Design and analysis of cell phone case from recycling plastic bottle

M T A Benhardy1*, A Solihin2, E F Primaseta3 and T R Sahroni4

1,2,3,4 Industrial Engineering Department, BINUS Graduate Program – Master of Industrial Engineering, Bina Nusantara University 11480, Jakarta, Indonesia

*Email: taufik@binus.edu

Abstract. Recognizing the large amount of plastic waste produced by humans today, recycling is one solution to reduce the accumulation of plastic waste. This study aims to analyze the recycling of HDPE (High Density Polyethylene) plastic waste into cell phone cases. This study compares the strength of recycled plastic cell case with other materials that are often used for cell phone cases in general. The methodology of this paper begins with the development of new 2D and 3D cellphone cases, and for processing with injection molding. The parameters are focused on the strength of the material. The simulation is presented using Autodesk Inventor with free fall analysis, and presented stress, displacement, main stress and strain. The results show that the results of stress analysis and material comparison between HDPE and other materials do not show significant differences in other words HDPE can be used as an alternative material for cell phone case materials.

1. Introduction

The problem of waste in Indonesia is a problem that has not been resolved to date [1]. Meanwhile, with the increase in population, it will also be followed by an increase in the volume of landfills generated from human activities.

The composition of waste generated from human activities is 60-70% organic waste and the rest is 30-40% non-organic waste, while the second highest composition of non-organic waste is 14% is plastic waste. Most plastic waste is a type of plastic bag or plastic bag in addition to plastic packaging. [2] Figure 1 shows a significant increase in plastic production from 1950 to 2015.
In 1950 the world’s plastic production was only 2 million tons, but after that annual plastic production increased to 200 times reaching 381 million tons in 2015 [3]. Seeing this data is very dangerous if the plastic waste is not managed properly.

Plastic is an organic material that has the ability to be formed into various forms, when exposed to heat and pressure. Plastic can be in the form of bars, sheets or blocks, if in the form of products can be in the form of bottles, food wrappers, pipes, tableware, and others. Plastic compositions and materials are polymers and other additives. Polymers are composed of monomers that are bound by chemical bond chains [2].

The advantages of plastic compared to other materials include strong, lightweight, flexible, rust resistant, not easily broken, easily colored, easily shaped, and good heat and electricity insulators. Therefore, plastic waste has many advantages if it can be used as recycled products [4].

Plastic is still one of the main materials for making various equipment in addition to iron, wood and paper. Plastics are considered to have several advantages compared to other materials which are lighter, practical, durable and waterproof so that it is widely chosen by consumers [5].

Recognizing the need to reduce plastic waste that exists today, the industry is pushing towards a more sustainable and low-pollution industry [6] for this reason it is quite interesting to utilize HDPE type plastic packaging waste to be used as a base material for making cellphone cases. Utilizing plastic waste, in addition to material cost efficiency, can also help the industry become more sustainable, therefore this study aims to analyze the feasibility of cell phone case design using new materials from waste plastic packaging materials with parameters focused on the strength of the material presented by using Autodesk Inventor.

2. Materials and Methods

The material examined in this study is plastic packaging material made from HDPE (High density polyethylene). This type of material has strong, hard, and blurry characteristics, which are commonly used in beverage bottles, white milk bottles and jerry cans [7]. Before the manufacturing process, the material must be ensured prepared so that it is ready to be printed using molds, the steps that need to be taken are to clean the used bottles so that they are not contaminated with other materials and also all types of dirt, and separate bottles according to the type and color of each. Then puree the used plastic bottle that has been cleaned to a size of ± 2mm to facilitate the melting process using a plastic cutting machine, then grind the plastic that has been cut with clean water to ensure there is no contamination of other ingredients and then dry in the sun to dry and ready to be printed. The work steps follow the following steps [5]:

![Figure 1. Global plastic production per year (Geyer, 2017)](image-url)
a) Prepare recycled plastic seeds ready for use and mix them with the color pigments
b) Put it into a mold with a heating system with a temperature of ± 230°C for approximately 10-
15 minutes until the material melts and can be formed
c) Forward the recycled plastic ore melting material into the desired "case" cell phone
d) Cool the printed product so that it hardens for about 10 minutes according to the product size
e) Check the printed product to make sure the product prints properly

Figure 2. Development HDPE cell phone case plastic recycled stage flow

In HDPE Cellphone Case Plastic Recycled development process starts from the initial stage of understanding 3D modeling of cell phone cases in general, then observes and analyzes the material potential by utilizing recycled plastic HDPE, then designs and analyzes the strength of the Plastic Recycled Cell Phone Case using an inventor program.

3. Results and Discussions
In previous research, HDPE waste used for Automotive Interior [8]. In this research, the design of the use of HDPE waste for other products was carried out. The result will generate the new product design that using HDPE plastic waste. The product was cell phone case that made of High-Density polyethylene or HDPE. Cell phone case materials generally use aluminum and polycarbonate materials but for this research using HDPE material. The comparison cellphone case material for plastic and aluminum as listed in Table 1.

Table 1. Comparison cellphone case material (Source: Hildenbrand, 2019) [9]

| Plastic (Polycarbonate)                     | Aluminium              |
|--------------------------------------------|------------------------|
| More affordable                            | Very strong            |
| Easy to hold                               | Modern and sleek-looking|
| Easy to customize or decorate              | Expensive              |
| less expensive                             |                        |

Product design used Xiaomi Redmi Note 5 cell phone as a model of case cell phone. The HDPE material was obtained from the recycle process of HDPE plastic waste. The cell phone case has a size of 16 x 7.5 x 9 cm with a standard design covering the back of the cell phone.
Figure 3. Cell phone case design

Figure 3 shows a model of a cell phone case as a result of the proposed by using the 3D Modeling Software Autodesk Inventor. In this study conducts free fall analysis test from the elevation of 3 meter. The test aims to determine the strength and stress level of the material. In this simulation shows the case fallen within a certain height and hit the floor in the bottom of the cell phone case. In addition, Figure 4 shows the force in bottom of the cellphone. The design is being further studied using CAD software simulation.

Figure 4. Force in bottom of cell phone case

The five force for this simulation such as 60 N, 70 N, 80, 90 N and 100 N. Yield Strength of HDPE material is achieved with 20.66 MPa and Ultimate Tensile Strength is reached at 13.77 MPa. The simulation using Autodesk Inventor software in the stress analysis section shows ability of the material in protecting the inside cellphone part. The following are the results of Free Fall Analysis test is listed in Table 2.

Table 2. Stress analysis result

| Name                  | 60        | 70        | 80        | 90        | 100       |
|-----------------------|-----------|-----------|-----------|-----------|-----------|
| Von Mises Stress (VMS)| 0.291801  | 0.253575  | 0.2898    | 0.326025  | 0.36225   |
| MPa                   | MPa       | MPa       | MPa       | MPa       | MPa       |
| Displacement          | 0.000626361 | 0.000730754 | 0.000835148 | 0.000939541 | 0.00104393 |
| mm                    | mm        | mm        | mm        | mm        | mm        |
| Contact Pressure      | 0.139717  | 0.162992  | 0.186279  | 0.209562  | 0.23286   |
| MPa                   | MPa       | MPa       | MPa       | MPa       | MPa       |
The simulation result is safety factor for all force didn’t have differences that is 15. The simulation focused on three parameters, Von Mises Stress (VMS), Displacement and Contact Pressure. In the Von Mises Stress section, the results obtained the force of 60 N is achieved at 0.21735 MPa, the 70 N force is noted with value of 0.253575 MPa, for 80 N force is achieved at 0.2898 MPa, the 90 N force is reached value of 0.326025 MPa, and for 100 N force is highlighted with 0.36225 MPa. Then the five forces it can be concluded that the increase of the force that applied, value of Von Mises Stress will increase too but the value of Von Mises Stress is not bigger than the yield strength, so the force applied to HDPE material is still on tolerance limits. In the Contact Pressure section, the results for a force of 60 N are 0.0599329 MPa, a 70 N force of 0.162992 MPa, an 80 N force of 0.186279 MPa, a 90 N force of 0.209562 MPa, a force of 100 N at 0.23286 MPa. Then the five forces it can be concluded that the increasing of the force applied, the value of Contact Pressure was increased. Afterwards in the Displacement section, the results for the force of 60 N are 0.000626361 mm, the 70 N force is 0.000730754 mm, the 80 N force is 0.000835148 mm, the 90 N force is 0.000939541 mm, the force is 100 N for 0.00104393 mm. Then from the five forces it can be concluded that the greater the force applied there will be an increased in displacement, but the change is not significant.

In the next stage, this study shows the simulation using a different cell phone case material (aluminum and polycarbonate). Aluminum and Polycarbonate are materials that are often used in cell phone cases. The Figure 5 to 7 show the results of the comparison between HDPE, Aluminum and Polycarbonate.

![Figure 5. Von Mises stress comparison](image-url)

![Figure 6. Displacement graph comparison](image-url)
Figure 7. Contact pressure graph comparison

Based on the results of the simulation, aluminum material has the lowest Von Mises Stress level compared to others while HDPE material has the largest Von Mises Stress. The difference between aluminum and HDPE of 0.060448 MPa for a force of 100 N. In aluminum materials have the smallest 1st Principal Stress while HDPE material has the largest 1st Principal than others. The difference between aluminum and HDPE of 0.08387 MPa for a force of 100 N. Then it was found that aluminum material has the shortest Displacement rate. While HDPE material has the longest displacement than others. The difference between aluminum and HDPE of 0.000351 mm for a force of 100 N. The polycarbonate material has the lowest Contact Pressure level while HDPE material has the highest Contact Pressure than others. The difference between aluminum and HDPE of 0.032785 MPa for a force of 100 N.

In addition, it is found that the value of von mises stress, displacement and contact pressure for HDPE is higher than other material (aluminum and Polycarbonate). However, the simulation also found that the differences among those materials are not significant. Therefore, the HDPE material could replace the existing cell phone case material.

4. Conclusion
The results of recycling HDPE waste can be used in making cell phone case. The result of recycle of HDPE plastic into a cellphone case proposed to reduce the spread of waste by managing it into a useful material for daily activities. The case has a size 16 x 7.5 x 9 cm. Based on the results of stress analysis in the Autodesk Inventor Program, if the force exerted is greater than the value of each measurement will increase. But it still visible because in VMS measurement, the result value smaller than yield. Based on comparison of stress analysis between the three materials, it can be concluded that aluminum is still the strongest material compared to polycarbonate and HDPE by having the smallest VMS, Displacement, and Contact Pressure. While HDPE material is the weakest material of the three materials, and other that that the difference is not significant. Therefore, the HDPE material is potential to be used as an alternative in a cellphone case.

References
[1] Mahyudin R 2017 Study of waste and environmental management problems at the final processing site (TPA) Journal of Environmental Engineering 3 66-74
[2] Purwaningrum P 2016 Efforts to reduce the incidence of plastic waste in the environment JTL 8 141-147
[3] Geyer R, Jambeck J R and Law K L 2017 Production, use, and fate of all plastics ever made Science Advances 3 700-782
[4] Putra H P and Yebi Y 2010 Study of utilizing plastic waste into creative products and services *Journal of Environmental Science and Technology* **2** 1

[5] Abdelrasoul G N 2016 Nanocomposite scaffold fabrication by incorporating gold nanoparticles into biodegradable polymer matrix: synthesis, characterization, and photothermal effect *Materials Science and Engineering* **56** 305-310

[6] Desita Putri Pradani, Murtanti Jani Rahayu, Rufia Andisetyana Putri 2017 Classification of characteristics of industrial impacts in industrial affected settlement areas in cemani, sukoharjo regency *Architectural Journal* **15** 215-220

[7] Frizky Puja Rahmita 2015 Reports on drainage and environmental sanitation survey reports on the process of recycling plastic waste into a product *Sultan Ageng Tirtayasa University*

[8] Sanguanwong K, Nikzad M, Sbarski I and Masood S H 2018 Polymeric feedstock from post-consumer and post-industrial plastic wastes for automotive interior applications *IOP Conference Series: Materials Science and Engineering* **455** 012048

[9] Hildenbrand J 2019 Metal vs plastic vs glass which best material phones Retrieved from https://www.androidcentral.com/metal-vs-plastic-vs-glass-which-best-material-phones, accessed March 2019