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A Study on Mechanical Behaviour of Coconut Fiber Composite as an Alternative Material for Mobile Phone Casing

Muftil Badri[1]

[1]) Department of Mechanical Engineering, Faculty of Engineering Universitas Riau, Pekanbaru, Indonesia

ABSTRACT – Mobile phone is one of the most widely used electronic products. Casing is part of a very important component of mobile phones. Mobile phone casing refers to the outer casing of the device that encompasses its internal components. Mobile phone casing materials have been widely developed, such as polyester, polyurethane, carbon fiber, wood and leather. This paper proposes conducting tensile tests to determine the mechanical characteristics of coconut fiber composites as an alternative material for mobile phone products. Finite element simulation of drop test is then conducted to determine the impact robustness of a product. The investigation of tensile characteristics was carried out using variations in fiber direction. Vacuum assisted resin infusion is used to manufacture mobile phone casing products. A finite element simulation of mobile phone casing with various drop test positions was also conducted and the impact behaviour of coconut fiber composite casing materials was also obtained. It was shown that coconut fiber can be used as an alternative material for mobile phone casing. The design of the mobile phone casing also needs to be considered the corner position of the casing because this is where the maximum impact stress occurs.

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1. INTRODUCTION

Natural fiber composites have the advantages of being lighter, environmentally friendly and cheaper [1]. Coconut fiber composites have advantages such as being easy to obtain in Indonesia and lower cost. This can reduce environmental pollution so that this composite can overcome environmental problems that may arise from the large amount of coconut fiber that is not utilized. Coconut fiber also does not have effects on health. [2].

Coconut coir as a fiber has higher impact strength than jute and kenaf fiber. The tensile strength of coconut fiber composites with random fiber orientation has a higher flexural strength and can potentially be used as a non-structural building. The impact strength of coconut fiber composites is higher the longer the coconut fiber and more significant the volume fraction of fiber in composite material [2]. Coconut fiber has potential as a composite reinforcement as an alternative material for mobile phone casing.

One of the composite manufacturing methods is vacuum assisted resin infusion (VARI), which utilizes a pressure difference from a vacuum pump. This pressure difference will cause the resin to be sucked and this goes into the mold. The resin will then fill the space between the fibers that have been arranged until the resin fills the composite material mold [3]. This method is able to produce a high distribution of resin on the fiber so that the resulting composite material becomes stronger and lighter. In the VARI method, the flow of matrix material is carried out by a constant vacuum pump pressure. This constant vacuum pressure distributes the matrix material to remain in the specified amount [4]. The vacuum pressure control system in the VARI method produces composite products that match the planning with the results achieved, the level of fiber volume fraction and the level of void volume fraction [5].

A continuum that is divided into smaller elements, these smaller elements are called finite elements. This process of dividing a continuum into small elements is often known as discretization. The finite elements are so named because they are finite in size (rather than infinitely small) and generally have a simpler geometry than the continuum. The finite element method can transform a problem with infinite degrees of freedom into a problem with a certain number of degrees of freedom to make the solution more straightforward. The main objective is to obtain approximate (not exact) values of stresses and transitions that occur in a structure [6].

This study aims to obtain the tensile strength of coconut fiber composites and conduct finite element simulations of impact drop tests on mobile phone casing. Coconut fiber reinforced polymer composites were manufactured using the VARI method. Static tensile test of coconut fiber reinforced

*Corresponding author: muftilbadri@eng.unri.ac.id
Penerbit: Jurusan Teknik Mesin, Universitas Riau, https://proksima.ejournal.unri.ac.id

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polymer composites was varied in three orientations such as aligned continuous, 2-D 0º/90º and random discontinuous fibers orientation. From these three variations, the maximum composite strength was selected. The highest tensile strength was then used as the material properties for finite element simulation. The finite element simulation of the impact drop test of mobile phone casing used the ANSYS R16.2 software. Finite element simulation was applied with several drop test positions including the mobile phone casing's top, back, side and corner.

2. METHODS

2.1 Materials

2.1.1 Materials preparation

Table 1 shows the constituent materials of the coconut fibers reinforced polymer composite [6].

Table 1 Constituents of composite materials

No	Materials	Specification
1	Polyester resin and catalyst	Resin eternal 2250, catalyst methyl ethyl ketone peroxide.
2	Sodium hydroxide	1 M
3	Coconut fibers	Continuous and discontinuous

Polyester resin is used as a matrix in the manufacturing process of the composite. The polyester resin used is Eternal 2250 resin with methyl ethyl ketone peroxide as the hardener.

Figure 1 shows the coconut fibers obtained from PT Multi Organik Coco Fiber. The length of the coconut fiber is about 5-15 cm, and the diameter of the fiber is about 0.1-0.5 mm. Sodium hydroxide is used to remove lignin in the fiber, the percentage of solution used is 5% with a sodium hydroxide concentration of 1 M [7].

Figure 1 Coconut fibers

2.1.2 Composite manufacturing process

Figure 2 shows the equipment setup of the manufacturing process of coconut fiber-reinforced composites using the VARI method [7]. Coconut fibers are arranged in the prepared mold, these and other parts are placed into the vacuum mold.

Figure 2 Experimental assembly for manufacturing of composite

Several steps of coconut fiber manufacturing preparation process. Coconut fibers are soaked in 5% sodium hydroxide solution [8]. The fibers are soaked for 60 minutes, after soaking the coconut fiber is washed with water. The fibers are then dried until the percentage of water in the fiber is 0%. The process then gives the surface layer of the wall in the mold and the composite is easily disassembled from the mold.

Coconut fibers are arranged in the mold based on the predetermined arrangement direction including aligned continuous, 2-D 0º/90º and random discontinuous orientations. The fibers were placed into the vacuum mold and then the mold was isolated. The tube on the resin bucket with the mold and resin trap up to the vacuum pump was then installed.

The equipment for the manufacturing process is assembled appropriately, and then the manufacturing process is executed using the VARI method. After the vacuum pump is active then adjust the pressure by closing the inlet then adjusting the control valve opening to adjust the pressure. The vacuum pump pressure is controlled at 10 cmHg.

The manufacturing process is then the process of fabricating coconut fiber composites. Polyester resin and catalyst are measured according to the mold, polyester resin and catalyst are put in a graduated cylinder. The homogenized polyester resin and catalyst are then put into the resin bucket. The vacuum pump is activated and the outlet and inlet valves are opened then the resin and catalyst will flow into the mold. Polyester resin that is in the mold and fully fill the mold cavity up to the outlet. The inlet and outlet valves are then closed so that no outside air enters the mold. The process can be stopped by turning off the vacuum pump.

The composite product was removed from the mold after the polyester resin phase was completely solid. The surface is smoothed and cleaned by grinding and cutting into standard test specimens.

2.2 Static tension tests

Static tensile testing of coconut fiber reinforced polymer composites according to ASTM D3039 standard.

*Corresponding author: muftilbadri@eng.unri.ac.id
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Experimental setup was conducted with a Universal Testing Machine. The tensile tests were executed at the Laboratory of Materials Testing, Department of Mechanical Engineering, Universitas Riau. Figure 3 shows experimental setup for static tensile test of composite materials. The test specimens prepared for each different fiber orientation direction were 20 specimens.

Figure 3 Experimental setup for static tensile test

Tensile strength of the obtained coconut fiber reinforced polymer composites was monitored, and the control charts of upper control limit, centre line, and lower control limit were determined. Upper control limit (UCL) is the upper data limit of the average of a data is

$$\mathrm{UCL} = \mu + 3\sigma \tag{1}$$

Centre line (CL) is the average of the experimental data. CL is determined by

$$\mathrm{CL} = \mu \tag{2}$$

Lower control limit (LCL) is the lower data control limit of the average experimental data.

$$\mathrm{LCL} = \mu - 3\sigma \tag{3}$$

μ is the average of the data, and σ is the standard deviation of the data. To determine the values of μ and σ by using the following equation

$$\mu = \frac{\sum x_i}{n} \tag{4}$$

x_i is the sum of all data values and n is the number of observations.

$$\sigma = \sqrt{\frac{\sum (X_i - X)^2}{(n-1)}} \tag{5}$$

2.3 Finite element simulation

Design of the shape and size of the mobile phone casing to be simulated follows the design of the iPhone 5. Figure 4 shows the shape and size of the mobile phone casing.

In addition to the impact drop test being able to be demonstrated using finite element simulation, there is a need to find out the failure modes to be resolved for a mobile phone casing product.

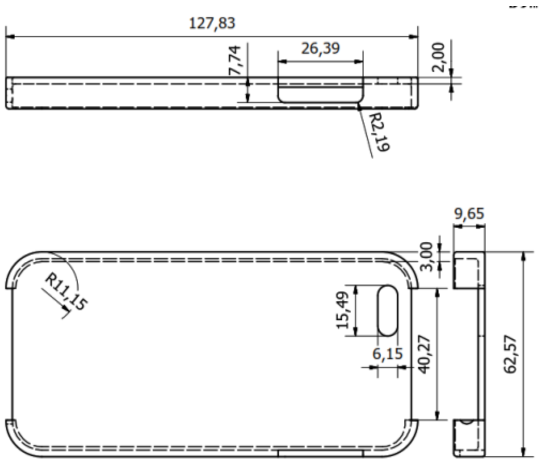

Figure 4 Design of mobile phone casing

Volume of the mobile phone casing design is 3.12×10^{-5} m^3, nodes 1911, number of elements 5985, mass of the casing4.09×10^{-2} kg. Impact loading on the contact surface of the mobile phone casing model was applied to the top, back, side and corner. The drop test loading was 1.12×10^{-2} kg with an observed propagation time of 0.15 s. Figure 5 shows the drop simulation finite element model (2.4) of the mobile phone casing design. The tensile strength properties of the finite element simulation used the maximum tensile strength of the coconut fiber reinforced polymer composite obtained from static tensile test.

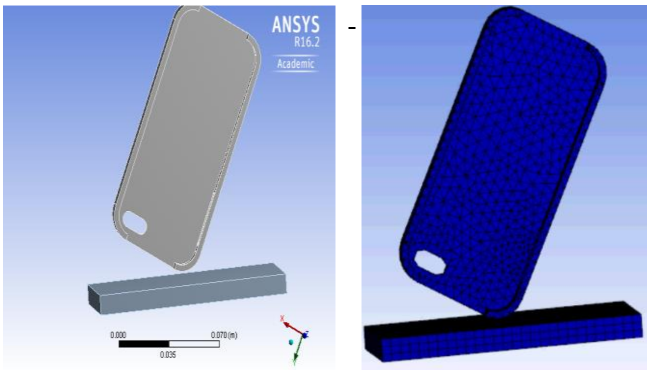

Figure 5 Finite element model of mobile phone casing

Energy conservation equation [8] applied to finite element simulation is as follows. (2. 8)

$$E_{TOT} = E_{KE} + E_I + E_V - E_W \tag{6}$$

E_{TOT} is total energy, E_{KE} is kinetic energy, E_I is internal strain energy, E_V is viscous energy dissipated, and E_W is external work done.

*Corresponding author: muftilbadri@eng.unri.ac.id
Penerbit: Jurusan Teknik Mesin, Universitas Riau, https://proksima.ejournal.unri.ac.id

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3. RESULTS AND DISCUSSION

3.1 Tensile strength of composite

From the tensile strength data obtained [6], tensile strength control charts with variations in fiber direction were determined: 1D continuous, 2D continuous, and random discontinuous directions. The control diagram parameters (μ), mean and standard deviation (σ) were calculated as follows.

$$\mu = \frac{\sum X_i}{n} = 12.86 \text{ N/mm}^2$$

$$\sigma = \sqrt{\frac{\sum (X_i - X)^2}{(n-1)}} = 3.25 \text{ N/mm}^2$$

UCL, CL, and LCL are determined by

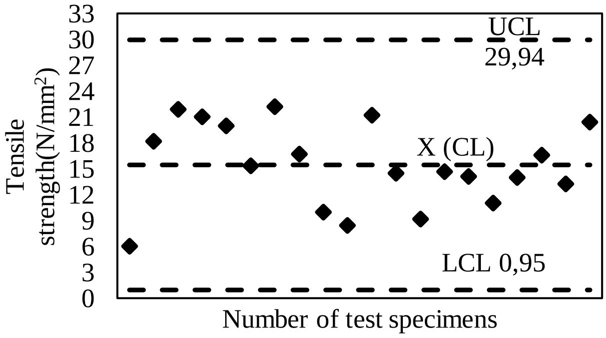
$$\text{UCL} = \mu + 3\sigma = 22{,}61 \text{ N/mm}^2$$

$$\text{CL} = \mu = 12{,}86 \text{ N/mm}^2$$

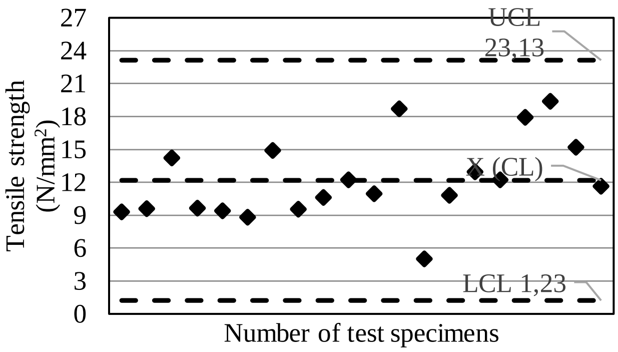
$$\text{LCL} = \mu - 3\sigma = 3{,}10 \text{ N/mm}^2$$

Figure 6 presents the static tensile strength control diagram of the aligned continuous fiber orientation composite, 2-D 0º/90º continuous fiber and random discontinuous orientations. All tensile strength test data is within the UCL and LCL lines obtained is within the accepted limits.

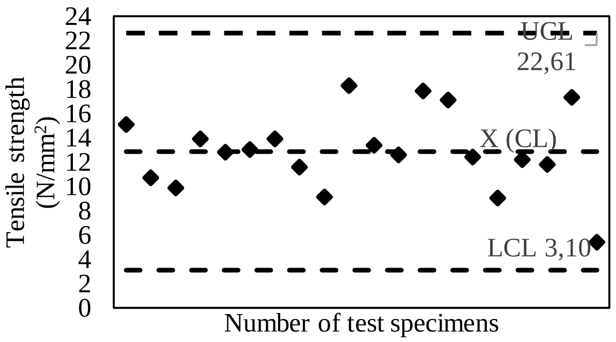
The tensile strength of coconut fiber composites in the aligned continuous fiber direction obtained is the highest compared to the 2-D 0º/90º and random discontinuous fiber directions. This indicates that the 1-D continuous fiber direction aligned to the loading direction exhibits the highest static tensile stress properties due to the interface between of fibers and matrix being able to withstand highest shear stress. The average tensile stress of this 1-D continuous fiber composite then entered as material properties in the finite element simulation of the drop test. The tensile strength of the coconut fiber reinforced polymer composite as a mobile phone casing material is 15.44 N/mm^2 which is the purpose described in this paper previously.



a. aligned continuous fibers orientation



b. 2-D 0º/90º fibers orientation



c. random discontinuous fibers orientation

Figure 6 Static tensile test results of coconut fiber reinforced polymer composites

Figure 7 shows the tensile strength of coconut fiber composites with continuous aligned, 2-D 0º/90º, and random discontinuous fiber directions. From the description above, the highest tensile strength value is in aligned continuous fiber composites. This can be clearly shown that in the finite element simulation drop test, the static tensile strength behaviour used as shown in the chart is 15,4 N/mm^2.

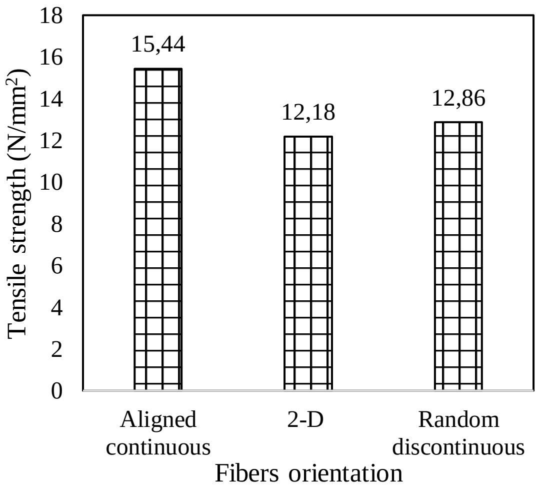


Figure 7 Comparison of the tensile strength of coconut fiber composite based on fiber orientation direction

*Corresponding author: muftilbadri@eng.unri.ac.id
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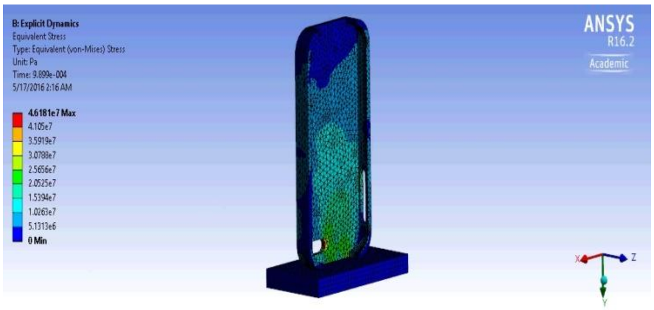
3.2 Drop test simulation of mobile phone casing

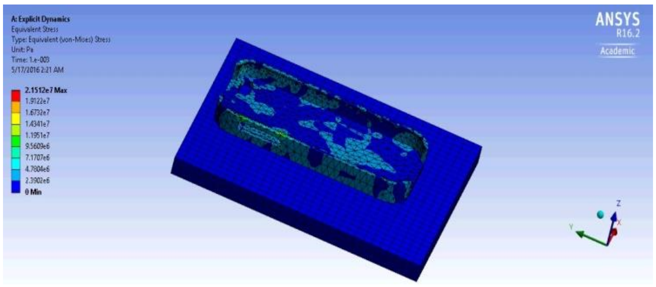
Study of coconut fiber composite material parameters as an alternative material for mobile phone casing including impact stress, impact propagation and stress concentration location due to drop test has been obtained. Observation of finite element simulation of surface damage and the position of product failure are the factors that determine the use of coconut fiber composite material as a mobile phone casing.

The finite element simulation program used for impact simulation is ANSYS R16.2. Three-dimensional finite element simulation, the prototype mobile phone casing product has several impact directions. One of the advantages of developing finite element simulation is able to reduce experimental impact testing. The finite element simulation focuses on the impact orientation of the drop test.

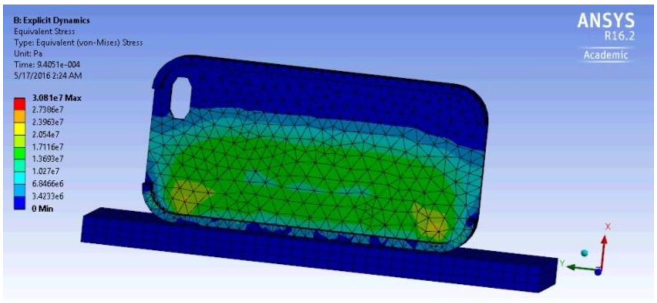
Figure 8 presents the comparison of the finite element simulation of the impact response to the mobile phone casing observed at several positions of the drop test method. The maximum impact stress of the mobile phone casing occurs at different impact propagation times. This shows that the total energy change of the mobile phone casing is different at different positions of the drop test. The maximum impact stress occurs at the corner location of 68.60 N/mm^2 where the impact propagation time is 1.05×10^{-3} s. The design of the mobile phone casing also needs to be considered at the corner of the casing because this is the location where the maximum impact stress occurs.



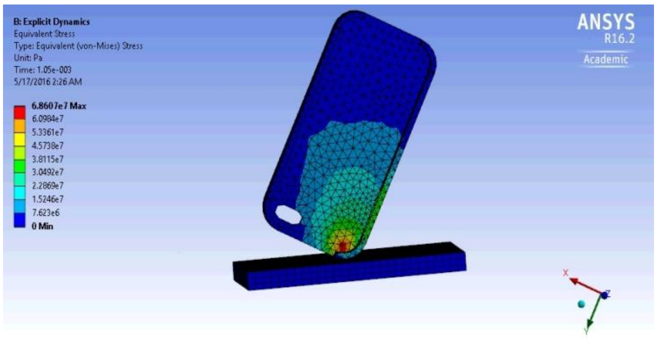
a. top, t = $9{,}899\times10^{-4}$ s



b. back, t = $1{,}0\times10^{-3}$ s



c. side, t = $9{,}899\times10^{-4}$ s



d. corner, t = $1{,}05\times10^{-3}$ s

Figure 8 The comparison of finite element simulation results at several position impact drop test

Due to the complexity of the components, the modelling of the mobile phone casing was simplified. The floor where the casing is subjected to impact loads is modelled using a single surface of non-deformable rigid elements. The modelling of mobile phone components such as LCD, PCB, battery and small components on the PCB are modelled as point masses for simplification.

Mobile phone casing model with a thickness of 2 mm according to the dimensions presented in Figure 4. The material type selected was coconut fiber composite with a tensile strength of 15.44 N/mm². The mesh size at the impact location point where stress concentration occurs is finer than the mesh at other locations of the model.

The resulting energy can give an indication of the impact behaviour of the mobile phone casing. During the initial impact, a certain amount of kinetic energy is converted into internal strain energy due to deformation around the impact point. The motion of the mobile phone casing and contact interaction will change some relative portions of kinetic energy and strain energy. During contact, the strain energy increases while the kinetic energy decreases. Vibration of the mobile phone casing structure causes changes in kinetic energy and internal energy.

One drawback of using finite element simulation to determine the impact response of mobile phone casing is that it is limited method for impact strength analysis. The simulation is not fully applicable to the actual operation of the

*Corresponding author: muftilbadri@eng.unri.ac.id
Penerbit: Jurusan Teknik Mesin, Universitas Riau, https://proksima.ejournal.unri.ac.id

mobile phone casing. Experimental testing is needed involving the complete mobile phone casing components with LCD, PCB, battery and other components. Failure of the casing will also cause failure to other components and of course also affect the damage response to the mobile phone casing.

From this study it has been observed that the coconut fiber composite has an impact response to the drop test load on the mobile phone casing. However, these results need to be continued by conducting experimental studies of drop impact testing of mobile phone casing products manufactured by coconut fiber composite materials.

4. CONCLUSIONS

The study of the mechanical behaviour of tensile strength of coconut fiber reinforced polymer composites with various fiber directions was conducted and the results were further used as material properties data of mobile phone casing. Finite element simulation of mobile phone casing with various drop test positions was also conducted and the impact behaviour of coconut fiber composite casing materials was also obtained. It was shown that coconut fiber can be used as an alternative material for mobile phone casing. However, further research in the form of drop test experiments is needed so that the accuracy of the response of the coconut fiber composite material as a mobile phone casing material can be known by involving other components actually.

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