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Design of organic fertilizer pellet machine with a capacity of 170.90 Kg/Hour using verein deutcher ingenieure 2222 method

Prasetio Aji Nugroho[1*], Subekti Subekti[1], Arvian Iswahyudi[1]

[1*] Mechanical Engineering Department, Faculty of Engineering, Universitas Mercu Buana, Indonesia. Jl. Raya Meruya Selatan, No. 1 West Jakarta, Indonesia

*✉ prasetioaj22@gmail.com

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Abstract: Due to population expansion and heavy consumption, there has been an increase in household garbage in recent years. One of the waste processing techniques that is kind to the environment is turning organic waste into organic fertilizer. Pellets created from organic fertilizer will be more convenient to use and effective. This study aims to construct an organic fertilizer pellet printing machine using the VDI 2222 method to turn organic fertilizer into pellets. this design approach is used to make sure the finished product or system satisfies defined technical requirements and customer needs. A variation of the design for an organic fertilizer pellet machine has been created based on the research, and the design evaluation is based on a survey. The third machine variation was picked as the best machine variant based on the design's outcomes. This machine is made of materials that are generally accessible on the market, has a solid construction, and a simpler manufacturing procedure. The organic fertilizer pellet mill can produce 8 mm x 22 mm pellets at a rate of 170.90 kilograms per hour. An electric motor and coupler acting as a gearbox transmission link power this machine. UNP Steel was used to construct the framework to increase strength and lessen vibration.

Keywords: Organic fertilizer; pellet machine; VDI 2222; waste processing

1. INTRODUCTION

Waste is separated into two categories based on its type and composition: organic waste and inorganic trash, both of which are both biodegradable and non-biodegradable. One of the main forms of garbage in Indonesia is domestic waste, which includes organic waste. Due to population expansion and excessive consumption, home garbage has been increasing over the past few years [1]. By turning garbage into organic fertilizer, it is possible to both cut down on landfill waste and create fertilizer that can be utilized to improve soil fertility and agricultural output [2]. In place of chemical fertilizers, which are more expensive and potentially harmful to the environment, organic fertilizers are becoming more and more popular. Additionally more environmentally friendly and improving soil fertility are organic fertilizers [3]. **Figure 1** shows the waste types, as well as the categorization of garbage.

Materials originating from living beings, such as food scraps, leaves, twigs, and paper, are referred to as organic waste [4]. Organic waste can be recycled in agricultural or gardening activities by acting as a valuable natural fertilizer for plants. Vegetable and fruit leftovers, eggshells, tea leaves, animal food scraps, and leaf litter are more forms of organic waste.

Non-organic waste is a sort of garbage that does not derive from living creatures and is difficult to breakdown. Materials like plastic, glass, metal, rubber, and chemicals can be found in this garbage. Non-organic trash needs to be handled differently, either through waste treatment or recycling. Batteries, electronics, tires, plastic bottles, food packaging, and chemicals like paints or medications are more examples of non-organic trash.

A kind of garbage known as B3 contains harmful and dangerous elements [5]. Hazardous and toxic materials are known by the abbreviation B3. If not properly managed, this kind of waste is extremely hazardous to both the environment and human health [6]. Chemicals like pesticides, dangerous substances like mercury, hospital waste, industrial trash, and other things are included in B3 waste. B3 trash must be handled specifically, and under the rules and guidelines established by the government, such as by adopting techniques of waste processing and management that are safe and under control.

Figure 1. Types of garbage

A breakthrough was made to produce organic fertilizer in the form of pellets to increase production [7]. Making organic fertilizer in the form of pellets can simplify storage and make it easier to distribute fertilizer to plants [8]. The concept for a vertical organic fertilizer pellet printer came as a result of realizing the prospects available [9]. The goal of this final project is to produce, design, and build a vertical-type organic fertilizer pellet molding machine with a capacity of 170.90 kg/hour and pellet dimensions of 8 mm x 22 mm. The advantage of this research is that it can lessen and solve the waste issue that exists all around us, particularly domestic organic waste that can be converted into pellets from organic fertilizer.

2. METHOD

A systematic and structured strategy is employed when developing products or technological systems using the Verein Deutscher Ingenieure (VDI) 2222 design technique [10][11][12]. This procedure is used to make sure that the system or product produced complies with established technical criteria and client needs [13][14][15]. There are four design flow criteria for VDI 2222, as depicted in **Figure 2**.

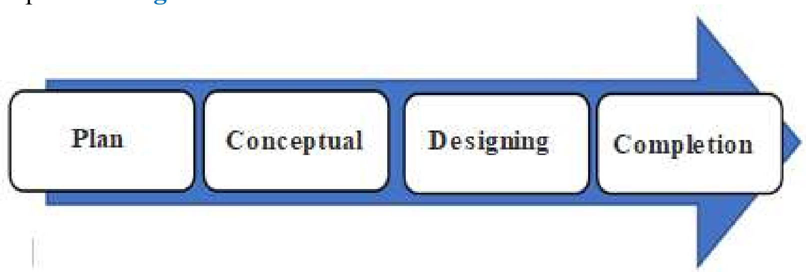

Figure 2. VDI 2222 design flow

The following are the four flow criteria used in the VDI 2222 approach for data compilation;

- Planning: The goal of this phase is to identify the work that needs to be done by digging deeper into product issues to make it easier to plan for the accomplishment of design goals or objectives. By obtaining evidence through interviews, examining the findings of relevant research, gaining knowledge from written and oral sources, analyzing the design in advance, and brainstorming, one can determine the issues encountered. A design review, which summarizes how the design problem might be divided into more manageable subproblems, is the outcome of this phase [16];
- Drafting: Explaining the product problem, the specifications that the product must meet, the specifics of the functions/subsystems, the selection of alternate functions, and alternative combinations are all part of the drafting process that leads to the final decision level. In the form of an idea, the outcomes are given;

- When designing, several elements must be taken into account to achieve the best possible results. a some of the design considerations;
  a. Standardization
  b. Machine components
  c. Material
  d. Machining
  e. Maintenance
  f. Economics
- Finalization: To make the process of working on machine manufacture easier, product arrangement drawings and functioning drawings must be made at this step. Additionally, the completion of the product designs, list of product components, material requirements, craftsmanship guidelines, and so forth [17].

A flow chart is created using the VDI 2222 design process, as shown in **Figure 3**.

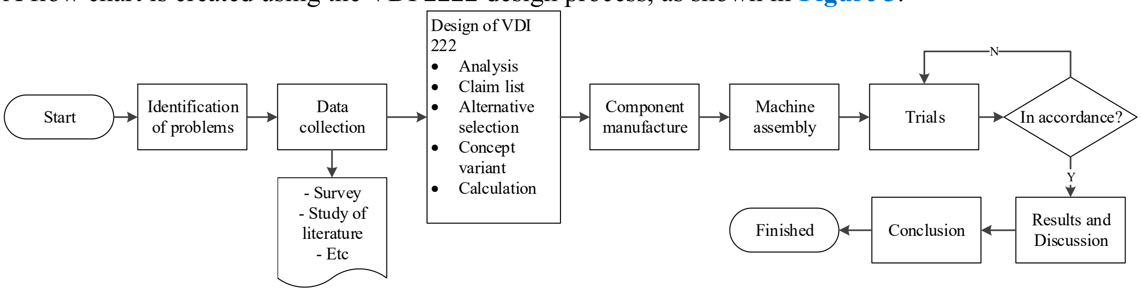

Figure 3. Flow chart

- The process of identifying issues or barriers that were encountered during the production of vertical pellet machines is known as problem identification. Identification of problems that need to be fixed or improved to achieve the best results is the goal of problem-solving.
- Techniques for gathering data are used to gather facts or information about a subject. The following is how the data collection process was carried out.
- Survey: For research to have a direct influence, study objectives must involve a problem that is present in the field.
- A literature study is carried out to gather sources for research-supporting materials. To facilitate research into and evaluation of earlier works, prior research investigations have developed into a reference that can be used using the VDI 2222 technique.
- Machine Design: At this point, the entire organic fertilizer pellet-making machine has been created by the researcher. the VDI 2222 design methodology.
- Making parts: At this point, the manufacture of the machine is completed. Where raw materials are processed using different machinery depending on the amount of effort. After that, the assembled components will be put together using those that have been finished and put through the machining process.
- Machine assembly: The components in this machine assembly have been created and have undergone the machining process. These parts will be put together to form a complete component, and they are assembled so that they can perform their intended functions. Furthermore, the design is carried out under the created machine design drawings.
- Trial: During the trial phase, the machine is tested in two different ways without the use of materials or loads to see whether the machine and its components can perform as intended. The machine will be tested with fertilizer ingredients during the loading stage so that it can be determined whether it can print fertilizer pellets with the required dimensions, which are 8 mm in diameter and 22 mm in length.
- A Standard Operational Procedure (SOP) will be created to enhance research instructions once it is established that all functions on this organic fertilizer pellet printing machine can operate under their purpose.

3. RESULTS AND DISCUSSION

3.1 Assessment of design results using the VDI 2222 method

The visual synthesis approach is applied during the design stage of the waste processing device in the form of pellets, displaying the made designs before choosing the model after taking into account its benefits and drawbacks. Three alternative concepts are used in the design, as seen in **Figure 4**.

(A) Concept 1 (B) Concept 1 (C) Concept 3

Figure 4. The design of a waste-processing device that produces pellets.

A. Concept 1

The fertilizer can move immediately down to the pressing system in the concept variant 1's vertical pellet press, where it can be processed into pellets of organic fertilizer using a hexagon-shaped conical hopper. This concept's variant 1 is driven by an electric motor. The disadvantage of this variation is that it uses an inefficient mechanism to press raw materials into pellet molds. In addition, it uses a diesel engine drive system, which increases operating costs.

B. Concept 2

In the second iteration of the concept, the vertical pellet mill incorporates a cone-shaped hopper into which the pellet material is fed before being pressed into the mold. Simply put, the mold's irregularly shaped holes will cause the pellets to emerge unevenly. In addition, the less effective mill model makes it challenging to press the material into the mold. A gear transmission system also makes the planning process more difficult.

C. Concept 3

Three concept variants were created in 3D design before the final choice. Each manufactured variant is evaluated and compared during the concept selection step. The idea of choice will be the one with the highest rating. This chosen concept is a variation of concept 3, but with a more complicated and effective design that ensures every component of the machine serves its intended role.

Each alternate function and component will be connected from one concept to the next when this design concept is evaluated. This widely used morphological method can be used to create the best design possible while still meeting current design requirements, and it can also be used to assess changes in each component. **Table 1** presents the principles that work best together.

Table 1. Alternative component functions

No.	Section Function	Condition		
		I	II	III
A	Material	Iron	Aluminum	Stainless Steel
				
B	Grinder type	Flat grinder	Bale grinder	Roller mill

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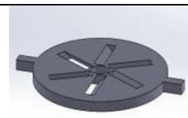
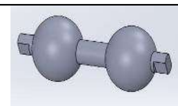
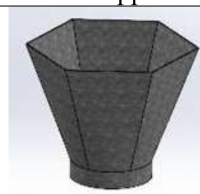
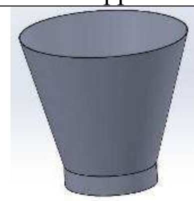
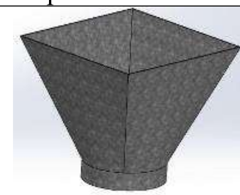
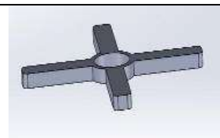
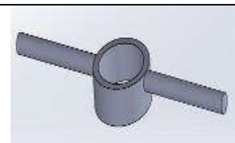
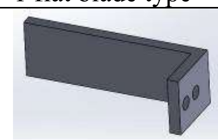
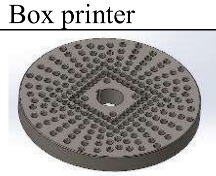
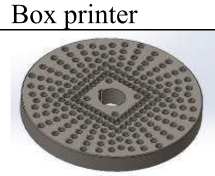
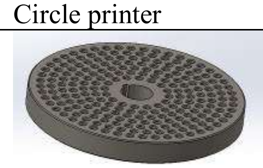
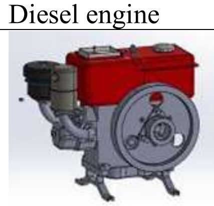
No.	Section Function	Condition I	Condition II	Condition III
				
C	Hopper type	6 facet hopper	Cone hoppers	Hope facet 4
				
D	Cutter type	4 blades	2 blades	1 flat blade type
				
E	Transmission System	Belts and pulleys	Bevel gears	Gearbox
				
F	Printer Type	Box printer	Box printer	Circle printer
				
G	Drive System	Diesel engine	Swervo motor	Electric motor
				
H	Mount frame	Hollow iron	Iron elbow	UNP iron
				
		Variation 1	Variation 2	Variation 3

There are three concept versions based on the evaluation of numerous chosen concepts. This is because idea 3 uses readily available materials, in addition to the fact that it is simpler to operate and maintain than concept versions one and two. The third concept makes use of iron components, roller grinders, 4-sided hoper forms, eye cutting system 1, a gearbox transmission, circular patterned mold type, and a 1-phase motor drive, with iron UNP serving as the mounting frame material. Regarding the findings of the morphology and assessment of the idea of weighting, **Table 2** and **Table 3** show the values of each.

Table 2. Morphological results

No.	Section Function	Type
A	Material	Iron
B	Grinder Type	Rollers
C	Hopper Type	4th Square Hopper
D	Cutter Type	1 Eye Cutter
E	Transmission System	*GearBox*
F	Printer Type	Circle Motif
G	Drive System	Single Phase Electric Motors
H	Stand Frame	UNP iron

Whereas design variation 3 received the highest score after all aspects of the assessment criteria came close to the ideal value results, making concept 3 the ideal outcome of the three existing concepts after going through the concept evaluation assessment, it was discovered in the evaluation of the weighting value of the combination function alternative.

Table 3. Evaluation of value weighting

Assessment criteria	Alternative Function Combinations								
	Evaluation		Nilai	I		II		III	
	B	P	Ideal	B	NI	B	NI	B	NI
Technical Assessment									
Achievement of Tool Functions	4	4	16	2	8	2	8	4	16
Making	4	3	12	2	8	3	12	3	12
Assembly	4	3	12	1	4	2	8	3	12
Security	4	4	16	3	12	2	8	4	16
Economic Rating									
Estimated price	4	3	12	1	4	2	8	3	12
Maintenance costs	4	4	16	2	8	1	4	3	12
Standard Components	4	3	12	3	12	2	8	3	12
Weight	4	2	8	1	4	2	8	3	12
Aesthetics	4	4	16	2	8	3	12	3	12
	36	30	120		68		76		116
Value Percentage			100%		81.6%		91.2%		96.7%

3.2 Calculation analysis and machine elements

3.2.1 Motor power calculation

$$P = \frac{T(lbf.ft) \times n(rpm)}{5250} \quad (1)$$

$$P = \frac{1.737(lbf/ft) \times 1330(rpm)}{5250}$$

$$P = 0.0439\ HP\ assumed\ to\ be\ 0.5\ HP\ in\ accordance\ with\ the\ existing\ market$$

3.2.2 Calculation of the design torsional moment (T)

Calculation of the design torsional moment (T), the value of Pd = 0.44 kW, and the value of n1 = 1330 get the results,

$$T = 9.74 \times 10^5 \frac{Pd}{n1} \quad (2)$$

$$T = 9.74 \times 10^5 \frac{0.44\ kW}{1330}$$

$$T = 322.52\ Kg/mm$$

3.2.3 Calculation of shear stress ($\boldsymbol{\tau a}$)

Next, determine the shear stress ($\boldsymbol{\tau a}$), where the value is determined by the computation:

- Material = S45C
- σB = 500 Mpa
- Sf1= 6,0
- Sf2 = 3,0

$$\tau\alpha = \frac{\sigma B}{sf1 \times sf2} \tag{3}$$

$$\tau\alpha = \frac{500}{6 \times 3}$$

$$\tau\alpha = 27{,}78\ kg/mm^2$$

To measuring the shear stress ($\boldsymbol{\tau a}$) 27.78 kg/mm^2

3.2.4 Determining the shaft diameter (ds)

In terms of determining the shaft diameter (ds)

- *Kt*=1.5
- *Cb*=2,0

  $\tau a = 27.78\ kg/mm^2$
- T =322.52 *kg.mm*

$$ds = \sqrt[s]{\frac{5.1}{\tau a} \times Cb \times Kt \times T} \tag{4}$$

$$ds = \sqrt[s]{\frac{5.1}{27.78} \times 2.0 \times 1.5 \times 322.52}$$

These findings lead to the value of ds = 5.6 mm (minimum shaft diameter).

3.2.5 Gearbox reduction ratio calculation

$$i = \frac{n1}{n2} \tag{5}$$

$$i = \frac{1330}{10}$$

The gearbox ratio computation yielded a value of 133 revs per minute.

3.2.6 Determining the vertical pellet machine's capacity by figuring out how much each pellet weighs

$$Pellet\ volume = \pi \times \left(\frac{8}{2}\right)^2 \times 22 \tag{6}$$

$$Pellet\ volume = 616\,\pi\ mm^3$$

Determine the daily volume of pellets produced;

$$Pellet\ volume = (616\,\pi\ mm^3) \times 227 \times 8$$

$$112064\,\pi\ mm^2$$

Calculate the waste's density in kg/mm^3;

$$Waste\ mass = \frac{481\ kg}{(1000^3\ mm^3)} = 0.000481\ kg/mm^3$$

Determine the pellet machine's daily capacity in kg:

$$Pellet\ machine\ capacity = 112064\ mm^3 \times 0.000481\ kg/mm^3 = 170.90\ kg/hours$$

With these results, it can be said that the machine has a large production yield and can meet the needs of the daily fertilizer production target. The machine can produce organic fertilizer pellets at a rate of 170.90 kg per hour, where this capacity is reached within 8 hours of work.

3 CONCLUSION

The goal of this study was to construct a 170.90 kg/hour organic fertilizer pellet machine with three versions, with variant 3 yielding the best results when tested using the VDI 2222 method. This machine may be used by anyone without the need for specific training. In addition, the machine design is created utilizing iron and other common components based on the examination of the calculations for each component. Similarty to this, combining a gearbox and electric motor can make the machine run more smoothly, resulting in pellets that are 8x22mm in size and free of fractures.

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