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The Innovation Breakthrough in Digital and Disruptive Era

Computational Fluid Dynamic Analysis in Spray Dryer Design By Distillation System Of Sea Water To Salt

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Abstract. Spray Dryer is the most widely used industrial process for drying. Continuous production can be carried out in powder or powder form from liquid raw materials. The feed to some desiccant may be a liquid in which the solid will float as light particles, or it may be in the form of a solution. Some drying products are resistant to rough handling and very hot environments, but some require careful handling at low or moderate temperatures. Computational Fluid Dynamics (CFD) in a spray dryer system design uses an atomization system to convert seawater into salt. The process of analyzing several needs, regarding the function of time from worker efficiency and the results of processing seawater into salt is the focus of researchers. The results of this research process are CFD analysis on spray dryer system design, analysis of mass flow rate and heat of drying air. The results from the analysis using CFD can be concluded, namely the spray dryer design specifications are $H_s = 1500$ mm $H_k = 200$ mm, diameter = 1100 mm. While the temperature of the hot air entering is 130°C and the pressure to the nozzle is 12.849 psi. The Spray Dryer as a result of the design planning is capable of producing 0.36 kg salt/hour with a seawater requirement of 10.25 kg. The results of the simulation of the inflow of hot air fluid and seawater spray on the nozzle, show the level of homogeneity of the mixture, this can cause seawater particles to separate, one of which is NaCl or salt. System efficiency is at 80% based on the mass of seawater processed to become salt.

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1 Introduction

Drying is a mass and energy transfer event that occurs in the separation of liquid or moisture from a material to a specified water content limit by using gas as the heat source fluid and liquid vapor receiver [1],[2]. Food drying serves two main purposes. The first purpose is as a means of preserving food [3]. Microorganisms that cause food spoilage cannot thrive and survive in environments with low moisture content[4]. In addition, many of the enzymes that cause chemical changes in food cannot function without the presence of water[5], [6]. The second objective is to minimize the cost of distributing foodstuffs because dehydrated foods will have a lower weight and smaller size[7].

The spray drying method is a method for producing dry powders from liquids or solutions with hot gases[8]. This method is most widely used in the processing of heat sensitive products such as food and medicine[9]. This method is capable of producing products in the form of powder or powder from ingredients such as milk, fruits and others[10].

Spray dryer is a form of drying that has been widely applied in the processing industry, especially the powdered food and beverage processing industries [11]. This method will affect the total solid material produced through the atomization process [12]. High drying air temperature will produce products with low moisture content and high total solids. In drying using a spray dryer, the fluid material will be atomized into small particles (droplets) to expand the surface or contact area of the fluid [13], [14]. Furthermore, the fluid particles will be contacted with hot air in a relatively short time to evaporate the water content.

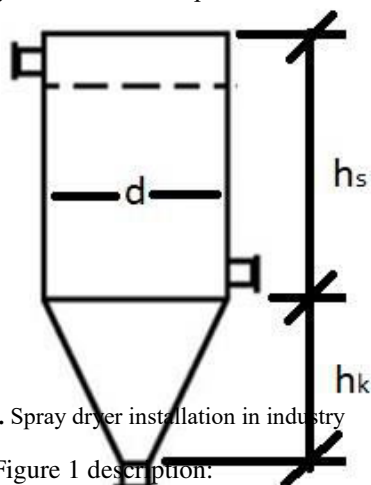


Fig 1. Spray dryer installation in industry

Figure 1 description:

1. Compressor 750 W / 220 V
2. Framework
3. Drain faucet
4. Material tank
5. Pressure gas input
6. Transfer hose
7. Atomizer
8. Heater
9. Blower
10. Control panel

11. Output material
12. Cyclone
13. Dryer tube
14. Spy window

Seawater generally has an average salt content of 34.5%. This means that one liter of sea contains 34.5 gram of salt [15]. The salt content contained in seawater is called seawater salinity. Salinity is defined as the weight in grams of all solids dissolved in kilogram of seawater if all bromine and iodine are replaced with chlorine in an equivalent amount, all carbonate is converted to oxidation and all organic matter is oxidized[16]. Salinity values expressed in g/kg are generally written in ‰ which means parts per thousand (ppt). The level of salinity of seawater determines the density of seawater. Density increases with increasing salinity and decreasing temperature. Meanwhile, seawater temperatures range from 18.7°C to 42°C. Based on the results of research on the composition of salt in seawater since 1859, it was explained that seawater has the same salt composition ratio for almost all waters in the world. In general, sea water has a salinity level of 35‰ or better known as standard sea water [14].

The dimensions of the spray dryer tube determine the planning in placing the system. This of course must be adapted to the general arrangement of fishing vessels which are the object of research, so that system planning does not interfere with the fishing process or activities while at sea. In this study, the design of the Spray Dryer tube is planned to have the following dimensions:

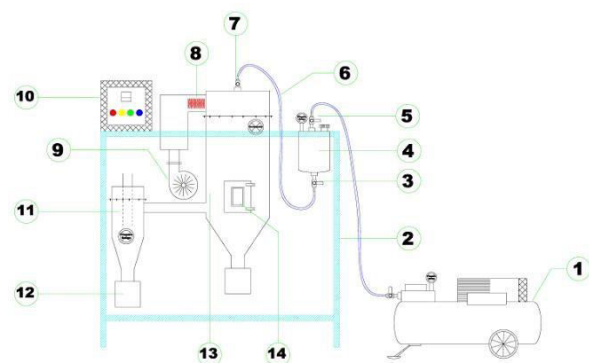


Fig. 2. Spray dryer tube dimensions

2 Research Methods

The methodology used in this study is to use the design analysis method on Computational Fluid

Dynamics using Ansys Fluent. The research methodology includes the main design of the spray dryer which will be implemented to solve problems or carry out the process of analyzing system design problems.

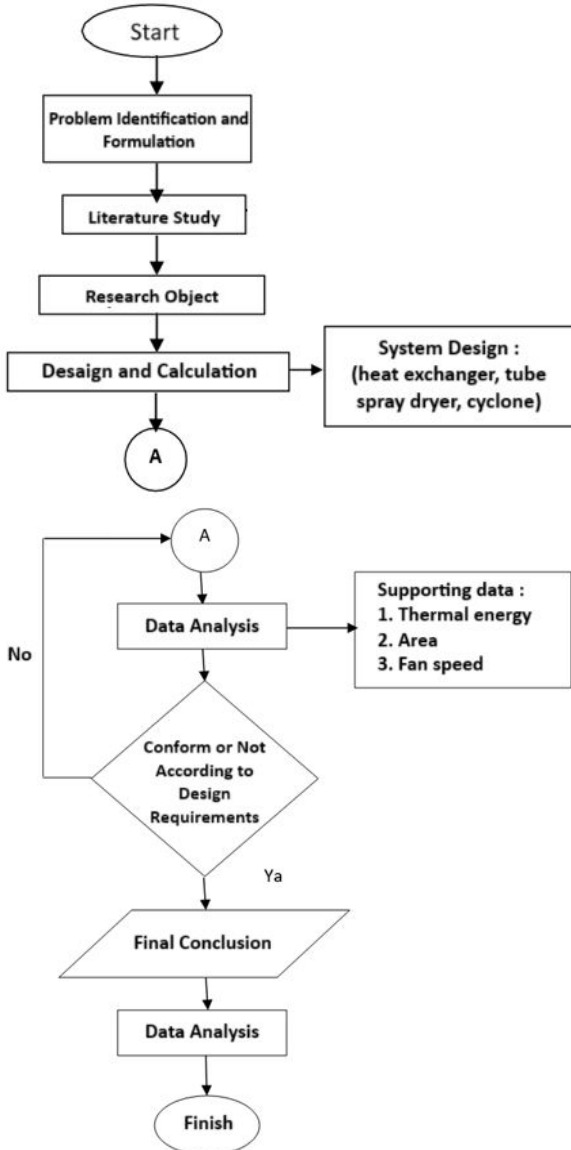


Fig. 3. The Steps of Research

By knowing the volume of drying air required by the system, we can obtain the flow rate of the drying air and the mass of drying air needed to evaporate the mass of seawater processed through the following equation [13].

$$Q_{air} = (m_{air} : \gamma) \times V$$

$$\dot{m}_{air} = Q_{air} / \gamma$$

The dimensions of the spray dryer consist of cylinder diameter (\emptyset), cone height (H_k) and cylinder height (H_s). By planning the droplet residence time, the volume of the spray dryer tube can be obtained through the following calculations [17].

$$V_{tube} = Q_t \times t_{stay}$$

$$= (Q_{material} + Q_{fluid}) \times t_{stay}$$

Simulation using CFD is carried out in several stages, namely designing a geometric model, conducting fluid checking, carrying out a wizard, entering data (input data), determining boundary conditions, entering simulation goals (goals) then carrying out the run process and finally waiting simulation results. The software used is Ansys Fluent.

3 Results and Discussion

Salt Production Capacity Planning :

- The planned salt production capacity is 10 kg/day
- 1 kg sea water = 3,5% = 35 gram salt ($NaCl$)
- $\rho_{sea\ water(27^\circ C)} = 1025\ Kg/m^3$
- Sea water volume = 10 liter = 10 kg = 0,01m³

$$\rho = m/V, \text{ so that, the equation to be } m = \rho \times V$$

$$m = \rho \times V$$

$$m = 1025\ kg/m^3 \times 0,01m^3$$

$$m = 10,25\ kg\ sea\ water$$

$$\dot{m} = m/t$$

$$\dot{m} = 10,25\ kg / 1\ hour$$

$$\dot{m} = 10,25\ kg/hour$$

If the mass of sea water that is evaporated every hour is 10.25 kg, then the salt produced every hour is 3.5% by mass of sea water.

$$\dot{m}_{NaCl} = 3,5\% \times \dot{m}_{sea\ water}$$

$$= 0,035 \times 10,25\ kg/hour = 0,36\ kg/hour$$

Spray Dryer Tube Dimension Calculation

$$\rho_{mix} = 1,29259\ kg/m^3$$

$$Q_{sea\ water} = \frac{\dot{m}_{sea\ water}}{\rho_{mix}}$$

$$= \frac{10,25}{1,29259}$$

$$= 7,929\ m^3/hour$$

$$= 0,132\ m^3/s$$

$$Q_{air} = 3200,74\ m^3/hour = 0,89\ m^3/s$$

The diameter of the spray dryer is designed with \emptyset size of 1100 mm. While the conical height (H_k) is 200 mm. The maximum droplet residence time is 1.5 seconds. So that the volume of the spray dryer tube is obtained through the following calculation:

$$V_{tube} = Q_t \times t_{stay}$$

$$= (Q_{sea\ water} + Q_{air}) \times t_{stay}$$

$$= 1,533\ m^3$$

$$= 1,5\ m^3$$

$$V_{tube} = V_{cylinder} + V_{conis}$$

$$= \pi r^2 H_s + 1/3 \pi r^2 H_k$$

$$H_s = (V_{tube} / \pi r^2) - 1/3 H_k$$

$$H_s = 1,5\ m$$

So that the main dimensions of the spray dryer tube are obtained as follows:

$$H_s = 1,5 \text{ m}$$

$$H_k = 0,2 \text{ m}$$

$$\varnothing = 1,1 \text{ m}$$

Seawater fluid flow is injected using a nozzle with a partial air pressure of 12.849 psi, while hot air enters with a temperature of 1300 C and hot air that comes out is 96° C. The following is a fluid flow of sea water and hot air made in ansys fluent.

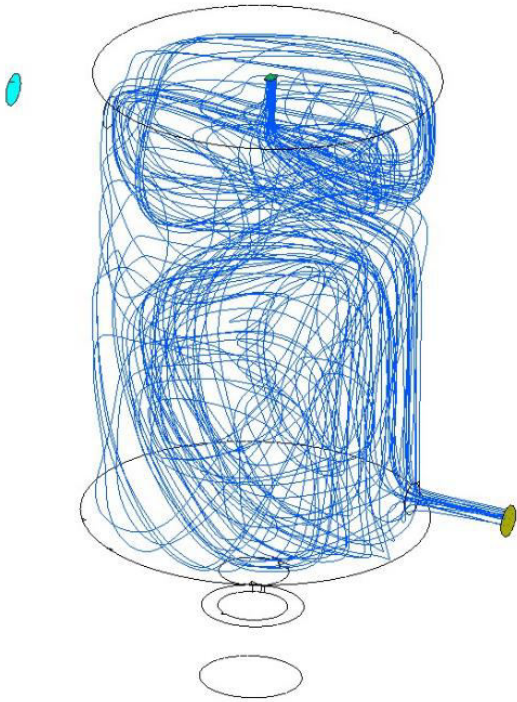


Fig. 4. Seawater fluid flow from nozzles

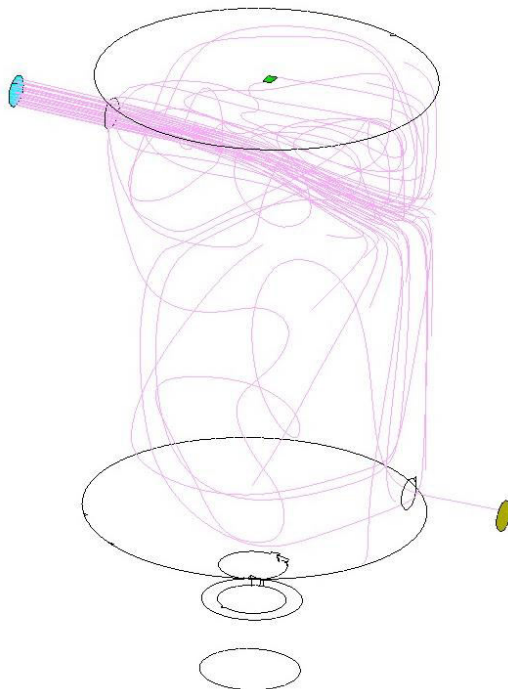


Fig. 4. Hot air fluid flow enters

The following shows the combined streamline and distribution of salt particles made on fluent ansys.

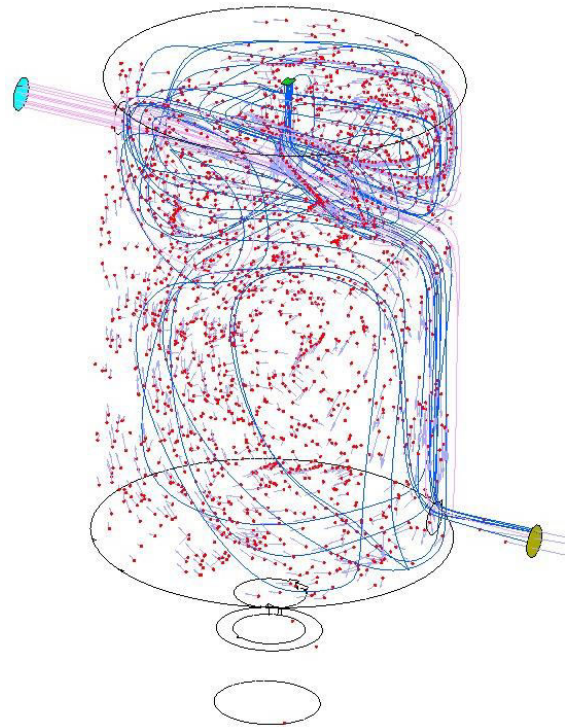


Fig. 5. Combined streamlines

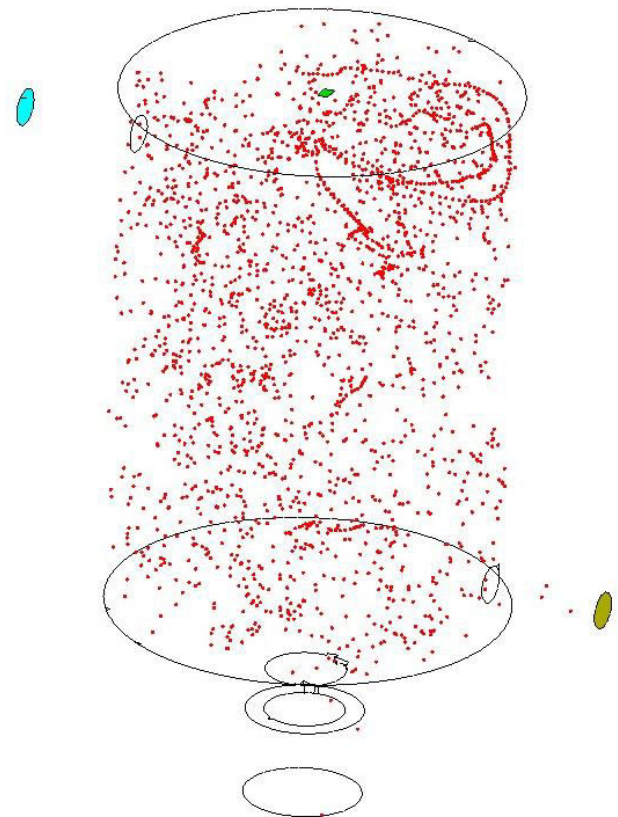


Fig. 6. Salt particle distribution

The following is the velocity contour of the combined fluid spray of seawater and hot air in a drying tube made on ansys fluent.

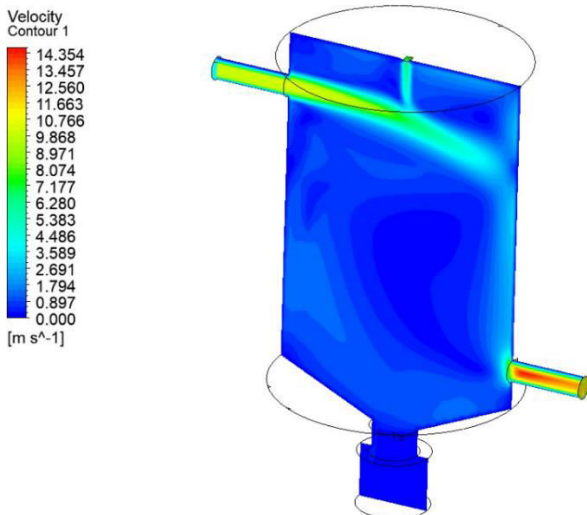


Fig. 6. Velocity contour

4 Conclusions

Analysis of the spray dryer design is $H_s = 1500$ mm $H_k = 200$ mm, diameter = 1100 mm. While the temperature of the hot air entering is 130°C and the pressure to the nozzle is 12.849 psi. The Spray Dryer as a result of the design planning is capable of producing 0.36 kg salt/hour with a seawater requirement of 10.25 kg. The results of the simulation of the flow of hot air fluid inlet and seawater spray on the nozzles show the level of homogeneity of the mixture, this is what causes the seawater particles to separate, one of which is NaCl or salt. System efficiency is at 80% based on the mass of seawater processed to become salt.

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