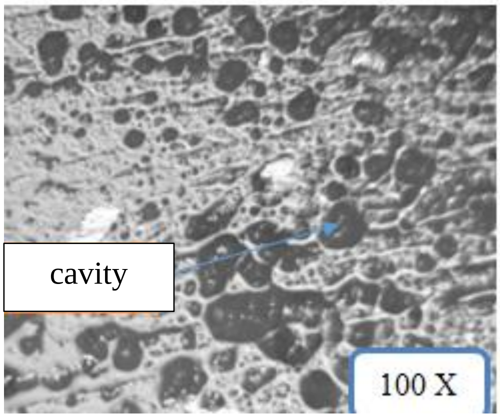

Figure 8. Bubles Microstructure std.10

The test results in Figure 8 show that the number of air bubbles present causes the specimen to become hollow so that when the hardness test is carried out it produces a low hardness value. This is because the HDPE mixture is higher than the mixture in Figures 6 and 7 above.

The more air voids present in the specimen, the less dense the material is, so the material becomes brittle. According to [11], the lowest porosity level based on the microstructure photo of the specimen was obtained in Al (raw material), while the highest (largest) porosity was obtained in the specimen with the addition of 15% kaolin, because ductile Al undergoes plastic deformation while hard particles (kaolin) only undergo elastic deformation, causing the gaps (cavities) in the specimen when the green body formation in the compaction process cannot fill the gaps (cavities) optimally.

CONCLUSION

From the whole process from manufacture to specimen testing above, it can be concluded that this recycled plastic hardness test is as follows:

1. From the hardness test data above, it can be concluded that the highest hardness level is BHN 2.63 Kgf/mm2, found in the material ratio of HDPE 31%, PET 54.14%, and Iron Powder 15%. This shows that the magnitude of the compression yield will be inversely proportional to the level of hardness or the value of the HBN itself.

2. As for the results of the microstructure, it shows that the density of the mixture greatly affects the level of hardness, while the air voids in the specimen will cause the material to break easily because the bonding power between the mixtures has a lower density level.

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