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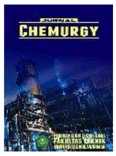

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Design of Reactor for The Production of Sodium Thiosulfate ($Na_2S_2O_3$) Crystal

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Abstrak

Dalam penelitian ini dilakukan perancangan dan analisis reaktor batch untuk produksi kristal Natrium Tiosulfat. Penelitian ini dilakukan dengan analisis komputasi dan perhitungan reaktor, pengaduk dan neraca massa menggunakan aplikasi Microsoft Excel. Pembuatan Natrium Tiosulfat diharapkan dapat ditingkatkan skalanya pada skala pabrik sehingga diperlukan tempat untuk mereaksikan bahan baku pembuatan Natrium Tiosulfat tersebut. Spesifikasi produksi natrium tiosulfat skala industri (1000 kali lebih besar dari skala laboratorium) memerlukan volume 186.1300 ft3, tinggi 2.8147 ft, dan satu buah pengaduk dengan daya 1800 Hp, berdasarkan perhitungan dari reaktor batch dan pengaduk. Perhitungan dilakukan dengan menggunakan Microsoft Excel tanpa mempertimbangkan faktor efektivitas. Hasil perhitungan menunjukkan bahwa desain dan analisis kinerja reaktor dapat diterapkan.
Kata Kunci: Reaktor, Produksi, Natrium Tiosulfat

Abstract

In this research, the design and analysis of a batch reactor for the production of Sodium Thiosulfate crystal was carried out. This research was carried out with computational analysis and calculations of the reactor, stirrer and mass balance using the Microsoft Excel application. It is hoped that the manufacture of Sodium Thiosulfate can be scaled up on a factory scale so that a place is needed to react the raw materials from which the Sodium Thiosulfate is made. The specifications for sodium thiosulfate production at an industrial scale (1000 times larger than the lab scale) require a volume of 186.1300 ft3, a height of 2.8147 ft, and one stirrer with a power of 1800 Hp, based on calculations from the batch reactor and stirrer. The calculations were performed using Microsoft Excel without considering effectiveness factors. The calculation results indicate that the reactor's design and performance analysis are applicable.
***Keywords**: Reactor, Production, Sodium Thiosulfate*

1. INTRODUCTION

In 2017-2020 the need for Sodium Thiosulfate is expanding and has very good prospects. This material is quite effective for use in the process of washing gold minerals. Washing minerals or gold mining products with using a Sodium thiosulfate solution can speed up the separation pure gold content from the ore slurry. Apart from that, currently there is a need for Sodium Thiosulfate Pentahydrate is widely used in the medical field, ranging from as an antidote to chemotherapy (Athallah, 2023).

Based on data obtained from the Central Statistics Agency and the Ministry of Industry of the Republic of Indonesia, the need for Sodium Thiosulfate The annual average of pentahydrate in Indonesia is 25,000 tons, whereas Indonesia currently does not have a Sodium Thiosulfate

Pentahydrate factory. Looking at this data shows that the need for Sodium Thiosulfate Pentahydrate in Indonesia has a large capacity and is always imported from other countries. Therefore, it is necessary to establish a Sodium Thiosulfate Pentahydrate factory, to meet the domestic demand for Sodium Thiosulfate Pentahydrate.

Table 1 Biro Pusat Statistik 2012-2016

Years	Import (Ton/Years)
2016	9,95
2015	0,19
2014	8,90
2013	0,22
2012	3,85

Sodium Thiosulfate or $Na_2S_2O_3$ is a type of Thiosulfate best known and widely used next to Ammonium Sulfate. Sodium Thiosulfate ($Na_2S_2O_3$) which is known on the market as "Hypo" is often confused with Sodium Hyposulfite ($Na_2S_2O_4$) which is commercially known as Sodium Hydrosulfite (Putri,2018).

A reactor serves as a location for various reactions to take place, whether they involve chemical transformations leading to a material transitioning from one state to another. These alterations may occur spontaneously or with the aid of external energy, such as heat. When producing reactors, it is crucial to guarantee that the reaction achieves optimal efficiency in generating the desired end product. This is essential for industries involved in reactor manufacturing to minimize operational expenses while maximizing product yield. The commonly encountered type of reactor in industrial settings is the stirred reactor, also referred to as a Continuous Stirred Tank Reactor (CSTR) (Mata & Smith, 1981).

In this research, the design and analysis of a batch reactor for the production of Sodium Thiosulfate was carried out. This research was carried out with computational analysis and calculations of the reactor, stirrer and mass balance using the Microsoft Excel application. It is hoped that the manufacture of Sodium Thiosulfate can be scaled up on a factory scale so that a place is needed to react the raw materials from which the Sodium Thiosulfate is made.

2. RESEARCH METHODOLOGY (METODOLOGI)

1. Synthesis of Sodium Thiosulfate

   The process of making Sodium Thiosulfate Pentahydrate (Na2S2O3.5H2O) takes place in a tank flow reactor stirred (RATB) without using a catalyst at a temperature of 80oC and pressure 1 atm. Reaction between Sodium Sulfite solution and Sulfur with a mole ratio of 1:4.

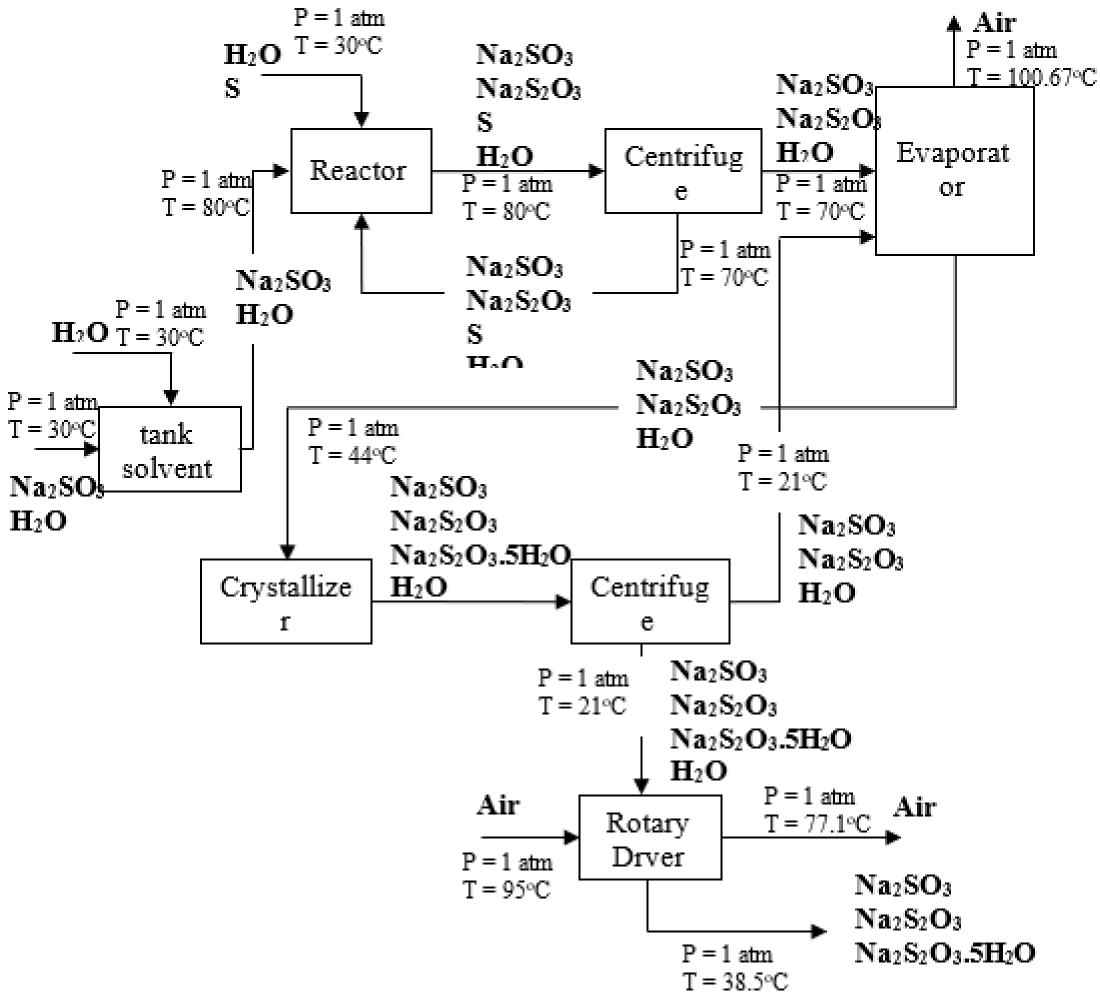

Figure 1 scheme for making Sodium Thiosulfate

$$Na_2SO_{3\,(aq)} + S_{(s)} \rightarrow Na_2S_2O_{3\,(aq)}$$

Figure 2 Mechanism Esterification Reaction (Mahreni, 2010)

2. Mathematical model for designed reactor

The material selected for the reactor is SA 240 Grade M Type 316 stainless steel with an upright cylinder type with a standard dished top cover and a conical bottom cover with an apex angle of 120˚ and the agitator is SA 240 Grade M Type 316 high alloy steel with an axial turbine type 4 blade angle of 45˚. The assumptions of specification are shown in table 2.

Table 2 Assumptions of specifications design of reactor and stirrer

Specifications	Reactor
Type	Upright cylinder with standard dished top and conical bottom with 120˚ apex angle
Temperature	80˚C
Pressure	1 atm
Operation time	An hour
Construction time	Stainless steel SA 240 Grade M Type 316
Allowable Stress (*f*)	18750

Welding	Double welded butt joint
Corrosion Factor	0.0625
Amount incoming substance	10311,02 lb/h
Volumetric rate	148,9040 ft^3/h
	Stirrer
Type	Axial Turbine with 4 Blades at an Angle of 45˚
Impeller material	High Alloy steel SA 240 Grade M type 316
Shaft material	Hot Roller Steel SAE 1020

The reactor was operated at room temperature and pressure (RTP) for an hour with a total incoming substance of 10311.02 lb/hour. The data for the mass balance analysis was collected manually using the Microsoft Excel application (equation 1-18). Table 3 displays the computed parameters for the reactor and stirrer. (Anggraini, 2018).

Table 3 Parameters of specifications design of reactor and stirrer

Section	Parameters	Equation	Eq
Dimension of reactor	Total Volume of Reactor	$Total\ Vol.of\ reactor = precursor\ vol. + 20\% \times blank\ psace\ Vol.$ Where Total vol. of reactor (ft^3)	(1)
	Vessel dimension (d_i)	$Total\ Vol. = V_{bottom\ lid} + V_{cylinder} + V_{top\ lid}$ $Total\ Vol. = \left(\frac{\pi d_i^3}{24\tan\left(\frac{1}{2}\alpha\right)}\right) + \left(\frac{\pi d_i^3}{4} \times Lc\right) + 0.0847 d_i^3$ Where α = 60˚ L_c = 1.5 d_i (in)	(2)
	Volume of liquid in the cylinder (V_{lc})	$V_{lc} = V_{liquid} - V_{bottom\ lid}$ Where V_{lc} (ft^3)	(3)
	Height of liquid in the cylinder (H_{lc})	$H_{lc} = \frac{V_{lc}}{\left(\frac{\pi}{4}\right) d_i^2}$ Where H_{lc} (in)	(4)
	Pressure of design (P_i)	$P_i = P_{atm} + P_{hydrostatic}$ $P_i = 14{,}7\ psia + \left(\frac{\rho(HL-1)}{144}\right) psia$ Where HL = 5.1463 P_i (psig)	(5)
	Cylinder thickness (t_c) and d_o standardization	$t_c = \left(\frac{p_i \times d_i}{2(f \times E - 0.6P_i)}\right) + C$ Where f = 18750 E = 0.8 C = 1/16 $d_o = d_i + 2t_c$ Where d_o (ft)	(6)
	Height of	$Total\ Vol. = V_{bottom\ lid} + V_{cylinder} + V_{top\ lid}$	(7)

	cylinder (L_c)	$$Total\ Vol. = \left(\frac{\pi d_i^3}{24\tan\left(\frac{1}{2}\alpha\right)}\right) + \left(\frac{\pi d_i^3}{4} \times Lc\right) + 0.0847 d_i^3$$ L_c (in)	
	Dimension of top lid	$$th_t = \frac{0.885 \times P_i \times d_i}{2(f \times E - 0.1P_i)} + C$$ Where th_t = top lid thickness (in) $$h_t = 0.169 \times d_i$$ Where h_t = height of top lid (in)	(8)
	Dimension bottom lid	$$th_b = \frac{P_i \times d_i}{2(f \times E - 0.16)\cos\left(\frac{1}{2}\alpha\right)} + C$$ Where α = 120° th_b = bottom lid thickness (in) $$h_b = \left(\frac{\frac{1}{2}h_t}{\tan\left(\frac{1}{2\alpha}\right)}\right)$$ Where α = 120° h_b = height of bottom lid (in)	(9)
	Height of reactor	$$Height\ of\ reactor = h_t + L_c + +h_b + s_f$$ Where s_f = 2.5 Height of rector (ft)	(10)
Stirrer	Impeller diameter (D_a)	$$\frac{D_a}{D_t} = 0.5$$ Where D_t = 77.6250 Impeller diameter (ft)	(11)
	Impeller height from the bottom of the tank (Z_i)	$$\frac{Z_i}{D_t} = \frac{1}{3}$$ Where Impeller diameter from the bottom of the tank (ft)	(12)
	Impeller length (l)	$$\frac{l}{D_a} = \frac{1}{4}$$ Where Impeller length (ft)	(13)
	Impeller width (W)	$$\frac{W}{D_a} = \frac{1}{5}$$ Where Impeller width (ft)	(14)
	Number of stirrer (n)	$$n = \frac{H_{liquid}}{2 \times D_a^2}$$ Where H_{liquid} = 61.7559	(15)
	The stirring power (H)	$$P = \frac{\varphi \times \rho \times n^3 \times D_i^5}{g_c}$$ Where φ = 0.9 g_c = 32.2 lb.ft/s^2.lbf P (Hp) $$H = (0.1 + 0.15)P + P$$	(16)

	Where 0.1 = estimation of the amount of power leakage in the process and bearing from the input power 0.15 = estimation of the amount of belt or gear leakage form input power H (Hp)	
Shaft diameter of stirrer (D)	$D^3 = \frac{16 \times T}{\pi \times S}$ $T = \frac{63025 \times H}{N}$ $S = 20\% \times 36000\ lb/in^2$ Where S = maximum allowable design shearing stress (lb/in^2) N = stirrer rotation = 100 rpm T = torsion moment (lb.in) π = 3 D (in)	(17)
Shaft length of stirrer (L)	$L = h + (l - Z_i)$ Where $h = L_c + h_t$ L (ft)	(18)

3. RESULT AND DISCUSSION

The vessel dimensions usually include the cylinder diameter, thickness, and length. The stirrer calculation is included in the dimensions of each component. Next, consider calculating and determining the thickness, upper, and lower lids of the reactor.

The reactor volume was calculated to be 186.1300 ft^3, with a vessel diameter of 62.1815 in, a cylinder height of 8.3706 in, and a cylinder thickness of 0.0714 in. After obtaining the vessel diameter, the height of the top and bottom caps was calculated to determine the overall height. The top cap has a calculated height of 10.5086 inches with a thickness of 0.0704 inches, while the bottom cap has a calculated height of 17.9715 inches with a thickness of 0.0803 inches. Therefore, the overall height of the reactor is 2.8147 feet. Table 4 shown the parameters of design reactor based on complete calculation.

Table 4 Reactor parameters designed based on calculations.

No	Parameters	Results
1	Total volume of reactor	186.1300 ft^3
2	Vessel dimension (d_i)	62.1815 in
3	Volume of liquid in the cylinder (V_{lc})	138.3917 ft^3
4	Height of liquid in the cylinder (H_{lc})	78.7883 in
5	Pressure of design (P_i)	4.3040 psig
6	Cylinder thickness (t_c)	0.0714 in
7	D_o standardization	5.1937 ft
8	Height of cylinder (L_c)	8.3706 in
9	Top lid thickness (th_t)	0.0704 in
10	Height of top lid (h_t)	10.5086 in
11	Bottom lid thickness (th_b)	0.0803 in
12	Height of bottom lid (h_b)	17.9715 in
13	Height of reactor	2.8147 ft

When considering the size of each component, including the stirrer (also known as an agitator), it is important to take into account the organic material being used. The stirrer typically consists of a series of motors as a drive pad and an impeller or blade that is adjusted accordingly. Stirring during the process of forming crude glycerol creates a flow pattern in the reactor, which can be adjusted based on the flow velocity. This design utilizes axial flow, causing flow parallel to the rotation axis.

The result of the stirrer calculation are shown in table 5. The number of stirrer is 1 piece with impeller diameter 38.8125 feet, impeller height from the bottom of the tank 25.875 feet, impeller width 7.7625 feet and impeller length 9.7031 feet. It is known that teh plate used in the stirrer is an axial turbine type 4 blades angle of 45˚. Turbine stirrer type is a type of stirrer that has many blades and is shorter in size. This batch reactor and stirrer specification calculation meets the requirements and standards for designing and operating a reactor in a production system. However, it does not include the calculation of the effectiveness factor.

Table 5 Stirrer parameters designed based on calculations.

No	Parameters	Results
1	Impeller diameter (D_a)	38,8125 ft
2	Impeller height from the bottom of the tank (Z_i)	25,875 ft
3	Impeller lenght (l)	9,7031 ft
4	Impeller width (W)	7,7625 ft
5	Number of stirrer (n)	1 piece
6	The stirring power (H)	1800 Hp
7	Shaft diameter of stirrer (D)	9,4976 in
8	Shaft lenght of stirrer (L)	2,7075 ft

4. CONCLUSION

The specifications for sodium thiosulfate production at an industrial scale (1000 times larger than the lab scale) require a volume of 186.1300 ft3, a height of 2.8147 ft, and one stirrer with a power of 1800 Hp, based on calculations from the batch reactor and stirrer. The calculations were performed using Microsoft Excel without considering effectiveness factors. The calculation results indicate that the reactor's design and performance analysis are applicable.

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