Design Analysis of Biomass Furnace in Seaweed Drying Machine

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Abstract: Seaweed cultivation is the choice of many people in coastal areas as their additional income. One of seaweed processing to have added value is by a drying process, which has been done by sun drying. The problem occurs when the rainy season comes, so that sun drying can no longer be done. Biomass is one of the abundant alternative energy which is easy to obtain, so it is suitable for the drying process of seaweed during the rainy season. This study aims to analyze the design of biomass furnace in the seaweed drying machine, especially volume, surface area, material selection, fuel consumption, and its testing. The method of calculating the dimensions, volume, and area of the biomass furnace, used is reverse engineering. While the method for material selection is done qualitatively, the result of this research is that the biomass furnace had a dimension of furnace volume as 0.531229 m³, the combustion chamber volume was 0.141229 m³, and the surface area of the furnace was 1.9 m². The best material chosen is mild steel material. The testing of biomass furnace was carried out for 5 times, with the result of temperature produced was 72°C, 74°C, 70°C, 71°C, and 70°C. Since the outcome temperature was still within the allowable range of 60 - 90°C, the furnace can be used for the drying process.

1. Introduction

One of the natural sources from the coastal area is seaweed. Seaweed cultivation becomes choice of society in the coastal area to increase the income. One of the seaweed processing, in order to add its economic value, is by drying, which is done conventionally by sun drying which needs drying time up to 4 days. The problem occurs when the rainy season comes so that the drying can no longer be conducted. The artificial drying process by using a machine is one of the solutions to overcome this problem so that it is still possible to conduct drying process despite the rainy season. The drying machine available in the market mostly uses fossil fuel, natural gas, and electricity, in which by using that kind on the machine it will increase production cost. Biomass is one of the alternative energy that is abundantly available, low cost and easily obtained so that it is suitable to be used as energy source for seaweed drying process in the rainy season.

The study related to biomass [1] and seaweed processing machine other than seaweed drying process with biomass furnace are seaweed boiler [2], meanwhile the result of the study related to biomass furnace using heat exchanger by a linear tube with the material of stainless steel as 64 pieces with the length of 0.65 m [3].

Meanwhile previous study related to the design of the biomass furnace of seaweed drying machine has been done with the result of biomass furnace using rice husk, the furnace has dimension of 700 mm x 700 mm x 1200 mm and burning room with the dimension of 600 mm x 650 mm x 1000 mm, furnace room volume as 0.39 m³ and air room volume used as 0.141229 m³, furnace room wall as the heat exchange medium using the material of mild steel with the surface area of 1.9 m² and wall thickness as 4 cm and the capacity of air blown by the fan is 4053.6 CMH [4].

This research is genuine and have not been done previously which has a more specific purpose to analyze biomass furnace design in the seaweed drying machine, specifically the volume, surface area, material selection, fuel consumption, and its testing.

2. Methodology

In general, the design method used is Pahl and Beitz method, which stated that the design is a process of creativity but it is not systematically directed therefore the probability to produce the result of design through the creativity will be limited [5]. The method of calculating dimension, volume and surface area of the furnace, is reverse engineering, in which the first thing to do to do is to calculate the dimension from the furnace itself, the size of the furnace shows the amount of biomass used, meanwhile the method to select the material is conducted qualitatively, which is the selection of material by selecting in accordance with the criterion required in order to ensure that the material selected can support the performance of the furnace and seaweed drying.
machine. Meanwhile, in the stage of testing biomass furnace, it has several procedures those are: preparing the furnace which would be tested, load the furnace with biomass as the fuel, to plug the blower, to burn the biomass in the furnace, the temperature produced will be flown up to 70 °C up to 90 °C.

3. Results and Discussion

3.1. Calculation of biomass furnace volume design

The first step to do is to calculate the dimension from the combustion chamber, the dimension of the furnace depends on the biomass volume used. The calculation or drying room using the principle of Reverse Engineering.

Technical data:
- \( S_0 = 0.7 \) m (designed)
- \( S_1 = 0.15 \) m (designed)
- \( 1/2 S_0 = 1/2 \times 0.7 \) m = 0.35 m
- \( 1/2 S_1 = 1/2 \times 0.15 \) m = 0.075 m
- slope angle 35.88° (designed)

Figure 1. Calculation of biomass furnace volume.

Figure 1 illustrates coordinate points and sectors from biomass furnace so that it will ease calculation of biomass furnace volume required.

3.1.1. Calculation of volume (ABCD.EFGH)

\[
\text{Volume ABCD.EFGH} = \text{length x width x height} \quad (1)
\]

\[
\text{Volume ABCD.EFGH} = AB \times BC \times CG = S_0 \times S_0 \times CG
\]

\[
\text{Volume ABCD.EFGH} = 0.7 \times 0.7 \times 1 \text{ m} = 0.49 \text{ m}^3
\]

3.1.2. Height calculation (OP)

\[
OP = OR - PR \quad (2)
\]

\[
\tan 35.88 = OR/OX
\]

\[
OR = \tan 35.88 \times OX = 0.723 \times 0.35 \text{ m} = 0.25305 \text{ m}
\]

\[
PR/\ OR = 1/2 \ S_1/ \ \ 1/2 \ S_0
\]

\[
PR = \frac{1/2 \ S_1 \times OR}{1/2 \ S_0} = \frac{0.075 \times 0.25305 \text{ m}}{0.35 \text{ m}} = 0.05422 \text{ m}
\]

\[
OP = OR - PR = 0.25305 \text{ m} - 0.05422 \text{ m} = 0.19883 \text{ m}
\]
3.1.3. Calculation of volume (EFGH.IJKL)

\[ \text{Volume EFGH.} R = \frac{1}{3} \text{surface area of base } \times \text{height} \quad (3) \]

Volume EFGH. \( R = \frac{1}{3} S_0^2 \times \text{OR} = \frac{1}{3} \times 0.7^2 \times 0.25305 \, \text{m} = 0.0413315 \, \text{m}^3 \)

Volume IJKL. \( R = \frac{1}{3} \text{surface area of base } \times \text{height} \quad (4) \)

Volume IJKL. \( R = \frac{1}{3} S_1^2 \times \text{PR} \)

Volume IJKL. \( R = \frac{1}{3} \times 0.075^2 \times 0.05422 \, \text{m} = 1.016625 \times 10^{-4} \, \text{m}^3 \)

\[ \text{Volume EFGH. IJKL} = \text{Volume EFGH.} R - \text{Volume IJKL.} R \quad (5) \]

Volume EFGH. IJKL = 0.0413315 m\(^3\) – 1.016625 x 10\(^{-4}\) m\(^3\) = 0.041229 m\(^3\)

Hence the volume of biomass furnace is the volume of ABCD.EFGH + Volume EFGH. IJKL = 0.49 m\(^3\) + 0.041229 m\(^3\) = 0.531229 m\(^3\)

3.2. Calculation of combustion chamber volume design

The first step to do is to calculate the dimension from the combustion chamber, the dimension of the furnace depends on the biomass volume used. The calculation or drying room using the principle of Reverse Engineering.

![Figure 2](image)

Figure 2. Calculation of biomass combustion chamber volume.

Figure 2 illustrates coordinate points and sectors of furnace combusting chamber so that it ease calculation of hot air chamber volume used.

Technical data:
- \( S_0 = 0.6 \, \text{m (designed)} \)
- \( S_1 = 0.65 \, \text{m (designed)} \)
- \( S_2 = 1 \, \text{m (designed)} \)

Calculation of volume (ABCD.EFGH)

\[ \text{Volume ABCD. EFGH} = \text{length } \times \text{width } \times \text{height} \quad (6) \]

\[ \text{Volume ABCD. EFGH} = AB \times BC \times CG = S_0 \times S_1 \times S_2 \]

\[ \text{Volume ABCD. EFGH} = 0.6 \, \text{m} \times 0.65 \, \text{m} \times 1 \, \text{m} = 0.39 \, \text{m}^3 \]

Hence the volume of hot air used is 0.531229 m\(^3\) – 0.39 m\(^3\) = 0.141229 m\(^3\)
3.3. Selection of Material biomass furnace

3.3.1. Type of material
Biomass furnace of seaweed drying machine using biomass as the fuel such as rice husk and wood, thus it needs strong material and heat resistance, such as stainless steel, mild steel or aluminum. The next step is from those materials it will be selected based on the demand.

3.3.2. Evaluation of biomass furnace material selection criterion
There are several criteria have to be fulfilled in the selection of the material of drying chamber wall, in order to make the wall of drying chamber can support the performance of drying machine considered from the performance and cost.
- Strong and durable: wall material of the wall have to be strong and fire resistance
- Production: the material of biomass furnace should be easily produced
- Assembly: the material of biomass furnace can be easily ensemble
- Cost: low material cost, in order to keep the production cost low

By considering the criterion evaluation, the material selection is the material which can fulfill the criteria above.

3.3.3. The consideration of biomass furnace material selection
- Stainless steel; Stainless steel has the highest heat treatment compared to mild steel and aluminum which is up to 1421 °C, this material is strong enough to fill the criterion, but it is the most expensive one.
- Mild Steel; Mild steel has heat treatment up to 343 °C. This material is strong enough to fill the criterion, and it is the lowest cost compare to mild steel and aluminum.
- Aluminum; Aluminum has heat treatment up to 660,3 °C. This material is strong enough to fill the criterion, but this material is hard to be in manufacturing.

3.3.4. Selected Material
Based on the evaluation of material selection criteria and consideration of biomass furnace materials selection, mild steel material is selected as a combustion chamber material. Mild steel material is chosen because it meets the following criteria:
- Strong and durable: Mild steel material is strong enough and can heat resistant.
- Production: Mild steel material can be produced easily.
- Assembly: Mild steel material can be easily ensemble.
- Cost: Material cost is low, so it is possible to reduce the cost of making it.

3.4. Testing of Biomass Furnaces
Tests were carried out on manufactured biomass furnaces, and test results in biomass furnaces obtain the following results:

<table>
<thead>
<tr>
<th>No.</th>
<th>Testing</th>
<th>Output Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>First testing</td>
<td>72</td>
</tr>
<tr>
<td>2</td>
<td>Second testing</td>
<td>74</td>
</tr>
<tr>
<td>3</td>
<td>Third testing</td>
<td>70</td>
</tr>
<tr>
<td>4</td>
<td>Forth testing</td>
<td>71</td>
</tr>
<tr>
<td>5</td>
<td>Fifth testing</td>
<td>70</td>
</tr>
</tbody>
</table>

Table 1 shows testing result in biomass furnace designed previously, from the above test results show that in the first test, the second and fourth temperature out more than 70 °C but because the output temperature is still within the allowed number of 60 - 90 °C, the furnace is used for the drying process of seaweed.
4. Conclusions

The conclusion of this research is that the biomass furnace had a dimension of furnace volume as 0.531229 m³, the combustion chamber volume was 0.141229 m³, and the surface area of the furnace was 1.9 m². The best material chosen is mild steel material. The testing of biomass furnace was carried out for 5 times, with the result of temperature produced was 72°C, 74°C, 70°C, 71°C, and 70°C. Since the outcome temperature was still within the allowable range of 60 - 90 °C, the furnace can be used for the drying process.

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References