3-D designing of an organic waste crusher

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Abstract. Organic waste can be used for something of value, such as compost, feed pellet, biomass pellet, and briquette. Before becoming such things, it takes a tool to make it smoother, called a crusher. The objective of this work is to do mechanical design and 3-D modeling on organic waste crusher. The steps for designing the organic waste crusher involve determining a conceptual physical geometry, conducting mechanical design, and finally, developing a 3-D working drawing. Manufacturing and testing of the crusher were conducted. 3-D modelling design was used for visualizing space requirements, improves drawing efficiency and accuracy. Mechanical design was applied for hopper, frame and blade. 3-D modeling process was used to draft the working drawing of an organic waste crusher. 3-D designing is very useful for providing accuracy. Mechanical design of designed crusher was determined. The working drawings of designed crusher are also presented. The leaf crushed with the designed crusher was ready for composting.

1. Introduction
Organic waste can be used for something of value [1,2]. Organic waste can be used for compost [3,4], feed pellet [5,6], biomass pellet [7], and briquette [8]. Before becoming such things, it takes a tool to make it smoother, called a crusher. To produce finer, better pieces of waste and not waste time, then a new breakthrough that can shorten the cutting time. One of them by creating a machine of an organic waste crusher.

One of the advantages of 3-D modeling compared to 2-D is 3-D modeling for design allows the designer to see what they would not see when designing in 2-D. For example, it provides the designer with the ability to physically see how much real condition of an object seen from all perspectives. In 2-D designing, the designer needs to provide a separate plan and elevation view to see the space requirements of an object, which takes longer to do.

The blades on the crusher have been presented in US Patent No. 2005/0109866 A1 published on 26 May 2005 entitled Shredder Blade Made by Punching and Bending [9]. The patent describes the two-edged blade that was made by pressing and bending the metal sheet into a blade using a machine. It can only crush paper sheets measuring about 4 mm x 40 mm into pieces of paper.

Another invention relating to a blade in a waste crusher machine is the US Patent No. 2009/0256020 A1 published on 15 October 2009 entitled Shredder Blades and Methods for Producing Shredder Blades and/or Shredder Blade Pairs [10]. The patent describes a three-edged blade that is manufactured using a method of pressing metal sheets until cut off to form a crusher blade. This method can only be done on metal sheets with a thickness of about 1 to 1.5 mm.

The processing of organic waste has been presented to US Patent No. 2002/6399366 BI published on 4 June 4 2002 entitled Method and Apparatus for Composting Organic Waste Together With Its
Packaging Cartoons, Boxes or Crates on Site [11], US Patent No. 2003/0230651 A1 published on 18 December 2003 entitled Method and Apparatus for Hydro-mechanically Disintegrating Organic Matter [12], and US Patent No. 2010/0162779 A1 published on 1 July 2010 entitled Apparatus and Method for Composting Organic Water [13]. These patents explained the ways to process organic waste into compost and organic waste processing by using hydro-mechanical methods. They do not explain the crushing of organic waste before it becomes compost.

The organic waste crusher has been presented in the US patent No. 2015/9010667 B2 published on 21 April 2015 entitled Organic Shredder Apparatus and Method for Operating an Organic Shredder [14]. The patent describes the provision of tools and methods for the reduction of organic materials and subsequent preparations for recycling or for safe self-contained exhaust systems. The machine is made with automation systems and requires additional energy to run the system. The size of the chopped machine count is still not too smooth. The enumerator has been presented in US Patent No. 2010/7832670 B2 published on 16 November 2010, entitled Materials Reducing Apparatus [15] and US Patent No. 2005/0193701 A1 published on 8 September 2005, entitled Apparatus for Processing of Organic Materials [16]. The patents explained the enumeration of the material without mentioning what materials and tools for enumerating grass. This tool is too specialized on certain materials for chopping.

There are many crushers had been built. However, work on crusher for cocoa waste leaves for composting have not been done yet. Therefore, it is imperative to study 3-D designing of an organic waste crusher. The disadvantages of the prior art blade invention can be solved by the invention of the crushing blade that has 16 tiny blades for each blade, the preparation process by means of casting, and the use of Japanese Standard (GIS) steel 405 G 1979 with S45C code as the material. The waste crusher blade in the present invention can produce finer crushed waste. The disadvantages of the former crusher invention can be overcome by the invention of this organic waste crusher. The result of this work is expected to be useful for cutting time and cost with better results.

The objective of this work is to do mechanical design and 3-D modeling on organic waste crusher. Especially for cocoa waste leaves before being processed for composting.

2. Preparation of the crusher

The steps for designing the organic waste crusher can be seen in Figure 1, involving determining a conceptual physical geometry, conducting mechanical design, and finally, developing a 3-D working drawing. Mechanical design was conducted for obtaining hopper, frame and blade. 3-D modeling process was used to draft the working drawing of organic waste crusher by using AutoCAD and SolidWorks software. Manufacture and brief functional testing were conducted after finishing the design steps.

![Figure 1. Flowchart of design steps.](image-url)
Cocoa leaves were used for functional testing of the crusher. The leaves were collected from Desa Pengadegan, Rancakalong Sumedang, Indonesia. After being crushed, the cocoa waste leaves were ready to be processed for composting stage. Cocoa waste leaves before being processed using the crusher can be seen in Figure 2.

3. The organic waste crusher

3.1. A conceptual physical geometry
In conceptual design, concept ideation is a critical activity [17]. Thus, the conceptual physical geometry of the organic waste crusher was developed from the schematic diagram of a crusher shown in Figure 3. The designed organic waste crusher uses gasoline and organic waste as an energy source and material input, respectively. The output of the machine is in the forms of noise, vibration, heat and finer of organic waste.

3.2. Mechanical design

3.2.1. Blade. The present step aims to provide a waste crusher blade with 16 tiny blades with hexagonal spindle holes that serve to chop and produce finer and smoother chopped organic waste. As the material, this blade uses S45C carbon steel (JIS G 4051) with Young Modulus \( E = 206843 \text{ N/mm}^2 \). Referring to Figure 4 and 5, a waste crusher blade was prepared by casting the carbon steel material in the blast furnace. The waste crusher blade has 3 to 20 tiny blades, which have five-pointed corners.
such as claws, two lower end claw corners, an upper-end claw corner, the first two claw angles, the second upper claw angle, and a rear claw angle. A claw curve below the lower end and the upper-end claw corner. A hexagonal shaft hole is in the center of the crushing blade. The waste crusher blade is arranged into a series of 26 blades connected with the shaft having two hexagonal shaped halves and the cylindrical axis section. The hexagonally shaped sections are perforated with a spherical and/or hexagonal shaft directly tied to the body of the waste crusher blade with a diameter of 100 to 200 mm and with a thickness of 8 to 15 mm. The cylindrical shaft portion as the successor shaft turns into a series of blade shredding into the pulley.

![Figure 4. Design of the blade.](image)

3.2.2. Hopper. The input unit or hopper is part of the crusher that serves to insert the organic waste into the box enclosing blades. Organic waste feeding is done manually with a horizontal direction. The position of the operator is on the front side of the machine to prevent exposure to spikes from organic waste. The specifications of the hopper are 642 mm long, 325 mm wide, and 480 mm high (Figure 6).
3.2.3. Frame. Frameworks function to support the whole crusher machine. Measurement of frame dimensions has already considered the aspects of ergonomics for operator comfort. The dimensions of the crusher frame are 710 mm long, 490 mm wide, and 530 mm high (Figure 7). The raw material for the frame is iron elbow that is expected to be able to support the whole machine and iron canals installed under the frame. Next to withstand the vibration, the frame is also expected to withstand the load, especially the box consists of blades. The component parts are then assembled and connected with welding, bolts, pads, pulleys, and belts. The result of the assembly of crusher can be unloaded with the aim of easy maintenance in case of damage, especially to enable periodical removal and sharpening of the blade.

3.2.4. Box consists of blades. To extend the drive motor movement to the waste crusher blade, a driving gear is needed. The embodiment comprises a driving gear tangential to a follower gear, so that the rotation is opposite inward for rotating the waste crusher blade where the rotary crushing blade rotates in contrast to the follower blade counter and the blade end is almost tangential to the rotating shaft and the follower shaft with a distance of 0.5-3 mm, preferably 2 mm, in chopping organic waste to produce a smoother count. The dimensions of the box consist of blades are 338.50 mm long, 285 mm wide and 195 mm high. Design and 3-D modeling of box consist of blades can be seen in Figure 8.
3.3. Working drawing of the designed crusher

Many tools have been utilized for simplifying and reducing the work process at the design stage, such as Computer Aided Design (CAD) technology that has been developed from the early 2-dimensional platform to 3-D based solid modeling [19]. For drafting the working drawings of the crusher, determined parameters obtained in the design analysis were used. AutoCAD and SolidWorks were used for modeling the 3-D details of the crusher. A more detailed view of the crusher can be presented on this and enables better visualization of what the fabricated product will look like. Figure 9 shows the top view, back view, and side view of crusher design with dimensions identified. The list of parts of the crusher is presented in Table 1. Figure 10 and 11 show the isometric view of the crusher.

| Part name                  | Quantity | Material          | Dimension         |
|---------------------------|----------|-------------------|-------------------|
| Frame                     | 1        | Iron elbow 50 x 5 | 710 x 490 x 530   |
| Box consists of blades    | 1        | Iron plat 2.3 mm  | 338.5 x 285 x 195 |
| Blades                    | 2        | S45C              | Described         |
| Hopper in                 | 1        | Iron plate        | Described         |
| Hopper out                | 1        | Iron plate        | Described         |
| Power                     | 1        | Standard          | 5 HP/3600 rpm     |
| Pulley                    | 1        | Aluminium         | Diameter 3”       |
| Pulley                    | 1        | Aluminium         | Diameter 10 “     |
| V-belt                    | 1        | Standard          | Type A No. 49     |
| Gear                      | 1        | Standard          | m=2.5; z=30       |
| Gear                      | 1        | Standard          | m=2.5; z=55       |
Figure 9. Top view (a), back view (b), and side view (c) of crusher design with dimensions.
Similar to previous work [20], the crushing roller models were created through SolidWorks, a 3-D design software. However, only some components were provided in the previous work, while in this work the entire crusher components are provided.

3.4. Manufacturing
Overall, the process of making an organic waste crusher is based on the drawings of the design work. The manufacturing process starts from blade casting, making hopper in, frame, box consists of blades, transmission system, and hopper out. By following the rules in designing a machine, especially agricultural machinery, in the end, the design of organic waste crusher can be manufactured. Figure 12 represents the manufacture of the box consist of blades, while the manufactured blade can be seen in Figure 13. The completed crusher can be seen in Figure 14.
Figure 1. Top view of the box consists of blades.

Figure 2. A blade after manufacture.

Figure 3. Manufacture of the organic waste crusher.

In order to reduce the wear rate, the curvature of the blade was designed and manufactured as small as possible. The smaller the curvature radius of the blade, the slower the wear rate. As the result, reducing the overall dimensions of the crusher [21].

3.5. Brief testing
For obtaining the functional test, brief testing was conducted using cocoa leaves. The main purpose of this test was for investigating the crusher ability, especially for crushing cocoa leaves. The crushed cocoa leaves can be seen in Figure 15.
4. Conclusion
3-D designing is more beneficial than 2D for providing any mechanical or manufacturing parts with high accuracy. Mechanical design of designed organic waste crusher for obtaining blade, hopper, and frame was determined. The working drawings of designed crusher are also presented. Cocoa waste leaves crushed with this crusher are ready for composting.

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References
[1] Chen Y, Liu H, Zheng X, Wang X and Wu J 2017 Appl. Energy 196 190–8
[2] Selvakumar P and Sivashanmugam P 2017 Fuel Proc. Technol. 165 1–8
[3] Neugebauer M and Sołowiej P Sołowiej2017 J. Cleaner Prod. 156 865–75
[4] Oliveira L S B L, Oliveira D S B L, Bezerra B S, Pereira B S and Battistelle R A G 2016 J. Cleaner Prod. 155 229–37.
[5] Cheng Z, Mo W Y, Man Y B, Nie X P, Li K B and Wong M H 2014 Environ. Int. 73 22–7
[6] Wong M H, Mo W Y, Choi W M, Cheng Z and Man Y B 2016 Environ. Poll. 219 631–8
[7] Li H, Jiang L B, Li C Z, Liang J, Yuan X Z, Xiao Z H, Xiao Z H and Wang H 2015 Fuel Proc. Technol. 132 55–61
[8] Brand M A, Jacinto R C, Antunes R and da Cunha A B 2017 Renew. Energy 111 116–23
[9] Simon H 2005 Shredder Blade Made by Punching and Bending US Patent 0109866 A1
[10] Sued C, Abramson A and Ou S T 2009 Shredder Blades and Methods for Producing Shredder Blades and or Shredder Blade Pairs US Patent 0256020 A1
[11] Seagren E 2002 Method and Apparatus for Composting Organic Waste Together with Its Packaging Cartons, Boxes or Crates On Site US Patent 6399366 B1
[12] Colson C M 2003 Method and Apparatus for Hydromechanically Disintegrating Organic Matter US Patent 0230651 A1
[13] Itzhak A and Moshsav S 2010 Apparatus and Method for Composting Organic Matter US Patent 0162779 A1
[14] Shelby L 2015 Organic Shredder Apparatus and Method for Operating an Organic Shredder US Patent 9010667 B2
[15] Arnorld N P and Glenn F B 2010 Materials Reducing Apparatus US Patent 7832670 B2
[16] Jason G S and Jon R E 2005 Apparatus for Processing of Organic Materials US Patent 0193701 A1
[17] Liu A, Wang Y, Teo I and Lu S 2018 Constraint management for concept ideation in conceptual design CIRP J. Manufacturing Sci. Technol. (In Press)
[18] Krayer N and Kart R 2018 Procedia Manufacture 21 878–89
[19] Ongkodjojo S and Gunawan H 2006 TECHNOSIM 2006: Simulasi dan Optimasi untuk Aplikasi Industri Proses, Manufaktur, dan Energi
[20] Gao H and Qu L G 2002 J. Mat. Proc. Technol. 129 649–52
[21] Savinyh P, Nechaev V, Nechaeva M and Ivanovs S 2016 Proc. Engineering for Rural Development (Jelgava) 1072–6