$$v = \pi r^2\ l = \frac{\pi d^2 l}{4} \quad (41)$$

$$L_R = \frac{4V_{RC}}{\pi d^2}$$

Heat Load Q

The total heat generated is expressed as

$$Q = \Delta H_{rA} F_{AO} X_A \quad (42)$$

Where

Q	=	Total heat load
ΔH_{rA}	=	Heat of reaction
F_{A0}	=	Initial molar flow rate of A
X_A	=	Fractional conversion

Heat Generated Per Unit Volume of Reactor

$$H_R = \frac{Q}{V_R} \quad (43)$$

Where

H_R	=	Heat generated per unit volume of reactor
Q	=	Total heat load
V_R	=	Volume of reactor

Input Parameters

The following data were obtained from literatures and used to run the MATLAB program for the designed reactor and Heat exchanger for styrene production via the catalytic dehydrogenation of ethylebenzene adopting an adiabatic condition for reactor operations

Table 3.1: Input Data for Packed bed Reactor for Styrene Production

Variable	Symbol	Value	Units
Reaction Temperature	T	903	K
Initial Concentration of A	C_A	1000	mol/m^3
Initial Volumetric Flow rate of A	VAO	0.001	m^3/sec
Initial molar flow rate of A	FAO	181.65	mol/sec
Pre-exponential factor	Ko	0.0000351	-
Reactor Diameter	D	0.5	m
Activation Energy of reaction	E	0.851	-
Conversion rate	x	0.90	
Gas constant	R	8.314	J/mol.K
Standard Heat of reaction	dHr	124.9	kJ/mol
Heat transfer coefficient of product	Kh	0.58	W/m.K
Mass flow rate of product	mp	2.42	Kg/sec
Viscosity of reaction mixture	n	5.2	kg/sec.m
Viscosity correction factor	nh	0.932	Kg/sec.m
Linear velocity of reaction mixture	v	0.0224	s^{-1}
Density of ethybenzene (A)	ρ	790	Kg/m3
Specific heat capacity	C_p	4.184	
Viscosity correction factor of product	np	20	kg/sec.m
Reactor thickness	Tr	0.05	m
Dirty overall film transfer coefficient	Ud	0.764	KJ/m^2K

Table 3.2: Data for Heat Exchanger Design

Variable	Symbol	Value	Units
Hot fluid	-	-	-
Inlet temperature	Ti	836.23	K
Outlet temperature	T_2	377.319	K
Mass flowrate	m	500	kmol/hr
Cold fluid			
Inlet temperature	Ti	433	K
Outlet temperature	T_2	793	K
Mass flow rate	m	181.64	kmol/hr

3. RESULTS AND DISCUSSION

3.1 Results

Table 3.1: Results for Reactor functional Parameters

Variable	Symbol	Value	Units
Volume of reactor	V_R	60.1	m^3
Length of reactor	L_R	7.6	m
Space velocity	Sv	9.5	min
Space time	St	6.5	min

Table 3.2: Design Results for Heat exchanger for Styrene Production

Variable	Symbol	Value	Units
Heat duty	Q	17289471.93	kJ/hr
Exchanged Area	A	1.263	m^2
Long men Temperature	LMTD	52.716	K
Shell side pressure drop	Gs	38242.78	atm
Pressure	P	0.01	atm
Tube side pressure drop	P	19284.7	atm
Over all coefficient	U_0	72.11	$W/m^{20}C$
Tube side velocity	v_t	0.0453	m/s

Manual calculations of the heat exchanger design were computed and simulated using MATLAB and the following results tabulated (see Table 4.1). The heat duty is 4802.63W and the area of the exchanged heat is $1.263m^2$. The values indicate that the heat exchanger design is good and reliable for the set function.

Table 3.3: Design Results for Heat exchanger's Parameters

Variable	Symbol	Value	Units
Correction constant	R	1.045	-
Correction constant	S	0.874	-
Tube length	L_t	6.10	m
Area of single tube	A_t	0.4867	m^2
Density	ρ	354	kg/m^3
Heat transfer Coefficient	Uo	72.58	

Shell side velocity	v_s	0.00947	m/s
Volumetric flow rate	v_0	0.0025	m3/s
Shell diameter	D_s	476	mm
Baffle spacing	L_b	0.512	m
Cross flow area	A_c	0.2639	m^2
Shell diameter	D_s	0.025	m
Number of baffles	N_b	11	
Reynolds number	Re	24.5-444.5	-

Table 4.2 indicates also some of the heat exchanger design parameters that were gotten from the manual and simulation calculations. The values must be obtained in other to determine, evaluate and rate the performance of the heat exchanger and the area of the exchanged heat.

3.2 Result of the Reactor Design and Simulation

The computer program written with MATLAB 2011 compiler for the design of a Packed bed Reactor for the production of ethybenzene via the Catalytic dehydrogenation of ethylbenzene produced the following results at T = 630 K are C_A= 1187mol/m^3 and V_{AO} = 0.001 m^3/sec. The effect of conversion on Volume, Length, Space time and Space velocity of the reactor were studied and the results are presented as profiles shown below:

3.3 Discussion of Heat Exchanger Results

The differential models were simulated using MATLAB 2011 Compiler to obtained Temperature profiles over the length of the heat exchanger at steady state time as shown below:

3.3.1 Steady State Temperature Profile of Shell and Tube Heat Exchanger Length at time of 90 sec

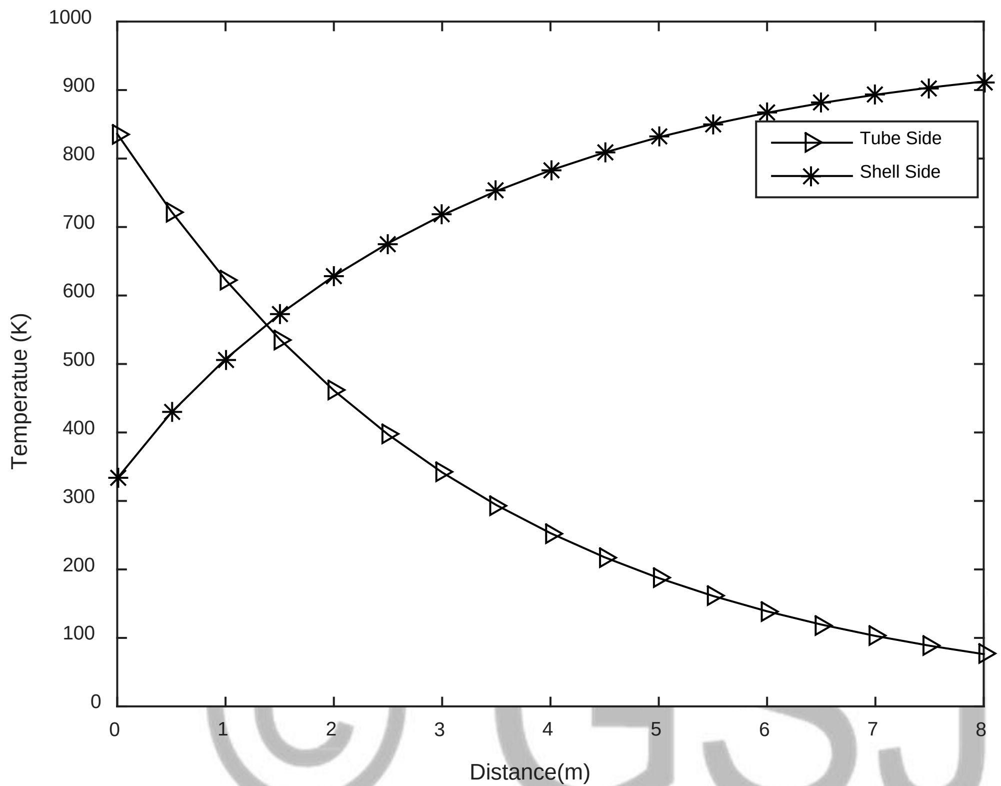

Figure: 4.1 Plots of Temperature Profiles for Heat Exchanger

The temperature profile of heat exchanger design at steady state along the length of the exchanger is shown in Figure 4.1. The profile is obtained at 90secs. The rating of the exchanger is at 333K and 836K initially for the heat exchanger and increases and decreases respectively exponentially to 912Kand 76K when the length increases from 0m to 8m and then remains constant throughout the remaining length.

4 Conclusion

The research on design of Adiabatic Packed bed reactor for styrene production has been carried out, the performance model for adiabatic Packed bed Reactor was used for simulation over a fractional conversion of 92% for the feed $x_A = 0.92$ was obtained , From the results obtained it shows clearly that the results gave a reliable data for the functional parameters of the reactor. These parameters includes reactor volume, reactor length, space time, space velocity, and rate of heat generation per reactor volume, the analysis of the energy balance equation of a packed bed reactor was essential in predicting the conversion of reactant along the reactor length with other process parameters. The relationship between the model obtained and the performance of the packed bed reactor depends on the process parameters such as the concentration of the feed (reactant), its speed of rapidness and the temperature of the reaction, hence an exponential increase in reactor temperature will give rise to the formation of side reaction an optimization of the operating condition will be necessary in other to ensure economic operate ability of the reactor.

The analysis of the heat exchanger yields a favorable steady state for reactor operations for styrene production the heat transfer coefficient was obtained as $U_0 = 72.58W/m^2.^oC$ with shell side pressure $P_t = 38242.78atm$

Area of the exchanger, $A = 1.263m^2$, tube length 6.10m, LMTD = 52.716K heat duty Q= 17289471.93kJ/hr and the steady state time was obtained to be 90 sec, the results obtained shows the design models are correct, predicting the amount of heat transferred for the heat exchanger and the steady state time for the designed reactor compares favorably with the output of an industrial reactor.

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