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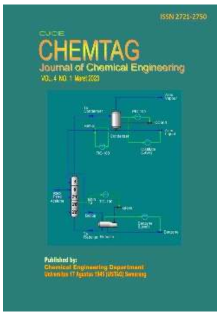

HEAT EXCHANGER DESIGN FOR WO3 SYNTHESIS USING HYDROTHERMAL METHOD

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Abstract

This study aims to analyze a heat exchanger (HE) design in the synthesis of WO3 using the hydrothermal method. The data were calculated using a Microsoft Excel application using several parameters and assumptions. The result found that shell and tube-designed heat exchangers have 80.04% effectiveness with initial heat transfer (Q) 383197 and some specifications included. However this result further calculation for fouling factor and appropriate value for TEMA standards

Keywords: *heat exchanger, WO3 nanoparticles, shell and tube, hydrothermal synthesis, HE design.*

Abstrak

Penelitian ini bertujuan untuk menganalisis rancangan heat exchanger (HE) untuk sintesis nanopartikel WO_3 menggunakan metode hidrotermal. Aplikasi Microsoft Excel digunakan untuk menghitung data berdasarkan beberapa parameter asumsi. Hasilnya diperoleh bahwa rancangan HE dengan tipe shell and tube memiliki efektivitas 80,04% dengan nilai perpindahan panas (Q) 383197 dan beberapa spesifikasi lain yang disertakan dalam tabel. Namun demikian, hasil ini masih memerlukan perhitungan lebih lanjut untuk menganalisis fouling factor dan nilai yang sesuai dengan standar TEMA.

Kata Kunci: *heat exchanger, nanopartikel WO3, shell and tube, sintesis hidrotermal, rancangan HE.*

1. Introduction

Heat exchangers are heat transferring device that provide the flow of thermal energy between two or more fluids at different temperature. Heat exchangers are used in different industries including manufacturing industries, chemical and food industries, and oil and gas, and electronics [1] [2].

Wolfram trioxide (WO_3) are used in various application due to its excellent performance. Some of this application are sensor [2] [3], photocatalyst [5], and photodetectors [6]. Several methods have been developed for synthesis of WO3 nanoparticles including sol gel method [7] [8], precipitation method [9], arc discharge [10] and hydrothermal method [11] [12].

The design of heat exchanger device have been done in several studies. In contrast to the referred studies, we conducted analysis and evaluation of the proses. This study aims to design heat exchanger for synthesis of WO_3 nanoparticles. In this study, the designed heat exchanger in this shell and tube type. This study is also expected to be a useful reference for designing heat exchanger.

2. Methods

2.1 Synthesis of WO_3 Nanoparticles

Figure 1 shows the procedural steps of the synthesis of WO3 using the hydrothermal method. Sodium tungstate dehydrates (3.3 gr) were added to 200 ml deionized water then the dropwise of HCl (2M) was added until the pH value reached 1.5. The solution was then transferred to a 200 ml Teflon-line stainless steel autoclave, sealed, and maintained for 48 hours at 180°C. Once the reaction was finalized, distilled water and ethanol were used to wash the resulting solid before being collected with centrifugation. Finally, the precipitates then dried at 60°C for 24 hours.

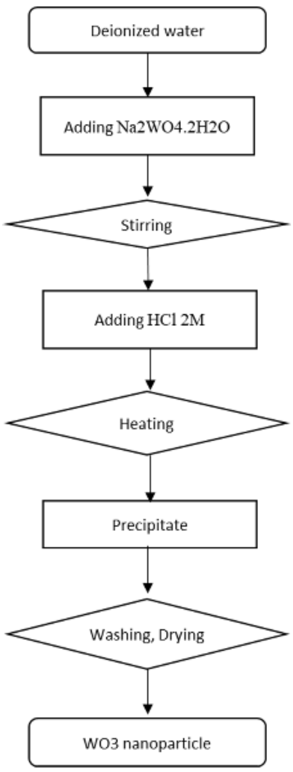

Figure 1. Synthesis of WO3 nanoparticles using hydrothermal method

2.2 Mathematical model for designed heat exchanger

Assumptions listed in **Table 1** were used for designing the fluid characteristics operating in HE. Several data assumptions were also used for the shell and tube HE design. In this design, paraffin oil was used as hot fluid while ethylene glycol was chosen as cold fluid. The hot fluid enters at 180°C then leave at 135°C with an incoming flow rate of 3.2 kg/s, while cold fluid enters at 105°C and leave at 120°C with a 2.1 kg/s flow rate income. Standard Tubular Exchanger Manufacturers Association (TEMA) was referred to in the process of collecting data regarding specifications. Thermal analysis was also calculated manually by using a basic Microsoft Excel application based on equations 1-27, parameters of heat exchange shown in **Table 2**.

Table 1. The assumption for fluid properties working on heat exchanger

	Shell side Hot fluid	**Tube side Cold fluid**
Inlet temperature, T_{in} (°C)	180	105
Outlet temperature, T_{out} (°C)	135	120
Fluid flow rate (kg/s)	3.2	2.1
Operating pressure (atm)	0.987	0.987
Specific heat (kJ/kg°C)	2.130	2.433
Density (kg/m^3)	800	1115

Table 2. Heat exchanger parameters for the calculation

Section	Parameter	Equation	Eq
Basic Parameters	The energy transferred (Q)	$Q_{in} = Q_{out}$ $m_c \times Cp_c \times \Delta T_c = m_h \times Cp_{h\times}\Delta T_h$ where, Q = Energy transfer (Wt) T = Fluid temperature difference (°C) Cp = heat specification m = mass fluid flow rate (Kg/s)	(1)
	Logarithmic mean temperature difference (LTMD)	$LMTD = \frac{(T_{hi} - T_{c_i}) - (T_{h0} - T_{c_o})}{ln\frac{(T_{hi} - T_{c_i})}{(T_{h0} - T_{c_o})}}$ where T_{hi} = Inlet hot fluid temperature (℃) T_{ci} = Inlet cold fluid temperature (℃) T_{ho} = Outlet hot fluid temperature (℃) T_{co} = Outlet cold fluid temperature (℃)	(2)
	Correction factor	$R = \frac{T_{hi} - T_{h_o}}{T_{co} - T_{ci}}$	(3)
		$P = \frac{T_{co} - T_{ci}}{T_{hi} - T_{ci}}$	(4)

	$$F = \frac{\sqrt{R^2+1}\ln[\frac{1-P}{1-PR}]}{(R-1)ln\frac{2-p(R+1-\sqrt{R^2+1})}{2-p(R+1+\sqrt{R^2+1})}}$$	(5)
Heat Transfer Field Area (A)	$$A = \frac{Q}{U \times LTMD}$$ where, Q = Energy transfer (W) LMTD = Logarithmic Mean Temperature Difference U = overall heat transfer coefficient	(6)
Number Of Tubes (N)	$$N = \frac{A}{\pi \times D_0 \times l}$$ where, N = Number of tubes A = *Heat Transfer Field Area* π = 3,14 D_0 = Tube diameter (m) l = Tube length (m)	(7)

3. Result and Discussion

The complete calculation of HE design shows in **Table 3**, several assumptions as listed in **Table 2** were used to develop a tube and shell type of HE design. The effectiveness of HE was found to be 80.04%, this value indicates the actual heat transfer rate that was divided by the maximum heat transfer rate. Initial heat transfer (Q) was also found to be 383197 W.

Table 3. Heat exchanger performance parameters based on calculations

Description	Type/value
Type of heat exchanger	Shell and Tube
Paraffin oil inlet temperature (°C)	180
Paraffin oil outlet temperature (°C)	135
Ethylene glycol inlet temperature (°C)	105
Ethylene glycol outlet temperature (°C)	120
Tube outside diameter, do (mm)	25.40
Tube inner diameter, di (mm)	21.18
Pitch, (mm)	25.40
Total tube number, N	17,602
Total Heat Transfer Surface Area in Tube (m^2)	0.0284
Mass Flow Rate of Fluid in Tube ($kg/m^2.s$)	1.0322
Reynold Number in Tube	1.29
Prandtl Number in Tube	298.76
Nusselt Number in Tube	0.32
Tube layout	Tringular
Shell inner diameter, Ds (mm)	203
Total Heat Transfer Surface Area in shell (m^2)	0.0258

Mass Flow Rate of Fluid in shell ($kg/m^2.s$)	81.3752
Reynold Number in Shell	135,634.82
Prandtl Number in Shell	148.47
Nusselt Number in Shell	2,526.34
Baffle spacing, B (mm)	50.8
Logarithmic Mean Temperature Difference (°C)	112.5
Area of Heat Transfer (m^2)	0.0258
Paraffin oil mass flow rate (kg/s)	3.2
Ethylene glycol mass flow rate (kg/s)	2.1
HE Effectiveness (%)	80.04
Number of Transfer Unit	70.33

Synthesis of the WO3 nanoparticle carried in several steps as shown in **Figure 2** whereas the HE design is shown in **Figure 3**. This method requires heating temperature up to 180 therefore in this design paraffin oil was used as the hot fluid while ethylene glycol was chosen as the cold fluid. The hot fluid enters at 180 and then leaves at 135 whereas the hot fluid enters at 105 and leaves at 120. The precipitate formed and then continued to dry at 90 for 48 hours.

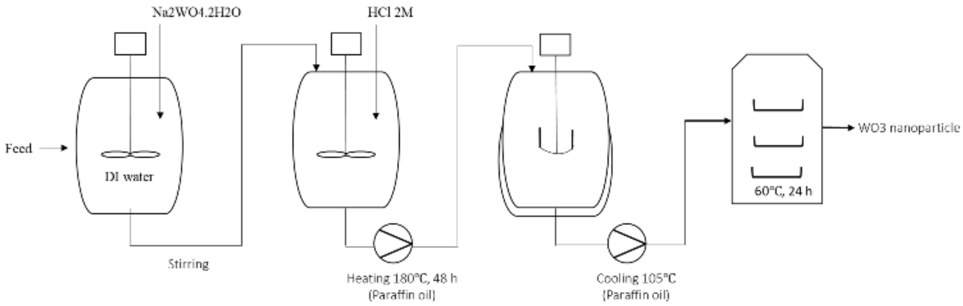

Figure 2. Flow process diagram for the synthesis of WO3 nanoparticles

These shell and tube HE designs fulfill minimum requirements based on the effectiveness value but there were no fouling factors calculated.

4. Conclucasion

Heat exchanger design with shell and tube type for WO3 synthesis using the hydrothermal method was found to have an effectiveness of 80.04% with initial heat transfer (Q) 383197 W. This design fulfills the minimum effectiveness requirements value. However, the results need further calculation for the fouling factor and appropriate value for TEMA standards.

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