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Design of a Seaweed Draining and Drying Machine Using Hybrid Energy

Perancangan Mesin Peniris dan Pengering Rumput Laut Menggunakan Energi Hibrid

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Abstract

Seaweed is a plant that is adaptable and is used in a variety of industries, such as food, cosmetics, and medication. However, the current seaweed processing technique, which entails sun drying, is still highly traditional and requires a significant amount of time. To speed up draining and drying seaweed, we developed a hybrid energy-powered seaweed draining and drying. The tool capacity of this design is 50 kg, and it applies the Pahl and Beitz method. The selected design is variant 3 with the highest weight value of 7.74. The design outcomes produce the following tool specifications the drive is equipped with a diesel motor with a power of 3.5 Hp, 2.6 kW, and 3600 rpm, as well as three solar panels of the MCS1100 model, each with a capacity of 100 Wp. The container dimensions of 382 mm diameter and 500 mm height. The seaweed is to be dried at a rate of 29.3 kg/m^2 per hour. The galvanized steel frame yielded a maximum working stress value of 126,223 N/mm^2, which is lower than the material's yield strength value of 203,943 N/mm^2. On the shaft made of S45C8 steel, the maximum working stress value after applying the load is 66.83 N/mm^2, which is also less than the material's yield strength value of 350 N/mm^2. This indicates that the stand and shaft design is safe, as the simulation process's maximum stress value does not surpass the material's yield strength value.

Keywords: design, seaweed, draining, drying, hybrid energy.

***SDGs*:**

12 RESPONSIBLE CONSUMPTION AND PRODUCTION

Abstrak

Rumput laut merupakan tanaman yang mudah beradaptasi dan digunakan dalam berbagai industri, seperti makanan, kosmetik, dan obat-obatan. Akan tetapi, teknik pengolahan rumput laut saat ini memerlukan penjemuran di bawah sinar matahari yang masih sangat tradisional dan memerlukan waktu yang lama. Untuk mempercepat penirisan dan pengeringan rumput laut, perlu adanya pengembangan mesin untuk penirisan dan pengeringan rumput laut bertenaga energi hibrida. Kapasitas produksi mesin yang direncanakan adalah 50 kg. Metode yang digunakan dalam perancangan adalah metode Pahl dan Beitz. Hasil konsep desain yang dipilih adalah varian 3 dengan nilai bobot tertinggi sebesar 7,74. Hasil perhitungan desain menghasilkan spesifikasi mesin, yaitu: penggerak dilengkapi dengan motor diesel dengan daya 3,5 Hp; 2,6 kW; dan 3600 rpm; memiliki tiga panel surya model MCS1100, masing-masing berkapasitas 100 Wp; dimensi wadah berdiameter 382 mm dan tinggi 500 mm. Rumput laut akan dikeringkan dengan kecepatan perencanaan sekitar 29,3 kg/m^2 per jam. Untuk rangka menggunakan baja galvanis dan berdasarkan hasil analisis simulasi menghasilkan nilai tegangan kerja maksimum sebesar 126.223 N/mm^2, yang lebih rendah dari nilai kekuatan luluh material sebesar 203.943 N/mm^2. Material poros penghubung terbuat dari baja S45C8, nilai tegangan kerja maksimum setelah pemberian beban adalah 66,83 N/mm^2, yang lebih rendah dari nilai kekuatan luluh material sebesar 350 N/mm^2. Hal ini menunjukkan bahwa desain dudukan dan poros aman, karena nilai tegangan maksimum hasil simulasi tidak melampaui nilai kekuatan luluh material.

Kata Kunci: desain, rumput laut, penirisan, pengeringan, energi hibrid.

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1. INTRODUCTION

Seaweed is one type of macroalgae that plays an important role in the marine ecosystem. The Thallophyta division classifies this plant, meaning its body structure consists of stems or thallus without leaves and roots. Seaweed can grow in various parts of the sea, from shallow waters to deeper depths. The composition of pigment molecules in their chloroplasts divides seaweed into three main groups: red (*Rhodophyta*), brown (*Phaeophyceae*), and green (*Chlorophyta*). Each group has different characteristics and roles in the marine ecosystem. A study by Yong et al. shows that climate change and damage to the environment have led to the rise of the blue carbon economy model (Yong *et al.*, 2022). In this model, marine ecosystems, especially seaweed, act as carbon sinks and green energy sources. This study shows how seaweed could help the bioeconomy and reduce our reliance on fossil fuels. Even though growing seaweed can be hard, there is evidence that this business could be a good alternative for food security, economic growth, and long-term climate change mitigation. Zhang et al. identified seaweed resources have grown rapidly in the past two decades due to their adaptability and sustainability (Zhang *et al.*, 2022). This study examines seaweed production and processing advances and industry challenges. Seaweed has many uses, but agronomic and processing issues require solutions to maximize its benefits. This research informs field development.

According to FAO data, global seaweed production continues to increase from year to year. In 2021 alone, the total seaweed production reached an astonishing figure of 36.3 million tons. The *Laminaria sp*. species is one of the most dominant types of seaweed in production, with a contribution of 36.7% (FAO, 2024). However, other seaweed types such as *Kappaphycus sp*., *Gracilaria sp*., *Undaria sp*., and *Euchema sp*. also contribute significantly to global production. In Indonesia itself, seaweed production is also very dominant, with the *Kappaphycus* alvarezii species being the prima donna with a production volume of 7.05 million tons, dominating 82.7% of the total global production (FAO, 2024).

Furthermore, Indonesia widely produces *Gracilaria*, accounting for 1.91 million tons, or approximately 32.1% of global seaweed production (Rahman and Abdullah, 2020). Given the significant potential for seaweed production in Indonesia, we hope to sustainably develop and utilize it for the preservation of the marine ecosystem and the well-being of the seaweed-producing communities. Seaweed also has various benefits that are beneficial for human health, such as high nutritional content and various applications in the food, pharmaceutical, and cosmetic industries.

According to research, seaweed is an important part of Indonesia's marine biodiversity and is very important to the economy and environment of the coastal areas. A comprehensive study that took place from 1993 to 2023 found 325 types of seaweed, including 103 *Chlorophyceae*, 167 *Rhodophyceae*, and 55 *Phaeophyceae* (Basyuni *et al.*, 2024). The amount and location of seaweed are affected by things in the environment like nutrients, predators, and light strength. Basyuni et al. did a study that shows how important seaweed is in the mangrove and coral reef environments on Indonesia's big islands (Basyuni *et al.*, 2024). The study also finds knowledge gaps that need more research to be filled for long-term management and use. These results show how important this marine resource is for Indonesia's economy and nature.

Nunukan Regency is located directly adjacent to Tawau, Malaysia, on the northern border of Borneo. This district is abundant in natural resources and has significant potential for producing high-quality commodities, including rubber, oil palm, and cocoa, alongside a thriving marine sector, particularly in seaweed cultivation (Bappedalitbang, 2024). Seaweed offers diverse applications, ranging from food and animal feed to fertilizer, biofuel, cosmetics, and pharmaceuticals. The Indonesian Ministry of Maritime Affairs and Fisheries has set a target for national seaweed production to increase by 2.92% from previous levels during the 2020-2024 period, aiming for a production volume of 10.99 tons in 2020 (Rahman and Abdullah, 2020). It is important to note that seaweed is typically sold in its dried form in the market.

The traditional method of processing seaweed involves sun-drying, which can take between three to four days. This lengthy process is often exacerbated by unpredictable weather conditions, leading to issues such as spoilage, which adversely affects marketability (Zhang *et al.*, 2022). Although there are several modern alternatives for draining and drying seaweed, including ovens and other equipment, these methods still depend on fossil fuels such as gasoline and diesel, which are non-renewable resources. Additionally, they require separate equipment for the draining and drying processes.

The research by Nagahawatta et al. studied into how hot hybrid gasification drying (HHGD) could be used to dry seaweed (Nagahawatta *et al.*, 2021). Seaweed usually has a lot of water in it, so it needs to be dried quickly and efficiently to keep its quality. Researchers investigated four types of brown algae and compared HHGD and freeze drying (FD). They found that there were no big changes in the nutrients or antioxidant activity between the two methods. Even though FD makes good products, its high prices and small capacity are problems. According to the study, HHGD might be a good option to FD for keeping the nutritional value of seaweed.

A study by Brigljević et al. combined a fast pyrolysis reactor, non-intensive processing, and the Bryton power cycle to come up with a process design that works (Brigljević, Liu and Lim, 2019). In this way, the machine almost doesn't need any energy. An efficient system for the utilization of solar energy in the production of renewable materials, energy storage, and electricity has been developed by integrating biomass processing facilities with solar energy. Golberg et al. recommend a novel integration of a macroalgal seaweed biorefinery and a solar thermal energy system in their research (Golberg *et al.*, 2021). This combination necessitates energy input for biomass cultivation and processing.

Sustainable agricultural products are being developed in response to studies on food security, sustainability, and the requirement of separating food costs from changes in fossil fuels. Solar dryers and other renewable energy sources are quite important in isolated locations with few traditional energy sources. Lamidi et. al. has concentrated on environmentally friendly drying methods including combined power and drying systems (Lamidi *et al.*, 2019). A potential solution for post-harvest trash, biomass-based systems concurrently generate heat and energy to dry agricultural goods.

A review by Saini et al. reveals that solar dryers are innovative tools that utilize solar energy to remove moisture from various materials, including agricultural products (Saini *et al.*, 2023). The advantages of solar dryers lie in their energy efficiency and lower environmental impact compared to mechanical dryers fuelled by fossil fuels. However, their reliance on weather conditions presents a significant drawback. Recent studies show that mixed-mode solar dryers are more effective in drying agricultural products than direct dryers. Saini et al. expect the solar dryer market to grow rapidly, reaching a value of USD 3.5 billion in 2023 and a CAGR of 10.6% until 2031.

A study by Pangan et al. found that using solar dryers for drying seaweed in the Philippines has helped farmers by making the drying process faster and more reliable (Pangan, Ampo and Barredo, 2021). This saves time, improves the quality of the seaweed, and increases profits. Weather conditions can affect traditional drying methods, thereby lowering the seaweed's value. The study also suggests using solar-powered ventilation and lighting systems in the dryers to keep the drying process going even at night.

The main challenge in seaweed processing in Indonesia is the use of fossil fuels in the draining and drying processes. Seaweed farmers currently need to invest more in separate machines for each process. However, we hope that innovation in the form of integrated draining and drying systems using hybrid energy will provide a solution to this problem. With machines that can perform the draining and drying processes simultaneously, seaweed farmers will become more efficient in the production process. Additionally, the use of hybrid energy, which combines solar electricity with diesel motors, can help reduce dependence on fossil fuels. This will certainly have a positive impact on creating a cleaner and more sustainable environment.

2. METHODOLOGY

The Pahl & Beitz design technique is employed in product development to guarantee the efficient operation of a seaweed draining and drying machine that utilizes hybrid energy. This research involves the analysis of needs, selection of design concepts, concept creation, concept evaluation, and design execution (Pahl and Beitz, 2013). Figure 1 illustrates the stages of the design process.

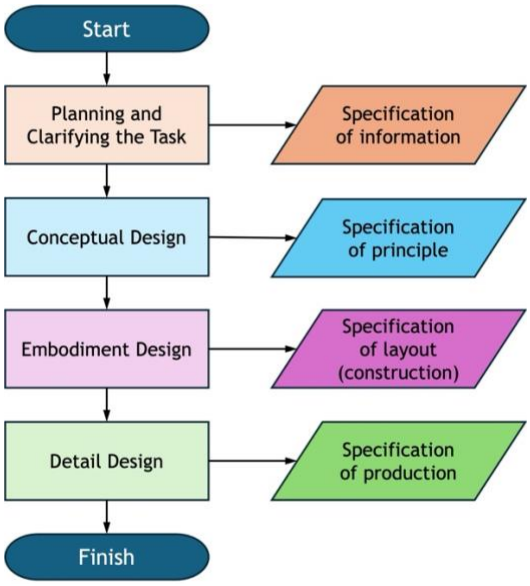


Figure 1. The stages of the design process.

Researchers will ascertain the requirements and issues that seaweed draining and drying machines must address throughout the needs assessment phase. This necessitates a comprehensive comprehension of consumers, the environment, and potential obstacles that may emerge during the seaweed draining and drying procedure. The next step is to choose an appropriate design concept according to the requirements. The following stage, concept development, involves taking rough concepts and turning them into more refined and tangible designs. We also conduct concept evaluations to ensure that the selected design meets the previously specified requirements. In the end, we put the idea into action to make a functioning machine for draining and drying seaweed. This hybrid energy seaweed draining and drying machine, which employs the Pahl and Beitz method, is expected to be a highly effective and efficient solution. This design's systematic stages should produce high-quality, user-satisfying items.

2.1. Planning and Clarifying the Task

The role of a designer commences with a defined problem. Each task entails constraints that may evolve; a comprehensive understanding of these constraints is crucial for identifying optimal solutions. Regardless of whether product planning has provided a list of initial requirements, designers must explicitly and thoroughly define tasks to focus explanations and corrections in the subsequent development process on the most critical aspects. To achieve this objective and establish a basis for subsequent decisions, it is crucial to create and consult a list of requirements (design specifications) (Pahl and Beitz, 2013).

This list is crucial within the framework of the original design, despite encompassing subtasks. When compiling a detailed list of requirements, it is essential to distinguish between demands and wishes for each item. Demands are conditions that must be met for the answer to be accepted. It is essential to explicitly define the minimum requirements. However, it is important to prioritize aspirations, as they only serve to increase expenses to a minimal extent. Some examples of these kinds of dreams are central locking and less upkeep. It is advisable to classify these wishes into three tiers of significance: important, moderate, and less important (Suwandi *et al.*, 2021).

2.2. Conceptual Design

Understanding the basic concept of the tool to be made, including its components, working mechanism, functional structure, and other requirements needed to support the machine's performance, is the first step in designing a machine (Pahl and Beitz, 2013).

2.3. Embodiment Design

The embodiment design phase represents a pivotal moment in the journey of creating a technical product. In this phase, the design will progress from the fundamental concept or initial product framework to a more intricate stage that is prepared for production. The design will be developed by considering a range of technical and economic criteria, as well as any additional relevant information (Suwandi *et al.*, 2021, 2023).

2.3.1. Design of container dimensions

The following equation (1) can be used to determine the volume of a container designed capable 50 kg of seaweed, given that seaweed has a density of 0.871 kg/l (Salim and Ernawati, 2015):

$$V = \frac{m}{\rho} \quad (1)$$

Where ρ is the seaweed's density (kg/l), *V* is the container volume (l), and *m* is the quantity intended for one draining and drying process (kg). A height of the container designed 500 mm, leading to the following equation (2) and (3) for calculating the diameter of the container:

$$V = \pi \times r^2 \times t \quad (2)$$

$$d = 2 \times r \quad (3)$$

Where *V* is the volume (l), *r* is the radius (mm), *h* is the height (mm), and *d* is the diameter (mm) of the container for the draining and drying.

2.3.2. Required power calculation

The motor specifications for this seaweed draining and drying are determined through theoretical calculations performed on load container and wet seaweed. The torque generated by the rotation of the 50 kg wet seaweed, the estimated weight of the 5 kg container, and the diameter base on the result of equation (3), the container can be determined using the following equation (4) (Khurmi and Gupta, 2005):

$$T = r \times F \quad (4)$$

Where *T* is the torque of motor (kgm), *r* is lever arm or distance between the axis of rotation to the point of the force (m), and *F* is the force acting on an object where draining and drying process (N).

Equation (5) can be used to determine the minimal motor power needed if the seaweed draining process is to be conducted at a reduced rotation speed of 500 rpm (Khurmi and Gupta, 2005):

$$P_{min} = T \times \frac{2 \times \pi \times N}{60} \quad (5)$$

Where P_{min} is the minimum motor power (Watt), *T* is the torque of motor (kgm), and *N* is the reduced rotation speed (rpm).

2.3.3. Belt & pulley planning

The existing transmission uses a belt and pulley to forward the rotation from the electric motor to the drain container. This transmission reduces the speed from electric motors power. The diameter of the pulley on the motor is 75 mm, which is derived from the dimensions of standard V-belts according to IS 2494-1974 (Khurmi and Gupta, 2005). The equation (6) determines the pulley used to reduce electric motor rotation to the shaft (Khurmi and Gupta, 2005):

$$\frac{N_1}{N_2} = \frac{D_p}{d_p} \quad (6)$$

Where N_1 is the existing speed rotation motor (rpm), N_2 is the reduces the speed (rpm), d_p is motor pulley diameter (mm), and D_p is container pulley diameter (mm).

The length of the belt circumference is determined by the following equation (7), where the distance between the shaft axis (C) is 1.5 to 2 times the largest pulley diameter and is necessary for the design of this seaweed draining and drying (Khurmi and Gupta, 2005):

$$L = 2C + \frac{\pi}{2}(D_p + d_p) + \frac{\pi}{4C}(D_p - d_p)^2 \quad (7)$$

Where *L* is the length of the belt circumference (mm), D_p is container pulley diameter (mm), d_p is motor pulley diameter (mm), and *C* is the distance between the shaft axis (mm).

2.3.4. Shaft and bearing planning

The most common shaft material on the market is S45C8, which has material properties with an ultimate strength of 660 MPa and a yield strength of 560 MPa (SAAJ, 2024). The fatigue limit of a shaft, according to ASME standards, is established at 18% of the tensile strength. In the case of materials such as S-C, considering the effects of mass and alloy steel, a safety factor of 1/18% is applied, resulting in 5.6, which is rounded to 6.0 (sf_1). In the presence of a key on the shaft, it is necessary to incorporate an additional safety factor (sf_2) ranging from 1.3 to 3.0 to the existing value (Khurmi and Gupta, 2005). The allowable shear stress on the shaft is defined by Equation (8) (Khurmi and Gupta, 2005):

$$\tau = \frac{\sigma_y}{sf_1 . sf_2} \quad (8)$$

Where τ is the shear stress material (kg/mm^2), σ_y is yield strength material (MPa), sf_1 is safety factor, and sf_2 is safety factor additional a key on the shaft. To find out the diameter size of the shaft to be used, calculate using equation (9), where T is the torque of motor (kgmm), τ is the shear stress material (kg/mm^2), and d is the diameter shaft (mm) (Khurmi and Gupta, 2005):

$$T = \frac{\pi}{16} \cdot \tau \cdot d^3 \quad (9)$$

2.3.5. Heating & solar panel planning

In this seaweed draining and drying machine, a heating element is required as a source of heat to aid in the drying process. The heating element functions by converting electrical energy into heat energy. The market-available products specify a heating element with dimensions of 400 mm in length and 20 mm in diameter, a maximum temperature of 280 °C, a voltage of 220 V, and a required power of 250 W. The drying process of seaweed in previous research required a temperature between 45 and 75 °C until the seaweed was completely dry (Setiawan, Jaya and Hestirianoto, 2011; Golberg *et al.*, 2021; Setiawan, 2023). Several components in this machine, including the electric motor and the heater, utilize electrical energy (see Table 1).

Table 1. Power requirement on machine.

No	Component	Required Power (Watt)	Number of Components	Total Power (Watt)
1	Electric motor	745	1	745
2	Heater	250	2	500
	Total Energy Required Tool			**1245**

The data in Table 1 shows that the machine needs 1245 W total electrical energy. The machine runs its electric motor and powers its integrated heater from this electrical energy. Alfith et al. reported that Indonesia has an average daily solar radiation intensity of 4.8 kWh/m^2 year-round, indicating significant potential for effective utilization (Alfith *et al.*, 2023).

The capacity requirement of solar panels is determined by the amount of energy (kWh) needed by the load during a specific period, as well as the level of solar radiation at the location. Various factors can affect the efficiency of the panels, such as temperature, inverters, batteries, and others. Therefore, the calculation results obtained in the field need to be corrected with a derating factor of approximately 67%.

The draining and drying machine were developed to utilize hybrid energy sources, integrating a diesel engine with solar panels. Equation 10 calculates the amount of solar panels needed to optimize the machine's performance:

$$PV_{area} = \frac{EP}{G_{av} \times \eta_{pv} \times TCF \times \eta_{out}} \quad (10)$$

Where PV_{area} is the Solar panel array area (m^2), EP is energy consumption (kWh), G_{av} is average daily solar insolation (kWh/m^2), η_{pv} is solar panel efficiency (MC1100 model), TCF is the temperature correction factor, and η_{out} is inventer efficiency (SDA-2000A model).

The generated power can be calculated using equation (11). Where *P (Watt Peak)* is the generated power and *PSI* is Peak Solar Insolation = 1000 W/m^2 (Setiawan, Jaya and Hestirianoto, 2011; Alfith *et al.*, 2023).

$$P\ (Watt\ Peak) = PV_{area} \times PSI \times \eta_{pv} \quad (11)$$

Equation (12) is used to calculate the number of solar panels needed in the design of a hybrid-powered seaweed draining and drying machine, based on the results of the power calculation:

$$N = \frac{P\ (Watt\ Peak)}{P_{mpp}} = \frac{P\ (Watt\ Peak)}{V_{mp} \times I_{mp}} \quad (12)$$

Where N is the number of solar panels (panel), P_{mpp} is the maximum power output of solar panels (Watt), V_{mp} is the Maximum voltage output of solar panels MC1100 model (Volt), and I_{mp} is the Maximum current output of solar panels MC1100 model (Ampere).

2.3.6. Drying time planning

Physical characteristics such as color, moisture content, and impurities can assess the quality of dried seaweed. The moisture content of fresh seaweed varies between species, but on average it reaches 95% (Salim and Ernawati, 2015). Meanwhile, dried seaweed suitable for marketing should have a maximum moisture content of 35% (Salim and Ernawati, 2015). To estimate the yield obtained during the drying process, a tool with a capacity of 50 kg can be used, which can be calculated using equation 13 (Putra *et al.*, 2024):

$$Moisture\ Content = \frac{wet\ seaweed\ weight - dry\ seaweed\ weight}{wet\ seaweed\ weight} \times 100\% \quad (13)$$

Equation 14 can be applied to determine the drying rate of seaweed during the draining and drying procedure in one hour (Putra *et al.*, 2024). Where X is the mass of steam (kg), t is the drying time (hours), M_s is the weight of dry material (kg), and A is the drying surface area (m^2).

$$Drying\ rate = \frac{M_S.X}{A.t} = \frac{M_S.X}{(\pi.D.h)t} \quad (14)$$

2.3.7. Simulation of design strength

A simulation of load testing was carried out during the planning phase to assess the tool's strength and evaluate its durability. The loading simulation aims to evaluate the structural strength of the filtering component of frame and the shaft responsible for transmitting rotation from the motor to the filtering container. The selection of these two components is based on their capacity to bear the most significant load during tool operation. The frame supports loads from multiple components positioned above it, such as the cover, heater, and filtering container, in addition to the weight of the wet seaweed intended for filtration and drying. In the interim, the shaft supports the torque load while facilitating the rotation and movement of the filtering container.

2.4. Detail Design

Using the Pahl and Beitz methods, a design concept and selection of materials in accordance with the weighting values were determined (Pahl and Beitz, 2013). During the detailed design phase, assess the layout of product components, along with their shape, dimensions, and materials.

3. RESULTS AND DISCUSSION

3.1. Planning and Clarifying the Task

Table 2 shows the results of assessing the requirements of prospective customers or users of the hybrid energy seaweed draining and drying machine.

Table 2. List of identification requirements and needs.

Requirements	Demand (D) /Wishes (W)	Results Identification
Energy	D	Electricity/Solar panels/ Fossil
	D	Economical
Maintenance	D	Easy to operate
	D	Easy to maintain
	D	Easy to get parts
	W	Affordable production cost
Manufacture	W	Easy to make
	D	Easy to install (portable)
Material	D	Stainless
	D	Strong and Light
Safety	D	Mechanism does not harm
	D	Safe to use in the environment
Ergonomic	W	Size is not too big

One more important difference between demands and wishes is that evaluation only looks at versions that have met the demands, while selection of solutions rests on meeting the wishes. Before implementing a particular solution, it is essential to create a list of requirements and preferences, subsequently categorizing both quantitative and qualitative factors in a tabular format (Suwandi *et al.*, 2021).

3.2. Conceptual Design

3.2.1. Overall function

The overall functional structure illustrates the connection between the input and output of the hybrid energy-using seaweed draining and drying machine, subsequently revealing the primary structure required for its operation.

Figure 2 shows the main function of the draining and drying machines with hybrid energy. The input energy (Ei) is made up of electrical energy and fossil energy, and the output energy (Eo) is made up of mechanic energy and thermal energy. Furthermore, the input material (Mi) in the form of wet seaweed after the draining and drying process will produce output material (Mo) in the form of dried seaweed. The input signal (Si) is in the form of an "on" button, while the output signal (So) is in the form of an "off" button.

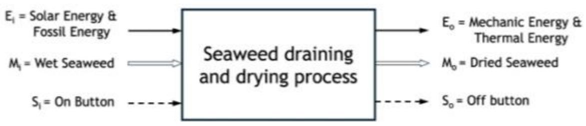


Figure 2. Overall function.

3.2.2. Sub-functions

The objective of the analysis procedure for this subfunction is to gain a more comprehensive understanding of each parameter and its role in the overall function structure. To identify potential issues and determine the appropriate solution, a thorough analysis is conducted, which involves the consideration of combinations of existing sub-functions. This process will help make the general function better and more effective. Furthermore, it is possible to make more precise and organized decisions when designing or modifying associated function structures with the assistance of comprehensive parameters. Accordingly, this sub-function analysis is a necessary step to make sure that the whole function structure works well and easily (see Figure 3).

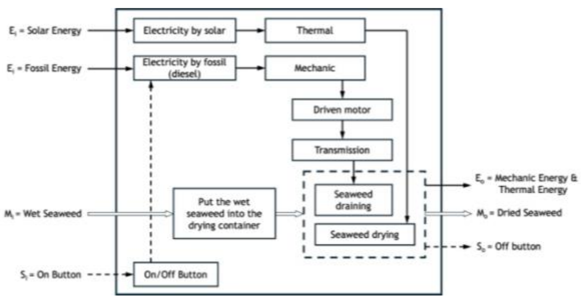


Figure 3. Sub-functions.

The main source of energy (E_i) is either diesel or electrical. Under clear sky, solar energy can run the seaweed draining and drying machine. On the other hand, we can make use of alternate energy sources including electrical and fossil fuels, which create both mechanic and thermal energy, in the case of overcast conditions. Rotating the filtering container in the transmission system using mechanic energy, the motor driver separates the water content from the seaweed washing process (Putra *et al.*, 2024). At the same time, the drying machine heats the seaweed using thermal energy, which makes sure that all the water evaporates properly. Moreover, the process of filtering and drying converts the input material (M_i) into wet seaweed, therefore generating dried seaweed as the product material (M_o). Input signal (S_i) and output signal (S_o) are produced by mechanic signals when the switch is "on' and "off".

3.2.3. Combinations of principles

A complete solution explanation, called system synthesis, involves principal integration. The functional structure demonstrates logical and physical linkages between significant or beneficial sub-functions, which underpins this integration. The biggest problem is guaranteeing the integrated principles' physical and geometrical compatibility to ensure energy, material, and signal flow (Suwandi *et al.*, 2021). Finding cost-effective and technically sound combinations of principles is another challenge.

Sub-function solutions encompass three distinct variations in form, material, or device operation, where sub-function components such as energy sources, drive motors, power transfer types, rotational reduction types, iron profiles for device frames, container materials, shaft types, bearing types, and container profiles are incorporated. The solution variations do not include other supporting components, as each variation necessitates their adjustment, thereby eliminating the need for additional solution variations.

The Morphological Chart or combinations of principles of the solutions for the seaweed draining and drying machine are illustrated in Table 3. Table 3 shows that the variant solution principal combination comes three different model, such as:

Variant 1: 1.1-2.2-3.1-4.1-5.1-6.2-7.1

Variant 2: 1.2-2.1-3.3-4.3-5.3-6.1-7.3

Variant 3: 1.3-2.3-3.2-4.2-5.2-6.1-7.1

Table 3. Combinations of principles of the solutions for the seaweed draining and drying machine.

No	Sub Function	Solution 1	Solution 2	Solution 3
1	Container draining and drying	Rectangle	Cone	Cylindric
2	Energy source	Electricity	Solar energy	Solar energy + Electricity
3	Tools stand (frame)	Elbow	Hollow	Pipe
4	Power Transmission	Chain	Belt	Gears
5	Rotary reduction	Sprocket	Pulley	Gears
6	Transfer rotary power	Solid Shaft	Hollow Shaft	
7	Supports the shaft	Ball Bearing	Roller Bearing	Tapper Bearing

V3 V1 V2

Figure 4 shows Variant 1, which applies a square profile model to the structure of the strainer and dryer container. Solar energy serves as the energy source. The support profile or frame of the device is L-shaped. The power transmission mechanism uses a chain with a sprocket as a rotation reducer. For rotational power transmission, Variant 1 uses a hollow shaft with bearings supporting the shaft using roller bearings.

Variant 2 (see Figure 5) utilizes a cone shape as a strainer and dryer container. Electricity functions as the energy source that drives the entire machine mechanism. The machine uses a specific type of pipe as its support profile or frame. Gear pairs are used for power transmission and rotation reduction. In Variant 2, the solid shaft functions as the power transmitter, and taper bearings provide the supporting roller bearings for the shaft.

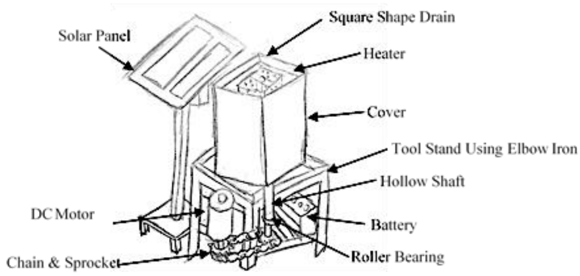


Figure 4. Concept sketch of Variant 1.

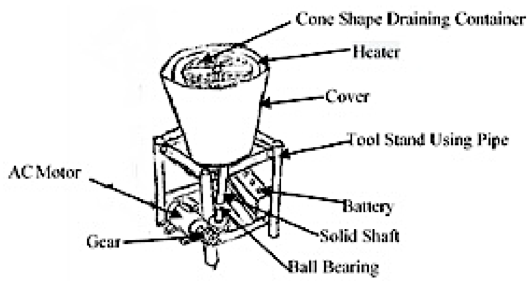


Figure 5. Concept sketch of Variant 2.

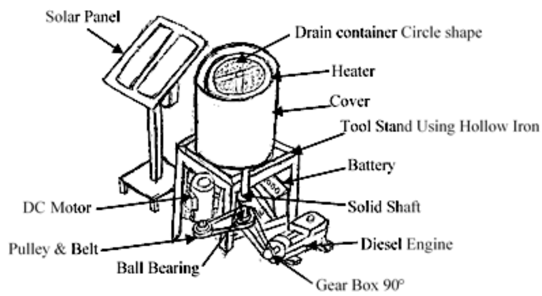


Figure 6. Concept sketch of Variant 3.

Figure 6 illustrates Variant 3, where a diesel engine and an electric motor serve as the driving motors for the seaweed draining and drying machine. This variant uses pulleys and belts to rotate the transmission from the driving source. Pulleys are utilized to facilitate more efficient and cost-effective procurement, thereby minimizing rotation. The belt operates seamlessly during the power transfer, ensuring a quiet transmission of rotation from the motor to the container rotation shaft. A solid shaft equipped with ball bearings is utilized to enhance the smoothness of rotation, and it is easily accessible in the market at a reasonable cost.

For added strength compared to other variants, the tool supports a hollow iron profile, while the dryer container utilizes a round stainless-steel profile for more hygienic seaweed processing. However, the cost is relatively high due to the suitability of stainless steel for food materials, and the availability of round-profile containers on the market simplifies the manufacturing process. Variant 3 utilizes a solar panel to transform sunlight into electrical energy, storing it in batteries for powering the electric motor and heating the device, thereby reducing the dryer's reliance on the national grid and fossil fuels.

3.2.4. Objectives tree

The selection of conceptual solutions is a critical step in initiating the concrete design phase of a project. This process often necessitates organizational and personnel changes to adapt to evolving project requirements. It is imperative to integrate suitable work structures into the various conceptual solutions and conduct a thorough evaluation at the conclusion of the conceptual design phase to facilitate product development. One must select a single concept, or a select few, from a multitude of proposed variants to proceed to the next stage. Only after adequately preparing the principal solution for evaluation can one make this decision, which carries significant responsibility. This may involve representing the solution through preliminary sketches and basic calculations (Pahl and Beitz, 2013; Suwandi *et al.*, 2021).

Following a thorough examination of possible solutions (see Table 3), it is essential to perform an in-depth analysis in relation to the requirements outlined in Table 2. The evaluation criteria are carefully assessed through the objective tree method, as shown in Figure 7.
This weighting procedure considers the importance of each criterion in influencing the project's success. By employing the objective tree approach, each evaluation aspect receives a proportional weight based on its importance. As a result, the weighting process produces more accurate and unbiased evaluation results, enabling well-informed decision-making and alignment with intended goals. Furthermore, this approach aids in identifying essential priorities for successfully reaching project objectives.

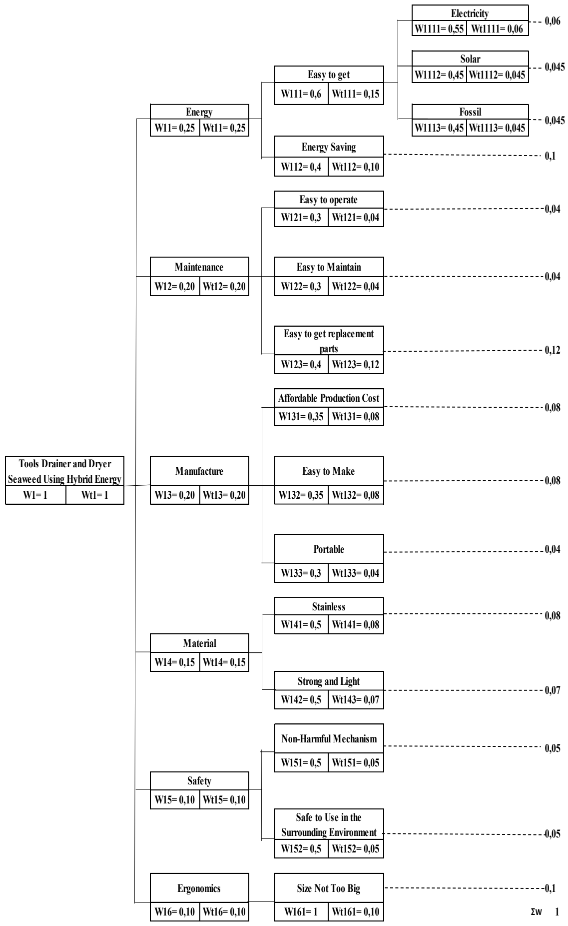


Figure 7. Objective tree.

3.2.5. Evaluation concept variant

The objective tree (see Figure 7) developed to determine the weighting of each essential evaluation criterion was utilized in assessing the various iterations of the solution derived from the Morphological Chart in Table 3 for the initial seaweed draining and drying.

The summarized weighting value is presented in an evaluation table, which will identify the solution variations to be utilized in the implementation of the seaweed draining and drying machine that possess the highest weighting value. The subsequent table assesses the different variations of hybrid energy seaweed draining and drying machine solutions.

Table 4. Evaluation of weighting variant solutions.

No.	Evaluation Criteria	Criteria Weight (Wt)	Parameter	Variant 1			Variant 2			Variant 3		
				Magnitudes	Value	Weighted Value	Magnitudes	Value	Weighted Value	Magnitudes	Value	Weighted Value
1	Electricity	0.06	Energy	High	9	0.54	High	9	0.54	Average	7	0.42
2	Solar	0.045	Energy	High	9	0.405	High	9	0.405	Average	7	0.315
3	Fossil	0.045	Energy	Low	5	0.225	Low	5	0.225	High	9	0.405
4	Energy Saving	0.1	Energy	Average	8	0.8	Average	7	0.7	High	9	0.9
5	Easy to operate	0.04	Design	Average	7	0.28	Average	8	0.32	Average	7	0.28
6	Easy to Maintain	0.04	Design	Average	8	0.32	Average	8	0.32	Average	7	0.28
7	Easy to get replacement parts	0.12	Cost	Average	7	0.84	Average	7	0.84	Average	8	0.96
8	Affordable Production Cost	0.08	Cost	Average	7	0.56	Average	8	0.64	Low	6	0.48
9	Easy to Make	0.08	Time and Cost	Average	6	0.48	Low	8	0.64	Average	7	0.56
10	Portable	0.04	Design	Average	8	0.32	Average	7	0.28	High	9	0.36
11	Stainless	0.08	Design	Average	8	0.64	Average	7	0.56	High	9	0.72
12	Strong and Light	0.07	Design	Average	7	0.49	Average	7	0.49	Average	8	0.56
13	Non-Harmful Mechanism	0.05	Performance	Average	7	0.35	Average	8	0.4	High	9	0.45
14	Safe to Use in the Surrounding Environment	0.05	Performance	Average	8	0.4	Average	7	0.35	High	9	0.45
15	Size Not Too Big	0.1	Design	Average	8	0.8	Average	8	0.8	Low	6	0.6
	TOTAL	1				7.45			7.51			**7.74**

Table 4 shows that the selected solution will be variant 3, which has the greatest weighted value of 7.74. By adopting a cylinder shape as the strainer and dryer container, Variant 3 shown in Figure 6 gives the impression of a larger capacity. Even though the diesel engine generates the electricity, the combination of electricity and solar energy sources creates its own unique advantage. The machine frame, which supports all components, uses a hollow profile. The machine uses pairs of pulleys and belts for power transmission and rotation reduction, while a solid shaft transmits power from the pulley to the container and the diesel engine. Variant 3 uses ball bearings to support the shaft.

3.3. Embodiment Design

By employing embodiment design, the product will achieve a sufficient level of detail, facilitating a seamless and effective production process. Each element of the design will be meticulously evaluated, encompassing choices of materials and the methods of production. Consequently, the subsequent detailed design phase can advance smoothly and transition directly into mass production. The design of embodiment is essential in guaranteeing that the final product aligns with established quality benchmarks and fulfils consumer requirements. This stage establishes a robust basis for the product's success in the market.

The Component specification calculation results from design of container dimensions, required diesel power motor, belt and pulley planning, shaft and bearing palnning, heating and solar panel planning, and drying time planning are summarized in Table 5.

To smooth the rotation of the shaft, it is necessary to use bearings that are suitable for the predetermined shaft size, which means providing a bearing on the shaft with an inner diameter of 30 mm. Khurmi and Gupta recommend using bearing number 306, which has an outer diameter of 72 mm and a width of 19 mm (Khurmi and Gupta, 2005).

Table 5. Calculation results.

Item	Parameter	Equation
Container dimensions	• Container volume (*V*) = 57.4 l	(1)
	• Radius container (*r*) = 191 mm	(2)
	• Diameter container (d) = 382 mm	(3)
Power motor	• Torque of motor (*T*) = 10.5 kgm	(4)
	• Minimum motor power (P_{min}) = 0.7 hp (1 hp available in the market)	(5)
Belt and pulley	• Container pulley diameter (D_p) = 210 mm (market standards, manufacturers implement a pulley outer diameter of 228.6 mm or 9 inches (SKF, 2024))	(6)
	• Length of the belt circumference (*L*) = 1380 mm	(7)
Shaft and bearing	• Shear stress material (τ) = 3.172 kg/mm^2	(8)
	• Diameter shaft (d) = 26 mm (standard shaft diameter size available in the market, specifically 30 mm)	(9)
Heating and solar panel	• Solar panel array area (PV_{area}) = 2,337 m^2	(10)
	• Generated power ($P_{(Watt\ Peak)}$) = 373.92 Watt	(11)
	• Number of solar panels (*N*) = 4 panels	(12)
Drying time	• Dried seaweed weight = 32.5 kg	(13)
	• Drying rate = 29.3 kg/m^2 hour	(14)

To align with what is available in the market, it is determined that the type of bearing to be used is a single-row deep groove ball bearing.

Simulation of design strength will implement a static loading simulation, employing the static loading technique alongside the simulation capabilities of SOLIDWORKS software. The simulation process will consider the maximum load that could be applied to the component, as static loading preserves a consistent magnitude, direction, and point of application. For the frame, hollow iron material is widely sold in the market with a size of 30 x 30 x 2 mm and galvanized iron material.

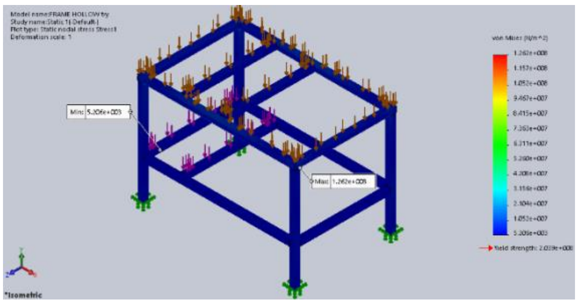


Figure 8. Stress simulation in the machine frame.

The highest and lowest stress values obtained on the stand after a static loading simulation are as shown in Figure 8. The highest stress is 126.223 N/mm^2, and the minimum stress value that occurs on the stand is 0.520607 N/mm^2. Table 6 shows the static loading simulation results for the frame.

Table 6. The static loading simulation results for the frame.

Variable	Results	
	Maximum	Minimum
Stress (N/mm^2)	126.223	0.520607
Displacement (mm)	0.186724	0
Strain	0.000237256	2.95747 x 10^{-8}
Safety factor	2	1.61574

Figure 9. Stress simulation of shaft.

Use readily available materials for the shaft, ensuring it has a diameter of 30 mm and an approximate length of 880 mm, using S45C8 steel. The highest and lowest stress values obtained on the shaft after simulating static torsion loading are as shown in Figure 9, the highest stress is

66.83 N/mm^2, and the minimum stress value that occurs on the shaft is 0.00000242986 N/mm^2. Table 7 displays the results of the static loading simulation on the shaft.

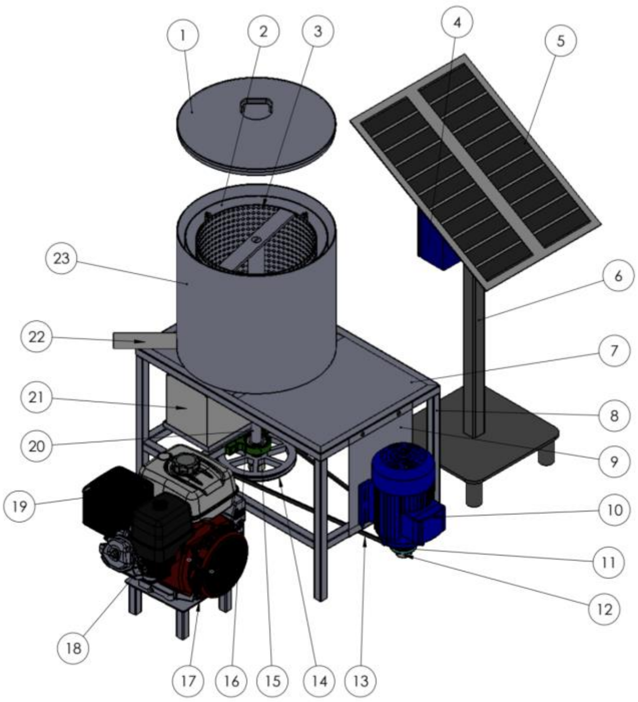
Table 7. Static loading simulation results on shaft.

Variable	Results	
	Maximum	Minimum
Stress (N/mm^2)	66.83	0.00000242986
Displacement (mm)	0.0984932	0
Strain	0.000234662	1.11916 x 10^{-11}
Safety factor	1.44041 x 10^8	1.44041 x 10^8

3.4. Detail Design

The following is shown in Figure 10, a 3D model concept design of a hybrid-powered seaweed draining and drying machine. Variant 3 is a unique and innovative design that utilizes a cylinder shape as the strainer and dryer container (see Figure 10). This design gives the impression of a larger capacity (50 kg), making it ideal for processing larger quantities of wet seaweed. One of the standouts features of Variant 3 is its utilization of both electricity and solar energy sources. Although a diesel engine may generate the electricity, the addition of solar energy enhances the machine's sustainability and environmental friendliness.

Variant 3 designs the machine frame to support all components, utilizing a hollow profile for added strength and durability. The pulley and belt pairs, along with a solid shaft acting as the power transmitter from the pulley to the container and diesel engine, achieve power transmission and rotation reduction. This ensures smooth and efficient operation of the machine. Variant 3 uses ball bearings to support the shaft, which provides stability and reduces friction during operation. This choice of bearing further enhances the overall performance and longevity of the machine.



Part Name:
1. Container cover
2. Heater assembly
3. Drain container
4. Control panel
5. Solar panel
6. Solar panel stand assembly
7. base plate for Container
8. Frame assembly
9. Bracket plate for AC motor
10. AC motor
11. Drive pulley
12. Nut M30
13. Belt
14. Transmission pulley
15. Pillow block
16. Bearing
17. Base plate for diesel motor
18. Diesel motor
19. Gear box
20. Shaft
21. Battery
22. Drainage channel
23. Container

Figure 10. 3D model design of seaweed draining and drying machine.

4. CONCLUSION

Based on the weight evaluation table for variant solution variations for seaweed draining and drying machine using hybrid energy, the selected design is variant 3 with the highest weight value of 7.74 obtained from the questionnaire results

This machine can draining and drying seaweed up to 50 kg per process with specifications including: Solar panels for energy (3 MC1100, 100 WP each); Electric motor (1 Hp, 745

W, 1400 rpm) and diesel engine (3.5 Hp, 2.6 kW, 3600 rpm); Container dimensions of 382 mm diameter and 500 mm height; Pulley and belt transmission system with drive pulley (85 mm) and transmission pulley (250 mm); Shaft dimensions (30 mm diameter, 880 mm length) made of S45C8 Steel. The calculation results to plan the drying rate of seaweed with a wet seaweed capacity of 50 kg per hour are 29.3 kg/m² per hour.

Simulation results show safe static load values for both the frame (safety factor of 1.615) and shaft (safety factor of 1.440). Maximum stress values do not exceed material yield strengths (203.943 N/mm² for frame, 350 N/mm² for shaft). Frame made of galvanized steel has a max working stress of 126.223 N/mm², while shaft made of S45C8 material has a max working stress of 66.83 N/mm² after load.

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