Journal of Ocean, Mechanical and Aerospace
-Science and Engineering-
30th July 2024. Vol.68 No.2

July 30, 2024

Development of Rice Threshing Machine Based Quality Function Deployment Approach – A Case Study

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Paper History

Received: 03-July-2024
Received in revised form: 20-July-2024
Accepted: 30-July-2024

ABSTRACT

Threshing rice is an important stage in agriculture, especially in rice production. The aim of this paper is to develop designs for multi-functional rice threshing machines using the Quality Function Deployment (QFD) approach. The case study was conducted on farmers in a village in Indonesia. Based on observations and survey results conducted with farmers, there was a problem with the rice threshing machine being used less than optimally, so that the time and cost of harvesting became greater. The research was carried out by collecting data by distributing questionnaires directly to 15 respondents. In this research, validity and reliability testing was carried out. The result was in the form of design development, the weight of the rice threshing machine was obtained at 35 kg, which was lighter than previously machine used by farmers. More, the development for new one was resistant to rust and has a fan that functions to separate the rice grains from the grain. Priority of technical characteristics based on weight and dual function of the tool. The dual function of the tool was to thresh and separate the rice with sides and empty ones. Furthermore, the development of rice threshing machine can tailored to the consumers needs.

KEYWORDS: *Rice Thresher Machine, Customer Need, Design, Quality Function Deployment (QFD).*

1.0 INTRODUCTION

The development of efficient and versatile agricultural machinery is crucial for enhancing productivity and sustainability, which in the realm of agricultural engineering is paramount. The rice threshing, a critical post-harvest process, often involves labor-intensive and time-consuming tasks. The traditional rice threshing processes have several drawbacks, such as the use of hand-powered using foot pedals and required the manual labor for operation [1-2]. Additionally, mechanical of manual rice threshing machines are quite heavy, demanding significant effort to move them across large fields [3-4]. Mechanical threshing machines, powered by small engines or electric motors, have revolutionized the way farmers process rice. These machines offer significant advantages over traditional pedal-operated threshing methods, making them a popular choice for both small-scale and large-scale rice cultivation. One of the primary benefits of mechanical threshing machines is their increased efficiency. Compared to the laborious process of manually threshing rice using foot pedals, these machines can separate the grains from the stalks much more quickly and effectively [1],[4],[5]. This efficiency boost allows farmers to process larger quantities of rice in a shorter amount of time, saving them valuable labor and time [3],[6].

Another advantage of mechanical threshing machines is their ability to handle larger volumes of rice. Unlike pedal-operated machines, which are often limited in their capacity, mechanical threshing machines can process significantly more grain per hour. This is particularly beneficial for farmers with larger fields or those who need to process large quantities of rice for commercial purposes. While mechanical threshing machines offer numerous advantages, they do require a reliable source of power. This can be either fuel, such as gasoline or diesel, or electricity. The choice of power source will depend on factors such as the availability of fuel or electricity in the region, the cost of these resources, and the specific needs of the farmer. Therefore, the mechanical threshing machines have become an indispensable tool for modern rice farmers. Their increased efficiency, ability to handle larger volumes of grain, and versatility make them a valuable asset for both small-scale and large-scale operations [7-10]. By adopting these machines, farmers can improve their productivity, reduce labor costs, and increase their overall profitability.

The study highlighted a significant issue faced by farmers in Indonesia: the sub-optimal performance of rice threshing machines [11-15]. These machines, essential for rice harvesting, were found to be inefficient, leading to increased harvesting time and costs. To address this problem, the

researchers proposed a novel approach using the Quality Function Deployment (QFD) method. By applying the QFD, they were able to develop a rice threshing machine that not only met the technical specifications but also aligned with the farmers' needs and preferences [11],[16]. More, by applying the QFD approach to the design of a paddy harvesting machine, it is possible to create a product that is not only efficient but also ergonomic and safe for farmers [11],[16].

The QFD, a structured approach to product development, ensures that customer needs and expectations are translated into tangible product attributes [17-23]. By employing QFD, it can bridge the gap between market demands and engineering solutions [24],[25]. This methodology provides a systematic framework for identifying customer requirements, translating them into technical specifications, and ensuring that the final product meets or exceeds expectations [17],[26].

The QFD comprises four distinct phases that collectively cover the entire product development lifecycle, from initial conception to final production [27],[28]. The QFD can ensure that a product aligns precisely with the needs and expectations of its customers. To address these challenges, this study aims to develop the design of rice threshing machine using the Quality Function Deployment (QFD) method based on the wishes of the community. Benefits of development of rice thresher designs can be easier for people to use rice thresher, saving time, reducing the level of accidents in working on rice and designing lightweight rice thresher devices. The QFD, a systematic approach to product development, was employed to ensure that the redesigned rice threshing machine would directly address the farmers' needs. The translating the farmers' requirements into technical specifications, the researchers were able to create a product that was tailored to the specific needs of the agricultural community. By applying QFD to the development of rice threshing machines, manufacturers can ensure that their products meet the specific needs of their target customers. This approach can lead to the creation of more efficient, durable, and cost-effective machines that provide significant benefits to farmers and the agricultural industry.

2.0 RESEARCH METHOD

This study employed the Quality Function Deployment (QFD) method, which developed the The House of Quality (HoQ). The HoQ is a critical component of the Quality Function Deployment (QFD) methodology, serving as a structured tool to translate customer needs into technical requirements [17-23],[29]. The HoQ facilitates communication between various stakeholders involved in product development by clearly outlining the relationship between customer desires and engineering characteristics. The first step in applying the QFD involved identifying and understanding the specific needs and expectations of the farmers who will use the rice threshing machines. This can be accomplished through surveys, interviews, and observations. The direct interviews with farmers can reveal their experiences and challenges with existing threshing machines, while observations can identify inefficiencies in the current processes. The questionnaire survey was first developed then the copies were distributed to be filled out by the participating farmers of the study. Once customer needs were identified, which should be rated based on importance.

Then, the House of Quality (HoQ) was constructed to identifying the customer needs (WHATs), their importance, and the engineering characteristics (HOWs) that may be relevant to those needs. Here are the main components of the House of Quality [30-35]:

1. Customer Requirements (WHATs)

This section lists the specific needs and expectations of customers regarding the product or service. It is often referred to as the "Voice of the Customer" (VOC) and can be gathered through surveys, interviews, and market research. Each requirement is typically assigned an importance rating to indicate its priority for customers. The study focused on farmers in Pakkat District, located in North Sumatra Province, Indonesia. Observations and survey findings revealed that the rice thresher machines were not being utilized to their full potential, leading to increased time and costs associated with the harvesting process.

2. Technical Requirements (HOWs)

These are measurable characteristics or specifications that the product must meet to satisfy customer requirements. Technical requirements are derived from the engineering perspective and represent how the product will fulfill the identified customer needs.

3. Technical Correlation Matrix (Roof)

Often referred to as the "roof" of the HoQ, this matrix evaluates how different technical requirements interact with each other. It helps identify potential conflicts or synergies between technical features, allowing teams to understand how changes in one area may affect another.

4. Interrelationship Matrix and Prioritized Technical Requirements

This matrix illustrates the relationship between customer requirements and technical requirements. Each cell in this matrix indicates the strength of the relationship, typically using symbols or numerical values to denote whether the relationship is strong, moderate, or weak. This helps identify which technical features are most critical for meeting customer needs. In this matrix, technical requirements are ranked based on their importance and impact on fulfilling customer needs. This prioritization guides development efforts by highlighting, which features should be focused on to enhance overall product to meet the customer's requirements.

5. Design Improvement

Based on insights from QFD, prototypes are developed incorporating prioritized features such as improved mobility, ergonomic designs, and enhanced threshing efficiency. Field tests with farmers are conducted to gather feedback on prototype performance and usability. This iterative process ensures that the final design meets all critical needs and is user-friendly.

3.0 RESULT AND DISCUSSION

To identify user needs for the rice threshing machine, both interviews and questionnaires were conducted on farmers in a village in Indonesia. Fifteen individuals participated in the survey by completing the questionnaires. Demographic data

revealed that seven respondents were male and eight were female. The age group with the highest representation was 17-25, with four respondents. Over 45-year-olds accounted for seven respondents, while the age group of 35-45 had the fewest respondents, with only four individuals. The results of this user research were then analyzed to determine the key attributes of the product.

3.1 Customer Requirements

Product attributes are the inherent characteristics or qualities of a product. Based on the interpretation of user needs, through a questionnaire survey, eight essential attributes were identified, encompassing factors such as safety, ease of use, affordability, comfort, durability, portability, minimalist size, and aesthetic appeal**.**

- Safety refers to the inherent characteristics of a product or process that prevent harm to people or damage to property. In the context of a rice threshing machine, safety encompasses features and designs that minimize the risk of accidents, injuries, or damage to the machine itself. This includes aspects such as the machine's stability, guarding mechanisms to protect operators from moving parts, and electrical safety measures.
- Ease of use refers to the simplicity and intuitiveness with which a product can be operated. For a rice threshing machine, this means the controls should be easy to understand and operate, requiring minimal training. The machine's design should also be such that common tasks, like loading and unloading, are straightforward and efficient.
- Affordability refers to the affordability of a product. In the context of agricultural machinery, farmers often operate on tight budgets. A low-cost threshing machine would mean it is priced competitively without compromising on essential features or quality.
- Comfort refers to the physical ease and well-being of the user during operation. For a threshing machine, this could mean features like adjustable handles, reduced noise levels, and a design that minimizes physical strain on the operator.
- Durability refers to the ability of a product to withstand wear, tear, and damage over time. A durable threshing machine should be built with high-quality materials and components to ensure a long service life, even under harsh operating conditions.
- Portability refers to the ease with which a product can be moved from one location to another. For farmers with small plots or those who need to transport the machine between fields, a lightweight and easily maneuverable threshing machine is desirable.
- Minimalist size refers to the physical dimensions of a product. A smaller threshing machine can be advantageous for farmers with limited storage space or for those who need to transport the machine frequently.
- Aesthetic appeal refers to the visual attractiveness of a product. While functionality is paramount, a threshing machine that is visually appealing can enhance the user experience and overall satisfaction.

The assessment result of the level of customer importance is the customer's perception of how important each attribute is to meet consumer needs/expectations. The total score is obtained from the average total value obtained for each question item in the questionnaire filled out by the farmers divided by the number of samples.

Table 1: Total score result for threshing machine attributes

Attributes	Total score
Safety	58
Ease of use	57
Affordability	57
Comfort	52
Durability	55
Portability	57
Minimalist size	40
Aesthetic appeal	38

3.2 Technical Requirements

A rice threshing machine is an essential agricultural tool used to separate rice grains from their husks. The performance and efficiency of this machine are significantly influenced by its design and the materials used for its components. The following are the primary technical characteristics to consider when designing and constructing a rice threshing machine:

- Driving Mechanism: In addition to the threshing cylinders, another essential component is the driving mechanism that powers the cylinders. This can be a rotating shaft or a vibrating mechanism. The choice of driving mechanism is influenced by the machine's capacity and the type of power source used (e.g., gasoline, diesel, or electric).
- Hopper Shape: The hopper is the part of the machine that holds the unthreshed rice before processing. It is typically shaped like a funnel or a box with a narrowing bottom. An ergonomic hopper design makes it easier for farmers to feed the rice into the machine.
- Material of Components: Apart from the threshing cylinders, other components such as shafts, gears, and bearings are also made of strong, corrosion-resistant materials. The appropriate choice of materials affects the durability and lifespan of the machine.
- Frame Material: The machine frame is usually made of sturdy iron or steel to withstand loads and vibrations during the threshing process.
- Overall Shape: The overall shape of a rice threshing machine varies, but it is generally elongated with the main part being a drum containing the threshing cylinders.
- Dimensions: The overall size of a rice threshing machine is determined by its capacity and power source. Larger capacity machines generally have greater dimensions to accommodate increased throughput.
- Weight: The weight of a rice threshing machine is a crucial factor to consider, particularly for farmers with limited storage space or those who need to transport the machine frequently. A lighter machine is generally more portable and easier to maneuver.
- Aesthetics: While functionality is paramount, the aesthetic appeal of a rice threshing machine can also be a consideration. Factors such as color, design, and overall appearance can contribute to the user's overall satisfaction and perception of the machine.

3.3 Technical Correlation Matrix

Determining the value of how important the relationship between these technical characteristics was obtained by distributing questionnaires to determine the relationship

between technical characteristics to experts. Determining the relationship between technical characteristics is useful as a consideration for designing tools. The results of determining the relationship between technical characteristics can be seen in Figure 1.

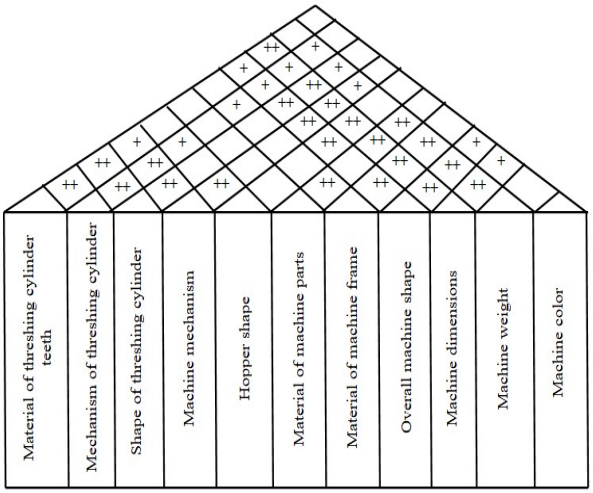

Figure 1: The relationship between technical characteristics

In Figure 1 depicts the correlation between various factors related to a threshing machine of technical characteristics. The "++" symbols indicate strong correlations, while "+" symbols suggest medium correlations. Based on the diagram, the material of the threshing cylinder teeth appears to have the strongest influence on the overall machine, as it is directly connected to several key factors such as the mechanism of the threshing cylinder, its shape, and the material of the machine parts. The shape of the threshing cylinder also plays a significant role, affecting the machine mechanism, hopper shape, and overall machine shape. Other factors, such as the material of the machine frame and machine dimensions, seem to have moderate correlations with the overall machine design.

3.4 Result of Interrelationship Matrix of House of Quality (HoQ)

The relationship between customer needs attributes and technical response was arranged in a matrix. This matrix assesses the strength or otherwise of the relationship between technical responses and product attributes that are consumer needs. The results of the relationship between voice of customer and technical characteristics can be seen in Figure 2. The level of relationship in question starts from a scale of strong, moderate, weak, and not related at all.

Value 5 = indicates a strong relationship
Value 3 = indicates a moderate relationship
Value 1 = indicates a weak relationship
Value 0 = indicates no relationship at all

It can be seen in Table 2, a comparative analysis of the relative weights assigned to technical and customer requirements. The examination of the relative weight values becomes evident that certain aspects are prioritized over others for design of threshing machine. The customer requirements emerge as a significant focal point, with several categories receiving substantial weight. Safety was deemed paramount, reflecting the utmost importance of product security for threshing machine. Ease of use, affordability and portability also hold considerable weight, indicating that user-friendliness and cost-effectiveness are key considerations. Durability are given moderate weight, suggesting that these factors, while important, may not be as critical as safety, ease of use, affordability and portability.

Technical requirements receive varying levels of attention. The overall machine shape and machine dimensions received the higher relative weight score, 2070 and 1956 respectively. Machine mechanism (1880) and mechanism of threshing cylinder (1884) awarded the second priorities.

Table 2: Results of weighting the relationship between technical characteristics and voice of customer

Technical Requirement / Customer Requirements		Material of threshing cylinder teeth	Mechanism of threshing cylinder	Shape of threshing cylinder	Machine mechanism	Hopper shape	Material of machine parts	Material of machine frame	Overall machine shape	Machine dimensions	Machine weight	Machine color
Safety	58	5	5	5	5	3	5	5	5	5	5	0
Ease of use	57	5	5	3	5	5	3	1	5	3	3	0
Affordability	57	3	5	3	5	1	5	5	5	5	3	3
Comfort	52	3	5	1	5	5	5	3	5	5	5	3
Durability	55	5	3	3	5	1	5	5	5	5	5	0
Portability	57	5	5	5	5	5	5	5	5	5	5	0
Minimalist size	40	5	5	5	5	5	5	5	5	5	5	1
Aesthetic appeal	38	1	3	1	0	3	0	1	5	5	0	5
Relative Weight		1700	1884	1372	1880	1430	1766	1586	2070	1956	1652	557

JOMAse | Received 03-July-2024 | Accepted: 30-July-2024 | [(68) 2: 99-105]
Published by International Society of Ocean, Mechanical and Aerospace Scientists and Engineers, www.isomase.org., ISSN: 2354-7065 & e-ISSN: 2527-6085

Journal of Ocean, Mechanical and Aerospace
-Science and Engineering-
30th July 2024. Vol.68 No.2

July 30, 2024

Material of machine parts (1766) and material of threshing cylinder teeth (1700) awarded the third priorities. Other technical aspects, such as hopper shape, material of machine frame, machine weight, and machine color, receive lower weight, suggesting that they may be less critical in determining the product's success.

3.5 Development of Rice Thresher Machine Design

Based on matrix of the relationship between customer requirements and technical requirements in Table 2, the overall machine shape and machine dimension awarded the highest priority for rice thresher machine design. The overall shape and dimensions of a machine often play a pivotal role in determining its functionality, efficiency, and aesthetics. A well-considered machine design not only ensures that the machine performs its intended tasks effectively but also contributes to its overall appeal and usability. The higher relative weight score of 2070 for the overall machine shape suggests that it is a particularly significant factor in the design process. The shape of a machine can influence its stability, aerodynamics, and ergonomics. For instance, a streamlined shape can reduce drag and improve energy efficiency, while a more compact design can save space and materials. Additionally, the shape of a machine can impact its aesthetic appeal and user experience.

Similarly, the high relative weight score of 1956 for machine dimensions highlights their crucial role in machine design. The dimensions of a machine directly affect its size, weight, and capacity. Accurate dimensions are essential for ensuring proper fit and function within a specific environment or application. For instance, a machine that is too large or too small may not be able to perform its intended tasks effectively. Moreover, the dimensions of a machine can impact its manufacturing costs, transportation requirements, and maintenance needs. By carefully considering the shape and dimensions of a machine, designers can create products that are not only functional and efficient but also aesthetically pleasing and user-friendly.

The correct height of the rice threshing machine frame can help workers avoid future injuries, pain and bad body shape by maintaining proper posture and comfort while working. Based on anthropometric data of male and female native Indonesian citizens, the hip height is 103-105 cm, arm length (fingertip-shoulder) is 70-80 cm and forward reach is 70-75 cm [36].Therefore, the height of the rice threshing machine dimension was 75 cm with a width of 45 cm and a length of 50 cm. The frame dimension result design is depicted in Figure 2. To achieve a proper posture for threshing machine size users, the height of the hopper was designed at 30 cm and the width of the machine frame was designed at 75 cm. The hopper dimension result design is depicted in Figure 3. The hopper was placed on top of the machine frame. A hopper plate acts as a gatekeeper for material exiting the hopper. The hopper material was a plate made of stainless steel. The hopper shape was designed to be oriented towards the safety of farmers when carrying out the rice threshing process. This is because when threshing rice, the ash residue produced will fly out of the tool, thus disrupting eye and respiratory health. The hopper design with a smaller hole shape will minimize ash from flying out of the tool.

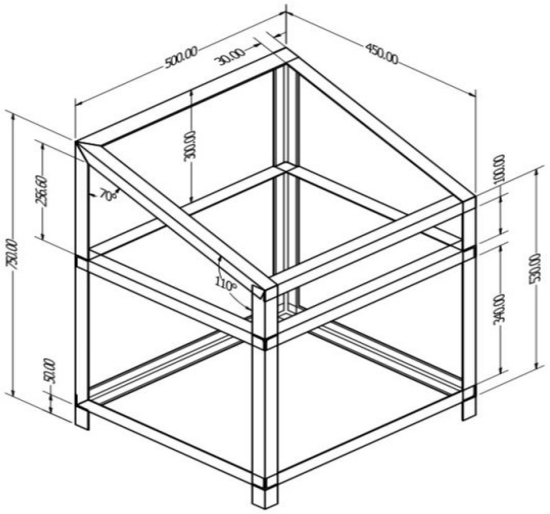

Figure 2: Frame design of threshing machine

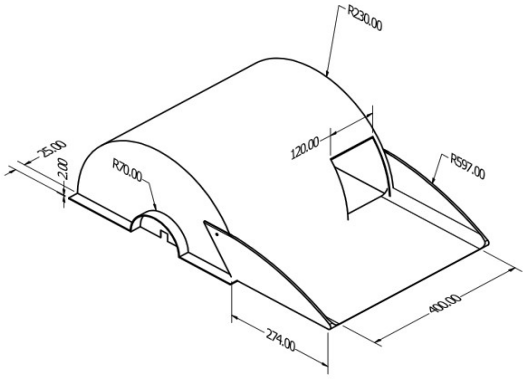

Figure 3: The hopper design

The development of the rice threshing machine has a function for threshing rice seeds and also separate rice grains from the remaining grain. The machine mechanism was designed the rice stalks threshing enters and falls into the cylinder teeth cutting and then down to the to the hopper outlet channel. Shape of threshing cylinder was diameter of 130mm and length of 435mm (Figure 4). The technical characteristics of materials were resistant to corrosion, which intended to the rice threshing machine can last longer. The material was used stainless steel, the selection of this rust-resistant material that offer excellent resistance to rust or corrosion. Then, the design used the bolt-shaped threshing tool. This shape was intended to be easy to replace when the threshing teeth was damaged and can thresh more rice grains, at the end of the threshing teeth, there were also 4 squares that function to fan and remove rice stalks from inside the threshing tool. The shape of the threshing teeth on the developed tool can be seen in Figure 4.

JOMAse | Received 03-July-2024 | Accepted: 30-July-2024 | [(68) 2: 99-105]
Published by International Society of Ocean, Mechanical and Aerospace Scientists and Engineers, www.isomase.org., ISSN: 2354-7065 & e-ISSN: 2527-6085

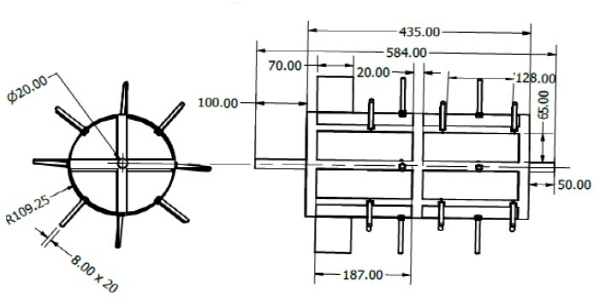

Figure 4: The design of rice threshing cylinder teeth

The technical characteristic of the weight of the tool are very much needed for the process during the work, which was easy to move and easy to carry to the middle of the rice fields. The weight of the threshing machine was calculated based on the simulation carried out on a application and the resulting tool weight of 35 kg. The machine utilizes a gasoline engine, which offers the benefit of generating electricity from fuel and being easily portable to rice fields for threshing. The design incorporates a fan that separates rice grains from the chaff through rotation, powered by the engine. This multi-functional feature enhances the machine's efficiency, resulting in cleaner rice output. Furthermore, the technical characteristics of the color of the rice threshing machine are very much needed for the durability of the material so that it is not easily damaged.

4.0 CONCLUSION

This paper applied the Quality Function Deployment (QFD) approach to process design for ensures that the product design of rice threshing machine is aligned with the customer's demands, providing a quality and valuable solution for farmers and agricultural workers. Based a case study resulted eight key attributes were identified for the rice thresher design: safety, ease of use, affordability, comfort, durability, portability, compact size, and aesthetic appeal. These attributes were supported by technical responses such as tool dimensions, threshing teeth material, tool material, machine frame material, tool mechanism, tool weight, machine color, threshing mechanism, threshing teeth shape, and hopper shape. The result of matrix of House of Quality (HoQ) revealed the most important priorities of the technical responses. The machine's overall shape, dimensions, and threshing mechanism were deemed most important, receiving the highest weight scores. Material selection for the machine parts and threshing cylinder teeth followed closely behind. Less emphasis was placed on factors like hopper shape, frame material, weight, and color. The future development of this paper is to manufacture and testing the performance of the threshing machine developed.

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