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Application of Reverse Engineering for Modified Anchor Impeller

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ABSTRACT

One of the processes of wet area is the separation of soybean's skin using water as its media, with the cycle time is 45.59 minutes. The object of this research is the wet area on Tempe production in Indonesian Tempe House (ITH) at Bogor City to reducing the cycle time by designing soybean peel separator machine. This research was conducted using the reverse engineering method by performing an in-depth analysis of the tools used and developing the existing peel separator equipment based on user needs. Concept screening and concept scoring are done to select one of the best concepts of 48 possible concepts. The result of the selected concept of the soybean peel separator is the need for a propulsion motor as a replacement energy source for the operator's power and the mechanisms for separating skin and soybeans using water force from the bottom of the container. After that, the concept will be done by make a prototype and testing it in Rumah Tempe Indonesia with the result of cycle time is 70.77 minutes for all processes in a wet area, which means the cycle time is decreasing 39%.

***Keywords*:** reverse engineering, tempe, food industry, redesign

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1. INTRODUCTION

In general, tempe is made from soybean seeds produced by home industries or small industries (Liem et.al., 1977; Astuti et.al., 2012). The Indonesian Tempeh House (ITH) is a pilot unit for the hygienic and environmentally friendly tempe industry. In addition, tempeh is used as a meat substitute in Indonesia (Medwid and Grant, 1984; Nout and Rombouts, 1990). Thus, ITH was used as a product development center for tempe producers in Indonesia. The quality of tempe production can be monitored with several variables based on the provisions written in SNI 3144: 2009. This standardization helps companies to monitor the quality of tempeh during production. In addition, based on the 2015 National Economic Survey of Indonesia (NESI), tempe is consumed by 32.1% of households in Indonesia, which means it occupies the third highest position after fresh soybeans and tofu. The amount of tempe consumed in 2015 rose by almost 20% of the total tempe consumption in 2014.

The quality of tempe was also observed by reviewing the production process. ITH uses 12 stages of production standards adopted by the Indonesian Tempe Forum (ITF). This stage is divided into two different areas, namely wet and dry areas. The wet area consists of sorting, boiling, soaking, cleavaging, peel separating, soaking (with hot water), and washing. Meanwhile, dry areas consist of drying, inoculating, packaging, and fermentation processes. It can be seen in Table 1, that the process of separating soybean husk takes a longer cycle time than other processes (Vaidehi et.al., 1996; Babu et.al., 2009; Astuti et.al., 2012).

Table 1. Production Time.

No.	Activity	Time (second)
1	Boiling Preparation	11,87
2	Cleavaging	17,48
3	Peel separating	4246,2
4	Soybean washing	63,26

This process utilizes centripetal force and lift force of the liquid to direct the epidermis up to the surface of the water and along with the addition of water discharge, the epidermis will be wasted through the drain path attached to the lip of the tube. Meanwhile, soybean seeds do not come up to the surface and settle at the bottom of the tube because of the gravitational force. This process must be carried out for 30 minutes until the epidermis of soybeans is unable to rise to the surface of the water. However, the husk of the soybeans that were successfully peeled was heavily attached to the nylon brush mounted on the container. Meanwhile, the level of cleanliness that can be achieved using an agitator in the soybean shell separator container is only 41%, while to achieve the cleanliness target (90%) soybeans must be processed using a manual method. This manual method is carried out using a bamboo sieve (Liem et.al., 1977; Nout et.al., 1992; Astuti et.al., 2012).

2. METHODE

2. 1. Reverse Engineering

Reverse Engineering (RE) is one methodology for obtaining information from components of a machine that aims to improve it. In the aviation industry, this methodology is able to reduce a large number of components through re-engineering of products, designs, and manufacturing processes (Gameros et al., 2015). However, RE can be interpreted as a process of gathering information and analysis of existing systems to improve system optimization (Montanha, 2007).

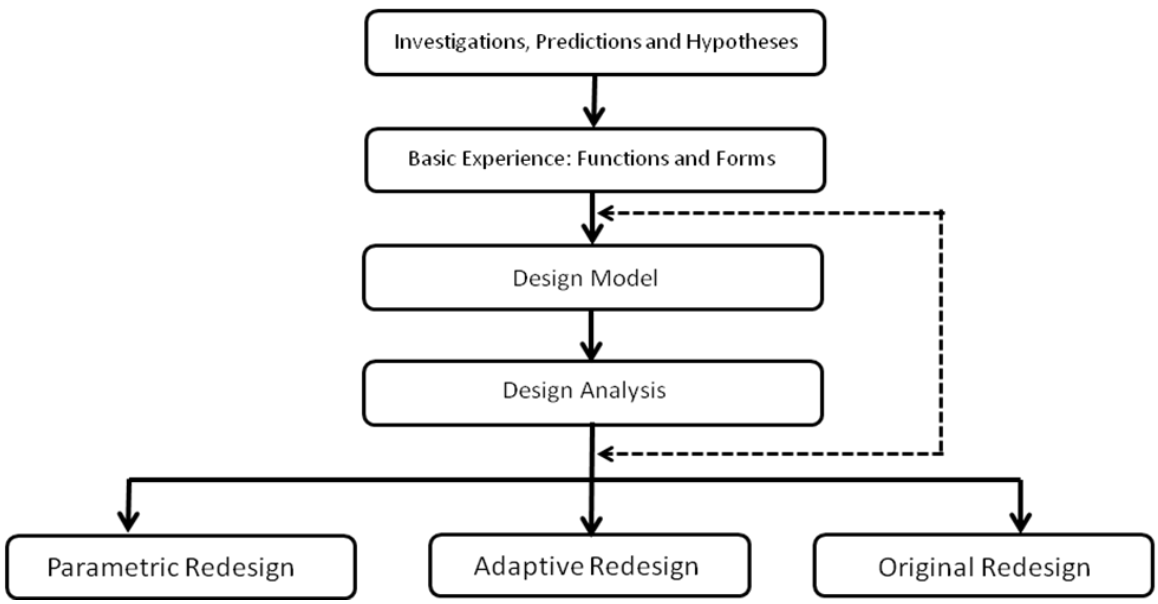

Figure 1. The Framework of reverse engineering and redesign methodology
(Source: Otto and Wood, 1998)

Reverse engineering is a redesign methodology. This means that it is a design process that is applied to an existing product, or at least to a prototype or detailed concept. It is normally a process that uses a variety of techniques in the form of models, charts, diagrams, guidelines, and normative theories to dissect and fully understand a product. Stated consisely, reverse engineering "...initiates the redesign process, wherein a product is observed, disassembled, analyzed, and documented in terms of its functionality, form, physical principles, ASME Design Theory and Methodology Conference, 1996 2 manufacturability, and assimilability. The intent of this process step is to fully understand and represent the current instantiation of a product" (Otto and Wood, 1998).

Although reverse engineering is most widely used for redesign purposes, it can be used for other reasons as well. There exists at least five possible motivations behind reverse engineering a product: (1) benchmarking, (2) critical study and evaluation of a competitor's product, (3) quality improvements, (4) cost reduction, and (5) basic product/technology knowledge. Within this context, there can exist sub-design processes and methods that focus on a specific aspect of the design. Highly popular examples of these are Design for Manufacturing (DFM) and Design for Assembly (DFA).

RE is widely used in manufacturing, industrial design, and reproduction. Yau et al. state that RE relates to the creation of a computer-aided design (CAD) of physical objects that can be used as a design tool to make the production of an object, extract design concepts, and re-engineering existing components (Ciocănea et.al., 2017). Although it consists of several design analysis procedures and manufacturing processes, RE is not only a matter of geometry but also material and function (Valerga et al., 2015). As can be seen in Figure 1, there are five main processes of the reverse engineering approach (Otto and Wood, 1998).

They are:

The Investigation, Prediction, and Hypothesis

This investigation and prediction stage is intended to ascertain the problem boundaries of product development, predict product functions, and analyzes the weaknesses of previous products.

Product Decomposition

One of the bases of product development is the process of disassembly from existing machines so that it can be known how to improve its components.

Functional Analysis

After decomposition of the existing product then the next action is doing a functional analysis on the process of soybean skin separation.

Morphological Analysis

Morphological analysis of the product is carried out to separate components into several alternatives. The alternatives formed lead to different concepts for further analysis to choose the best concept. Based on the background of the problem, what will be analyzed in this section is the agitator/stirrer section.

2. 2. Concept selection

In choosing a concept, the first step that must be done in determining the percentage of relative weight in each concept to be chosen. This percentage depends on the product attributes and the level of importance of each attribute. The determination of the percentage of relative weight makes it easier to choose concepts based on their importance with more systematicity. For this study, the determination of relative weight was carried out using in-depth interview methods with previous machine users.

Model Design

After going through the concept choosing process, one of the best concepts is obtained (Tay and Gu, 2003). Furthermore, the identification process is carried out on the components of the agitator from the design to the material used.

Concept Prototyping and Testing

This time the testing tool focuses on cycle time, water use, electricity use, and cleanliness of the separation of soybean skin. Tool testing was carried out using three agitators with different designs, namely by modifying the type of anchor impeller, elongated paddle, and helical impeller design. Data collection was carried out by using soybean epidermis separation container with the design referenced from research conducted by Desai et.al (2016).

3. TOOLS AND APPROACHES

Use of the Existing Product

The previous agitator design was in the form of a rectangular plate that had space in the middle. It is this agitator that helps to separate the epidermis from its seeds by utilizing a rotational force (Abe and Starr, 2003; Karray et.al, 2011). This rotating force is combined with a constantly increasing water mass that helps the skin to be wasted through the drainage path attached to the tube which utilizes the lifting capacity of the liquid. With this design, the soybeans that are stirred are able to release the epidermis and its shoots, but the distribution of the material is uneven (Karray et.al, 2011). Although it is stirred, the soybeans which are at the bottom are trapped a lot because they cannot rise to the surface, so the epidermis cannot be wasted optimally.

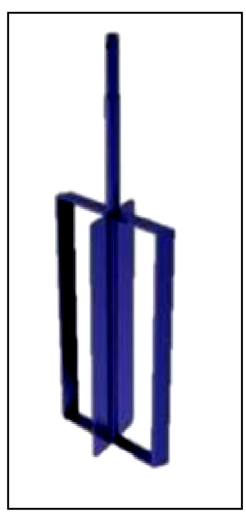

Figure 2. Previous Agitator

Referring to the previous study, the level of cleanliness of soybeans in soybean husk separator was 41%. To reach 41%, this machine takes 1890.11 seconds, equivalent to 31.5 minutes (Asiri, 2015). However, to meet the target of soybean hygiene at Rumah Tempe Indonesia by 90%, the process of separating soybean husk must be continued by a manual process using a sieve system carried out by human labor for 45 minutes.

Figure 3. Existing Container Design

In the existing container concept shown in Figure 3, the filter on the top of the cylinder is useful for holding soybeans to remain in the cylinder and leaving the peel filtered through the exhaust path (Asiri, 2015; Ciocănea et.al., 2017). This agitator functions to stir soybeans and water without using human strength. This machine utilizes centrifugal and centripetal forces that appear when water and soybeans are subjected to a rotating force.

User Needs Identification

User needs or user needs are used as the main reference for product development because the user or user knows how the soy epidermis separator can work well. Here are some user needs from the epidermis separation process at ITH of Bogor City:

1) The brush used is dynamic.
2) Agitator can separate the peel from soybean seeds faster and cleaner.

Previous Agitator Weakness

The weakness analysis of the previous product was done to find out the focus of the development of soybean skin separator machines. Based on observations made, there are weaknesses in the use of previous types of agitators. Agitators available at ITH of Bogor City, only help to rotate soybeans but are less helpful for the release of soybeans. This affects cycle time, so the time needed to achieve a standard level of cleanliness (90%) becomes longer.

Decomposition of Structures

Structure decomposition has a purpose to understand each machine component. In addition, decomposition of the structure also helps define the parts that are possible to be removed. The soybean epidermis separator machine previously consists of 3 main components that have their respective functions; container, agitator, and wire filter. All components involved will be explained in a more detailed version and will be compared to other components. This stage is carried out to facilitate the analysis process for each component. Here are the previous machine components

Product Morphological Chart

The product morphologycal chart is the way in which all product feature choices are made alternative by comparing alternative choices based on existing products. The choice of initial thinking of product development is then combined to create a systematic solution. The result of this morphological analysis is the result of concept selection based on the comparison of existing concepts.

Table 2. Morphological chart of soybean separator machine

Function	Existing	Alternative		
		Option 1	Option 2	Option 3
Storage of Water And Soybeans	Cylinder	Cylinder	Cube	-
Stirring Mechanism	Existing Agitator	Elongated Paddle	Helical Impeller	Anchor Impeller
Brush	Wire Filter	Nylon	Stainless-steel	-

As can be seen in Table 2 above, there are 3 main functions that each have an alternative. Every alternative function is obtained from the benchmarking process on other machines that have similar mechanisms. So, the number of possible combinations is 2 x 3 x 2 = 12 concepts. After being reduced, the alternatives used are reduced and focus more on research objectives. The number of combinations that occur becomes 3 x 2 = 6 combinations.

Concept Selection

In choosing a concept, the first step that must be done in determining the percentage of relative weight in each concept to be chosen. This percentage depends on the product attributes and the level of importance of each attribute.

The determination of the percentage of relative weight makes it easier to choose concepts based on their importance with more systematicity. For this study, the determination of relative weight was carried out using in-depth interview methods with previous machine users. This concept chosen because of the highest score obtained.

Figure 4. Selected concept

Prototyping and Testing

This stage is carried out based on alternative design concepts. The prototype is made based on the standard size and limitations of making tools from Rumah Tempe Indonesia, Bogor. This machine testing focuses on cycle time.

Table 3. Cycle time after using a developed machine

	Existing	**Anchor Impeller**
Cycle Time (minutes)	70,77	65

The first objective of this study is to reduce cycle times where this has been fulfilled, namely the reduction of cycle times from 70.77 minutes to 65 minutes or reduced by 9% from the previous time. This 9% cycle time reduction was achieved by using an anchor impeller type agitator.

4. CONCLUSION

This agitator carried out the process of separating soybean husk for 28 minutes until there were no more soybeans that rose to the surface with a speed of 78 rpm. When the process with the agitator is complete, the level of cleanliness of the soybeans achieved is 44%. However, this figure is still below the Indonesian Tempe House standard, which is 90%. So, the process must be continued by manually using a sieve for 37 minutes. This process aims to achieve a 90% level of cleanliness. After that, the water use calculation process is carried out.

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