Design and Frame Strength Evaluation of Salt Washing Unit Capacity 50 Kg/hour

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ABSTRACT – The salt washing unit is part of the salt processing machine. This unit's function is to wash raw salt with brine. This unit has a motor, agitator blade, washing chamber, and frame. The frame structure strength of the salt washing unit needs to be evaluated to ensure safety. This research aims to design the salt washing unit and obtain simulation results of frame structure strength to ensure the safety of the salt washing unit. This research was carried out by simulation to look for stress, strain, and changes in the shape of objects (displacement). The frame strength simulation was carried out using Solidwork software. The salt washing unit with a 50 kg/hour capacity has been designed. It has a cylindrical shape with 990 mm in height and 680 mm in diameter. From the simulation results of strain, it can be concluded that the minimum point is 1.80 \times 106 Mpa, and the maximum point is 1.63 \times 105 Mpa. From the simulation results of displacement, it can be concluded that the minimum point is 0 mm and the maximum point is 2,296 mm. The maximum stress is 5.254\times106 N/m², and the minimum stress point is 1.803\times106 N/m².

Introduction

Salt is an important commodity that has quite high demand throughout the year. Salt can be obtained in three ways, namely, evaporation of seawater by sunlight, salt rock mining, and from saltwater wells [1]. Based on data from the Ministry of Industry in 2021, the industrial and manufacturing sectors were the sectors that required the highest demand for salt, namely 84% or the equivalent of 3,926,044 tonnes [2]. The total national salt demand in 2021 was 4,671,700 tons, of which local salt contributed 1,593,799 tons, and the import allocation was 3,077,901 tons [3].

Indonesia has a large sea area, which has potential for development in the marine and fisheries sector. One potential that can be developed is sea salt, which is abundant. The average production of raw salt for a group of conventional salt farmers in one region of Indonesia was 239.32 kg/day [4]. The development of the sea salt industry in Indonesia has good prospects. In fact, the need for salt is predicted to continue rising along with the increasing need for direct consumption and industrial markets (food, pharmaceuticals, cosmetics, etc.) [5]

Until now, most salt production is carried out individually by salt farmers, so salt production has low productivity and relatively low quality, so it does not meet the specifications required by the domestic industry [6]. Several machines used to increase the purity of salt have been investigated. The research used a screw-type salt washer for salt has been done [7]. Several machines used to increase the purity of salt have been researched[8][9][10][11]. To become a consumption salt, impurities originating from Ca2+, SO42-, Fe3+, Mg2+, and sludge ions must be removed. Several ways that can be done to improve the quality of salt are by recrystallizing the salt and washing the salt [12]. The aim of this research is to design a salt-washing unit with a processing capacity of 50 kg/hour. This unit washes the raw salt with brine using a stirring method to dissolve impurities and increase NaCl value.

Materials and Method

A. Materials

To fulfill the purpose of the simulation and calculation, the following material criteria were needed:

1) An AC motor as a driving motor.
2) Gearbox with a ratio of 1:40
3) Blade, stainless 304 on all sides.
4) 304 stainless axes connecting the gearbox and the blade.
5) Hollow stainless steel for frame structure
6) Stainless faucet for saltwater output
7) The washing unit was made from 1 mm thick 316 stainless steel plate

B. Design of Washing Unit

The washing unit was designed to carry out the washing process of raw salt from brine using the stirring method. The blade mixer was driven by an AC drive motor. The washing chamber was designed in a cylindrical shape to guarantee a
good mixing process. The design of the salt washing unit is shown in Figure 1.

Figure 1. Salt Washing Unit

1. Inlet hole 5. Washing Chamber
2. Blade 6. Frame
3. Gearbox 7. Outlet Hole
4. Motor AC

Figure 2 is a 2-dimensional modeling form of the main structure frame. This design is a planning stage before 3-dimensional modeling. The design must include all information.

C. Calculation of Power requirement

The power requirement was calculated using the following equations

\[ T = F \times r \]  
(1)

\[ \omega = \frac{2 \pi n}{60} \]  
(2)

\[ P = T \times \omega \]  
(3)

T = Torque (N.m)
F = force (N)
r = circle radius
n = shaft rotation (rpm)
P= Power (Watt)
\omega = angular velocity (rad/s)

D. Frame Strength Simulation

The frame strength simulation was carried out using Solidwork software. Simulation analysis was performed using static features. Analysis of the simulation results of the frame strength was carried out to determine the minimum and maximum values of strain, which the level of deformation can lengthen, shorten, enlarge, and shrink. A change in the shape of an object (displacement) is the movement of material from the starting point to the endpoint after being exposed to a compressive force or load (force) from the pressing process. The tension (stress) is a reaction force that works to return an object to its original unified shape.

Results and Discussion

A salt-washing unit with a processing capacity of 50 kg/hour has been constructed, as shown in Figure 3. The washing chamber was made from material SS316 plate 1 mm thick. Frame material was constructed using hollow stainless steel. The prototype of the salt washing unit is shown in Figure 3.

A. The Dimension of Washing Chamber

The capacity of the washing chamber can be found by calculating the volume of the washing chamber. 50 kg raw salt and 50 kg brine were processed in the washing chamber. 50 kg of raw salt equals to 48.8 dm$^3$ and 50 kg of water equals to 50 dm$^3$. Hence, the total volume of material that was processed in this chamber was 98.8 dm$^3$. The design of washing chamber capacity is shown in Figure 4.
Volume A

\[ \text{Volume A} = \pi \times r^2 \times t \]
\[ = 3.14 \times 30 \, \text{cm}^2 \times 45 \, \text{cm} \]
\[ = 127.170 \, \text{cm}^3 \]
\[ = 127.17 \, \text{dm}^3 \]

Volume B

\[ \text{Volume B} = \frac{1}{3} \pi \times r^2 \times t \]
\[ = \frac{1}{3} \times 3.14 \times 30^2 \times 7 \]
\[ = 6,954 \, \text{cm}^3 \]
\[ = 6.954 \, \text{dm}^3 \]

The total capacity of the washing chamber is 127.17 dm\(^3\) + 6.59 dm\(^3\) = 133.76 dm\(^3\)

B. Power Requirement

\[ T = 100 \, \text{kg} \times 9.81 \, \frac{\text{m}}{\text{s}^2} \times 0.3 \, \text{m} \]
\[ T = 294,3 \, \text{m} \]
\[ \omega = \frac{2\pi n}{60} \]
\[ \omega = \frac{2\pi(35)}{60} \]
\[ \omega = 3,66 \, \text{j} / \text{s} \]
\[ P = 294,3 \, \text{Nm} \times 3,66 \, \text{j} / \text{s} \]
\[ = 1.078,12 \, \text{Nm/s} \]
\[ = 1,45 \, \text{HP} \]

Based on the calculation results above, it can be seen that the power required as the main driver for the salt washing machine is 1.45 HP. Based on the available motor power in the market, an electric motor with a power of 1.5 HP was used for this washing unit.

C. Frame Strength Analysis of Salt Washing Unit

The strength of the structure depends on the shape or type of construction which is used to withstand the load. The frame structure used hollow stainless steel construction because this material is not easily corroded and has characteristics that are strong and sturdy enough to support excessive loads.

<table>
<thead>
<tr>
<th>Description</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield strength</td>
<td>174 Mpa</td>
</tr>
<tr>
<td>Tensile strength</td>
<td>(5.8 \times 10^8) N/m(^2)</td>
</tr>
<tr>
<td>High</td>
<td>55 cm</td>
</tr>
<tr>
<td>Momen of inertia</td>
<td>6095 kgm(^2)</td>
</tr>
<tr>
<td>Wide</td>
<td>68 cm</td>
</tr>
<tr>
<td>Length</td>
<td>68 cm</td>
</tr>
</tbody>
</table>

Static features were examined using the finite element method to determine the stress on the material, and the structure was subject to static or dynamic loads or forces. Therefore, the strength of the washing unit frame structure could accept the workload of the components contained in the Salt Washing unit. Frame Structure Simulation with 3-dimensional software was useful to carry out the analyses to prove the validity of a construction design.
The displacement simulation of the frame structure was carried out and shown in Figure 6. It can be concluded that the minimum point of displacement of the frame structure of the salt washing unit was 0 mm, and the maximum point of displacement was 2.296 mm. Then, in the simulated design, the blue color indicates that there was no change in shape in that part, while in the designs that are green to yellow, it indicates a change in shape in that part.

![Figure 6. Simulation of displacement in frame structure](https://i.imgur.com/qQoQ0.png)

**Figure 7. Simulation of stress in frame structure**

It can be concluded from the picture above that the maximum stress of the washing unit frame structure was $5.254 \times 10^6$ N/m², and the minimum stress was $1.803 \times 10^6$ N/m². The Mixer Frame Structure, which receives the most stress in the bluish-green part, this means that it can be seen in the parameters next to the Frame Structure image, at a value of $1.755 \times 10^6$ N/m² and on the bottom surface of the Mixer Frame, at a value of $1.724 \times 10^6$ N/m².

**Conclusion**

The salt washing unit with a processing capacity of 50 kg/hour has been designed with dimensions of 990 mm in height and 680 mm in diameter. The construction consists of a washing chamber made of SS316 plate, a frame made of hollow stainless steel, and an AC motor of 1.5 HP. The simulation results show that the strain has a minimum point of $1.80 \times 10^8$ Mpa and a maximum point of $1.63 \times 10^8$ Mpa, displacement has a minimum point of 0 mm and a maximum point of 2.296 mm, and a maximum stress of $5.254 \times 10^6$ N/m² and a minimum of $1.803 \times 10^6$ N/m².

**Acknowledgments**

Thank you to the Kedaireka Matching Fund Program from the Ministry of Education, Culture, Research and Technology Indonesia and PT. Matra Kreasi Mandiri for supporting this research.

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https://doi.org/10.59097/jasae.v1i2.18


