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DESIGN OF PLASTIC MELTING EQUIPMENT WASTE BANK SCALE USING QUALITY FUNCTION DEPLOYMENT METHOD

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Abstract. The COVID-19 pandemic has triggered the rise of online purchases, resulting in the accumulation of plastic packaging waste. Plastic is most widely used because it is lightweight, flexible, cheap and easy to obtain, but its waste is difficult to decompose, which has an impact on the environment. Eco-bricking is one way that waste banks often reduce the amount of plastic waste. The obstacle in making eco-bricks is sore hands and calluses because it takes a lot of energy to compact the plastic. On the other hand, there is a lot of concentrated cooking oil waste that is still untreated, causing difficulties when disposing of it. Through this research, the design of a waste bank scale plastic melting machine is carried out with the raw materials of plastic bags and concentrated cooking oil into new materials that are more useful. The Quality Function Deployment (QFD) method with an Ergonomics approach is the basis for the stages of making product design from collecting consumer voices to making detailed tool designs. The operation of the tool uses simple technology so that it is easy to use by members of the Gurami Semanu waste bank. A total of 34 respondents will be the basis for determining product design. The results of the design of a bank-scale plastic melting tool in the form of a lidded stainless-steel pot with a stirrer. The heater used for melting uses LPG gas with automatic operation using a button.

Keywords : waste bank, plastic waste, melting machine, QFD.

1. INTRODUCTION

The problem of waste has long been a topic of discussion for all circles of society, starting from the smallest community groups such as households to the ministry, but has not been able to overcome it. Plastic is one type of waste that is increasingly accumulating, especially during the COVID-19 pandemic due to the large number of purchases via online which results in almost all package packaging coated with plastic so as not to get wet in the rain. Plastic is most widely used in everyday life because it is lightweight, flexible, cheap and easy to obtain, but the waste is increasingly unstoppable and the most worrying thing about the environment is that plastic is difficult to decompose so that it will further pollute the environment. The solution to handling plastic waste that is being developed is eco-bricking, but eco-bricking requires a long time and strong labor.

The partners in this research are members of the Gurami Semanu Waste Bank consisting of 34 men and women. So far, plastic waste has been used by the Gurami Waste Bank into eco-brick products. The products produced are chairs, tables, decorative shelves, and various household equipment. Based on initial observations, there were some complaints felt by eco-brickers in the form of reddish bruises when first making eco-bricks after several times working, calluses appeared around the palms of the hands caused by the friction force of the hands with the pressing stick when inserting plastic pieces into the bottle. Other complaints include left and right hands aching and getting tired quickly because it takes extra energy to compact the plastic into the eco-brick.

Based on the results of the NBM (Nordic Body Map) questionnaire, complaints were obtained on several parts of the body felt by eco-brickers, namely very painful conditions in the neck, shoulders, upper arms, palms, waist and back. The results of initial observations that have been made show that the working position when making eco-bricks causes MSDs (Musculoskeletal disorder) as shown in Figure 1.


Figure 1. Eco-bricking Process

Eco-bricking requires that all plastic used to make eco-bricks must be clean and dry so a selection and washing process is needed if dirty before the plastic is put in a plastic bottle. On the other hand, the community also has used cooking oil waste which has been processed into soap and candles, but limited to good used cooking oil while the black and thick used cooking oil is not suitable for use because it requires a more expensive process to purify. The members of the Gurami Semanu Waste Bank hope that there are other solutions for processing plastic waste other than being used as eco-bricks so that recycling plastic waste becomes easier while utilizing the concentrated and unprocessed used cooking oil. Therefore, they hope that there are other solutions for processing plastic waste besides being utilized into eco-bricks.

Based on these problems, research was conducted to process used cooking oil and plastic, especially crackle because it is too much wasted to become a new material as a substitute for conblock in the hope that the results of waste processing can produce an easier and more useful process. Making this new material requires a melting tool that is safe, simple, and affordable. Given that the users of this tool will be the public involved in waste bank activities, it is hoped that the smelting tool can be used by all members of the Waste Bank. Through simple technology combined with the needs of waste processing tools, a simple tool design can be made but can help solve problems in the abundance of plastic waste and obstacles in making Eco bricks. This melting tool is a plastic melting tool with crackle plastic raw materials and concentrated used cooking oil to become a new material, namely conblock. The novelty of this research is the melting process between crackle plastic waste and concentrated used cooking oil but has not yet reached the test related to the strength of the new material produced.

As research related to alternative plastic waste management is for asphalt mixtures as a durability enhancer [10] where the asphalt mixture is an aggregate and asphalt binder which is derived from petroleum [9]. Some studies provide the addition of recycled polymers to be used as additives in asphalt mixtures. The results of these studies showed a similarity in the mix materials with the modified binder [11]. The addition of these additives will provide an increase in the durability of the asphalt and will also obtain high economic benefits [8].

Research on the utilization of plastic waste for road construction has also been carried out in Ghana by utilizing HDPE and PP plastic types for asphalt mixtures [13]. In this research, the type of plastic waste was melted manually with a temperature between 1600-1700C. Further research was conducted by Sevil Kofteci [22]. In this study only uses 1 type of plastic waste, namely HDPE as a mixture for making asphalt and aims to determine the effect of HDPE plastic material on the performance of asphalt mixtures.

In the field of construction materials PET can be used as a cement mixture with demolition construction waste [10]. Construction and demolition produce stone waste in urban areas, these wastes are generally diverted to landfills. To reduce the amount of waste disposed of, there is a possibility of using the waste in brick products [13]. Sustainability is currently a top priority in the construction industry. Nowadays plastic can be used as an aggregate so it will be one way to handle plastic waste [9].

2. METHODS

This research is basic research that tries to find a solution to the problem of reducing non-organic waste, especially plastic bags, packets of online delivery packages, and other plastic bags used to fill eco-brick bottles. The waste is utilized together with concentrated used cooking oil waste to be processed together.

2.1 Population, Sampling, Sampling Technique

The population of this study were the users of eco-brick printer products, namely the managers and members of the Gurami Semanu Garbage Bank, a total of 34 people consisting of 28 mothers and 6 fathers so that sampling used nonprobability sampling. Nonprobability sampling allows for any member of the population to be selected into a sample with zero chance. This technique is carried out based on certain characteristics which include circumstances, quantity, volunteerism and so on. The sampling in this study used purposive sampling where respondents were determined by the researcher because not everyone understands how to Eco brick and has done it.

2.2 Data Collection Method

Data collection is done by distributing open questionnaires to respondents to get the voice of consumers or respondents regarding the tools to be made. Respondents in the study were all managers and members of the Gurami Semanu Waste Bank totaling 34 people consisting of 26 women and 8 men. Based on the results of collecting consumer voice data, a closed questionnaire was made to select variables that are considered important by consumers in the design of the tool to be made. Consumer voice data is used to obtain keywords from consumer desires for form, function and other variables that will be attached to the tools made. All this data will be used to create a house of quality. HOQ is the initial stage of a long series of processes in product design.

2.3. Research Design

This research tries to provide a solution to the problem of processing plastic waste by presenting a tool that can melt plastic so that it can be formed into new materials. Figure 2 shows the design of the research to be conducted, starting from the abundance of plastic waste, which has recently been widely reprocessed into eco-ricks. Eco-bricks have helped reduce waste, but there are still obstacles in making them because they still use human labor, so they take a long time and require extra energy to compact.

The Waste Bank carries out the mandate in the 3R (reuse, reduce, recycle) program for organic and non-organic waste. The 3R program is very likely to be implemented if there is support from all parties including the surrounding community. The community cannot be expected to have much role in processing waste independently but can support this program if assisted with waste processing equipment that can be used together.

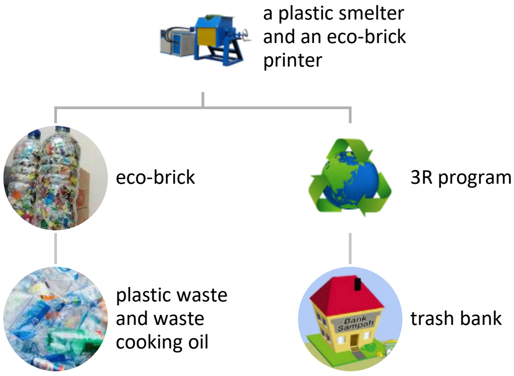

Figure 2. Flow of research

Appropriate waste processing equipment is a plastic smelter and an eco-brick printer. The stages in product design are carried out to produce tool designs that are in accordance with consumer desires. The research stage begins with the preparation of a closed questionnaire based on consumer voices from an open questionnaire as shown in Figure 2. The results of the questionnaire distribution were used to compile HOQ so that the desired product quality was obtained. Next, component requirements planning, production process planning and manufacturing planning were carried out. Based on this planning, the product design was determined through several considerations so that the resulting product design was in accordance with consumer desires.

Product design is made in the form of 3-dimensional images using solid works software to facilitate the manufacture of product prototypes. Through simple technology combined with the need for waste processing tools with crackle plastic and used cooking oil as raw materials, a waste bank scale plastic melting tool design was made to become an eco-brick that can be operated by all members of the waste bank. In the future, this tool can be used jointly with other waste banks under BumKal management.

3. RESULTS AND DISCUSSION

Data on consumer needs and desires were obtained by filling out questionnaires. The questionnaire used in data collection is an open questionnaire with the aim of getting as many needs and wants from consumers as possible-determination of the sample through consideration and specific criteria according to research needs. The considerations used in determining the respondents in this questionnaire were members of the Gurami Semanu trash can who are used to making eco-bricks and have received socialization regarding eco-bricks. This eco-brick printer will be used by partners, namely the Gurami Garbage Bank in Semanu, although it is possible that other waste banks can also use it.

Based on this, there were 34 members of the waste bank consisting of 26 women and 8 men who were respondents. Table 1 shows the results of collecting consumer voices regarding their needs and desires for the design of a waste bank scale plastic smelter.

Table 1 Attributes of consumer needs and wants

No Attribute	Attribute
1	Hands are not exposed to heat during the process
2	Ease of cleaning
3	It's not difficult to operate
4	There is a tool to remove the smelting results
5	Fuel is easy to get
6	Can be moved at any time
7	The size of the tool according to the room (not big)
8	There is an automatic stirrer
9	The tool is not heavy
10	Tools are not easy to rust
11	Cheap price
12	There is a temperature indication
13	There is a place to add ingredients
14	There is a timer

Based on the results of consumer voting, a closed questionnaire was prepared to assess the level of consumer interest using the Likert scale as shown in Table 2.

Table 2 Level of consumer interest

	Attribute													
	1	2	•3	4	5	6	7	8	9	10	11	12	13	14
Importance level	5	4.9	5	4.8	5	4.9	4.9	5	5	5	5	4.9	3.9	3.1

3.1 House of quality (HOQ)

House of quality is the first stage in the application of the Quality Function Development (QFD) methodology, used to translate customer needs or requests based on the results of consumer voice screening. The results of the HOQ preparation can be seen in Figure 3.

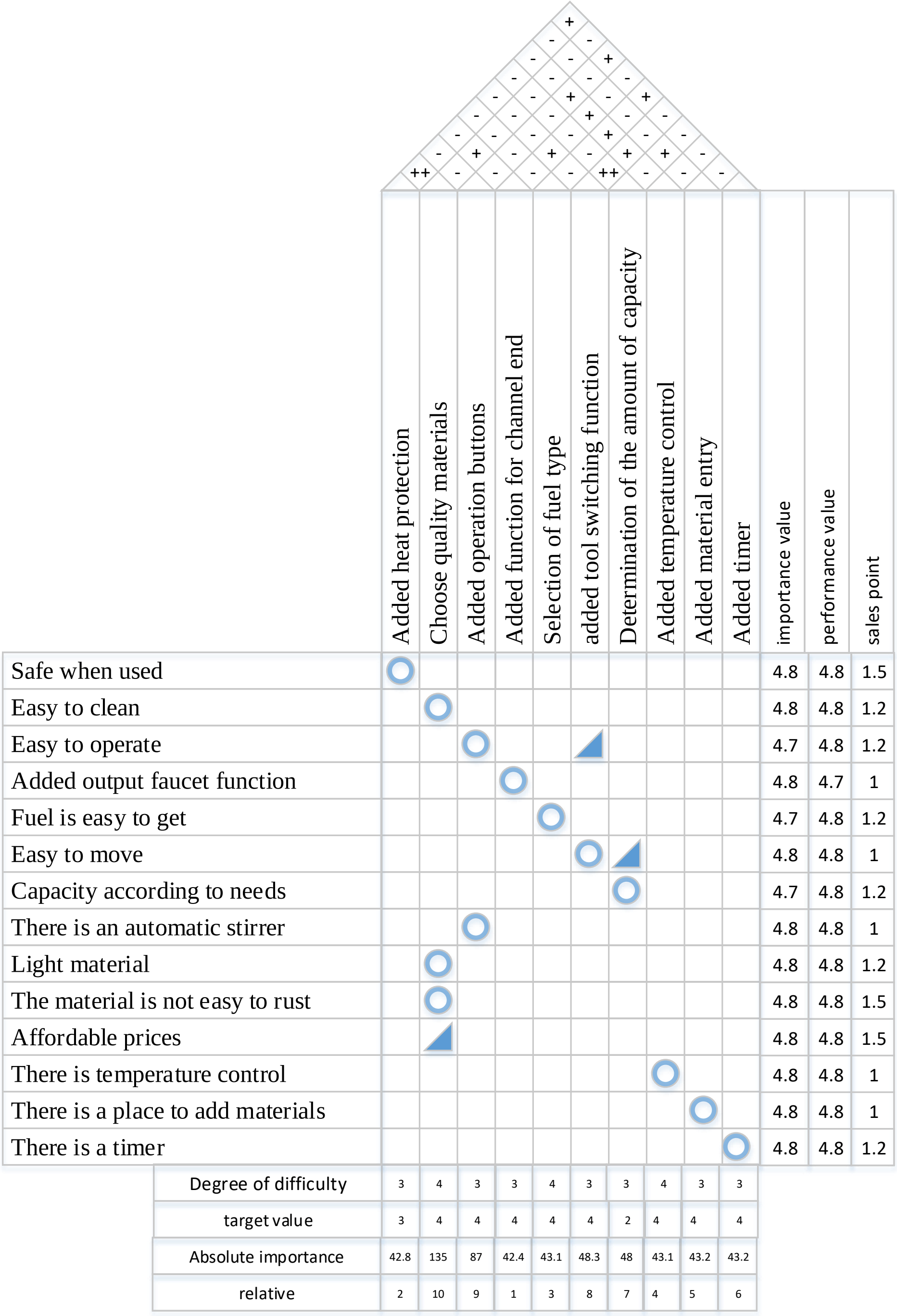

Figure 3 House of Quality

3.2 Part deployment

Part deployment is the process of determining the parts that will be used to arrange products according to consumer expectations as described in the HOQ. The results of the preparation of the deployment part are shown in Figure 4.

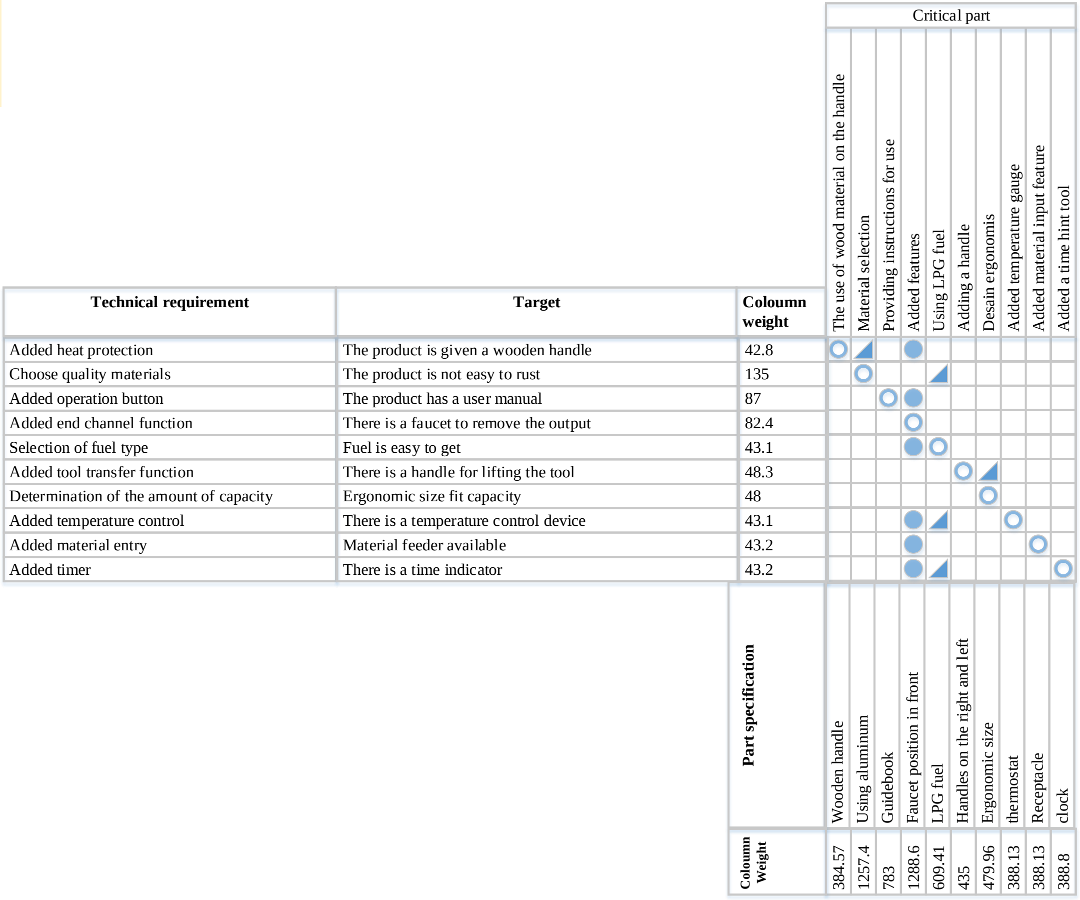

Figure 4 Part deployment

3.3 Design of a Plastic Melting Tool

Several things are considered in designing a plastic smelting tool as described below:

Anthropometric Data

Anthropometric data were taken from measurements of all 36 members of the Gurami waste bank plus several Semanu residents. The results of measuring the Anthropometric data are 36 body dimension data, then the 5th percentile, 50th percentile, and 95th percentile is calculated as the basis for determining product size. Table 3 shows the results of determining the percentiles and selecting the body dimensions used according to the product design requirements.

Table 3 Body dimension requirements for tool design

Dimensions	Percentile (cm)		
	5	50	95
Body height (D1)	117.51	152.55	187.60
Eye height (D2)	108.21	142.19	176.17
Elbow height (D4)	73.1	95.62	118.14
Fingertip height (D7)	40.53	60.36	80.18
Knee height (D15)	36.13	48.09	60.05
Shoulder width (D17)	26.32	38.72	51.13
Length of forward arm (D24)	48.33	66.15	84
Forward grip length (D25)	43.72	56.69	69.67
Length of arm span to side (D32)	111.38	152.68	194

Percentiles are used to adjust the size of the tool to fit the worker's body size so that it is comfortable to use. Following are the results of selecting percentiles for each dimension:

Body height (D1)
In the body height dimension (D1) the small percentile or 5th percentile is used. The body height dimension is used to measure the height of the tool to be designed. Selection of the 5th percentile so that users of the smallest tools have no difficulties when operating the tool. The 5th percentile size value on D1 is 117.51 rounded up to 118 cm.

Eye Height (D2)
In the eye height dimension (D2) the small percentile or 5th percentile is used. The eye height dimension is used to adjust the height of the plastic smelting tool to be designed. Selection of the 5th percentile so that users of the smallest tools have no difficulties when monitoring the plastic smelting process. The 5th percentile size value on D2 is 108.21 cm rounded up to 109 cm.

Elbow height (D4)
In the elbow height dimension (D4) the small percentile or 50th percentile is used. The elbow height dimension is used to determine the height of the mixing container for the tool to be designed. The 50th percentile is used so that all tool users can operate the stirrer comfortably. The 50th percentile size value on D4 is 95.62 cm rounded up to 96 cm.

Fingertip Height (D7)
For the fingertip height dimension (D7), the largest percentile or 95th percentile is used. The fingertip height dimension is used to adjust the height of the operational button for the tool to be designed. The 95th percentile is used to adjust the smallest size so that the tool user can reach the operational buttons comfortably. The 95th percentile size value on D7 is 80.18 cm rounded up to 81 cm.

Knee height (D15)
For the knee height dimension (D15) the largest percentile or 95th percentile is used. The knee height dimension is used to adjust the height of the final canal which is the place for channeling the smelting results into the ecobrick mold. The 95th percentile is used to adjust the largest size so that tool users can reach the end channel facilities comfortably. The 95th percentile size value on D15 is 60.05 cm rounded up to 60 cm.

Shoulder Width (D17)
For the shoulder width dimension (D17), the normal or 50th percentile is used. The shoulder width dimension is used to adjust the width of the tool to be designed. The 50th percentile is used so that all tool users can operate the tool comfortably during the production process. The 50th percentile size value on D17 is 38.72 cm rounded up to 39 cm.

Forward Arm Span Length (D24)
For the forward hand span length dimension (D24), the small percentile or 5th percentile is used. The forward hand span length dimension is used to adjust the size of the tool's distance from the front point of the tool to the back point of the tool to be designed. The 5th percentile is used to adjust the smallest size so that tool users can reach all the facilities in front of them comfortably when operating the tool. The 5th percentile size value on D24 is 48.33 cm rounded up to 49 cm.

Forward Grip Length (D25)
For the forward hand grip length dimension (D25), the small percentile or 5th percentile is used. The forward hand grip length dimension is used to adjust the size of the tool's distance from the leading point of the tool to the back point of the tool to be designed. The 5th percentile is used to adjust for the smallest size the user of the tool can hold the plastic smelter cover comfortably. The 5th percentile size value on D25 is 43.72 cm rounded up to 44 cm.

Length of Hand Span to Side (D32)
For the long dimension of the hand span to the side (D32), the small percentile or 5th percentile is used. The long dimension of the hand span to the side is used to adjust the size of the tool's distance from the right point of the tool to the left point of the tool to be designed. The 5th percentile is used to adjust the smallest size so that tool users can carry the plastic smelter comfortably when using or cleaning the tool. The 5th percentile size value on D32 is 111.38 cm rounded up to 112 cm.

A recap of all the anthropometric dimensions used according to the selected percentiles results in the dimensions of the plastic bag smelting tool. as presented in Table 4. Determination of the dimensions of the size of the tool to be designed is shown in Table 4 with details: the height of the tool is at intervals of 109 - 118cm, the height of the mixing container is 96 cm, the height of the operational button is 81 cm, the height of the final canal is 60 cm, the width of the tool is at intervals of 39 - 112cm, and the tool length is in the size interval of 44 - 49cm.

Table 4. Dimensions of the plastic smelter

Tool Dimensions	Anthropometric Dimension	Percentiles	Size (cm)
Tool + furnace height	D1, D2	5	109 - 118
Container Height	D4	50	96
Operational Button Height	D7	95	81
Final Channel Height	D15	95	60
Tool Width	D17, D32	50, 5	39 - 112
Stirrer length	D24, D25	5	44 - 49

3.4 Analysis of Materials and Products Forming Plastic Melting Equipment

The plastic smelting tool is made based on the consideration of the various constituent components with the following explanation:

There are two alternatives for selecting heating devices, namely LPG and electricity. The type of LPG heater uses LPG gas as a heating source while the electric heating type uses electrical components as a heating source.

There are two alternatives for selecting the type of stirrer, namely helical ribbon, and paddle anchor. Both types of stirrers are suitable for the process of mixing materials that have a high level of viscosity and operate at low rpm rotational speeds. Helical ribbon is used in various levels of viscosity. This type is operated with minimum clearance between the tube wall and the stirrer. This type also allows axial flow at low speeds [18]. Paddle anchors are suitable for use at a high level of viscosity. This type will be optimal if it is driven with a low stirring speed [18].

There are three alternatives for choosing the Final Channel Location, namely the position in front, below, and by casting. The positions of the front end and bottom pour lines are more suitable for use with LPG heater types. When using an electric heater, the three positions of the final channel location can be used.

There are three alternatives for choosing the type of material, namely steel, stainless steel, and aluminum. The material used is divided into two types of parts, namely the frame and the mixing bowl. The frame section uses a material suitable for the material being melted, namely steel, while the material in the mixing vessel has two alternative materials, namely stainless steel, and aluminum.

Based on the choice of morphological chart, several alternative designs were developed. The results of the selection of components are as follows: Electric heater, paddle anchor type stirrer, three layers of tube, output valve on the bottom side, steel frame material, aluminum stirrer container material.

The results of the waste bank scale plastic smelter design using Solidworks software are shown in Figure 5, while the details of the constituent components can be seen in Figure 6.

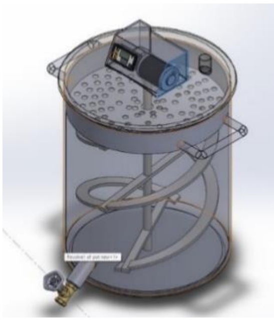

Figure 5. Design of a garbage bank scale plastic smelter

Figure 6. Design of a waste bank scale plastic smelter

3.5 Description of Tool Use

The plastic smelter is a production tool that uses electricity and heat. Electrical energy is used to rotate or stir automatically from plastic bags and used cooking oil. Meanwhile, heat energy is sourced from an LPG gas stove which is useful for heating raw materials while stirring. In use, the operator of the tool manually inserts the ingredients into the mixing container, then if you want to stir, the operator must first turn on the stirrer by pressing the operational button.

Then the stove heater is turned on by rotating the stove lever according to the desired amount of fire (temperature). The stirring process continues until all the ingredients are dissolved and mixed into a thick liquid which is ready to be poured into the ecobrik mold container. After use, to remove the production results, the operator must prepare a container for the plastic smelting results. Pouring the mixed results is done by releasing the container hook then pouring the container through the output faucet to move the produce.

This result is in line with several studies by Intan [21], and Bhushaiah [18] which have utilized plastic waste to turn into bricks or the like as building materials. Various studies have carried out mixing plastic with a mixture of other materials to be melted together, which basically has the same goal of reducing plastic waste to be melted down into new materials [21].

4. CONCLUSION

This research has resulted in a design proposal for a waste bank scale plastic smelter in accordance with the needs and desires of consumers. This tool is used to melt plastic bags mixed with used cooking oil to become a new material in the form of conblock. This melting tool is a plastic melting tool with crackled plastic raw materials and concentrated used cooking oil to become a new material, namely conblock. The novelty of this research is the melting process between crackle plastic waste and concentrated used cooking oil but has not yet reached the test related to the strength of the new material produced.

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