LOGIC
Journal of Engineering Design and Technology
Vol.20 No.3 November 2020; p. 152 - 159

p-ISSN : 1412-114X
e-ISSN : 2580-5649
http://ojs.pnb.ac.id/index.php/LOGIC

DESIGNING A ROTARY COMPOSTER TOOL WITH AN ERGONOMIC APPROACH TO THE ORGANIC GARBAGE PROCESSING PROCESS

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Abstract. Garbage is one of the problems facing the Indonesian society. The production of garbage resulting from various individual activities is increasing each day. University of Ahmad Dahlan (UAD) Yogyakarta as one of the colleges in Yogyakarta has the potential to produce garbage of large amounts. Under the strategic plan of environmentally insightful campus development, garbage processing will be carried out by the institutions of University of Ahmad Dahlan and academic civitas. The average garbage produced by UAD 4 campus activities is 170 kg/day with an organic waste composition of 22.57 kg and non-organic 147.43 kg. During this time the garbage was directly distributed to the Piyungan landfill without being processed first, as the campus party had not been available garbage processing devices. The purpose of the study was to design organic garbage processing tools into compost fertilizers. The study used an ergonomic approach by utilizing anthropometric data in the determination of size from the design. Anthropometric data used in this study are *Tinggi Bahu Duduk (TBD)* or Shoulder High Sitting, *Lebar Pinggul (LP)* or Hip Width, *Pantat Popliteal (PP)* or Popliteal Butt*, Tinggi Siku Berdiri (TSB)* or Standing Elbow Height, *Panjang Lengan Bawah (PLB)* or Lower Arm Length, *Lebar Bahu Atas (LBA)* or Upper Shoulder Width, and *Tinggi Lutut (TL)* or Knee Height. The result of the study was an ergonomic Rotary Composter tool design operated by one person manually with dimensions 115 cm long, 148 cm wide, 115 cm tall, 60 cm barrel diameter, seat rest height 58.75 cm, 41.23 cm seat width, seat base length 45.39 cm, the distance between seats, tool height 114.94 cm, with tool 37.33 cm wide, seat rest 50 cm, 13 cm, seat width, and seat height 59.08 cm.

Keywords : garbage, ergonomic, anthropometric, compost, rotary composter.

1. INTRODUCTION

One of the environmental problems facing Indonesian society is garbage. The production of garbage resulting from a wide variety of individual activities is increasing each day. The life patterns and cultures of people who tend to be consumptive are concerned with problems that arise from the garbage. Therefore, the garbage management system must be done precisely and systematically by involving the means and infrastructure of the slaughter [1]. Yogyakarta is one of the destination areas of many, be it with educational purposes or tourism. The large number of migrants who come to Yogyakarta impacts an increase in the amount of garbage each day. Garbage is an item already unused and discarded by its owner. By its nature, the garbage is divided into 2 types that are organic garbage and inorganic garbage. Organic waste is a decomposing litter whereas inorganic litter is a litter that is not easily decayed by nature. So that it does not matter seriously, garbage processing should be done well. Organic garbage processing into compost fertilizers will be more useful than burned which results in pollutants for air [2].

The general of an increasing population will be followed by the increase in garbage capacity generated. Increasing population is a good quality of life, accompanied by the advancement of science impacts shifting the life patterns of communities that tend to be consumptive will go along with increasing amounts of garbage produced [1]. The University of Ahmad Dahlan (UAD) with a student count of 20 thousand more potentially produces garbage of great capacity. Following the strategic plan of developing the environmentally insightful in the University of Ahmad Dahlan, garbage processing will be carried out by the University component and student to reduce the amount of garbage present in the UAD campus environment.

Based on the first observations, the amount of garbage produced by activities in campus 4 of the University of Ahmad Dahlan averaged 170 kg/day, with an organic garbage composition of 22.57 kg and non-organic garbage of 147.43kg. This observation aims to find out the amount of organic garbage produced by everyday campus activities. Observations are also conducted at the DLH of Yogyakarta which aims to see the process of processing organic garbage into compost fertilizer.

The absence of facilities or tools to process garbage in UAD campus 4 neighborhoods impacted the garbage pile of campus activities proceeds directly distributed to the Piyungan landfill without being processed first. That because it is not yet optimal utilization of the garbage present in the UAD campus environment, both organic and non-organic garbage.

The resulting impact of some of those factors is that the volume of garbage in the Piyungan landfill continues to grow every day. In general, organic waste will be treated into compost fertilizers to be used as organic fertilizer for plants. The process of processing organic garbage into compost fertilizer takes approximately 4 weeks if done without using the machine.

2. METHODS

The research was conducted at the Campus 4 in University of Ahmad Dahlan Yogyakarta. The research object is an ergonomic design of rotary composter tools to process organic waste into compost. The manufacture of tool design is done by studying human limitations, excesses, as well as characteristics and utilizing that information with the primary purpose of achieving a good quality of work without ignoring aspects of its user's health, safety, as well as comfort [3]. Research began by conducting preliminary observations for issues related to trash handling.

The collection of anthropometric data was performed directly, further used as the primary data in the study. Data processing uses SPSS software to determine tests of normality, uniformity tests, and adequacy tests. The design of the rotary composter tool aims to process organic waste. The next stage has conducted an analysis by considering the percentile value for the design of the appliance to be conveniently used.

3. RESULTS AND DISCUSSION

3.1 Data of Anthropometric

Anthropometry is one branch of ergonomic science relating to the dimension measurement of the human body that can be used to design ergonomic facilities. The importance of applying ergonomics to all matters related to humans has to do with the people's comfort of the surrounding environment [4]. Anthropometry comes from the word “Anthro” meaning human, and “Metron” meaning size [5]. Anthropometric data is used to know and establish the size of the designed tool. Anthropometry will essentially concern the physical size or function of the human body, including linear size, weight, volume, motion space, etc. The one function of anthropometry is to be used as an ergonomic consideration in requiring human interaction [6]. The absence of uniformity between size, form of means, as well as job infrastructure. It becomes a performance-limiting factor of labor [7]. Anthropometric data is obtained directly from measurements against 15 office boy workers who will use this product as well as additional from Industrial Engineering or FTI UAD student data of 15 undergraduates. The measured anthropometric data among them are, *Tinggi Bahu Duduk (TBD)* or Shoulder High Sitting, *Lebar Pinggul (LP)* or Hip Width, *Pantat Popliteal (PP)* or Popliteal Butt*, Tinggi Siku Berdiri (TSB)* or Standing Elbow Height, *Panjang Lengan Bawah (PLB)* or Lower Arm Length, *Lebar Bahu Atas (LBA)* or Upper Shoulder Width, and *Tinggi Lutut (TL)* or Knee Height. The measurement results data can be seen in Table 1:

Table 1. Data of Anthropometric

	Using (cm) in DATA OF ANTHROPOMETRIC						
	TBD	LP	PP	TSB	PLB	LBA	TL
1	60	35	45,9	101,8	44	40	51
2	55,9	40	55	115	41	45	57
3	50	40	42	106	41	47	52
4	55	40	42	117	35	48	54
5	45	39	44	119	37	47	55
6	56	38,5	38	108,5	37,5	47	55
7	60	38	46	123	45	43	56
8	56	32	41	103	40	46	57,5
9	56	38	49	114	41	46,5	54
10	61	34	48	105	44	55	52
11	63	34	49	121	45	43	53
12	58	32	45	106,5	45	44	56
13	58	33,4	51	106	39	42	56,4
14	57	38	45,4	107,4	43	45	55
15	57	31,7	46,7	117,8	38,8	45	54
16	62,3	40	42,6	124,3	38	42,3	54
17	65,2	32,4	56,6	123	35,4	44,3	57
18	61	35	41	107	37	43	57
19	59	36	37,2	116,4	39	42	52
20	53,34	33	44	117	38	42	55
21	55,88	33	40	104	36	43	55
22	58,42	29	46	116	44	44	55,7
23	56	39	52	106	42	45	55
24	55	28	44,5	127	39	48	57
25	63	31	56	118	36	45	52
26	59	33	54	135	44	44	57
27	60	37	47,3	115	45	41	53
28	56	37	43	124	35	46,5	51
29	61	37	65	123	42,5	45	57
30	55,5	40	45	121,5	36	48	54

4.2 Anthropometric Data Testing

a. Normality Test

Normality tests are conducted to find out whether or not the data already collected is a normal distribution. Normality tests are conducted using the help of SPSS software. In testing, using the Kolmogorov–Smirnov Z test, as for the test procedures as follows [8]:

1) The hypothesis:
   H_0 : Normally distributed data
   H_1 : Data is not normally distributed
2) $\alpha = 0,05$
3) Critical area: H_0 accepted if Sig. > α

Data processing results using SPSS software in full can be seen in the following Table 2:

Table 2. The Result of Normality Test

	N	SIG.	α	Description.
TBD	30	0,057	0,05	Normal
LP	30	0,165	0,05	Normal
PP	30	0,091	0,05	Normal
TSB	30	0,089	0,05	Normal
PLB	30	0,148	0,05	Normal
LBA	30	0,079	0,05	Normal
TL	30	0,16	0,05	Normal

b. Data of Uniformity Test

Anthropometric data uniformity tests are performed so that all data used is within the predetermined control limit. Here's a step in performing the uniformity of the data:

1) Searching for the average value of the data with the following (1) equation:

$$\bar{X} = \frac{\sum Xi}{n} \tag{1}$$

Description:
$\bar{X}$: Average observation result data
Xi : 1-th measurement result data
n : Data amount

2) Calculating the standard deviation by following equation (2):

$$\sigma = \frac{\sqrt{\sum(xi-\bar{x})^2}}{n-1} \tag{2}$$

Description:
σ : Standard deviation of the population
N : The data amount of observations
xi : 1-th measurement result data

3) Affirmative Specifies the *Batas Kontrol Atas (BKA)* or upper control limit and the *Batas Kontrol Bawah (BKB)* or lower control limit used as limiters of extreme data discard using the following equations (3) and (4):

$$\text{BKA} = \bar{X} + k\,\sigma \tag{3}$$
$$\text{BKB} = \bar{X} - k\,\sigma \tag{4}$$

Description:
$\bar{X}$: Average observation result data
σ : The standard deviation of the population
k : The index coefficient of the confidence level.

Based on the above equation, the recapitulation results of the uniformity test of data of each anthropometric dimension are displayed in Table 3 below.

Table 3. The Result of the uniformity Test

Dimension	N	×	σ	BKA	BKB	Description
TBD	30	57,6	4,01	65,64	49,59	Uniform data
LP	30	35,47	3,50	42,47	28,46	Uniform data
PP	30	46,74	6,10	58,94	34,54	Uniform data
TSB	30	114,94	8,40	131,73	98,15	Uniform data
PLB	40	40,11	3,43	46,97	33,24	Uniform data
LBA	30	44,89	2,87	50,63	39,15	Uniform data
TL	30	54,65	1,97	58,59	50,72	Uniform data

c. Data Adequacy Test

Data adequacy tests are conducted to test whether the data taken is sufficient by knowing the magnitude of the value of N'. When N'<N. Then the measurement data is considered sufficient that there is no need for data retrieval anymore. Equation (5) is an equation used to perform data adequacy tests.

$$N' = \left[\frac{\frac{k}{s}\sqrt{N\left(\sum_{i=1}^{n} Xi^2\right) - \left(\sum_{i=1}^{n} Xi\right)^2}}{\left(\sum_{i=1}^{n} Xi\right)}\right]^2 \tag{5}$$

Description:
N' : The number of observations that should be made
Xi : 1-th measurement result data
s : The degree of rigor desired
k : Confidence level index

The results from data adequacy tests are displayed in the following Table 4.

Table 4. The Result of Data Adequacy Test

	x	x^2	Result	Description
TBD	1728,54	100062,02	8	Adequate
LP	1064	38092	15	Adequate
PP	1402	66619	26	Adequate
TSB	3448,2	398381,04	8	Adequate
PLB	1203,2	48598	11	Adequate
LBA	1346,6	60683,28	6	Adequate
TL	1639,6	89722	2	Adequate

d. Determining Percentile Measures for Design

Percentile values from anthropometric data measurements are used as consideration for ergonomic product design [9]. Information about this percentile is important for determining the percentage of the user population that will be accommodated by the product being designed. Three percentile values are usually used in the design, namely small percentile, large percentile, middle percentile. Because anthropometric data are often assumed to be normally distributed, the middle percentile (50th percentile) is equal to the average value of a distribution. The selection of percentiles depends on the characteristics of the design dimensions. Typically, the 5th percentile is used as the minor percentile value and the 95th percentile is used as the large percentile value, to accommodate 95% of the population [3]. The percentile sizes used in this study were 5-th for small percentile sizes, 50-th for mean percentile sizes, and 95-th for large percentile sizes. Equations (6), (7), and (8) are the equations used to determine percentiles:

$$P_5 = \bar{x} - 1,645\ \sigma \tag{6}$$
$$P_{50} = \bar{x} \tag{7}$$
$$P_{95} = \bar{x} + 1,645\ \sigma \tag{8}$$

The results of the percentile calculations used can be seen in Table 5 below.

Table 5. Percentile Determination

Dimensions	P5	P50	P95
TBD	51,02	58,75	65,96
LP	29,7	35,47	41,23
PP	38,86	45,38	51,9
TSB	101,13	114,94	128,75
PLB	28,76	37,33	45,75
LBA	37,65	43,89	50,13
TL	51,39	55,24	59,08

4.3 Formulation of Design Concepts

A product is a technical object that is produced from engineering work, starting from designing, manufacturing, and other related activities [10]. Design starts from human thinking of a problem that requires a solution, be it a new solution or an old solution, but in a different way. The design concept of designing this rotary composter tool is an outline that is used to simplify the design process. The specifications of this design are:

1) The anthropometric data used to determine the height of the operator's seatback is the dimension of *Tinggi Bahu Duduk (TBD)* or Shoulder High Sitting using the 50th percentile, namely 58.75 cm.
2) The anthropometric data used to determine the operator seat width is the *Lebar Pinggul (PL)* or Hip Width data using the 95th percentile, namely 41.23 cm
3) The anthropometric data used to determine the length of the operator's seat base is *Pantat Popliteal (PP)* or Popliteal Butt using the 50th percentile, namely 45.39 cm.
4) The anthropometric data used to determine the height of the rotary composter is the *Tinggi Siku Berdiri (TSB)* or Elbow Height Standing using the 50th percentile, namely 114.94 cm.
5) Anthropometric data used to determine the distance between the operator's seat and the handle on the tool is the *Panjang Lengan Bawah (PLB)* or Forearm Length with the 50th percentile, namely 37.33 cm
6) The anthropometric data used to determine the seat back width is the *Lebar Bahu Atas (LBA)* or Top Shoulder Width with the 95th percentile, namely 50.13 cm.
7) The anthropometric data used to determine chair height is *Tinggi Lutut (TL)* or Knee Height using the

95th percentile, namely 59.08.

a. ***Rotary Composter Design***

The design of the rotary composter tool uses anthropometric data that has been previously processed in 2D and 3D as shown in Figures 1, 2, and 3.

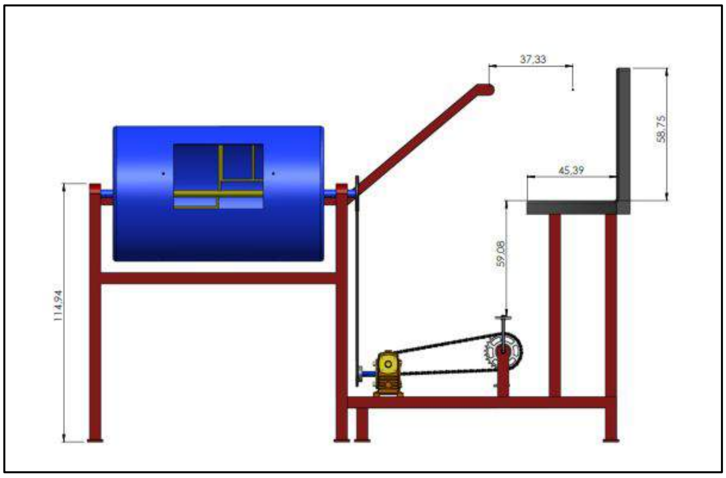

Figure 1 Design Front View

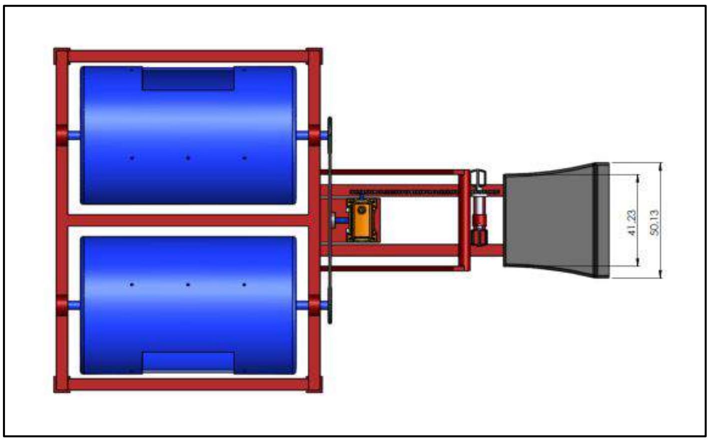

Figure 2 Design View Top

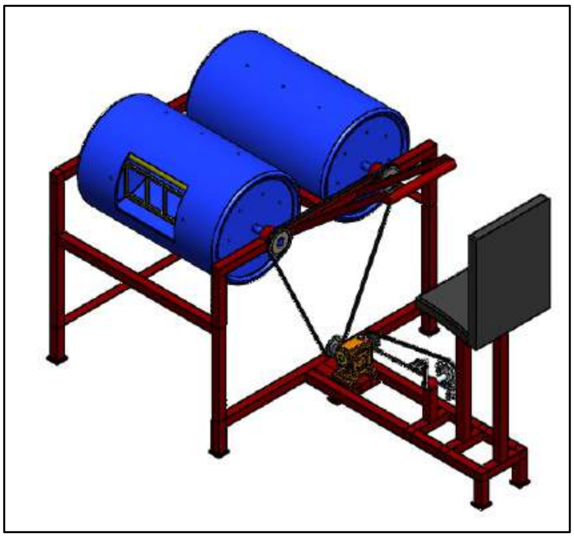

Figure 3 Design Perspective

b. Tool Specifications

Based on Figure 1,2,3 it can be explained that the specifications of the rotary composter tool are as follows:

1) The frame uses a 4cm hollow iron. The total length of the frame is 115 cm, width 148 cm, and height 115 cm.
2) The size of the drum used has a diameter of 60 cm, totaling 2 units. Drums are used to collect organic waste.
3) The gearbox used is the WPA 50 type with a ratio of 1:10. The gearbox is used to change the direction of the pedal rotation.
4) Pedals and chains used to move the drum.
5) The stirrer iron has a fin shape with a length of 40 cm and a width of 240 cm. The stirring iron is used to stir the organic waste in the drum.
6) The chair has a base width of 41.23 cm, a back width of 50.14 cm, and a chair height of 58.75 cm. The material used on the chair is plate iron. The chair is used by the operator in operating the rotary composter.

4. CONCLUSION

The results of the proposed rotary composter tool design using the *Tinggi Bahu Duduk (TBD)* or Shoulder High Sitting with the 50th percentile, namely 58.75 cm for the seat back size. *Lebar Pinggul (LP)* or Hip Width with the 95th percentile is 41.23 cm for the seat width. *Pantat Popliteal (PP)* or Popliteal Butt with the 50th percentile, namely 45.39 cm for the length of the seat base. *Tinggi Siku Berdiri (TSB)* Elbow Height Standing with the 50th percentile, namely 114.94 cm for the height of the frame. *Panjang Lengan Bawah (PLB)* or Forearm Length with the 50th percentile is 37.33 cm for the distance between the chair and the handle on the tool. *Lebar Bahu Atas (LBA)* or Top Shoulder with the 95th percentile, namely 50.13 cm for the width of the seatback. *Tinggi Lutut (TL)* or Knee Height with the 95th percentile is 59.08 cm for chair height.

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