DESIGN OF BIOMASS FIRED DRYER USING INTEGRATING DESIGN THINKING AND TRIZ METHOD

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ABSTRACT: In the context of Small-Medium Enterprises, the activity of drying wood is still somewhat reliant on solar energy. Drying using solar energy has numerous challenges, one of which is heat fluctuation due to changes in weather. To address this challenge, there is a need for a cost-effective and environmentally-sound dryer. In this paper product design of drying using integration of Design Thinking (DT) and Theory of Inventive Problem Solving (TRIZ) method. The aim from this study is to find out of design of wood dryer based on integration of DT and TRIZ. The results of product design based on integration DT and TRIZ is that the dryer design consists of two main parts, namely the biomass furnace and dryer chamber. The dimensions of the furnace are 80 cm × 90 cm, while the drying racks comprising the enclosure are sized according to the operator. Using anthropometry data, the maximum dimensions of the rack are 196 cm height and 70 cm width. Drying using a biomass dryer is faster than the solar dryer. Drying using a biomass dryer takes seven days to dry the wood to 8%

moisture content and takes one day to dry wood to 8% moisture content with a temperature of 150°C.

KEYWORDS: *Product design; Wood dryer; TRIZ; Design Thinking*

1.0 INTRODUCTION

Among forest produce, wood is of primary significance for humans. It may be processed to produce daily-use objects. Yogyakarta area in Indonesia has a significant wood-processing industry, which contributes a lot to the Indonesian economy [1]. The woodcraft sector is understood as one which may benefit the economy. Woodcraft is a creative art and design process which adds artistic value to wooden products [2]. The Gumawang village in Yogyakarta is among those villages where a majority of the individuals are craftsmen specialising in wood. The area is known for its high volume of wood production. Wood small-medium enterprises (SMEs) produce wooden handicrafts like educational games, souvenirs, kitchen utensils, and masks.

There is a massive demand for handicrafts, which are produced over a vast area. The scale of marketing is immense and includes foreign markets. Demand, production, marketing, and a large variety of handicrafts provide economic growth to SMEs. Increasing demand for handicrafts requires additional wood production, thereby leading to an increased demand for wood. Drying space becomes a roadblock since it is limited, thereby leading to the drying process needing more time. Wood SMEs is involved in wood drying using solar energy, which has immense potential in the context of conventional drying [3]. Rural areas are primarily reliant on this conventional technique; however, rains are problematic. Wood production is limited during the rainy season since drying times are significantly higher.

Many techniques are employed for drying, each having its benefits and drawbacks. Studies have focused on reducing reliance on solar energy for drying and have suggested an integrated technique, where biomass and solar energy are used together [4-7]. The drying duration may be reduced by using biomass-based energy instead of using only solar energy. Biomass may be effectively used, especially in developing countries where there is cheap availability of firewood [8-9]. Apart from a hybrid dryer, there is another closed dryer that uses biomass. Numerous studies that focus on using biomass as the sole energy source have been conducted [10-13].

Studies indicate that conventional drying is widely used for drying agricultural products; however, there is little discussion concerning the drying of wood. Literature suggests using waste heat from biomass as a cost-effective and efficient energy source [4, 14-16]. Wood artisans often have waste or residual wood, which may effectively serve as biomass required to fuel the dryer. DT is used to solve complex problems and to find solutions that users can appreciate. Few researches had reported the DT is used to solve complex problems and to find solutions that users can appreciate [17]. DT is also a solution-based approach used by designers to deal with complex problems. This approach is developing and widely used by companies for company development [18, 19]. Design Thinking is increasingly popular in a variety of professions including business management, healthcare, and social innovation [20]. Renato et al, 2023 studied a customized blueprint with Design thinking to creative problem-solving. The findings in this study reveal the initiative in making a blueprint for research and development [21]. Apart from the Design Thinking method, TRIZ is one of the development methods for new product development (NPD).

In Jeong's research [22], he conducted research on packaging design development using the TRIZ method In this study, the TRIZ method was used to carry out new product development (NPD) for elderly-friendly food packaging. The use of the TRIZ methodology for product innovation has also been carried out by Rau [23]. In this research the TRIZ method for innovation in green products. Analysis of functions and attributes is used to identify target product profiles with environmentally friendly features.

Furthermore, TRIZ is considered as a methodology that can be used to solve problems and support the creative process in the RnD process. TRIZ was developed by a Soviet engineer named Genrich Altshuller. TRIZ has stages to solve problems by starting from a specific problem and identifying contradictions that occur. The contradictions that have been resolved will be applied into general solutions to become specific solutions [24–26]. The objective of this paper is to design a biomass fuelwood-based wood dryer with a special focus on the ergonomics dryer. In this study using integration of DT and TRIZ for make a design of wood dryer.

2.0 METHODOLOGY

2.1. Proposed Approach

This study focuses on integration of Design Thinking (DT) and TRIZ method for design of biomass fired dryer. The framework of the integration of DT and TRIZ flowcharts of the design process as shown in Figure 1. In this framework DT will be an approach to problem definition. The next stage is the TRIZ method to be applied to technical analysis.

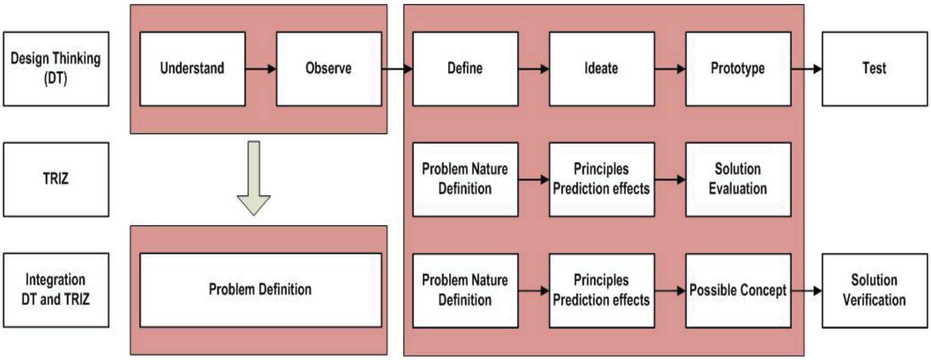

Figure 1: Framework of Integration of DT and TRIZ

2.1. Analytic Process

In this study, interviews and focus group discussions were conducted with workers. In DT method, interviewing is one of the first steps to get information about complaints and obstacles during the production process. The interview process is carried out directly to the owner and employees. In The DT method Interview is to explain the problem definition. Discussions were held to find solutions to problems identified during the interview. Participants in this discussion are owners and employees. In this discussion, it is hoped that the desiccant design can be obtained as expected.

3.0 RESULTS AND DISCUSSION

3.1. Design Thinking to support problem definition

The stages of Design Thinking in this study are empathize with users, then researchers define user expectations and needs, collect ideas, provide a passing product overview prototype, and confirm. If the user think the product is not as expected, then researchers will carry out the process of re-empathy in use get the correct customer insight. This study involved 4 workers in UKM Tunas Karya and 1 CEO. Identification of DT to support problem definition can see in Table 1.

Table 1: Design Thinking to support problem definition

Step of DT method	Identification
Empathize	Not too high the dryer, easy to operate, small electricity consumption, smoke does not pollute the environment, can accommodate a lot of products.
Define	The dryer is ergonomically built so that it fits within the operator's hand.
Ideate	The dryer is in a closed room. Adjusted to the operator's body size. There are 2 main parts, namely the dryer and the furnace. The heat source comes from burning biomass. Made a chimney to drain air. Try dryer.

3.2. Problem Treatment using TRIZ method

The main objective of the problem treatment step is to analyse the problem and propose a solution. In this step, use the help of TRIZ tools. This stage of handling this problem, is done using the following list:

i. Functional model formulation
ii. Engineering Contradiction statement
iii. Inventive principle
iv. Prototype

3.2.1. Functional model formulation

The based on DT method then formulates the problems that have been identified during the interview. Based on the TRIZ method the model function is generated from the sub-system and the super system. Figure 2 shows the graphical form of the function in making a wood dryer. To make a wood dryer, several subsystem components are needed. The components that are needed in making wood dryers are the drying chamber and furnace. In the manufacture of drying chamber, drying rack is a component needed to complete a wood dryer. In addition, to support the furnace, a chimney is needed to remove smoke from the furnace. The blower is used as one of the components needed to blow hot steam which will be distributed to the drying chamber.

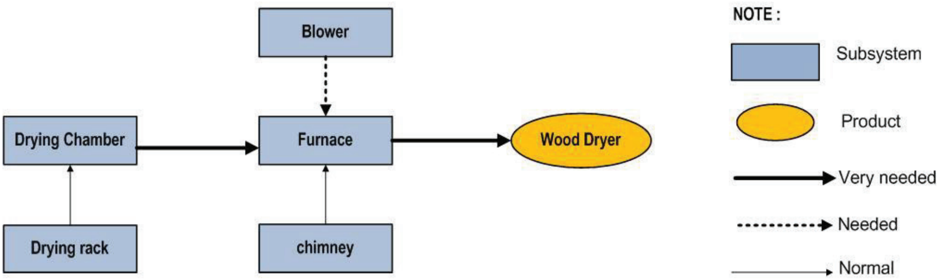

Figure 2: Function model diagram

3.2.2. Engineering contradiction Model

The technical parameters in TRIZ consist of 39 keywords that represent technical parameters. The use of parameters in TRIZ can solve problems and allow users to think more creatively. The current engineering parameters are matched with TRIZ system parameters as shown in Table 2.

Table 2: Current parameter with TRIZ 39 system

No	Requirements	TRIZ 39 system parameters
1	Operator ease of use	33 – Ease of operation
2	Drying chamber	17- Temperature
3	The source of heat	20 - Use of energy by stationary object

3.2.3. Inventive Principle Model

The next step for the problem-solving process using TRIZ is to identify general solutions using a contradiction matrix. The contradictory matrix on TRIZ has inventive principles to solve. Based on the research results, there are 3 incentives that can be used to make wood dryers. Inventive principle can see in Table 3.

3.3. Proposed Product

Based on the inventive principle recommended based on the contradiction matrix (Table 3), the next step is solving the problem by changing the general solution to be specific. Changing general solutions to specific ones is done by brainstorming with several designers who can provide input for prototyping. Based on TRIZ recommendation the proposed dryer comprises two parts, which are the furnace along with an attached chimney, as depicted in Figure 3. The dimensions of the furnace are 80 cm x 90 cm are wooden scrap is used to fire the furnace. The heat produced from combustion is then directed into the drying chamber using a fan.

Table 3: The inventive principle recommendation

No	Requirements	Parameters to improve	Recommendation TRIZ 40 inventive principles
1	Operator ease of use	33 – Ease of operation	Principle 3: Local quality a. Change an object's structure from uniform to non-uniform, change an external environment. b. Make each part of an object function in conditions most suitable for its operation. c. Make each part of an object fulfil a different and useful function.
2	Drying chamber	17- Temperature	Principle 35: Parameter changes a. Change an object's physical state (e.g., to a gas, liquid, or solid. b. Change the concentration or consistency. c. Change the degree of flexibility. d. Change the temperature.
3	The source of heat	20 - Use of energy by stationary object	Principle 25: Self-service a. Make an object serve itself by performing auxiliary helpful functions. b. Use waste resources, energy, or substances.

The drying chamber is the second part and comprises a rack, as depicted in Figure 3. The dimensions of the chamber are 3 m × 2 m, and it is constructed using zinc composite. The drying rack design is depicted in Figure 4. The drying rack is based on ergonomics since industrial workstations typically consider numerous ergonomic aspects considering operator attitude and position [27]. The working position must account for body shape, size, work capacity, and strength. Anthropometry is the field that considers these aspects [28,29].

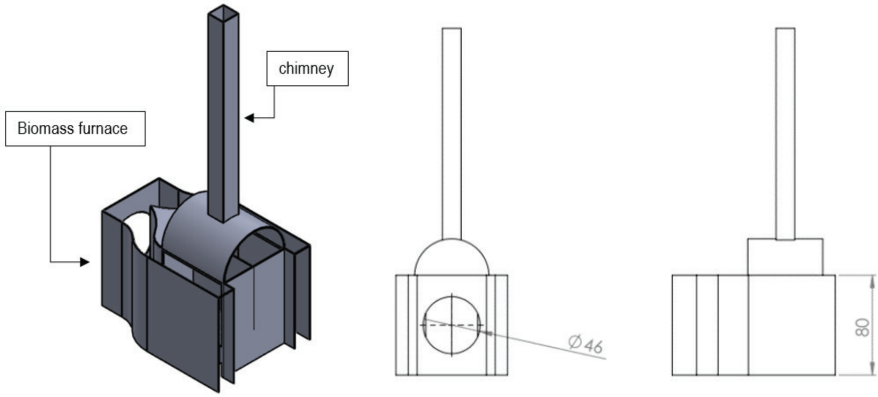

Figure 3: Biomass furnace

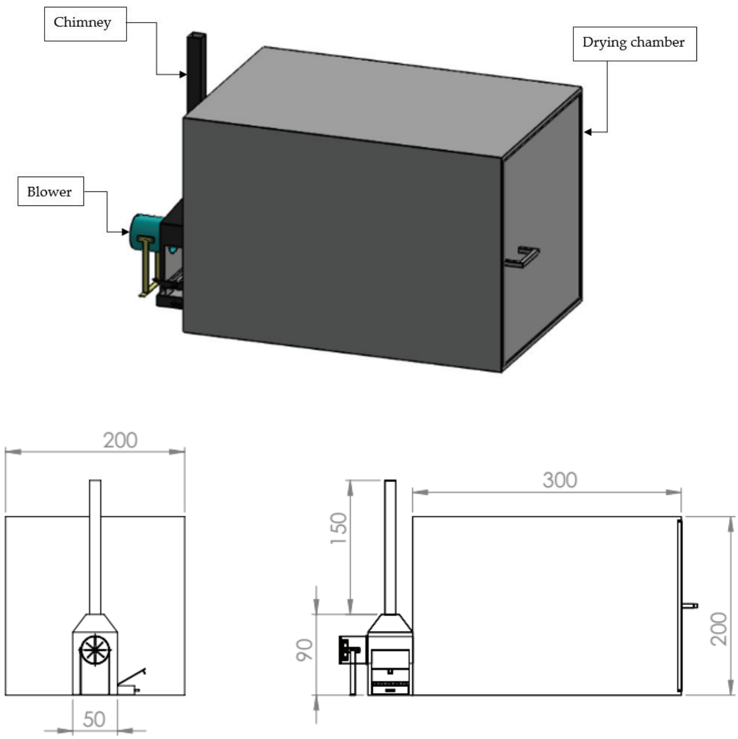

Figure 4: Drying chamber

Anthropometric data serve as the design basis and help determine the product dimensions and design. The drying rack is made from metal and acts as the platform where the material will be dried. Stratified iron is used to fabricate these racks, and the size is adjusted to suit the requirements of the operator. The anthropometric attributes considered for rack design are specified in Table 4.

Table 4 : Anthropometric data

Dimensions	Percentile 5 (P5) (cm)
Shoulder-hand grip	**166,21**
Sidearm reach	**69,58**
Standing overhead grip	**196,61**

The drying rack design considers several aspects concerning the setup, such as side hand reach and front reach, which helps the operator easily lift the product. Anthropometrical computations indicated a front reach of 166.21 cm, while the sidearm reach should be 69.58 cm. Based on these numbers, the maximum dimensions of the rack can be 196.61 cm height and 69.58 cm width. The distance between the shelves is 50 cm. Figure 5 depicts the drying rack shape.

Wood raw material have a water content more than 30% [30]. The water content of wood products which is suitable for making products is under 8% because it will not be affected by changes in humidity and climate so that the yield will not be moldy and will not crack easily [22, 26]. In this study, a comparison of drying times using solar dryer has obtained and a dryer that uses biomass as an energy source. A comparison of drying times can see in the Table 5.

Drying in direct sunlight is a traditional preservation technique that has low efficiency and also has a long drying time. This is in accordance with research by Suresh et al [31] which stated similar finding.

The use of biomass-fueled drying is an efficient form of drying. Kumar et al [32] conducted the research which aimed to develop a biomass-fueled grain dryer. The results of the performance analysis of the drying machine have good efficiency, and also the drying process is faster than traditional drying.

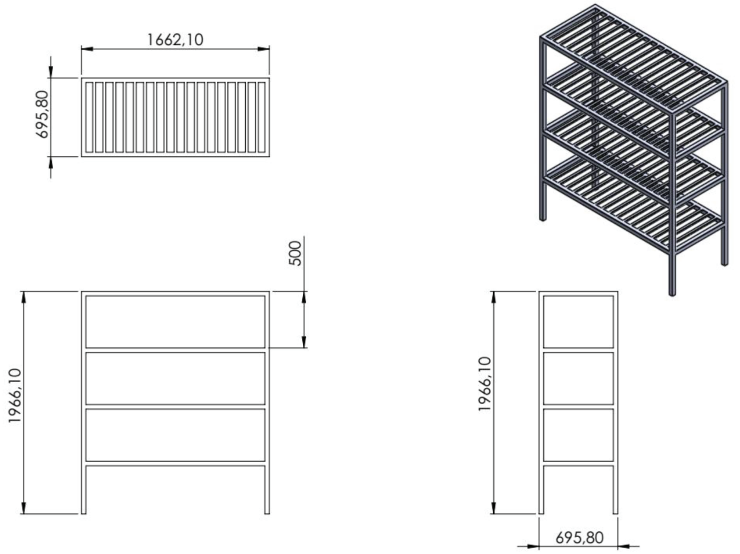

Figure 5: Drying rack

Table 5: A comparison of drying times

Solar Dryer (days)	Biomass dryer (days)
7	**1**

Table 5 shows that to get a standard water content of 8%, it takes one day when using a biomass dryer. Using a solar dryer takes a long time, around seven days to get 8% moisture content. Solar dryers are very weather dependent, so they take a long time. The use of a biomass dryer is very reliant on biomass that is burned as a heating source so that the resulting temperature reaches more than 150^0C so that the integration using a biomass dryer is faster than a solar dryer.

4.0 CONCLUSION

In this study new wood dryer developed using integration Design Thinking (DT) and Theory of Inventive Problem Solving (TRIZ) method. The application of the integration of DT and TRIZ methods helps designers identify technical solutions during the strategic design intervention process. The dryer design that uses biomass as an energy source proposed for SMEs. The dryer is designed considering the worker in the SMEs in wood industry. The results indicated that the biomass furnace, along with the drying chamber, forms the dryer, which has an 80 cm by 90 cm and uses wooden scrap as fuel. A fan pushes the hot air produced during wood combustion into the drying chamber, where drying racks are present. The racks used inside the chamber are designed using anthropometric data, which indicate a maximum height of 196 cm, while the width is capped at 76 cm. It is observed that use of a biomass dryer is more effective than a solar dryer. This biomass dryer's effectiveness can be seen from the shorter drying time, one day, when using a biomass dryer. This study contributes to knowledge by improving the integration of DT and TRIZ method to design the wood dryer.

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AUTHOR CONTRIBUTIONS

Conceptualization, O.A.; methodology, O.A.; software, O.A, S, and M.F.; re-sources, S ; writing—original draft preparation, O.A.; writing—review and editing, E.M and R.J.; supervision, E.M., and R.J. All authors have read and agreed to the published version of the manuscript

CONFLICTS OF INTEREST

The manuscript has not been published elsewhere and is not under consideration by other journals. All authors have approved the review, agree with its submission and declare no conflict of interest on the manuscript.

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