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RESEARCH PAPER

Design of Reactor for the Production of Zinc Ferrite

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Abstract: The development and analysis of a reactor design for the manufacture of zinc ferrite is the aim of this study. The design employs a Continuous Stirred Tank Reactor (CSTR) type, with the tank and stirrer serving as the reactor's primary structural elements. The requirements for the built tank and stirrer will significantly impact the safety and production of silicon dioxide. As a result, Microsoft Excel is used for the calculation process for designing this reactor. The results of the calculations are obtained for design pressure 4,304 psig, cylinder thickness 0.07 in, top cover thickness 0.07 in, top cover height 12.39 in, bottom cover thickness 0.08 in, bottom cover height 21.18 in, reactor height 44.34 in, impeller length 5.43 in, stirring power 5 hp and shaft length 15.98 in. This design can become a reference for the production of zinc ferrite to make it more efficient in the production process.

Keywords: Reactor, Zinc ferrite, CSTR, CAN

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INTRODUCTION

A reactor is a device where a reaction, whether chemical or nuclear, happens without any physical contact. A chemical reactor is any place where a chemical reaction occurs, whether on a small or large scale, such as a reactor on an industrial scale [1-3]. In a chemical reactor, energy changes can result from heating or cooling, rising or falling pressure, and liquid and mixer frictional forces [1]. The ideal pipe flow reactor is one in which the liquid flow is tubular, uniformly directed, moving at a constant speed, and without mixing axially [4]. The reactor comprises a tube, tube cap, thermocouple, and output pupa. Each of these components serves a specific purpose, such as the reactor tube serving as a container for the test material. The tube cover prevents air exchange in the tube. The thermocouple serves as a temperature reader during the procedure, and the output pipe serves as a steam outlet from the results going to the condenser [5].

Due to its relatively small band gap, tunable band edge by modulating grain size, and good photochemical stability, zinc ferrite (ZnFe2O4), a stable spinel-type (AB2O4) mixed metal oxide semiconductor, has been extensively used in many fields such as pigment, catalyst, and particularly as an effective visible light photocatalyst for pollutant degradation [6–9]. Nanostructure ZnFe2O4 is a potential solar energy material for photochemical processes because of its responsiveness to visible light and resistance to photoanodic corrosion [10].

Nanoscale metal oxides have been synthesized by different methods such as sol-gel, chemical co-precipitation, hydrothermal, and so on [11]. The sol-gel process is considered among these techniques because of the excellent control over chemistry, homogeneity, purity, and crystalline phase [12]. A tool design for zinc ferrite production is carried out to improve the zinc ferrite production system.

MATERIALS AND METHODS

Manufacture of $ZnFe_2O_4$

Citrate-nitrate auto-combustion synthesis (CAN) was used to create $ZnFe_2O_4$ nanoparticles. In 100 mL of distilled water, $Zn(NO_3)_2$ and $Fe(NO_3)_3$ were dissolved in a 1:2 molar ratio, and the mixture was then homogenized at 70 °C using a magnetic stirrer. The preceding solution received the proper amount of citric acid, and 90°C was chosen as the appropriate temperature to cause the water to evaporate. During the dehydration process, nitrate ions and citric acid underwent a polycondensation reaction that resulted in the gel's creation. The temperature was increased to 200°C once the gel had formed to burn the organic components and cause the reaction products to change into a brownish powder. The powder was calcined at 700°C, cooled gradually to room temperature, and then put away for use [13].

Silicon dioxide production equipment design necessitates a number of calculations, including those for material volume, reactor design, and determination of reactor dimensions. These calculations are manually performed using Microsoft Excel. The equation in Table 1 is the foundation for the data processing procedure.

Mathematical models for designing a reactor

Table 1. Calculation of reactor parameters.

Section	Parameter	Equation	Eq.
Reactor planning	Diameter vessel (D_i)	$V_{total} = \frac{\pi di^3}{24 \tan 1/2\alpha} + \frac{\pi di^2}{4} \times Ls + 0.0847di^3$	(1)
	Volume of liquid in the cylinder (V_{ls})	$V_{ls} = V_{liquid} - V_{top\ lid}$	(2)
	High liquid in the cylinder (L_{ls})	$L_{ls} = \frac{V_{ls}}{\left(\frac{\pi}{4}\right) \times di^2}$	(3)
	Design pressure (P_i)	$P_i = P_{atm} + P_{hydrostatic}$ Where, $P_{hydrostatic} = \frac{\rho(HL-1)}{144}$	(4)
	Cylinder thickness (T_s)	$T_s = \frac{P_i \times d_i}{2(f.E - 0.6P_i)} + C$	(5)
	Cylinder height (L_s)	$V_{total} = \frac{\pi di^3}{24 \tan 1/2\alpha} + \frac{\pi di^2}{4} \times Ls + 0.0847di^3$	(6)
	Top cover thickness ($th_{a)}$	$th_a = \frac{0.885 \times P_i \times d_i}{2(f.E - 0.1P_i)} + C$	(7)
	Top cover height (h_a)	$h_a = 0.169d_i$	(8)
	Bottom cover thickness (th_b)	$th_b = \frac{P_i \times d_i}{2(f.E - 0.6P_i) \cos 1/2\alpha} + C$	(9)
	Bottom cover height (h_b)	$h_b = \frac{1/2d}{\tan 1/2\alpha}$	(10)
Reactor stirrer	Impeller diameter (D_a)	$D_a = D_t \times 0.5$	(11)
	Impeller height from tank bottom (C)	$C = \frac{1}{3} \times D_i$	(12)
	Impeller length (L)	$L = \frac{1}{4} \times D_a$	(13)
	Impeller width (W)	$W = 0.20 \times D_a$	(14)
	Number of stirrers (n)	$n = \frac{H_{liquid}}{2 \times {D_a}^5}$	(15)
	Reynold number (N_{Re})	$N_{Re} = \frac{L^2 \times n \times \rho}{\mu}$	(16)
	Stirring power (P)	$P = \frac{\varphi \times \rho \times n^3 \times {D_i}^5}{gc}$	(17)
	Stirrer shaft diameter (D)	$D = \frac{\# \times T}{\pi \times S}$	(18)
	Shaft length (L)	$L = h + l - Z_i$	(19)

RESULTS AND DISCUSSION

This article uses a Continuous Stirred Tank Reactor (CSTR) reactor to produce zinc ferrite. In the CSTR, all reactor sites will have the same temperature, concentration, and reaction rate between the reacting chemicals. The pressure controller is one of the numerous controllers installed on the CSTR reactor to control a reactor system. Continuously high pressure within the system has the potential to explode. In order to keep the closed system safe, the pressure inside the reactor must be regulated to maintain the pressure there. The continuous mixing tank reactor (CSTR) operates by adding the reactants to be utilized and removing the products. At the same time, the contents of the vessel are vigorously churned with internal agitation or recycled internally (or externally).

Table 2. The results of the calculation of the reactor and the stirring dimension specification.

No.	Parameter	Result
1.	Type of reactor	Continuous stirred tank reactor (CSTR)
2.	Reactor volume ($_{\mathrm{Total}}$)	8619.24 L
3.	Diameter vessel (D_i)	73.29 in
4.	Volume of liquid in the cylinder (V_{ls})	6418.64 L
5.	High liquid in the cylinder (L_{ls})	92.87 in
6.	Design pressure (P_i)	4.304 psig
7.	Cylinder thickness (T_s)	0.07 in
8.	Cylinder height (L_s)	10.77 in
9.	Top cover thickness (th_a)	0.07 in
10.	Top cover height (h_a)	12.39 in
11.	Bottom cover thickness (th_b)	0.08 in
12.	Bottom cover height (h_b)	21.18 in
13.	Reactor height	44.34 in
14.	Impeller diameter (D_a)	21.73 in
15.	Impeller height from tank bottom (C)	14.55 in
16.	Impeller length (L)	5.43 in
18.	Impeller width (W)	4.24 in
19.	Number of stirrers (n)	1
20.	Reynold number (N_{Re})	96282.86
21.	Stirring power (P)	5 Hp
22.	Stirrer shaft diameter (D)	1.54 in
23.	Shaft length (L)	15.97 in

The tank and stirrer are the two primary pieces of a continuous stirred tank reactor (CSTR), and the design of these parts will depend on the substance being generated. A motor drives the hanging shaft, which is used to attach the impeller to the tank during the procedure. The tank has mantles, heat coils, inlet, output holes, and wells for thermometer placement inside. The liquid moving through the vessel will eventually return to the impeller thanks to the internal flow pattern created by the impeller. Due to the stirrer's rotation in the fluid, mixing takes place in the stirrer tank. This agitator's motion cuts through the fluid and has the potential to generate eddy currents that circulate throughout the fluid system. Therefore, the stirrer is the most crucial component in a liquid phase operation with a stirred tank. Given that the stirrer's form and size will impact the mixing process's efficiency and the needed power, good mixing can be achieved.

Several calculations are done to acquire the right tank and stirrer specifications for zinc ferrite production to generate good zinc ferrite utilizing a Continuous Stirred Tank Reactor (CSTR). Table 3 displays the total calculation outcomes for the reactor specification and the stirrer dimensions made using Microsoft Excel.

CONCLUSION

The reactor design for zinc ferrite production uses a Continuous Stirred Tank Reactor (CSTR) type. From the results of calculations with Microsoft Excel, the size results for the reactor design to be made are design pressure 4,304 psig, cylinder thickness 0.07 in, top cover thickness 0.07 in, top cover height 12.39 in, bottom cover thickness 0.08 in, bottom cover height 21.18 in, reactor height 44.34 in, impeller length 5.43 in, stirring power 5 hp and shaft length 15.98 in

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