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Design and performance test of a water hyacinth (*Eichhornia crassipes*) and coconut shell charcoal briquette mixing machine

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Abstract

Dependence on fossil fuels such as oil and natural gas gives rise to various problems, including rising energy prices, limited supply, and environmental impacts in the form of high carbon emissions. Therefore, efforts are needed to develop alternative energy sources based on local raw materials such as biomass briquettes which can be made from various organic waste, such as water hyacinth and coconut shells. The objectives of this research focus on the design, manufacture, and performance testing of briquette mixing and molding machines, as well as analysis of the quality of briquettes produced from a mixture of coconut shell charcoal and water hyacinth with the addition of paraffin wax as an adhesive. The machine was designed using dimensions of 1000×500×500 mm, equipped with a spiral mixer supported by an S45C steel shaft. This research presented a method of making briquettes with various compositions of water hyacinth and a mixture of coconut shell charcoal and paraffin wax as adhesives, and tested for calorific value, ash content, and combustion rate. The best results were obtained from a mixture of 70% coconut shell charcoal, 30% water hyacinth, and 5% paraffin wax, with a calorific value of 6.285 cal/g, an ash content of 2%, and a stable combustion rate of 0.12–0.16 g/min. The addition of paraffin wax has been shown to improve combustion stability and energy efficiency. The research results show that the designed mixer and briquette press machine function effectively, and briquettes made from biomass waste with natural adhesives have great potential as an environmentally friendly and economical alternative fuel.

Keywords:
Briquettes, water hyacinth, coconut shell charcoal, electric motor.

1 Introduction

Energy needs in Indonesia continue to increase along with population growth and industrial activity. Dependence on fossil fuels such as oil and coal gives rise to various problems, including limited reserves, rising prices, and negative impacts on the environment due to greenhouse gas emissions. Therefore, efforts are needed to develop alternative energy sources that are renewable, environmentally friendly and economical.

One alternative energy source that has the potential to be developed is biomass briquettes. Briquettes are solid fuels made from processed organic waste that has a high calorific value. The use of biomass waste as raw material for briquettes not only contributes to energy diversification, but also helps reduce the volume of waste that pollutes the environment.

Environmental problems caused by the increasing volume of organic waste are becoming increasingly complex along with the growth of the industrial sector and the increasing population. As a tropical country, Indonesia has significant potential to develop biomass-based renewable energy. Two types of biomass waste that are abundant in Indonesia but have not been optimally utilized are water hyacinth (*Eichhornia crassipes*) and coconut shells. The water hyacinth is known as an aquatic plant with a very high growth rate and is often considered a weed because it can clog water channels, damage aquatic ecosystems, and disrupt fishing activities and water transportation [1][2]. Meanwhile, coconut shells, despite having great potential as raw materials for the food and non-food industries, are often only partially utilized, the rest being thrown away as waste [3]. This raises environmental problems and challenges in efforts to manage resources sustainably.

On the other hand, the availability of fossil energy sources, which are increasingly decreasing, encourages the need to develop alternative energy which is environmentally friendly and renewable [4][5]. One alternative solution to this problem is to process water hyacinth and coconut waste into fuel briquettes. The use of biomass-based briquettes is a potential solution because they have a high calorific value, a relatively simple production process, and contribute to reducing waste. Briquettes made from a mixture of water hyacinth and coconut shell charcoal have been proven to have a quality that meets alternative fuel standards [6][7]. In addition, previous studies have shown that the addition of paraffin wax as an adhesive can increase index durability of briquettes up to 20% compared to flour-based adhesives [8][9], and plays a role in increasing inter-particle cohesion and the calorific value of briquettes.

However, the manual briquette production process, especially at the raw material mixing and molding stages, still faces challenges such as low production efficiency and inconsistent product quality. The manual mixing process often produces an inhomogeneous mixture, thus affecting the calorific value and combustion stability of the briquettes. In addition, molding using simple tools results in uneven briquette shape and density, which ultimately affects the durability and final quality of the product. To overcome this problem, the development of an integrated mixing and briquetting machine is necessary to improve mix homogeneity, productivity, and product quality consistency. Performance testing of this machine is very important to ensure that the designed device is capable of producing briquettes with standard physical and energy characteristics, while supporting the management of biomass waste into a more efficient, environmentally friendly and sustainable alternative energy source.

Performance testing of the mixing and briquetting machines was carried out to ensure that the equipment developed is capable of producing briquettes with physical and energy characteristics that meet the established standards and can contribute to efforts to utilize organic waste into more efficient and sustainable alternative energy. Furthermore, the development of briquette molding and mixing technology is not only relevant from a technical perspective, but also has social and economic impacts. This machine has the potential to be applied to small to medium-scale industries that are often found in rural areas, thereby creating new jobs, increasing the added value of local waste, and strengthening community energy security. Thus, this research not only contributes to the fields of mechanical engineering and renewable energy, but also supports the sustainable development goals agenda in the aspects of clean energy, technological innovation, and environmental management [10].

2 Research methodology

2.1 Flow diagram

The flowchart in this study describes a systematic workflow in solving the design problems of a mixer machine and briquette press (Fig. 1).

The process begins with problem identification to identify existing needs and constraints, followed by literature and field studies to obtain a theoretical basis and actual conditions in the field. After that, the working drawing is identified as the basis for the machine design process. The next stage is machine fabrication according to the design that has been made, followed by testing the tool to ensure its function and performance are in accordance with the plan. The test results are then processed at the data processing stage, so that they can provide an overview of the performance of the machine that has been developed. The entire series of activities is then documented systematically in the form of a research report. With this research methodology flowchart, each stage can be carried out in a scheduled and structured manner so that the research objectives can be achieved well.

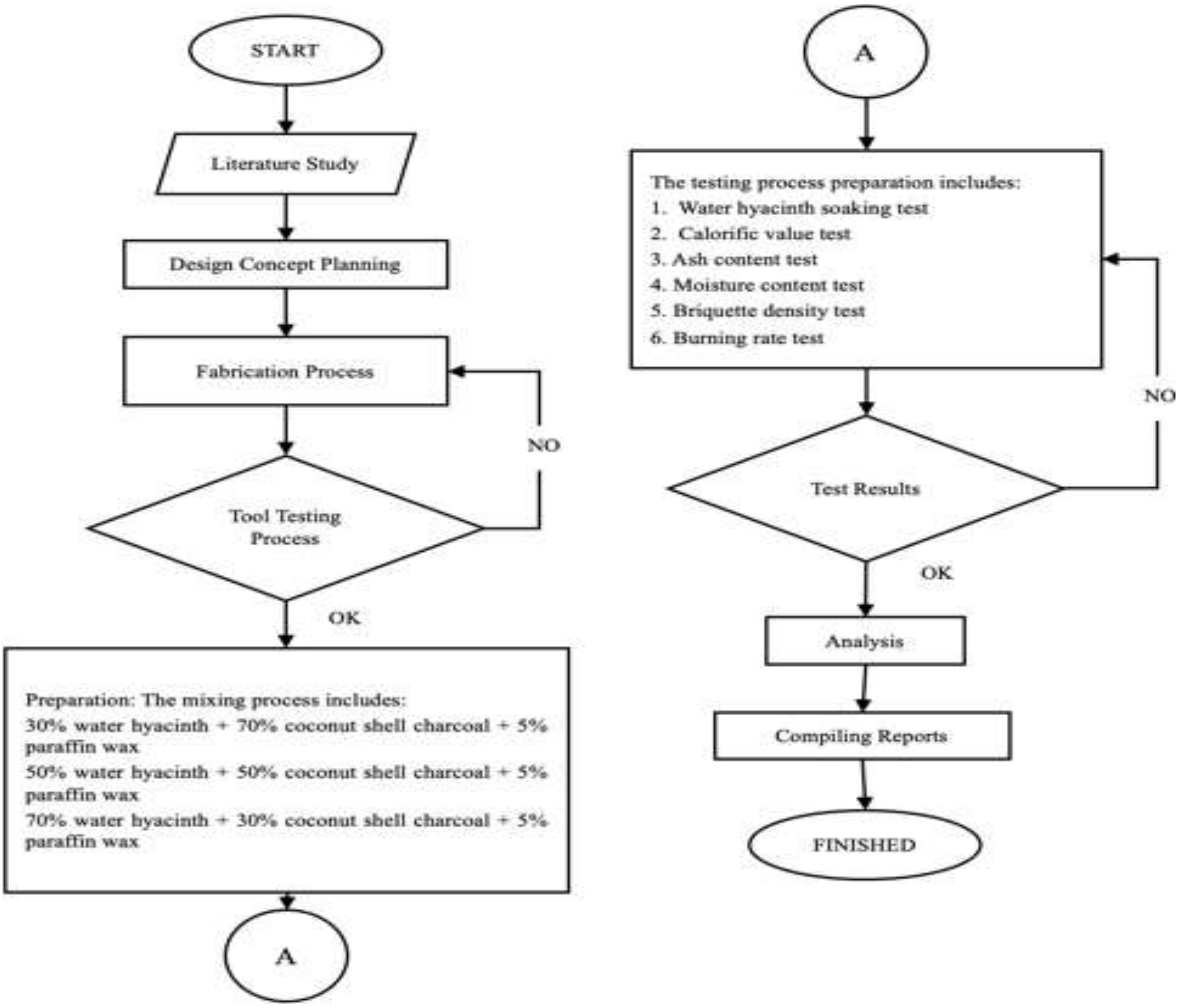


Fig. 1. Work scheme for design, manufacturing, and testing of the mixer briquette making machine.

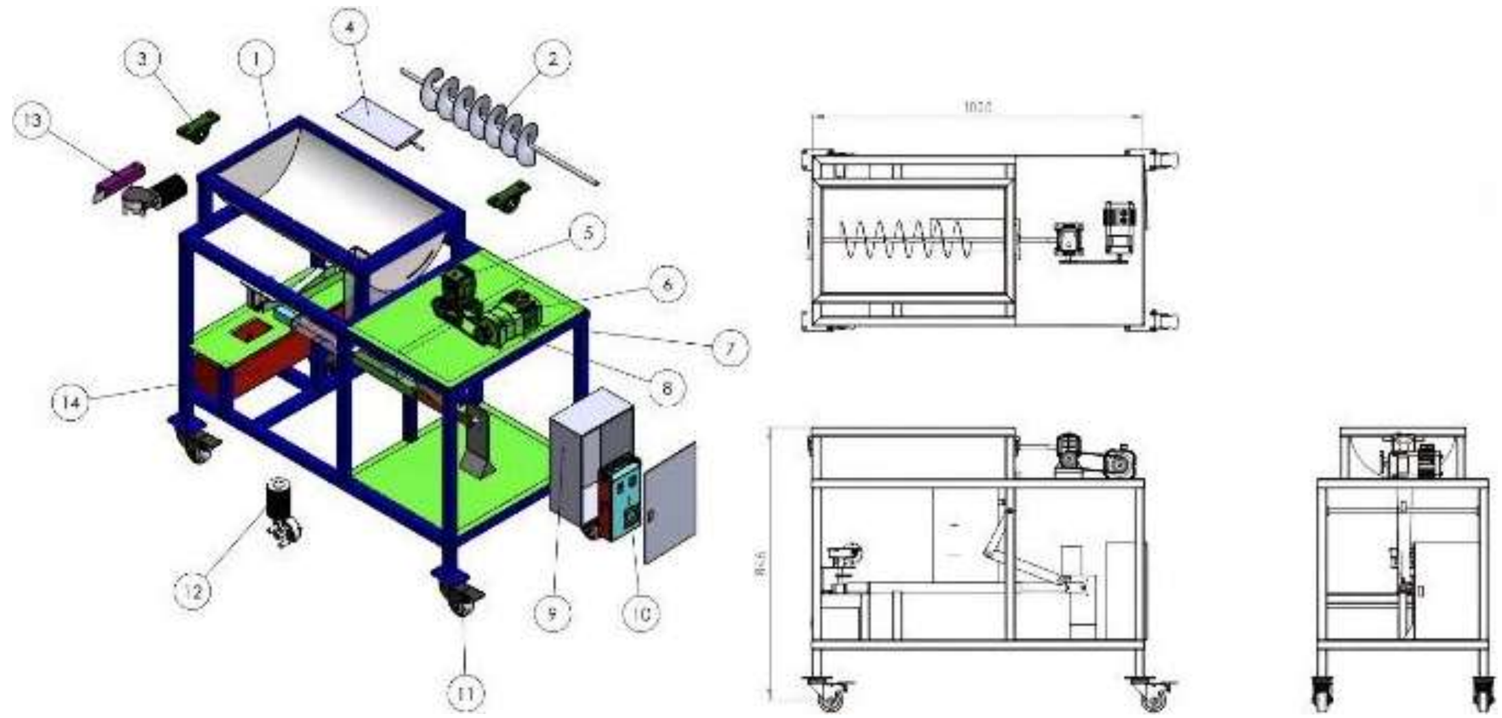
The mixing process includes: (1) 30% water hyacinth + 70% coconut shell charcoal + 5% paraffin wax (specimen A); (2) 50% water hyacinth + 50% coconut shell charcoal + 5% paraffin wax (specimen B); (3) 70% water hyacinth + 30% coconut shell charcoal + 5% paraffin wax (specimen C).

The water hyacinth mixing process involves drying and shredding, while the coconut shell undergoes a combustion process before the mixing process. In the briquette molding process, we use a previously manufactured tool to ensure a neat appearance and uniform texture during the compaction and mixing process, which is carried out by a conveyor system. The briquette size is 3 cm × 3 cm, according to the output funnel of the tool (Fig. 2). Testing is carried out using heat testing, ash content testing, and combustion rate testing.

This mixer and briquette press has overall dimensions of 1000 mm in length, 500 mm in width, and 500 mm in height. These dimensions reflect a compact size suitable for both laboratory and small-scale production. The detailed dimensions and visual appearance of the machine as shown in Fig. 3.

The analysis and calculations in this study provide a technical overview of the feasibility of the design of the mixing and briquette making machine, while ensuring that the machine can operate optimally and efficiently. The calculations begin with shaft planning, with the S45C material chosen because of its high tensile strength. The analysis results show that the shaft torque is 3,633.02 kg/mm², the shear stress is 4.835 kg/mm², and the required shaft diameter is 16 mm.

Fig. 2. Briquettes.



Information:

1. Machine frame
2. Briquette mixer
3. Bearing pillow block up 202-10
4. Cover mixer
5. Reducer gearbox WPA 40
6. Electric motor
7. V-belt
8. Pully
9. Panel box
10. Power supply
11. Castor wheel
12. Motor wiper
13. Briquette cutter
14. Storage box

Fig. 3. Components and 2D design of briquette making mixer machine.

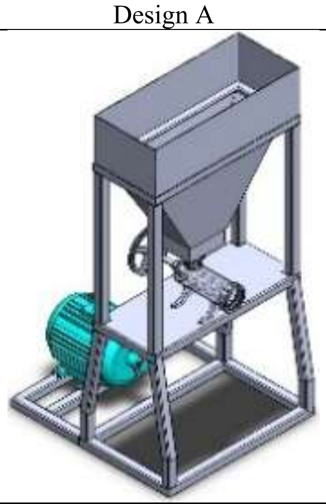
The load analysis resulted in a support reaction force of 124.998 N with a maximum bending moment of 18.75 Nm, which confirms that the shaft is strong enough to withstand the working load during the mixing process. In the transmission design, the system uses pulleys, V-belts, and gearboxes with a 1:10 ratio. The required V-belt length is 23 inches with an A-type cross-section. The power calculations show an output torque of 26.97 Nm, an input torque of 269.7 Nm, an electric motor output power of 378.26 watts, and a power before the gearbox of 445.01 watts. These results indicate that the electric motor used is suitable for the operational needs of the machine.

Furthermore, in designing the wiper motor, an analysis was carried out for two functions, namely as a briquette pusher/pressor and as a cutter. The wiper motor for pushing and pressing the briquettes requires a torque of 1.1140 Nm with a power of 11.65 watts, while the briquette cutter only requires a torque of 0.007845 Nm with a power of 0.082 watts. This shows that the selected wiper motor is very efficient and appropriate for the load capacity it carries.

Overall, the results of this analysis indicate that the technical calculations support the design of the mixer and briquette press machine. Every component, from the axle, frame, transmission, to the drive motor, is designed with safety, power efficiency, and load resistance in mind. Thus, the resulting design is not only theoretically feasible but also has strong practical implementation prospects.

Design planning is the initial stage in the machine development process, where a preliminary plan is created for the machine's shape and operating mechanism. The purpose of this comparison is to determine the simplest yet most effective and efficient design. A comparison of the two designs is presented in the Table 1.

Table 1. Comparison of design concepts

Comparison	Design A	Design B
3D sketch		
Mobility and flexibility	It has no wheels, is static and difficult to move.	Equipped with wheels on all four legs, so it is easy to move and flexible for use in various locations.

In this stage of the process, the designer chooses design B because it has several advantages compared to design A. In this design process, the mixer and briquette press frame uses 30 mm × 30 mm × 1 mm galvanized hollow steel. The frame design is shown in the Fig. 4.

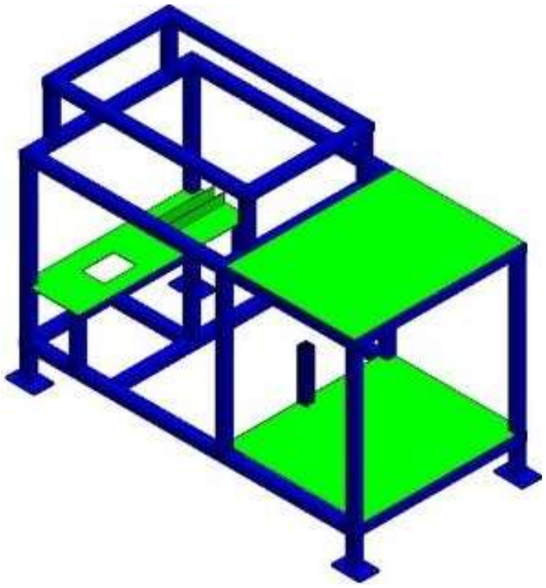


Fig. 4. Frame of the mixer briquette making machine.

The mixer frame and briquette press are designed using 30×30×1 mm galvanized hollow steel. This material was chosen for its relatively low cost, easy availability, and corrosion resistance. Based on the load analysis, the frame receives a total mass of 28,694 kg**,** which comes from machine components such as bearings, shafts, spirals and briquette material. This load distribution is then calculated manually and used by software to ensure structural stability.

Load analysis shows that the reaction force received by the frame is balanced, with a value of 71.735 N at each cross-section. The results of the Shear Force Diagram (SFD) and Bending Moment Diagram (BMD) analysis show agreement between manual calculations and simulations, with a maximum moment of 10,796 Nm. The moment of inertia calculation yielded a value of 16,278.66 mm^4, which was then used to determine the maximum stress of the frame at 9.9846 MPa. This value is well below the allowable stress of galvanized steel, making it safe [11][12].

In addition to manual calculations, simulations were also carried out using SolidWorks 2024 with a load of 286.94 N. The simulation results showed a stress value of 5.402 MPa, a displacement of 0.071 mm, and a Factor of Safety (FOS) of 37.750. Meanwhile, manual calculations produced a FOS value of 20.7133, which still indicates a high level of security. Based on the comparison of manual and simulation results, all calculations show that the mixer and briquette press machine frames have adequate levels of strength and safety. Thus, the designed frame is not only able to withstand operational loads, but also ensures stability and a long service life of the machine.

2.2 Machine working system

The mixer's electrical system uses a three-phase electric motor controlled by a Miniature Circuit Breaker (MCB), contactor, and push button. The mechanism starts by activating the MCB, then pressing the green button to start the motor, and pressing the red button to stop the mixing process. This system is designed to ensure efficient and safe mixing of briquette materials (Fig. 5).

In the briquette making machine, the electrical system uses a wiper motor as the main drive, supported by a power supply, relays and limit switches. The wiper motor pushes the briquette mixture until it reaches the limit switch, which then signals the cutting motor to cut the briquettes automatically. Once cutting is complete, the power is cut off and the machine stops working, ensuring precision and consistency in the printing process.

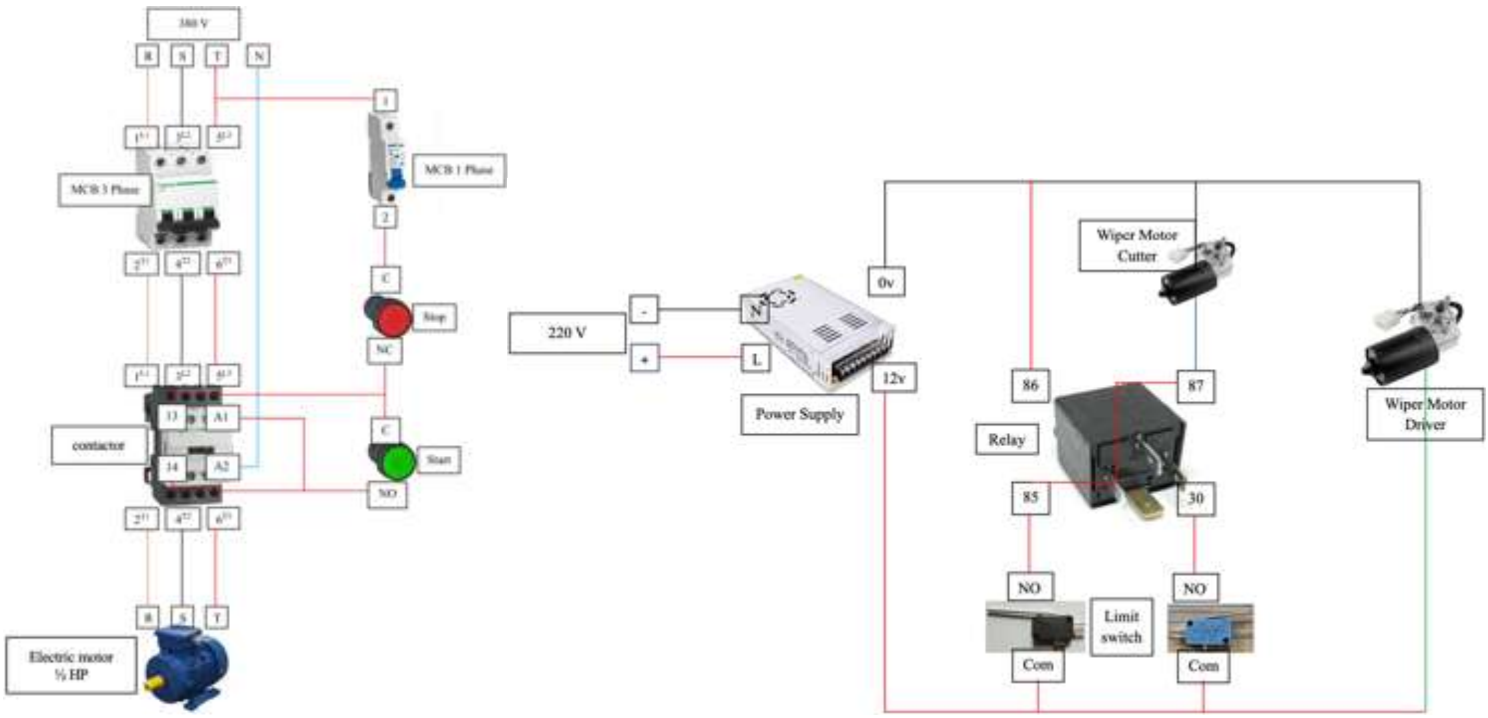


Fig. 5. Electrical circuit.

From an operational perspective, machine use begins with checking important components such as V-belt tension, cable condition, and MCB function. After the machine is turned on, the briquette material is put into the mixer to be stirred until homogeneous, then poured into the mold. The molding process is carried out automatically with the help of limit switches, and the resulting briquettes are removed from the storage container after the process is completed. The usage procedures also emphasize safety aspects, such as ensuring the motor is completely off before opening the cover, using tools when loading materials, and keeping the machine clean for longer life. Overall, the working system of this machine combines a simple electrical design with an automation mechanism, so that the mixing and briquette molding process can be carried out more quickly, safely, and produces products with uniform quality.

2.3 Design planning

The machine design process begins with two alternative designs for comparison. The selected design excels in terms of mobility, component layout, modularity, stability, mixing performance and briquetting precision. Its advantages include wheels for easy mobility, an open design for easier maintenance, and a parallel mixing and molding system that increases production efficiency (Fig. 6).

Fig. 6. Design of a mixer briquette making machine.

Material selection takes into account price, market availability, as well as the strength and functional suitability of the component. The selected materials are expected to support machine performance while remaining economical. Next, analysis and calculations are carried out using software SolidWorks 2024, which includes simulations and manual calculations. The analysis includes the FOS, frame loading using SFD and BMD, and strength analysis of the main components.

Once the design and materials are declared feasible, the next stage is to create 2D working drawings using SolidWorks 2024 to facilitate the manufacturing process according to the design dimensions and specifications.

2.4 Fabrication process

The fabrication process of a mixing and pressing machine for briquettes from water hyacinth waste and coconut shell charcoal with paraffin wax adhesive is carried out through several main stages, starting from detailed design planning, preparation of tools and materials, fabrication, assembly, and final finishing. The initial stage begins with an analysis of the working drawings to ensure that the dimensions and function of each component are in accordance with the design. Next, prepare materials such as hollow iron, plates, and shafts, as well as supporting equipment such as drills, grinders, sheet metal scissors, and welding machines (Fig. 7).

Fig. 7. Briquette mixing machine manufacturing activity.

In the fabrication stage, the process includes marking, cutting, bending, drilling, and welding. Marking is done according to the technical drawing, followed by cutting the material using a grinder or sheet metal scissors, and bending the mixer container. Drilling is done on components that require holes for bearings or connections, followed by welding the frame and other components to form the main structure of the machine.

The assembly stage includes the assembly of all components, from the mixer system and molds to the drive components. The connections between components are reinforced with bolts, while the connection surfaces are first cleaned with a grinder to ensure strength and neatness. At this stage, the electrical system is also assembled, which consists of a three-phase electric motor as the main drive, a gearbox as a speed reducer, and a control panel equipped with MCBs, contactors, and on/off switches to support operational safety and efficiency.

The final stage is the finishing process, which includes painting or applying a protective coating to increase the machine's resistance to corrosion, checking the connections, and testing the smooth operation of the shaft, stirring mechanism, and printing system. Through this series of fabrication processes, the machine was successfully built according to the design, taking into account aspects of strength, practicality, and durability to support efficient briquette production.

The fabrication process of the water hyacinth and coconut shell charcoal briquette mixing and molding machine was carried out at the Indramayu State Polytechnic campus on March 17, 2025. This process is carried out in stages by combining material components until they become a ready-to-use system. The equipment used in the fabrication process includes hand drills, hand grinders, sheet metal shears, welding machines, calipers, wrenches, bevels, and thread taps. This equipment supports various activities ranging from cutting, measuring, assembly, to welding.

The fabrication process consists of several main steps. First, material preparation includes preparing angle iron, plates, and shafts according to the design. Second, marking is done by marking the material using a marker, ruler, bevel, and steel ruler to ensure accurate cutting. Third, the material is cut using a grinding machine and metal sheet scissors. Fourth, the plates are machined to form the hopper frame components for the mixing machine and briquette press machine. Fifth, welding is carried out using the SMAW method to unite the main components. After welding, finishing is carried out by grinding, smoothing, and filling in welds that are not neat, followed by a polishing process using a polishing grinding machine.

This series of steps is carried out systematically so that the resulting mixing machine and briquette press machine have a sturdy, precise structure and are in accordance with the technical design that has been made previously.

2.5 Machine operating procedures

The press machine is designed for ease of use while ensuring safety. The procedure begins by checking the engine components such as the V-belt, cable connections, and MCB to ensure everything is in good condition [13]. Next, the electric motor and wiper motor plugs are connected to a three-phase power source, and then the MCB is turned on. Operation begins by pressing the green push button to activate the electric motor, while the user must ensure the surrounding area is safe from hands or objects that could get into the rotating parts.

After the motor is running, the briquette mixture is put into the mixer container according to the specified measurements to ensure that the container capacity is maintained. The mixing process continues until homogeneous, and then the motor is turned off by pressing the red button and MCB. The mixed material is then inserted into the mold using tools to avoid direct contact with sharp or hot objects. The resulting briquettes are removed from the storage box with gloves so as not to crush them. Once the process is complete, the plug is removed with dry hands and the machine is cleaned before being stored in a dry place. This procedure ensures that the machine functions optimally, produces quality briquettes, and is safe for reuse.

2.6 Tool testing

The mixing machine and briquette making machine are then tested to ensure their performance is in accordance with the design and simulation. Once the machine is functioning properly, the next stage is preparing the raw materials consisting of coconut shell charcoal, water hyacinth, and paraffin wax as an adhesive. Coconut shells are first dried processed through pyrolysis to produce charcoal, and then ground to a size of 50–100 mesh. Water hyacinth is harvested, washed, dried, then chopped and pyrolyzed into charcoal before being ground to facilitate mixing. Paraffin wax is melted so that it can be used as an adhesive in making briquettes. The processed of making briquettes is carried out by mixing coconut shell charcoal powder and water hyacinth according to a certain ratio with the addition of liquid paraffin wax until homogeneous, then the mixture is poured into a mold and compacted using a molding machine.

The resulting briquettes are then dried in an oven or under the sun until the water content is reduced. The final stage is briquette testing, which includes a water hyacinth yield test to determine the ratio of dry and wet materials, a calorific value test to determine the heat energy produced, an ash content test to see the combustion residue, and a combustion rate test to assess the stability and efficiency of the briquette flame. The test results were analyzed and compared with standard and conventional briquettes, so that a general picture can be obtained of the quality, advantages, and potential of briquettes as an alternative fuel that is more environmentally friendly and economical.

3 Results and discussion

Performance testing of the mixer and briquette press machine was carried out to ensure the design meets actual performance and to evaluate the quality of the resulting product. Based on the engine rotation test using a tachometer, the actual RPM values for the motor, reducer, mixer shaft, and press shaft show results close to the theoretical calculations, so the transmission system is considered to be operating stably.

The briquette making process uses coconut shell charcoal powder, water hyacinth charcoal, and paraffin wax in three composition variations (Fig. 8). Product test results showed that the briquettes exhibited uniform size, good density, and shape stability after drying. In terms of yield, the composition dominated by coconut shell charcoal produced the highest efficiency of 95.1%, while the composition dominated by water hyacinth tended to decrease the yield due to greater shrinkage.

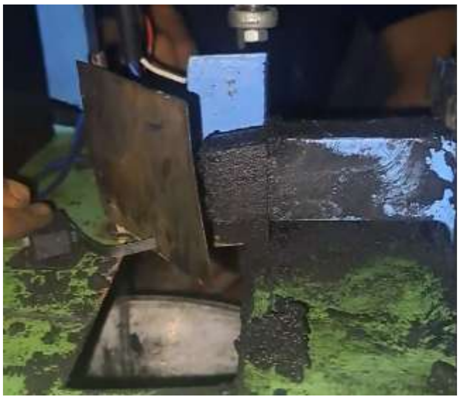


Fig. 8. Briquette making process.

The results of the calorific value test showed that the variation of 70% coconut shell charcoal: 30% water hyacinth with the addition of 5% paraffin produced the highest value, namely 6.285 Cal/g, exceeding the minimum standard of SNI briquettes (>5,000 cal/g). This is shown in Table 2 and Fig. 9.

Table 2. Heat test results

Variation	Temperature (◦C)		
	5 minute	1 hour	2 hours
1	320	360	250
2	323	130	193
3	305	151	64

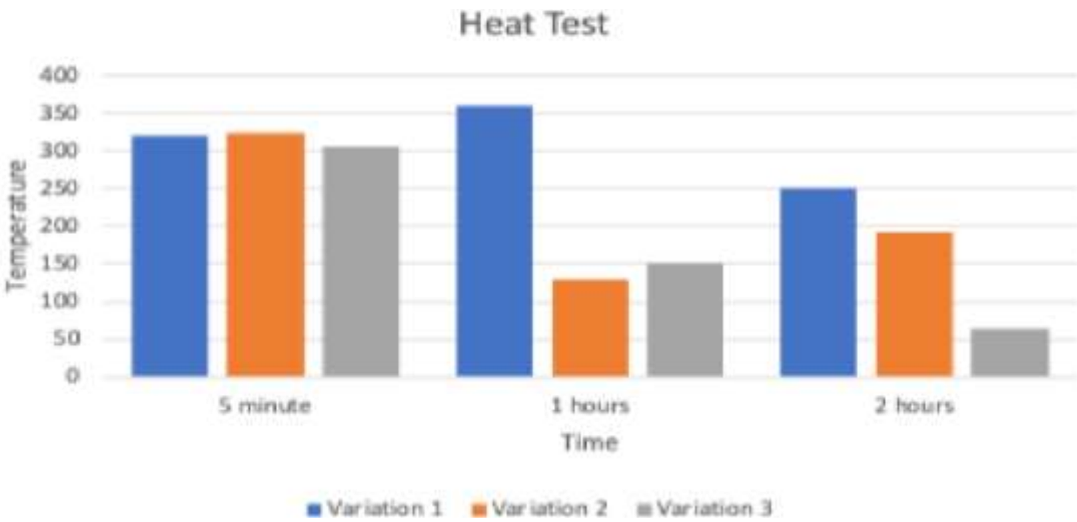


Fig. 9. Heat test bar diagram.

Formulation of the heat formula (Eq. (1)), where m is water mass (kg), ΔT is highest temperature – lowest temperature (◦C), c is Cal/(g.◦C) and M_{briket} is 3.5 g.

$$Q = m \times c \times \Delta T \quad (1)$$

$$\begin{aligned} Q &= m.c.\Delta T \\ &= 200 \times 1 \times 110 \\ &= 22{,}000 \text{ Cal} \\ &= 0.482 \text{ kcal} \end{aligned}$$

Measured calorific value = 22,000 / 3.5 = 6,285 cal/g

Table 3. Briquette quality standards

Characteristic	Quality standards			
	Japan	UK	US	SNI
Water content (%)	6-8	3.6	6.2	<8
Ash content (%)	3-6	5.9	8.3	<8
Fly rate (%)	15-30	16,4	19-24	<15
Carbon content (%)	60-80	75.3	60	>77
Density (gr/cm^3)	1-1.2	0.46	1	>0.44
Compressive strength kg/cm^2)	60-65	12.7	62	50
Calorific value (kcal/gr)	6000- 7000	7300	6500	>5000

Ash content test results also support this, with the best samples leaving only 2%–3% residue, indicating cleaner combustion [14]. This is shown in Table 4 and Fig. 10.

In addition, the achieved combustion rate ranged from 0.12–0.16 g/min, indicating a stable combustion process and good energy efficiency, as shown in Table 5 and Fig. 11.

Table 4. Ash content results

Sample	Ash content
1	3%
2	2%
3	15%

Table 5. Combustion rate results

Sample	Burn rate
1	0.12 g/min
2	0.13 g/min
3	0.16 g/min

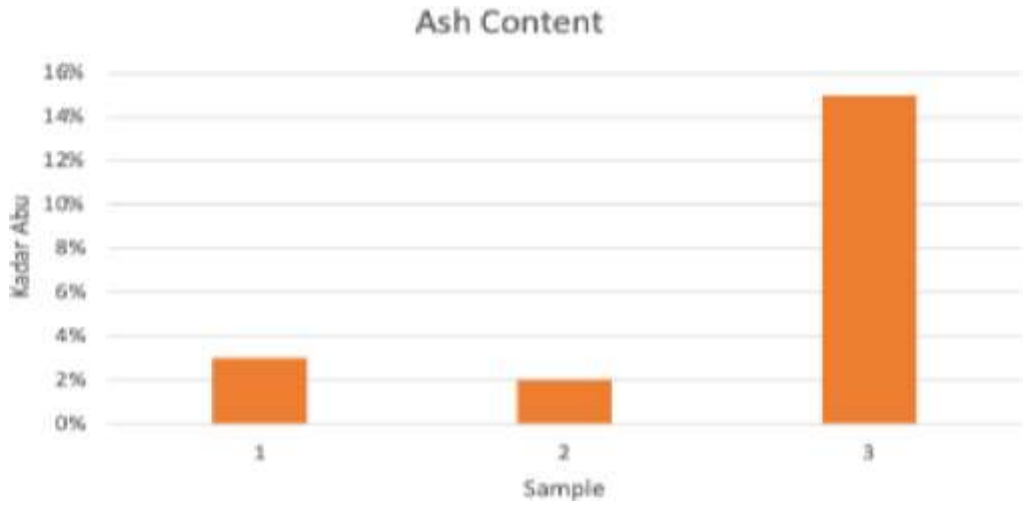


Fig. 10. Ash content test bar chart.

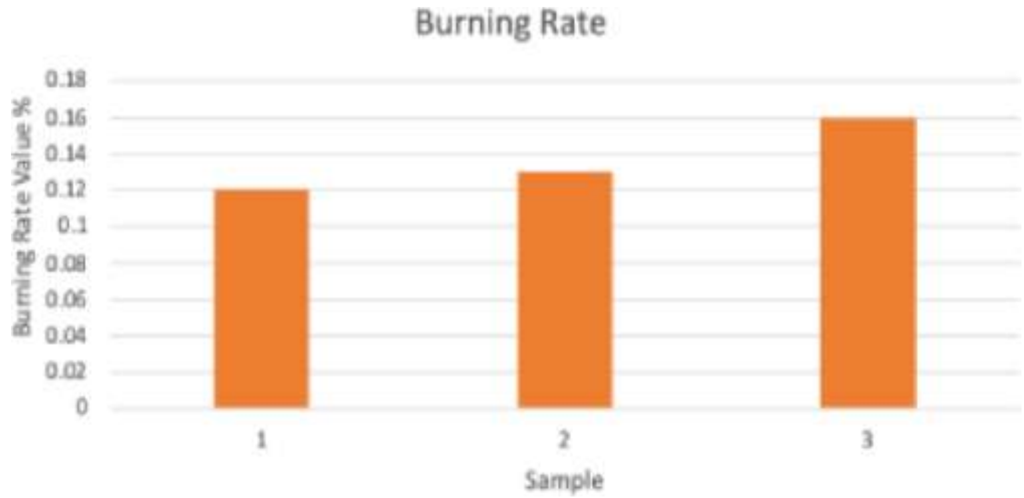


Fig. 11. Burn rate bar graph.

Overall, the designed machine is capable of operating according to specifications, producing briquettes that meet international quality standards (Japan, UK, US) and SNI, both in terms of calorific value, ash content, and physical strength. This proves that the use of water hyacinth waste and coconut shell charcoal with the addition of paraffin wax has great potential as an alternative fuel that is environmentally friendly and economical.

4 Conclusions

This study designed, manufactured, and tested a mixing and briquette molding machine with reliable performance and structural safety. The main conclusions are: (1) The machine operates effectively using an electric motor for mixing and a wiper motor for pressing. Structural analysis confirms that the shaft, frame, and transmission system meet strength requirements with high safety factors. The machine achieves a mixing time of 4 minutes 20 seconds and a molding time of 2 minutes 24 seconds, producing uniform briquettes; (2) The optimal briquette composition consists of 70% coconut shell charcoal, 30% water hyacinth, and 5% paraffin wax. This formulation yields the highest calorific value (482,000 calories), the lowest ash content (2%), and a stable combustion rate of 0.12–0.16 g/minute; (3) The produced briquettes demonstrate high energy efficiency, good combustion stability, and suitability as an environmentally friendly and economical alternative fuel; (4) The developed machine offers advantages over conventional systems, including improved energy efficiency, modular construction, lower production costs, and flexibility in raw materials.

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