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THERMAL TEST OF 3D PRINTING FILAMENTS FROM PLASTIC WASTE AS AN ENVIRONMENTALLY FRIENDLY PRINTING MEDIA ALTERNATIVE

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A B S T R A K

Plastik adalah senyawa polimer alkena dengan bentuk molekul sangat besar. Semakin banyak yang menggunakannya, semakin banyak limbah yang dikeluarkan. Salah satu cara untuk mengurangi sampah plastik di Indonesia dapat dilakukan dengan cara mendaur ulang. Dengan cara tersebut dapat meminimalisir sampah yang berjenis HDPE yang sudah tidak terpakai lagi.Pengolahan sampah plastik di industri dapat dilakukan dengan cara membuat filamen 3D printing. Dengan teknologi dari 3D printing, perusahaan dapat membuat sebuah prototype (purwarupa) tanpa harus menghabiskan bahan baku ataupun material. Penelitian ini bertujuan untuk menganalisis hasil uji termal limbah tutup botol HDPE dan termoplastik yang digunakan dengan memanfaatkan daur ulang tutup botol sebagai bahan campuran termoplastik dengan variasi formulasi yang berbeda-beda. Metode riset yang akan digunakan terdiri dari beberapa tahap yaitu: 1). Pemilahan tutup botol plastik HDPE ; 2) Grinding ; 3) Proses ekstruksi 4) Uji pengukuran diameter filamen 3D Printing 5) Uji coba.

A B S T R A C T

Plastic is an alkene polymer compound with very large molecules. The more people use it, the more waste is released. One way to reduce plastic waste in Indonesia can be done by recycling. In this way, you can minimize HDPE waste that is no longer used.
Processing plastic waste in industry can be done by making 3D printing filaments. With 3D printing technology, companies can make a prototype without having to spend raw materials or materials. This research aims to analyze the thermal test results of waste HDPE bottle caps and thermoplastics which are used by utilizing recycled bottle caps as a thermoplastic mixture with different formulation variations. The research method that will be used consists of several stages, namely: 1). Sorting of HDPE plastic bottle caps; 2) Grinding; 3) Extrusion process 4) 3D Printing filament diameter measurement test 5) Test run.

1. INTRODUCTION

Plastic waste, especially drinking water bottle packaging, increasingly produces drinking water bottle waste that accumulates in the environment. drinking water bottle waste can also be called bottled drinking water waste. The use of bottled drinking water in Indonesia is still widely consumed but the processing of its waste is inadequate. not only the bottle body is a problem of environmental pollution, bottle caps are also a problem of environmental pollution.

Bottle cap waste is often found around the environment which causes unsightly. Sometimes we forget that what can pollute the environment is not only the bottle body but also the bottle cap. We are too focused on processing plastic bottle waste by putting aside the processing of bottle cap waste. therefore it is necessary to process bottle cap waste which aims to reduce environmental pollution problems.

The amount of bottle cap waste found around the environment requires us as a society to be able to process the waste in order to minimize the existing waste. bottle cap waste needs attention too, not just the bottle body. one way to manage bottled drinking water waste can be used as Filament.

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Bottle caps made from HDPE that are no longer used can be an alternative in making Filament. Later Filament can be used as a material in the process of making 3D Printing. 3D printing filament is a thermoplastic material in the form of a spool of thread which is generally available in two standard diameters of 1.75 mm and 2.85 mm. Acrylonitrile butadiene styrene (ABS) and Polylactic acid (PLA) are the most widely used thermoplastic materials in 3D printing applications. The use of recycled bottle cap materials both as a whole and mixing with thermoplastics commonly used in 3D printing applications is expected to be an alternative material that is more environmentally friendly. Filament manufacturing is done by extrusion method. In the extrusion method there are thermal characteristics (melting point), in the manufacturing process using nozzle temperatures of 200 ˚C, 210 ˚C and 220 ˚C, so that with this method it can be known the exact control parameters of the extrusion machine melt results and become more efficient to produce 3D printing filaments. This testis expected to overcome the current waste problem.

2. METHOD

2.1 Pemilahan Limbah Tutup Botol Plastik (HDPE)

The collection of used bottle waste and caps is carried out in the campus environment by inviting the entire campus community to collect used bottles and caps. The strelization process on the bottle is done by washing with soap and rinsing with distilled water, then cut into pieces washed again with distilled water and then heated in the oven for three minutes at 300 C (Okatama, 2016).

2.2 Grinding Process

The plastic bottles are then ground using a crusher into small pieces of about 10-20 mm. The small pieces of plastic bottles were then mixed with bottle caps. The mixed materials were fed into a twin-screw extruder to produce granule-shaped plastic ore, then molded by injection molding method with 5-zone heating (120°C - 200°C) on the barrel, resulting in test specimens. Test specimens are made with reference to ASTM standards which are then used for mechanical properties testing. Filament prototypes were made in the form of threads with a diameter of 1.75 mm using a filament extruder.

2.3 Extrusion Process

The development of rapid prototyping technology that uses 3D printing technology can make the process of making a product faster. There are several types of rapid prototyping that exist today including Fused Deposition Modeling (FDM), Selective Laser Sintering (SLS), and Stereolithography (SLA) (Badri, 2015). FDM is a method of prototyping by melting thermoplastic material using an extruder mechanism. Then the manufacturing process is carried out through a layer-by-layer process (Tatsuaki, 2006). The material generally used in FDM is in the form of Filament, in the FDM process the extruded filament material will harden quickly after being ejectedthrough the nozzle.

2.4 3D Printing Filament Diameter Measurement

Commercial 3D printing filaments used today have a diameter of 1.75 -2.85 mm (Mikula et al., 2021). There are also filaments with a diameter of 0.5-3.0 mm. However, most 3D printing machines on the market generally accommodate filaments with a diameter of 1.75-2.85 mm. Measurement of filament diameter using a caliper.

2.5 3D Printing Trial

According to Setiawan (2019), the working mechanism of the 3D Printing machine is divided into 3 parts, namely:

1. 3D Object Model

   3D object models can be created using specialized software for 3D design models supported by printer devices such as solidwork, catia, autocad and delcam.

2. Printing Process

   After creating the 3D design, the printing process can be done directly on the 3D printer machine. The printing process depends on the size of the model.

2. RESULT AND DISCUSSION

The manufacture of 3D printing filaments that have been carried out in the campus environment using an extrusion machine has gone well and all activities in the proposal have been carried out from beginning to end. The first step of the research we did was to collect drinking water packaging and sort the bottle bodies and bottle caps. This activity takes a period of 2 weeks through the dropbox media placed in the campus area. the second step is that we go to cooperate with collectors to exchange bottle bodies to collectors and collectors provide bottle caps that we have agreed on. the third step is to chop the bottle caps using a grinding machine, this process takes 3 days with a machine on campus, after grinding we weigh the results of the chopping with a few.

Filament formulations with a mixture of HDPE resins including formulations of 100% bottle cap and 0% HDPE resin, 75% bottle cap and 25% HDPE resin, 50% bottle cap and 50% HDPE resin, 25% bottle cap and 75% HDPE resin. the fourth step is to extrude the chopped bottle cap, this extrusion process takes 2 weeks. The fifth step is to measure the diameter of the filament that has been made, the diameter of the filament produced from 4 formulations is 1.75 cm. Based on the diameter measurement results and the print test results, it was found that the best formulation is 75% bottle cap + 25% resin because the diameter produced is quite uniform and meets industry standards (1.75 - 2.85 mm) which is 1.75 mm.

Table 1. Data bottle cap weight before grinding (grams)

Bottle cap weight after grinding (grams)	
Before	After
630	602,8
146	118,89
488	465

Table 2. Formulation Sample Initial Weight (grams) Final Weight (grams)

No	Formulation	Initial Wight (Gram)	Final Weight (grams)
1	100 % HDPE	100	75.81
2	75 % HDPE + 25% Resin HDPE	100	74.34
3	50 % HDPE + 50% Resin HDPE	100	73.69
4	25 % HDPE + 75% Resin HDPE	100	74.48

Table 3. Sample Formulation Temperature (Celsius)

No	Formulation
1	100 % HDPE
2	75 % HDPE + 25% Resin HDPE
3	50 % HDPE + 50% Resin HDPE
4	25 % HDPE + 75% Resin HDPE

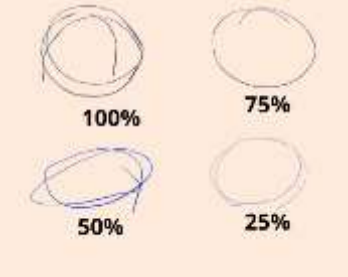

Figure 1. Extruded Filament

Figure 2. Filament Printing Results

3. CONCLUSION

In the Physical Thermal Test of 3D Printing Filaments from Plastic Waste as an Alternative Environmentally Friendly Print Media, it was found that the weight of the intact bottle cap after grinding the weight decreased, with the first initial weight of 630 grams to 602.8 grams, then 146 grams to 118.89 grams then 488 grams to 465 grams. Similarly, when an extrusion process is carried out on a formulation where each formulation has an initial weight of 100 grams but after extrusion the weight changes, the first experiment was carried out on a 100% HDPE formulation weighing 75.81 grams. 75% HDPE + 25 HDPE Resin to 74.34 grams. 50% HDPE + 50% HDPE to 73.68 grams. 25% HDPE + 75% HDPE Resin becomes 74.48 grams. When the extrusion process requires a temperature including the formulation of 100% HDPE requires a temperature of 220°C. 75% HDPE + 25 HDPE Resin temperature 210°c. 50% HDPE + 50% HDPE temperature 200°c. 25% HDPE + 75% HDPE Resin temperature 200°c. So, in the extrusion process, the more percentage of HDPE formulation, the higher the temperature required. The best formulation is 75% bottle cap + 25% resin because the diameter produced is quite uniform and meets industry standards (1.75 - 2.85 mm) which is 1.75 mm.

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