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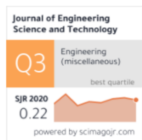

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ALTERNATIVE DESIGN OF MOULDING TOOL FOR A SUGARCANE BLOCK ENTERPRISE IN WEST SUMATRA INDONESIA

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Abstract

Sugarcane block business is one of the small and medium enterprises, which subsist in District Agam, West Sumatra, Indonesia. This study proposed a design of moulding tool by considering the ergonomic aspects to improve productivity. Interview and questionnaire survey was conducted on the workers. Kano model and Quality Function Deployment (QFD) method were used to investigate the customer requirements. There were 12 requirements considered for designing the moulding tool to realize customer satisfaction. Engineering characteristics that occupy the priority to be accomplished in the design were the design structure and ergonomic design. While the strong material (14.39%) and using rack and pinion mechanism (12.29%) are the priority for the design requirements. The study resulted in an ergonomic sugarcane block moulding tool using press system with rack and pinion mechanism, which considers the musculoskeletal complaints of workers and the hygiene factor.

Keywords: Design, Ergonomic, Moulding tool, Small and medium enterprise, Sugarcane block.

1. Introduction

Small and Medium Enterprises (SMEs) still come to be a vital income for most people in developing countries, especially in rural areas [1]. SMEs also sustenance a stable native economy by delivering job occasions and industry variety [2]. In entire Asian economies, SMEs are considered the engine of economic growth by their numbers and the significant economic and social contributions. SMEs are very vital not only as a source of employment but, potentially, as a growth engine for the economy [3]. In Indonesia, according to the Ministry of Cooperatives Small and Medium Enterprises noted that the SMEs contribution to the gross domestic product increased from 57.84% to 60.34% in the last five years [4]. However, most SMEs in Indonesia are commonly hereditary businesses, which operate along traditional lines in production and marketing. It has been argued that most problems faced by SMEs are related to the low levels of labor productivity, technological backwardness, and skill levels within the workforce [5]. Thus, in certifying the country's economic growth, more attention should be paid into SMEs development [6].

One of the micro enterprises, which subsist in West Sumatra, Indonesia, is sugarcane block enterprise located in District Agam. District Agam is central of sugarcane planting and processing in West Sumatra with 8,274 tons/year sugarcane production from 4,053 hectares of land area [7]. Producing sugarcane blocks is the main livelihood of people here, which has been done by family farmers and lasts for generations. The excellent potential unfortunately not yet fully supported by the facilities and infrastructure available in the production process of sugarcane blocks.

Sugarcane blocks in this business are produced through three stages starting from sugarcane milling, boiling, and moulding into sugarcane blocks. One process needs to be improved in the sugarcane block production process was the moulding process. Some following problems are found in the moulding workstation: (1) The product size is not uniform; (2) The size difference is caused by the traditional moulding process using the coconut shell; (3) The moulding process is unhygienic because the moulds (coconut shells) are placed scattered on the floor; (4) The musculoskeletal disorder (MSD) indication on the worker was found in the moulding process.

Figure 1 shows the workers' posture in the moulding process. The sugarcane blocks were scattered on the floor and far from the worker arm's reach. Workers conduct these activities repetitively and sit by folding their foot for about five hours a day. During the repetitive tasks, the musculoskeletal system can begin to fatigue if enough recovery time is not provided [8]. In a preliminary study, Rapid Entire Body Assessment (REBA) was used to assess the working posture. REBA is a widely used technique of work posture analysis proposed by Hignett and McAtamney [9]. It is a means to assess posture (entire body) for risk of work-related MSDs using scores from 1 = negligible risk to 11 = very high risk, implement change. REBA has been extensively used in many studies related to working posture evaluation [10-12]. In the preliminary study, it was found that REBA score for the workers' posture in the moulding process is "8" meaning the working postures of the workers have been exposed to potentially high risk to the workers and modification were highly needed.

Therefore, there is a need to design an ergonomic moulding tool for sugarcane block enterprise in District Agam. There was no previous studies found, which have discussed and developed the tool for solving these problems. This study proposes an ergonomics design of moulding tool for sugarcane block enterprise to solve the problems faced by workers.

Functionality is an essential factor considered in designing products for making them work. Nevertheless, in recent times, there are other factors needed by customers that can make them more satisfied with the products they use. In this case, usability, pleasurable appeal, emotion, and safety, which are some of the ergonomic design criteria are considered more imperative by customers. Thus, adapting the ergonomic design principles is essential in a product design process [13].

Product ergonomics is an interdisciplinary scientific discipline focused on the kind of relations between humans and other system elements. The main focus of ergonomic design is the compatibility of objects and environments with human factors. An ergonomic solution should not adversely affect the other characteristics of a product. It synchronizes the task functions with the human abilities while completing the tasks [14]. In various companies, whole phases of product development generally are handled by engineering specialist without involving the ergonomist [15]. The design, which cannot fulfil customer requirements, and ergonomics design principles will result in defective product design [16]. Thus, this study implemented ergonomic oriented-design in designing a moulding tool for sugarcane block business.

Fig. 1. Workers posture in moulding process.

2. Method

2.1. Method selection

Quality Function Deployment (QFD) and the Kano model were used in this study to attain customer requirements for designing an ergonomic moulding tool for sugarcane block. QFD is a substantial methodology to improve customer satisfaction and decrease product expenses and cycle time [17]. It is a methodology, which is the most commonly used by researchers to investigate the design requirements in a product design process [18-22]. Kano et al. [23] developed Kano model in 1984. Kano model is a method to ascertain customer requirement and expectation through a preference classification technique.

Kano model categorizes customer requirements into six categories based on their ability to meet customer satisfaction: must-be (M), one-dimensional (O), attractive (A), indifferent (I), questionable (Q), and reverse (R). Categories that affect the highest customer satisfaction is Attractive, One-dimensional and Must-Be [24]. Hashim and Dawal [15] integrated the QFD and Kano model successfully in the design of ergonomic workshop workstation in a school based on the voices of the customer. QFD and Kano model integration are also appropriate implemented in this study because they have the similar main focus that is the voices of the customer. Thus, it is decided to select the integration of QFD and Kano model as the method in this study to design the sugarcane block moulding tool.

2.2. Questionnaire development

The questionnaires were developed by considering the voices of customers collected through the interview to the sugarcane farmers and workers in District Agam. The participants were four males with an average age of 40 years. They were chosen based on the educational background (at least high school graduates) and the experience in sugarcane processing more than 20 years, to make sure that the objectives of the research were achieved. The interview protocol contents were related to the complaints, needs, and expectation about sugarcane block mould that were required by the workers.

The interview results were then summarized and used as the customer requirements (attributes) for developing the sugarcane block moulding tool in the questionnaire. The requirements then, grouped based on quality dimension elements from Garvin [25]. The quality dimensions were chosen such as performance, feature, and durability. The performance is related to the necessary ability of the new mould development such as production capacity, product cycle time, and the quality of sugarcane produced. The feature is associated with the additional capability of the product, while the durability is related to product lifetime. The researcher added two more elements: ergonomic and economic aspect because those elements were essential to the development of sugarcane mould. Ergonomic aspect was strongly related to the research objectives, and the economic aspect was related to the farmer purchasing power. All dimensions and the requirements were then evaluated by an academic expert to determine, which types of requirements that were important and had a more significant influence on customer satisfaction. The requirements obtained are presented in Table 1.

The questionnaire was developed into three parts: (1) Kano questionnaire; (2) Important level questionnaire; (3) Satisfaction level. Experts validated the developed questionnaires before distributed. The questionnaires used all the requirements in Table 1 as the questions. The Kano questionnaire consists of two kinds of pair's question, functional and dysfunctional. The functional questions are asked positively, and dysfunctional questions are asked negatively. The scales used were Likert scale (1 = dislike to 5 = like). The important level questionnaire was designed to assess the critical variable to be implemented. The scales used were Likert scale (1 = not important to 5 = very important). The satisfaction level questionnaire was designed to assess the satisfaction level of the customer toward the product. The scales used were Likert scale (1 = not satisfy to 5 = very satisfy). The questionnaires used in the study are presented in *Appendix A*.

Table 1. Customer requirements of sugarcane block moulding tool.

No.	Dimensions	Customer requirements
1	Ergonomic	The mould is comfortable when used The mould is safe when used The mould does not cause injury to the workers
2	Performance	The finish goods could fulfil the demand of the market The moulding process is fast The finish goods have the uniform size The finish goods have the soft texture The mould can be used easily The mould can be cleaned easily
3	Feature	The mould could produce variance shape of sugarcane block The finish goods have the standard weight
4	Durability	The mould has a long lifetime
5	Economic	The mould price is low

2.3. Data collection

The questionnaires were distributed to sugarcane workers in District Agam, West Sumatera, Indonesia. The purposive sampling was used to select the workers to participate in the survey. The purposive sampling may be necessary because the study wants specific criteria in the sample. One of the criteria was that workers have worked for at least 20 years and had a lot of experience in making the sugarcane block. Thus, twenty sugarcane workers, consisting of 16 male and four female aged between 40-55 years participated in the survey. The secondary data of the study were anthropometric data, which were used to determine the dimension of improvement facilities proposed. The anthropometric data were obtained from Indonesian Anthropometric sites [26].

2.4. Data analysis

2.4.1. Kano model

Kano method aims to determine the functional and dysfunctional aspect of the moulding tool. The functional and dysfunctional aspects were taken from the questionnaire results. The considering characteristics want to observe were O, A, M, R, Q, and I. The results of functional and dysfunctional questionnaires were translated into Kano category using Kano evaluation table [23].

2.4.2. Quality function deployment (QFD)

QFD approach was extensively used to define the design characteristics of a new or developed product. The primary phase in QFD was the development of the House of Quality (HoQ) or QFD phase 1. The HoQ recognizes the customer requirements and then creates the precedence for design requirements [27]. HoQ is signified in a diagram, which defines the association between customer demands and the needs placed on the product characteristics [28]. Results acquired from Kano Model method were combined into the HoQ.

Two phases of QFD were involved in the study. QFD phase 1 was the first step of the QFD method, which aims to obtain the relationship of customer requirements with engineering characteristics. It identified the relationship among engineering characteristics. QFD phase 2 was the second step of the QFD method, which aims to transform engineering characteristics from QFD phase 1 into the design characteristics. This phase was one of the crucial elements of the QFD method because it was the one, which permits the alteration to be conducted between what the customer desires and what the designer proposes. The ergonomic criteria was effectively included in the product design process at this phase [29].

2.5. Evaluation

REBA methods were used to evaluate workers posture using the mould in the new workstation. The scores of REBA become the indicator of MSD risk. REBA scores before and after improvement were then compared.

3. Results

3.1. Kano and QFD analysis

The resulting analysis of the Kano model is presented in Table 2. The chosen categories derived from Blauth Formula [30]:

- If the total of (O+A+M) > the total of (I+R+Q) so, the highest grade is obtained from O, A, or M.
- If the total of (O+A+M) < the total of (I+R+Q) so, the highest grade is obtained from I, R, or Q.
- If the total of (O+A+M) = the total of (I+R+Q) so, the highest grade is obtained from all Kano categories; O, A, M, I, R, or Q.

The chosen Kano category of the first attribute in the ergonomic dimension (the mould is comfortable when it is used) was O. This category was obtained from the first rule of Blauth's formula. Total of (O+A+M) was 20, the total of (I+R+Q) was 0. Therefore, (O+A+M) was greater than (I+R+Q). The category chosen was the highest score among O, A, and M categories. The highest score was 12, which belongs to the O category. Thus, the selected category of the first attribute in the ergonomic dimension was O (One-dimensional).

It was found an indifferent category in one of the feature dimensions, which is "The mould could produce sugarcane block with various shapes." It means that the requirement will not deliver the satisfaction or dissatisfaction to the customer whether or not the customer requirements are satisfied. Therefore, this requirement was deleted and no longer used in the subsequent analysis. The results of the Kano model analysis were then used in developing the QFD phase 1 (HoQ). The HoQ matrix is presented in *Appendix B.*

Table 2. Recapitulation of the chosen Kano category for each requirement.

Dimensions	Customer requirements	Categories						O+A +M	I+R +Q	The Chosen
		A	M	O	R	Q	I			
Ergonomic	The mould is comfortable when used	2	6	12	0	0	0	20	0	O
	The mould is safe when used	2	6	12	0	0	0	20	0	O
	The mould does not cause injury to the workers	2	7	11	0	0	0	20	0	O
Performance	The finish goods could fulfil the demand of the market	1	15	2	0	0	2	18	2	M
	The moulding process is fast	0	14	2	0	0	4	16	4	M
	The finish goods have the uniform size	7	4	2	0	0	7	13	7	A
	The finish goods have the soft texture	7	6	2	0	0	5	15	5	A
	The mould can be used easily	2	7	8	0	0	3	17	3	O
	The mould can be cleaned easily	3	11	5	0	0	1	19	1	M
Feature	The mould could produce sugarcane block with various shapes	8	0	1	0	0	11	9	11	I
	The finish goods have the standard weight	8	4	1	0	0	7	13	7	A
Durability	The mould has a long lifetime	4	5	10	0	0	1	19	1	O
Economic	The mould price is low	0	6	13	0	0	1	19	1	O

QFD phase 2 or product design phase aims to get part characteristics. This phase requires creativity and innovative team ideas. Product concepts were created during this phase, and part specifications were documented. The steps of QFD phase 2 were explained as follow:

- Determining Part Characteristics; Part characteristics were obtained from engineering characteristics. Part characteristics are detail product parts, which had been discussed with a mechanical expert. Part characteristics obtained were: (1) Using a press system with a rack and pinion mechanism to make the easier system; (2) Strong material. The main body of the product was made from strong material to hold the pressure and force; (3) Strong design structure, which considered the force given to the product; (4) Strong joint system. Joint system of the product must be strong because the joint mechanism of this tool will be used continuously while moulding process; (5) Soft material texture. The material texture of mould must be soft so that the finish goods are uniform; (6) Non-stick material. The non-stick material was chosen as the material of mould to prevent sticky of sugarcane block. (7) Sixteen moulds in one batch. Some moulds were chosen based on workload and processing time; (8) Fit operator's percentile. The tool was designed comfortable by fitting to operator's percentile so that operator could work in normal posture; (9) Light material. The light material was chosen to reduce the operator's workload; (10) The mould is cylindrical. The cylinder shape was selected because it is easy to use; (11)

Material resists to any weather condition. It is related to the long lifetime of the product. The material chosen must consider the weather resistant.

- Determining relationship between part characteristics and engineering characteristics.
- Determining absolute weight.
- Determining percentage priority.
- Grading percentage priority.

The results of QFD phase 2 (part characteristics, as attached in Appendix C) became the reference to design the stressor and the mould.

3.2. Moulding tool design

The moulding tool for sugarcane block was designed based on data analysis of Kano model and QFD. Anthropometric variables were considered in developing the moulding tool. Thus, the product is comfortable for the workers. The design of the moulding tool was divided into two main parts, the mould, and the stressor. Diameter and thickness of the mould were designed considering the certain mass of sugarcane block.

The mould designed with 16 holes is presented in Fig. 2. Each holes can produce 200 gram of sugarcane block. The number of holes was determined based on the diameter and thickness of the sugarcane after considering the sugarcane mass. The mould was made from wood (Eugenia Uniflora) because it can absorb the water and is not sticky. So that, the sugarcane block will be easy to release and will produce good shape as desired. This type of wood is also commonly used by sugarcane workers to mould the sugarcane block. It is also light material, so the workers quickly move it. Anthropometric data used in the design was handbreadth variable using the 50th percentile. The stressor was applied to press the sugarcane block in the mould. The stressor implemented press system with rack and pinion mechanism. The primary material of stressor was chromium steel. This material was chosen because of strong, safe, and anti-corrosive. The handle grip material was made of rubber. The anthropometric data used to design the stressor were presented in Table 3.

Fig. 2. Sugarcane block mould.

Table 3. Anthropometric data for stressor design.

Part of product dimension	Anthropometric variable	Percentile	Final dimension (cm)
Mould grip length	Hand breadth	50th	8
Mould grip diameter	Hand length	50th	14
Mould height	Elbow height - table height	50th	40

Figure 3 shows the final design of the sugarcane block stressor. The complete parts and function were explained as follows: (1) Steer is used to arrange the height of punch; (2) Handle grip is used to push down the punch; (3) Springs work to hold the punch when it is pulled down; (4) Punch works to press sugarcane block in the mould; (5) Mould space is a space given to the mould in the stressor.

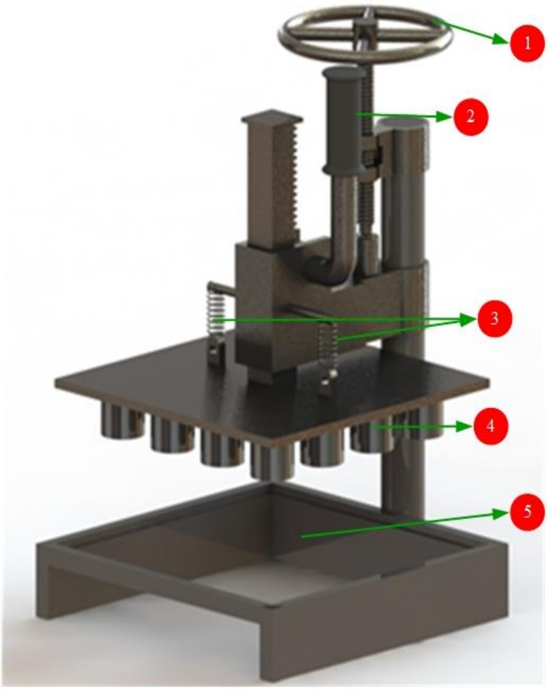

Fig. 3. Sugarcane block stressor.

The parts of the stressor consisted of:

- Steer: is used to arrange the height of punch,
- Handle Grip: is used to push down the punch,
- Springs: work to hold the punch when it is pulled down,
- Punch: works to press the sugarcane block in the mould,
- Mould Space: is a space given to the mould in the stressor.

The assembly of mould and stressor is shown in Fig. 4. The mechanism of the tools is explained as follows: (1) The handle is pulled down 90º; (2) The punch will pull down either; (3) Springs will hold the punch to its maximum stress; (4) Sugarcane block is pulled out by the punch; (5) The handle is released to its normal position.

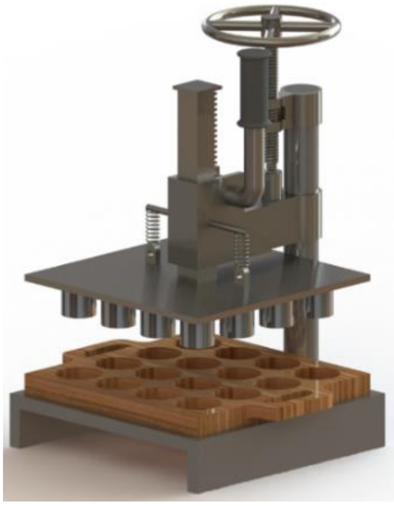

Fig. 4. Sugarcane block moulding tool.

3.3. Work facility design

Some work facilities were also designed supporting the moulding process to implement the ergonomic workstation. They were proposed based on the problems presented earlier. The proposed facilities were:

- The table for moulding
- The table for finish goods

There was a need for a table to support the moulding process with the function to place the mould as well as the finish goods. Anthropometric data was used in designing the table (Table 4). The table was also created by implementing the ergonomic principles by MacLeod [31] such as work in a neutral posture, reduce excessive forces, keep everything in easy reach, work at proper height, and reduce excessive motions. The table length was 208 cm, considered the number of mould placed on the table and allowance. Figure 5 shows the new design of moulding workstation and facilities.

Table 4. Anthropometric data for moulding table.

Part of product dimension	Anthropometric variable	Percentile	Final dimension (cm)
Table height	Popliteal height + elbow rest height + allowance	5^{th}	85
Table width	Thumb tip reach + allowance	5^{th}	68

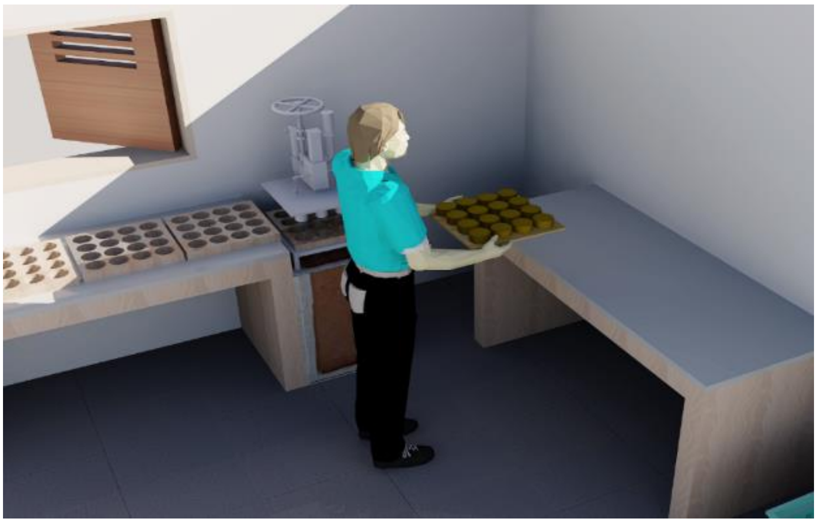

Fig. 5. The new moulding workstation.

3.4. Evaluation of moulding tool design

The proposed moulding tool of sugarcane block and the moulding workstation were simulated. Some unnecessary elements in the previous process before using the new device were removed, so, the moulding process was faster. The illustration of manual moulding is shown in Fig. 6. REBA scores were obtained and showed significantly different results. The manual moulding using the stressor resulted in "2" score of REBA. Thus, the evaluation score indicated that the proposed workstation using the stressor was better than the previous workstation (REBA score = 8) because of the lower MSD risk (Table 5).

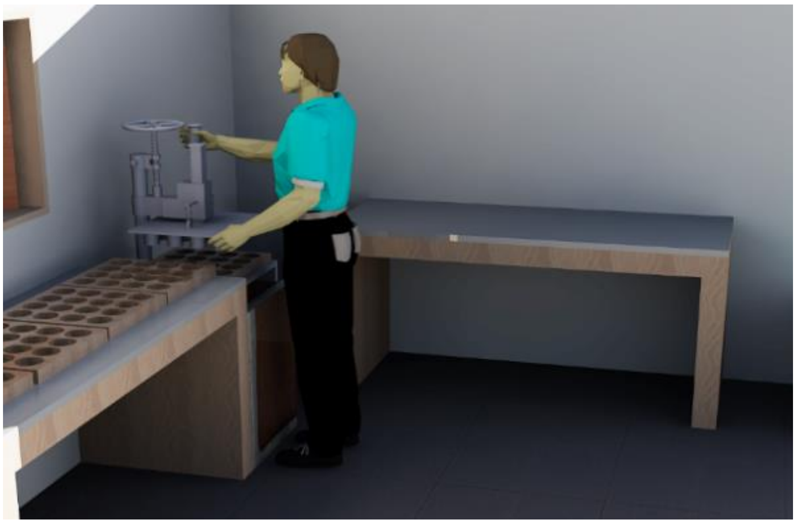

Fig. 6. Manual moulding with new tool.

Table 5. Comparison of REBA scores before and after improvements.

No.	REBA step	Score	
		Before improvement	**After improvement**
1	Neck	2	1
2	Trunk	3	1
3	Legs	1	1
4	Posture Score Table A	4	1
5	Force/Load	0	0
6	**Score A (Table A + Force/Load)**	**4**	**1**
7	Upper Arm	3	3
8	Lower Arm	1	1
9	Wrist	2	1
10	Posture Score Table B	4	3
11	Coupling	2	0
12	**Score B (Table B + Coupling)**	**6**	**3**
13	**Score C**	**6**	**1**
14	Activity	2	1
15	**TOTAL (Score C + Activity)**	**8**	**2**

4. Discussion

The study is purposed to design the moulding tool for sugarcane block business by considering the ergonomic aspects. Kano model and QFD method have been implemented to determine the moulding tool design requirements. This combined method has been widely used by Xu et al. [24], Garibay et al. [32], Chang and Chen [33], and Nordin and Razak [34]. Based on the application of the combined methods, there were 12 requirements should be considered for designing the moulding tool to realize customer satisfaction. A requirement was deleted because it was included in "Indifferent" category, which means that the requirement will not deliver the satisfaction or dissatisfaction to the customer whether or not the customer requirements are satisfied.

Among those 12 requirements, three requirements must be implemented in the design. If these three customer requirements were met by the moulding tool, then automatically, the customer satisfaction was also attended, but if not, the user will feel dissatisfied. The first requirement was meeting customer demand. Understanding and fulfilling each customer’s requirements has been recognized as a pressing challenge for companies across industries [35]. Conceptually, understanding customer needs leads to products that are desirable, feasible, and saleable (to the mass market) [36]. The next requirement was the fast process and easy to clean. Those two performance requirements were also an essential aspect to be considered in the design [37].

Three customer requirements included in the attractive category. When those requirements are met, the customer satisfaction can exceed the standard of satisfaction. The requirements were related to the uniform size, the soft texture, and the standard weight of the product. However, this was not necessary to be realized. Users will not feel disappointed in the design results if not met. These attributes are also called excited factors, which do not impact dissatisfaction but can enhance satisfaction, and should be improved to attract the customers and promote customers loyalty [38].

Then, all customer requirements from ergonomic, durability, and aspect were included in the one-dimensional category. This category was significant in determining customer satisfaction. The concept of this category was the higher the performance, the higher the customer satisfaction will be, and the lower the performance, the lower the customer satisfaction will be [39]. Thus, the criteria's in this category should be more prioritized compared to other categories in the designing process. Ergonomics is now a fundamental part systems design in many industries [40]. Integrating ergonomics into the engineering design of new workplaces and production systems is believed to be an essential proactive strategy to enhance good working conditions and production efficiency [41]. Applying ergonomics late in the development process makes meaningful change difficult since budgets have already been allocated and most decisions are already locked in [42].

The customer importance levels shown on the QFD phase 1 indicate that all customer requirements obtained are considered essential to exist in the design. It is indicated from the levels, which are above the value of 4. Customer requirement that is the priority for users to existing in the moulding tool is the finished goods could fulfil the demand of the market (i = 5), and the moulding process is fast (i = 5). On the other hand, the customer satisfaction levels on the moulding tool commonly used today were enough to give satisfaction to the users. It was indicated by the value of satisfaction levels above the value of 4. The highest level of satisfaction were the moulding process is fast (u = 4.95), and the mould price is cheap (u = 4.95). Unfortunately, the moulding process and the mould used today was still not following the requirements of an ergonomic work system. Ergonomic was an aspect that must be considered in the design of this product, based on Kano analysis, therefore, the old moulding process and mould tool used today, must be improved following the customer desires by considering aspects of ergonomics, durability, and economic. Meanwhile, customer requirements that provide the lowest level of satisfaction to the user were the finish goods have uniform size (u = 4.15) and the soft texture (u = 4.20). This was taken into consideration the design of the proposed moulding tool. Thus, by using the recommended moulding tool, the finished product can have the same size and a smoother texture.

To be able to meet the customer requirement, it was determined the technical characteristics. The moulding tool design produced seven engineering characteristics. The QFD phase 2 matrix shows the percentage of importance of engineering characteristics for customer requirements obtained previously. Engineering characteristics that occupy the priority to be realized in the design of the moulding tool were the design structure (i = 21.77) and ergonomic design (i = 19.84). The structure design was related to the primary function of the product and ergonomic design related to user comfort. Both of them had been appropriated with the main objectives of the research. Furthermore, it was also found the priority of design requirements should be realized in the moulding tool are strong material (14.39%) and using rack and pinion mechanism (12.29%).

All results obtained from the customer requirement, engineering characteristics, and part characteristics analysis serve as consideration in designing moulding tools for a sugarcane block enterprise in West Sumatra Indonesia. Based on those results, the moulding tool was created with the general descriptions as follow: (1)

Implemented rack and pinion mechanism in order to make comfortable while using; (2) Implemented adjustable press system to adjust the thickness of sugarcane block; (3) The materials were strong and solid with perfect join system; (4) Material texture was soft and non-stick to prevent sticky while moulding; (5) Number of moulds in one batch were sixteen moulds; (6) Product dimension fitted to worker's percentile; (7) The materials were light and weather resistant.

The REBA scores before and after improvements were used to evaluate whether the proposed workstation is better than the previous one. REBA had been widely used as a tool for evaluating the musculoskeletal risk while working [43, 44]. The evaluation results show that the REBA scores after improvements were lower than before improvements. The risk level of MSD sharply decreased. The improvements conducted in the proposed workstation such as changing working posture from folding leg to normal standing posture. This improvement resulted in enormous effect to the decreasing of REBA scores. Another improvement conducted was the normal position of the worker's arms reach. The working elements were simpler because the mould was neatly arranged. Some items were eliminated such as arranging the mould and reaching the mould, which was far from the workers.

The new design of sugar block moulding tool has proven to have advantages in terms of ergonomics. Besides that, the new design is also more financially profitable. Benefits obtained from the financial side include: (1) the process is faster and more efficient. By using the new design, the moulding process to pour the juice one by one using the traditional mould has been eliminated. The time needed for the moulding process using traditional method is usually 1 hour per day and done by 2 workers, which produces as much as 30 kg of sugarcane block. Whereas by using the alternative design, the moulding process can be done in approximately 20 minutes by only one worker who produces 30 kg of sugarcane block. This means that with the use of the moulding tool, it can save moulding time by 83%; (2) the process is more hygienic, because the moulding process is not done on the floor and the sugarcane blocks are not placed scattered on the floor anymore; (3) the sugarcane blocks resulted from the new design of moulding tool have better quality with uniform and standard size. Each hole produces 200 grams of sugarcane block. So that there are big opportunities for sale to a wider market such as supermarkets and abroad, currently, the sale of sugarcane block sugar is generally carried out in traditional markets in the West Sumatra region and beyond; (4) save labour, so it can reduce the production costs.

5. Conclusions

It was revealed that design structure, as well as ergonomics, were the principal factor in engineering characteristic in emerging a new or improved product as customers currently are aware of the significance of safety and ergonomics. This study has been proposed the new design of sugarcane block moulding tool, which considered the ergonomic, economic, and durability aspects. The proposed design of the moulding tool, as well as its work facility, can answer the problems related to the product size differences, the unhygienic moulding process, and the MSD indication on the worker. There will be an improvement of work posture while worker using the moulding tool such as changing work posture from folding leg to normal standing posture. This improvement will give a significant effect to the decreasing of MSD indication on the workers. Other improvements were normal position of worker's arms reach and simpler working elements because the mould was neatly arranged. Some working elements can be eliminated such as arranging and reaching the moulds, which were far from the workers. Besides, from the economic side, the proposed design provide benefits from the side of saving work time and labour, so that it can further increase the productivity. A limitation of this study was that a prototype of the proposed design had not been made. Future research will create a prototype of the design and evaluate it. Furthermore, other workstations in sugarcane block process should be given attention to improving such as refining workstation and heating workstation thus the productivity could be higher.

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Nomenclatures

A	Attractive
f	Adjustment factor
I	Indifferent
j	Adjustment importance
k	*k* value of M = 0.5, O =1, A =1.5
M	Must-be
O	One-dimensional
O	Medium relation
⓿	Strong relation
Q	Questionable
R	Reverse
R_0	Improvement ratio
R_1	Adjusted improvement ratio
t	Customer satisfaction target
u	Customer satisfaction

Greek Symbols

Δ	Weak relation

Abbreviations

HoQ	House of Quality
MSD	Musculoskeletal Disorder
QFD	Quality Function Deployment
SMEs	Small and Medium Enterprises

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Appendix A

Table A-1. Kano functional questionnaire.

No.	Customer requirements	Like	Expect	Neutral	Live with	Dislike
1	The mould is comfortable when used The mould is safe when used The mould does not cause injury to the workers					
2	The finish goods could fulfil the demand of the market The moulding process is fast The finish goods have uniform size The finish goods have the soft texture The mould can be used easily The mould can be cleaned easily					
3	The mould could produce variance shape of sugarcane block The finish goods have the standard weight					
4	The mould has a long lifetime					
5	The mould price is cheap					

Table A-2. Kano dysfunctional questionnaire.

No.	Customer requirements	Like	Expect	Neutral	Live with	Dislike
1	The mould is not comfortable when used The mould is not safe when used The mould is affected injury to the workers					
2	The finish goods can't fulfil the demand of the market The moulding process is longer than before The finish goods are not uniform in size The finish goods don't have the soft texture The mould is difficult to use The mould is hard to clean					
3	The mould can’t produce variance shape of sugarcane block The finish goods have no standard weight					
4	The mould has a short lifetime					
5	The mould price is expensive					

Table A-3. Important level questionnaire.

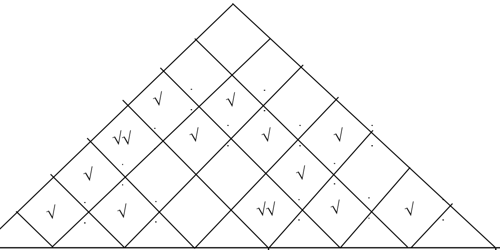
No.	Customer requirements	Very important	Important	Quite important	Less important	Not important
1	The mould is comfortable when used The mould is safe when used The mould does not cause injury to the workers					
2	The finish goods could fulfil the demand of the market The moulding process is fast The finish goods have the uniform size The finish goods have the soft texture The mould can be used easily The mould can be cleaned easily					
3	The mould could produce variance shape of sugarcane block The finish goods have the standard weight					
4	The mould has a long lifetime					
5	The mould price is cheap					

Table A-4. Satisfaction Level Questionnaire.

No.	Customer requirements	Very satisfy	Satisfy	Quite satisfy	Less satisfy	Not satisfy
1	The mould is comfortable when used The mould is safe when used The mould does not cause injury to the workers					
2	The finish goods could fulfil the demand of the market The moulding process is fast The finish goods have the uniform size The finish goods have the soft texture The mould can be used easily The mould can be cleaned easily					
3	The mould could produce variance shape of sugarcane block The finish goods have the standard weight					
4	The mould has a long lifetime					
5	The mould price is cheap					

Appendix B

House of Quality (QFD Phase 1)



Customer Requirements	Engineering Characteristics *i*	Design: Design structure	Design: Geometric accuracy	Design: Multi Molds	Design: Ergonomic design	Material: Material weight	Material: Material texture	Material: Material resistance	Kano Category	*k* value	Customer Satisfaction, *u*	Customer satisfaction target, *t*	Adjustment Factor, *f*	Improvement ratio, R_0	Adjusted Improvement Ratio, R_1	Adjustment Importance, *j*
The mold is comfortable when used	4,90	○	Δ	Δ	●	●	○	Δ	O	1,00	4,80	5,00	0,90	1,04	1,98	9,70
The mold is safe when used	4,85	●		Δ	●	○	Δ	Δ	O	1,00	4,85	5,00	0,90	1,03	1,96	9,50
The mold does not caused injury to the worker	4,85	●			●	○	○	Δ	O	1,00	4,70	5,00	0,90	1,06	2,02	9,80
The finish goods could fulfill the demand of the market	5,00	○	○	●	Δ	Δ	Δ		M	0,50	4,90	5,00	0,85	1,02	1,39	6,94
The molding process is fast	5,00	Δ	○	●	Δ	Δ	Δ		M	0,50	4,95	5,00	0,80	1,01	1,36	6,78
The finish goods have uniform size	4,15	○	●				○		A	1,50	4,15	4,00	0,45	0,96	1,68	6,98
The finish goods have soft texture	4,20	Δ	○	Δ	○	Δ	●		A	1,50	4,20	4,00	0,45	0,95	1,66	6,98
The mold can be used easily	4,55	○	Δ	Δ	●	○	Δ		O	1,00	4,45	4,00	0,75	0,90	1,57	7,16
The mold can be cleaned easily	4,60	●		Δ	○	○	○		M	0,50	4,40	4,00	0,80	0,91	1,22	5,61
The finish goods have standard weight	4,20		●	●		Δ			A	1,50	4,40	4,00	0,45	0,91	1,59	6,67
The mold has a long lifetime	4,55	●			○			●	O	1,00	4,70	4,00	0,75	0,85	1,49	6,78
The mold price is cheap	4,95	○			Δ	○	●	●	O	1,00	4,95	4,00	0,95	0,81	1,58	7,80
Absolute Weight		249,50	127,20	150,90	227,35	133,90	157,25	100,10								
Priority Percentage		21,77%	11,10%	13,17%	19,84%	11,68%	13,72%	8,73%								

No	Symbol	Meaning	Value
1	Empty	Not Linked	0
2	Δ	Possibly Linked	1
3	○	Moderate Linked	3
4	●	Strongly Linked	9

No	Symbol	Meaning
5	√√	Strong Positive Relationship
6	√	Weak Positive Relationship
7	Empty	No Relationship
8	××	Strong Negative Relationship
9	×	Weak Negative Relationshp

Appendix C
QFD Phase 2

Engineering Characteristics		Part Characteristics	Using rack and pinion mechanism	Strong material	Adjustable press	Strong join system	Material texture softly	Nonstick material	Sixteen molds in one batch	Fit to operator's percentile	Light material	The mold shape is cylindrical	Material resists to any wheater condition
		i											
Engineering Characteristics	Design structure	21,77	⓿	⓿	⓿	⓿			○	○	○	Δ	
	Ergonomic design	19,84	○	○	○	○	○	Δ		⓿	○		
	Material Texture	13,72	Δ	Δ			⓿	⓿			○		○
	Multi Molds	13,17		○	○	○		○	⓿	⓿	○	Δ	
	Material weight	11,68	○	⓿	○	○	○		○	Δ	⓿		
	Geometric accuracy	11,10	⓿	○	○	○	○		Δ	Δ		⓿	
	Material resistance	8,73		○	○	○	Δ				Δ		⓿
Absolute Weight			404,06	473,26	389,45	389,45	260,05	182,80	229,93	385,09	319,33	134,81	119,76
Priority Percentage			12,29%	14,39%	11,84%	11,84%	7,91%	5,56%	6,99%	11,71%	9,71%	4,10%	3,64%

Note:

No	Symbol	Meaning	Value
1	Empty	No Relationship	0
2	Δ	Weak Relationship	1
3	○	Medium Relationship	3
4	⓿	Strong Relationship	9