DESIGN AND CONSTRUCTION OF A MICROCONTROLLER-BASED ALTERNATING CURRENT (AC) ELECTRIC MOTOR AS A CORN THRESHING TOOL

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Abstract

The integration of Bulukumba Regency area, especially in Laikang Village, Kajang District, is one of the vast corn farming areas because it is located in a mountainous area. Corn is one of the food crops as a substitute for rice, besides corn is also used as animal feed. In general, farmers thresh corn manually (human power) without using machine tools, so it requires a lot of energy, time and very low production results, so that the manual corn threshing method becomes inefficient. One alternative that must be done is to design a microcontroller-based corn threshing machine. This study aims to design a microcontroller-based Alternating Current (AC) Electric Motor as a corn threshing tool that functions to separate corn kernels from the cob so that it can accelerate production in corn threshing. This study uses an experimental method that explains systematic and planned experiments to prove the truth of a theory. Respondents in this study were farmer groups in Laikang Village, Kajang District, Bulukumba Regency. This study has 6 stages, namely: 1) implementation of research preparation; 2) research permit; 3) field observation; 4) data collection techniques; 5) data processing; and 6) research results. Based on the trial results, farmers stated that the design of a microcontroller-based alternating current (AC) electric motor as a corn threshing tool functioned well.

Keywords: Design, Electric Motor, Alternating Current (AC), Microcontroller, Corn Thresher.

INTRODUCTION

The role of the national agricultural sector has become highly significant because most people depend on agriculture for their livelihood, such as food fulfillment and economic needs. This dependency is particularly evident among farmers, especially those living in rural areas, where farming activities have become local wisdom and have been passed down from generation to generation within certain communities [1]. Corn is one of the main secondary crop commodities in Indonesia with relatively broad uses, especially for human consumption and livestock feed. Corn is also a commodity demanded in the global market [2]. Corn is an agricultural product that contains nutrients almost similar to rice. In addition to being a staple food, it can also be processed into various food industry products, such as snacks and others. Corn can also be used as a mixture for animal feed. The challenge faced by Indonesian farmers today is the increasing openness of commodity markets as a consequence of the global free-market era. To anticipate this free-market era, Indonesian agricultural commodities must have competitiveness, both comparatively and competitively, with competing commodities from other countries, especially ASEAN [3].

Shelling is one of the post-harvest handling processes for corn farmers, in which quality and timing become crucial during post-harvest operations [4]. Technological advancements in the agricultural sector continue to evolve, with various agricultural production machines emerging, such as agricultural product processing machines and other production equipment that assist farmers in processing and producing agricultural products [5]. Indonesia ranks 8th among the world's largest corn-producing countries. The Ministry of Agriculture published that Indonesia's average corn production from 2014–2018 was 24.27 million tons, based on data from the Food and Agriculture Organization (FAO). In 2016, the demand for corn for food and feed in Indonesia was estimated to be 41% and 28% respectively of the total use and loss of corn (FAO, 2019). The remaining 31% was for other uses, seeds, and losses. The total use and loss amounted to 23.84 million tons, while production in 2016 reached 23.58 million tons [6]. The use of agricultural tools and machinery (alsintan) in the modern agriculture era has become essential for farmers in managing crop cultivation activities, from land processing, planting, harvesting, to processing products, especially as farm labor has become increasingly scarce and expensive [7]. Along with the growth of agricultural output, agricultural product processing has inspired innovations to create tools that simplify processing before marketing. After conducting field observations, researchers found that the farming group in Laikang Village, Kajang District, Bulukumba Regency faces low productivity after harvest because they still use traditional corn shelling methods, which require significant time, energy, and produce very low output. Generally, corn shelling is still done manually by hand. Besides being tiring, manual shelling is time-inefficient, and its output capacity is very limited [8]. Traditional corn shelling methods are neither optimal nor efficient. Improper shelling techniques can increase product loss. This issue is worsened by the high cost of corn shelling machines and the lack of government assistance. In Laikang Village, 90% of residents are corn farmers, and the average harvest per farmer reaches 1 to 2 tons or even more.

The advantage of a microcontroller-based Alternating Current (AC) electric motor is its ability to maximize corn shelling because it has control features that allow adjustment of gearbox rotation speed. A corn shelling machine is a device that operates with the help of a motor as its main driver, intended to facilitate the shelling process of dried corn as a food ingredient [9]. Previous research has designed a microcontroller-based DC to AC converter [10]. Another study developed a corn shelling machine with a capacity of 100 kg/hour by Rivanol Chadry et al., 2017. The machine uses a combustion engine and a disk mechanism but still has several weaknesses [11]. Corn shelling machines have been widely developed and even mass-produced. However, some weaknesses still exist, such as the intensive involvement of operators and the output that is still mixed between cobs and kernels [12]. The research problem in this study is how to increase productivity in corn shelling so that farmers no longer use traditional methods and can work more effectively. The objective of this study is to design and develop a corn shelling machine that uses an Alternating Current (AC) electric motor as its main driver and is controlled by a microcontroller system. This design aims to create an efficient and stable machine that can increase productivity in corn shelling, particularly for farmers in rural areas. With microcontroller utilization, the machine is expected to automatically adjust motor rotation speed according to workload, resulting in optimal and consistent performance. In addition, this study aims to produce an innovative agricultural tool that is more energy-efficient, easy to operate, and economically valuable as an alternative solution to manual or conventional corn shellers still widely used today.

METHOD

This type of research uses a qualitative method. Qualitative research is a study that examines the quality of relationships, activities, situations, or various materials [13]. The experimental method refers to systematic and planned trials conducted to prove the validity of a theory [14]. The data collection technique used in this study is field research, which involves conducting direct observations in the research location to gather data according to the needs of corn farmers.

Observation

Observation is a data collection technique that is highly useful for obtaining natural and in-depth data about a phenomenon or behavior [15]. The observation method involves conducting research directly in the field. This study is planned in two cycles, with two meetings in each cycle [16]. Observation activities involve directing attention toward an object by utilizing all the senses. Thus, observations can be carried out through sight, hearing, touch, and taste. In this observation activity, the process is not simply observing something, such as admiring a beautiful view. Instead, observations in research must fall within the scope of scientific activities.

Literature Study

A literature study is research related to reading, collecting, recording, sorting, and organizing the literature that has been obtained [17]. This stage aims to obtain theoretical foundations, enrich insights, and understand previous research findings that can serve as references or comparisons. Through literature study, the researcher can understand the development of technologies, methods, or concepts that have existed previously, ensuring that the research conducted has a clear direction and can fill gaps or shortcomings in earlier studies. Thus, the literature review becomes an essential foundation for formulating problems, determining methods, and developing a conceptual framework in a study. This research employs a descriptive qualitative approach, which aims to understand phenomena experienced by the research subjects. The development of the tool includes designing the device, constructing it, and testing its use. The design stage involves creating the circuit schematic. After the schematic is completed, the next stage is constructing the frame and installing the electric motor along with other components.

The final stage is testing; if the tool does not function properly, the design process is repeated from the beginning. If the tool works well, it is considered successful. The workflow of the development process is illustrated as follows:

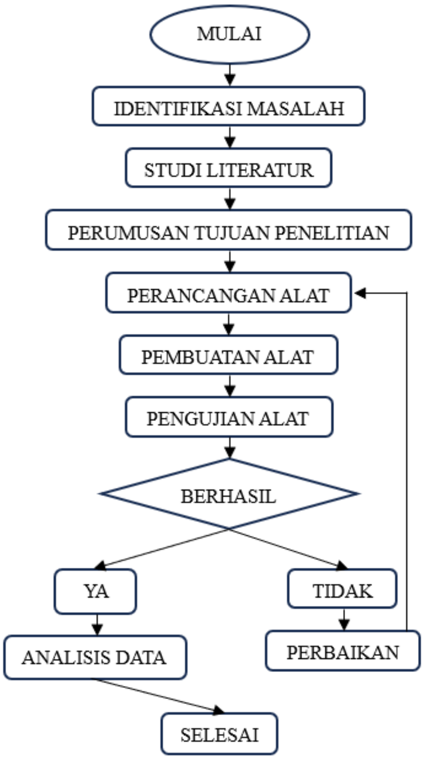

Figure 1. Research flowchart.

Materials and Tools

The threshing cylinder is the main component of the machine, where the process of separating corn kernels from the cob takes place. In this machine, the threshing cylinder is designed using 6 mm thick strip iron as the main frame or structure supporting the rotating force. Meanwhile, the cylinder walls are made of 5 mm thick cylindrical iron plate, which serves as the surface where the threshing spikes or beaters attach.

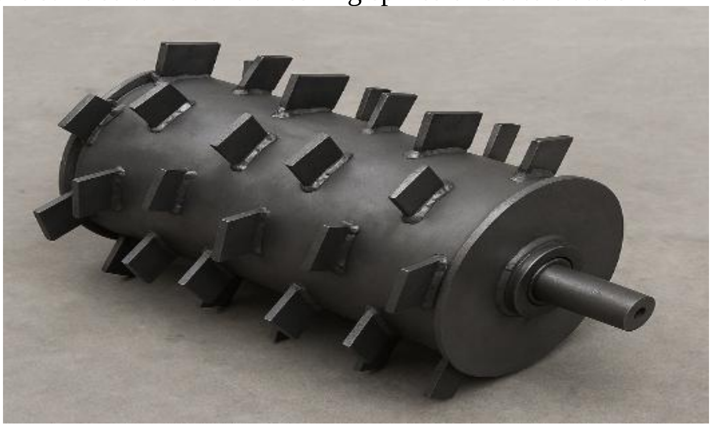

Figure 2. Thresher cylinder.

The drive pulley is a crucial component in the power transmission system, transmitting rotation from the motor to the sheller shaft via a belt (V-belt). In this device, the drive pulley is mounted directly on the 220V AC electric motor shaft and has a 2-inch diameter. This smaller size was chosen to generate high initial motor speeds. This rotation is then transmitted via the belt to a larger (4-inch) receiving pulley mounted on the sheller shaft, resulting in a reduction ratio of 1:2.

Figure 3. Drive pulley.

The A-5 type V-belt on the corn thresher serves as the power transmission medium from the electric motor to the threshing cylinder drive pulley. This belt was chosen because it can efficiently transmit motor rotation while minimizing slippage, ensuring stable threshing performance. The V-shaped cross-section of the belt provides a firm grip on the pulley groove, reducing vibration and optimally distributing motor power. Furthermore, the A-5 type V-belt allows for adjustment of the rotation ratio between the motor pulley and the cylinder pulley, allowing for adjustable threshing speed. Other advantages include its flexibility, wear resistance, and ease of maintenance, making it a practical and economical choice compared to gear transmission systems.

Figure 4. V-belt.

The electric motor serves as the primary drive in the corn thresher system, converting electrical energy into mechanical energy in the form of rotation. The motor used in this device is a 220-volt alternating current (AC) motor, commonly available in household power grids, making it easy to operate. This AC motor was selected based on its rotational stability and its ability to generate sufficient power to drive the threshing cylinder via a V-belt transmission system. This power output allows for more effective and efficient threshing of corn, ensuring the machine's performance is more reliable and meets farmers' needs.

Figure 5. Electric motor.

The bearings used are rolling bearings, due to their relatively low friction and simple lubrication. The pin is a small but vital mechanical component in a power transmission system, as it locks the connection between the pulley and the shaft, allowing them to rotate together without slipping. In this corn thresher, the pin is made of steel, as it has high tensile strength, is resistant to friction, and can withstand the torque generated by the motor. 6) A brushed DC motor speed controller is an electronic component used to regulate the rotational speed of a DC motor according to system requirements. This speed control is generally achieved using the Pulse Width Modulation (PWM) method, which involves changing the duty cycle of the electrical signal sent to the motor. Through PWM, motor speed can be controlled efficiently without wasting excessive energy, as full current flows even when the average voltage decreases.

Figure 6. Controller.

RESULTS AND DISCUSSION

This research involved several stages, focusing on the design and development of a corn thresher based on an AC electric motor controlled by a microcontroller. These stages began with identifying equipment needs in the field and reviewing literature related to AC motor technology and automatic control systems.

Observation Stage

The observation stage is the initial step in the research process, aiming to identify real-world problems before designing technical solutions. Observations were conducted directly by the researcher using a qualitative approach, including: a) Interviews. The first step in the observation stage was to interview the heads of farmer groups in the Kalukulohe area, Laikang Village, Kajang District. These interviews aimed to gather information about agricultural activities, challenges faced by farmers, and the current condition of agricultural equipment used. b) Field findings: Based on interviews and direct observations, it was discovered that farmers experience difficulties during the harvesting process, particularly in threshing corn. This process is still carried out manually by hand, which is time-consuming and requires significant effort. This results in low work efficiency and increases the physical burden on farmers. c) Problem Identification: The main problems identified from this observation were long threshing times, limited work capacity, high labor requirements, and inconsistent threshing results. d) Solution Formulation: Based on the identified problems, the researchers formulated a solution in the form of designing an automatic corn threshing machine using an alternating current (AC) electric motor controlled by a microcontroller. This machine is expected to speed up the threshing process, reduce farmers' workload, and produce cleaner and more consistent threshing results.

Trial Results

Interviews with farmer groups in the Kalukulohe area, Laikang Village, Kajang District, yielded positive feedback regarding the performance of the designed machine. Farmers stated that the microcontroller-based alternating current (AC) electric motor design for the corn threshing machine functioned well during field trials. The machine was able to thresh quickly, stably, and produce clean results. Farmers also felt that using this machine significantly reduced their workload compared to manual processes. Additionally, a microcontroller-based automatic control system is considered very helpful because it reduces the need for supervision during the process. Corn threshing machine design and operation:

Figure 7. Tool design results.

Minimum Motor RPM

Minimum RPM is the lowest rotational speed that still allows the threshing process to continue effectively without stalling the motor or losing torque. This minimum RPM is determined based on the motor's characteristics, namely the type of AC motor, the mechanical design of the tool, and the type of dry or wet corn. In testing this tool, the minimum RPM capable of effectively threshing corn was in the range of 400 to 500 RPM. Below this value, the motor remained running, but the impact force on the kernels was reduced, resulting in incomplete separation of the kernels from the cob. The threshing capacity is capable of threshing approximately 10 ears of corn per minute, significantly improving the threshing process compared to the manual method, which previously required approximately 3 minutes for 10 ears, now only 1 minute. The threshing results were clean, with few damaged kernels, and fewer kernels remaining on the cobs.

Test data: 1) Number of ears processed, N = 10 ears; 2) Measurement time, t = 1 minute = 60 seconds; 3) Average weight per cob = 200 grams = 0.2 kg; 4) Total weight of corn processed = 10 × 0.2 = 2 kg; 5) Number of corn kernels threshed = ± 95% of total kernels; 6) Loss or damage to kernels = ± 5%; 7) Motor rotation during the trial = 1500 rpm; 8) Motor electrical power = 0.5 HP (373 Watt).

Per minute $K_{(\frac{tongkol}{menit})} = \frac{N}{t} = \frac{10}{1} = 10\ Tongkol/menit$ (1)

Per second $K_{(\frac{tongkol}{detik})} = \frac{10}{60} = 0{,}1667\ Tongkol/detik$

Per hour $K_{(\frac{tongkol}{jam})} = 10 \times 60 = 600\ Tongkol/jam$

Per hour (kg/jam) $600 \times 0{,}2 = 120\ kg/jam$

Threshing efficiency $n = \frac{95}{100} \times 100\% = 95\ \%$

Based on trials, the threshing capacity is 120 kg/hour with a threshing efficiency of 95% and kernel damage of approximately 5%.

Rotation Control

With a microcontroller, users can adjust the motor speed to suit their needs, such as slowing down the rotation for wet corn to prevent crushing, or speeding up when threshing dry corn. This control is achieved through modules such as an inverter (VFD) for the AC motor, a relay with a timer delay system, and an RPM sensor to monitor rotation speed.

Pulley Size

The pulley is a critical component in the power transmission system from the motor to the sheller shaft. The pulley size determines the rotational speed ratio (RPM) between the motor and the shaft, which significantly impacts the effectiveness of the threshing process. The motor pulley is 2 inches in size, mounted directly on the 220V AC motor shaft. A smaller size allows the motor to rotate at high speeds, but when the power is transmitted to a larger pulley on the sheller shaft, the speed decreases but the torque increases. The threshing shaft pulley is 4 inches in size and is mounted on the shaft that drives the drum or cylinder of the corn threshing machine. The larger size of the motor pulley creates a 1:2 reduction ratio, meaning the motor's rotation is transmitted at half speed to the threshing shaft, but with twice the torque. The ratio between the motor pulley and the threshing machine is:

$$R = \frac{Pulley\ pemipil}{Pulley\ Motor} = \frac{4}{2} = 2:1$$

CONCLUSION

Based on the results of observations, interviews, design, and field testing, it can be concluded that a corn thresher based on an Alternating Current (AC) electric motor and a microcontroller can provide an effective solution to the problems faced by farmers, especially in the corn threshing process. The main problems identified were long threshing time, high labor requirements, and less clean and inconsistent results. With the designed tool, the threshing process becomes more efficient, faster, and cleaner. Tests show that this tool is able to thresh an average of 10 ears of corn per minute, with a minimum effective rotation in the range of 400–500 RPM. Below this rotation, effectiveness decreases due to insufficient crushing power. The tool design uses a 2-inch motor pulley and a 4-inch sheller shaft pulley to create a 2:1 ratio, producing sufficient torque to support the threshing process without sacrificing stability. The microcontroller-based control system also provides flexibility in adjusting the motor speed as needed, either through a timer, relay, inverter, or RPM sensor.

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