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RESEARCH ARTICLE

AN EXPERIMENTAL INVESTIGATION OF DYNAMICS OF SODIUM THIOSULPHATE REACTION WITH HYDROGEN PEROXIDE IN A PACKED-BED REACTOR

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ABSTRACT

Packed bed reactors are important and have gained popularity because of their ideal plug flow behavior, low maintenance cost and reduced loss due to attrition and wear. Here, we wanted to carry out simulation for the same. For development of simulation, we first chose Dispersion model and Tanks in series model. RTD experiments were carried out for the reactor. Reactions between sodium thiosulphate and hydrogen peroxide were carried out at different temperature and concentration. Results of the reactions were analyzed and then simulation was carried out based on it.

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INTRODUCTION

An experimental investigation of dynamics of sodium thiosulphate reaction with hydrogen peroxide in a packed bed reactor had been carried out in the present study. The packed bed reactors for industrial synthesis are generally operated over a long production period with almost constant operating parameter. The task of process control engineering is simply to keep these parameters optimal by evaluating parametric sensitivity of the system. Experiments were carried out with KCL as a tracer to study (to find) RTD of the packed bed reactor. The information is used to evaluate model parameters (No. of tanks in series - N) Experiment with different reaction temperature were carried out and the results obtained were used to check the parametric sensitivity of the system. The theoretically predicted parameter value (temp) are compared with those obtained using Tanks in series and Backmix models. The results indicates reasonably good match of the model over the parameter value study.

Literature / Theoretical Aspects

Large number of industrial product synthesis is carried out in a packed bed reactor. The flow behavior in such reactor is normally non ideal and hence can be described by models such as tanks in series model and backmix model. Tanks in series model contains equal size completely mixed compartments arranged in series. The material and energy balance equations for all the tanks in series are simultaneously solved using numerical such as Runge Kutta or Mid point average methods. The single parameters to be estimated in this model is the no. of tanks N (The theoretical equation to find No. of tanks is $N = 1/\sigma\theta^2$) Which is based on its magnitude describes the flow behavior for the non ideal situation. In the present study both the Tanks in series and Back mix (Dispersion model) were used to predict the parametric sensitivity.

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Dispersion Model

In plug flow if some degree of back mixing or intermixing there then it is called dispersed plug flow model or the dispersion model. For molecular diffusion in the x direction the governing differential equation is given by fick's law.

$$\frac{\partial C}{\partial t} = D\frac{\partial^2 C}{\partial x^2}$$

here D, is the coefficient of molecular diffusion (dispersion coefficient)

Tanks in series model

The tanks in series model is widely used to represent nonideal flow. Here we assume that fluid flow through a series of equal

size ideal stirred tanks and the one parameter of this model is the number of tanks in this chain.

$$\sigma\theta^2 = \frac{1}{N}$$

(where N is number of tanks in chain or series)

$$\sigma\theta^2 = \frac{\sigma^2}{\bar{t}^2} = 2\left(\frac{D}{uL}\right)$$

$\bar{t}_i =$ mean residence time in one tank

$\bar{t} = N\bar{t}_i =$ mean residence time in the N tank systems

$$\sigma^2 = 2\left(\frac{DL}{u^3}\right)$$

$\frac{D}{uL}$ is vessel dispersion number

if $\frac{D}{uL} \to 0$ there will be negligible dispersion hence plug flow

if $\frac{D}{uL} \to \infty$ there will be large dispersion hence mixed flow

In the present study both the Tanks in series and Back mixed (dispersion model) were used to predict the parametric sensitivity.

We have selected an exothermic homogenious liquid phase reaction between sodium thiosulphate and hydrogen peroxide system to simulate the none liner parameter of the packed bed reactor because we are having information of kinetics and value of kinetic parameter, significant heat of reaction and thermodynamic properties. The reaction is irreversible and obeys the following stochiometric equation.

$$2Na_2S_2O_3 + 4H_2O_2 \rightarrow Na_2S_3O_6 + Na_2SO_4 + 4H_2$$

Rate equation $(-rA) = KC_AC_B$

Where,

K = Rate constant min^{-1} = 1.63 x 10^{13} C_A exp (-81140/T)
E/R= 1840 K
C_A= Concentration of Sodium thiosulphate gmole/cc 1.0 M
C_B= Concentration of Hydrogen peroxide gmole/c 1.4 M

Experiment set up and procedure

Experimental set up

Reactor was a stainless steel vessel of inner diameter about 8cm and height 11 cm. Stainless steel lid was sealed at the top of the reactor so that no vapors escape during the experiments. Thin wall of reactor (1mm) was selected so that the minimum temperature gradient will be there. The reactor was fixed with minimum support in order to minimize the heat losses by the mechanism of unsteady heat condition. The covering lid was provided holes for thermometers. 3mm diameter steel balls were used as packing.

The reactor was provided with inlet at the bottom and outlet at he top of the reactor. The system is shown in Fig. 1. Chemical used for experiments were laboratory great.

Figure - 1 EXPERIMENTAL SET-UP

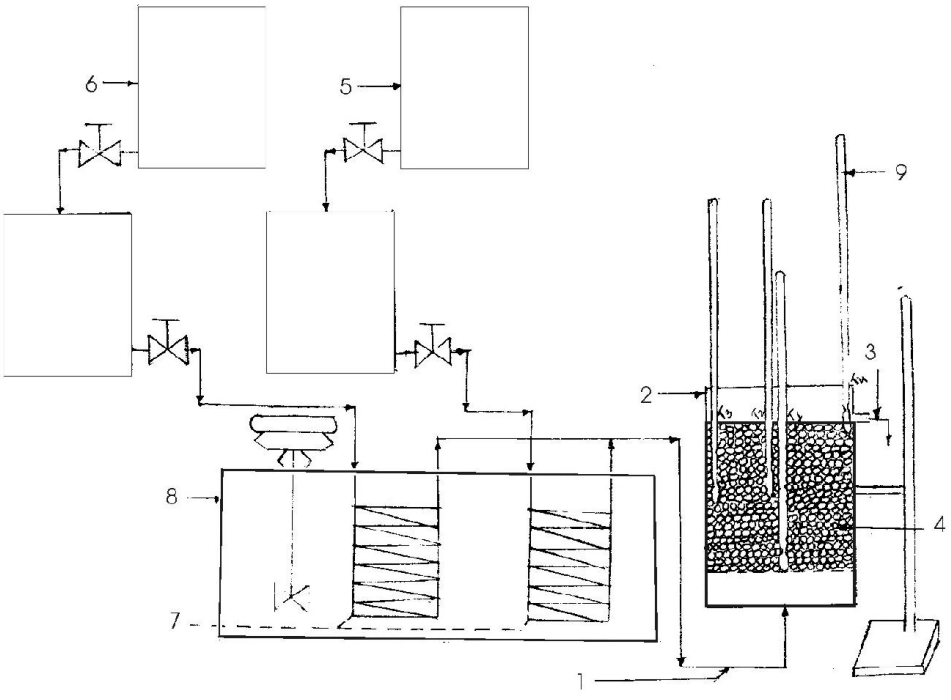
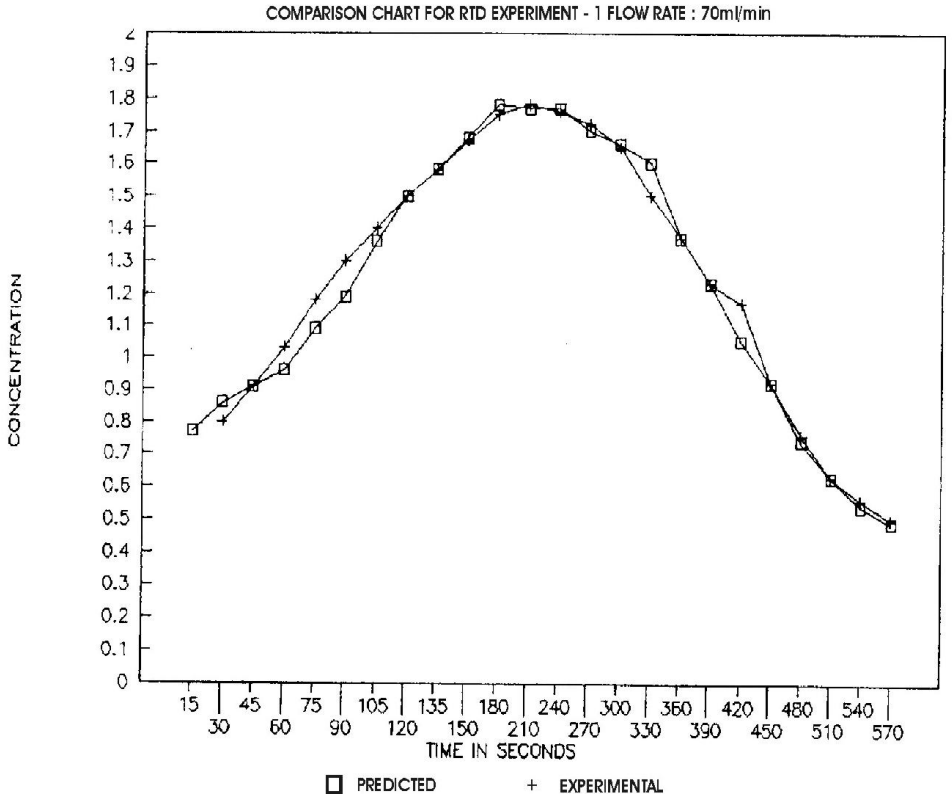


Figure - 2



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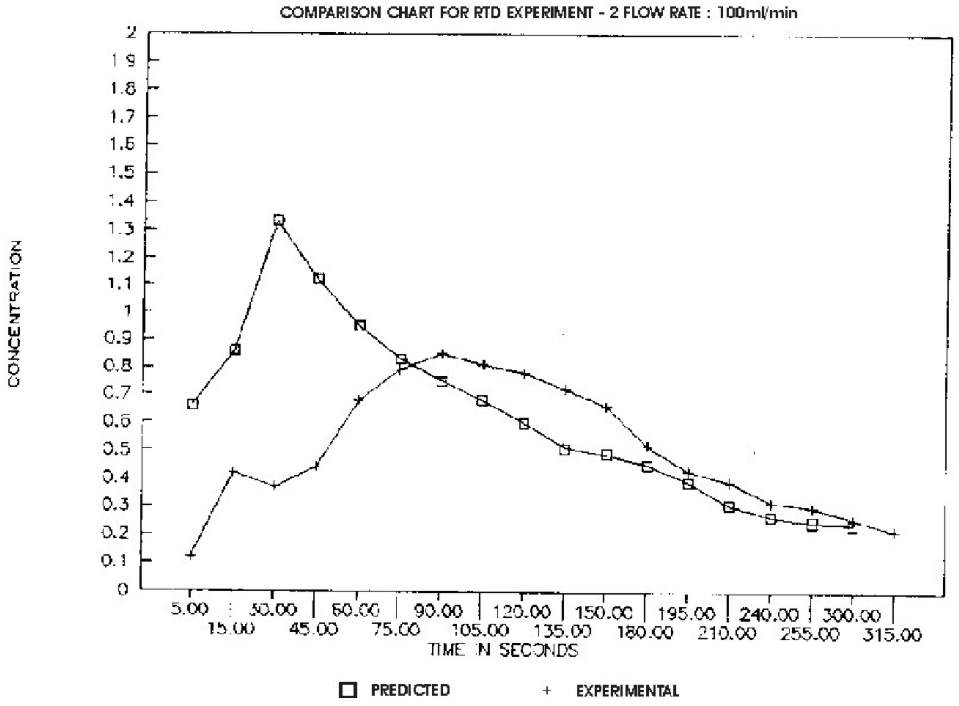


Figure - 4

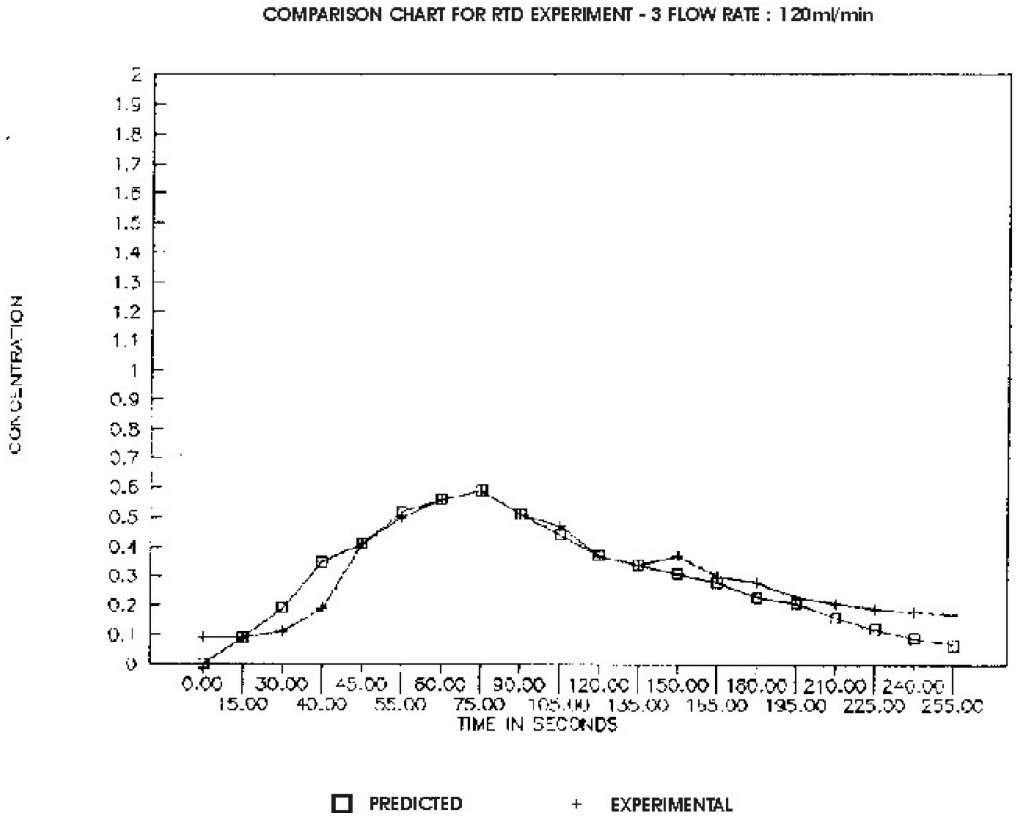
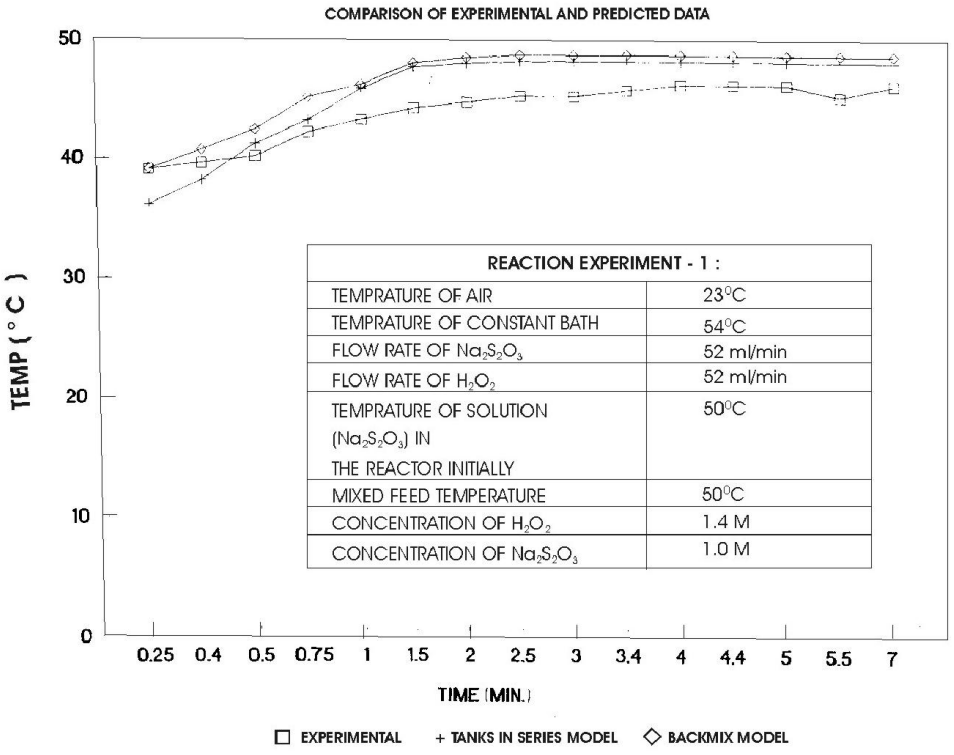


Figure - 5



REACTION EXPERIMENT - 1 :	
TEMPRATURE OF AIR	23°C
TEMPRATURE OF CONSTANT BATH	54°C
FLOW RATE OF $Na_2S_2O_3$	52 ml/min
FLOW RATE OF H_2O_2	52 ml/min
TEMPRATURE OF SOLUTION ($Na_2S_2O_3$) IN THE REACTOR INITIALLY	50°C
MIXED FEED TEMPERATURE	50°C
CONCENTRATION OF H_2O_2	1.4 M
CONCENTRATION OF $Na_2S_2O_3$	1.0 M

Figure - 6

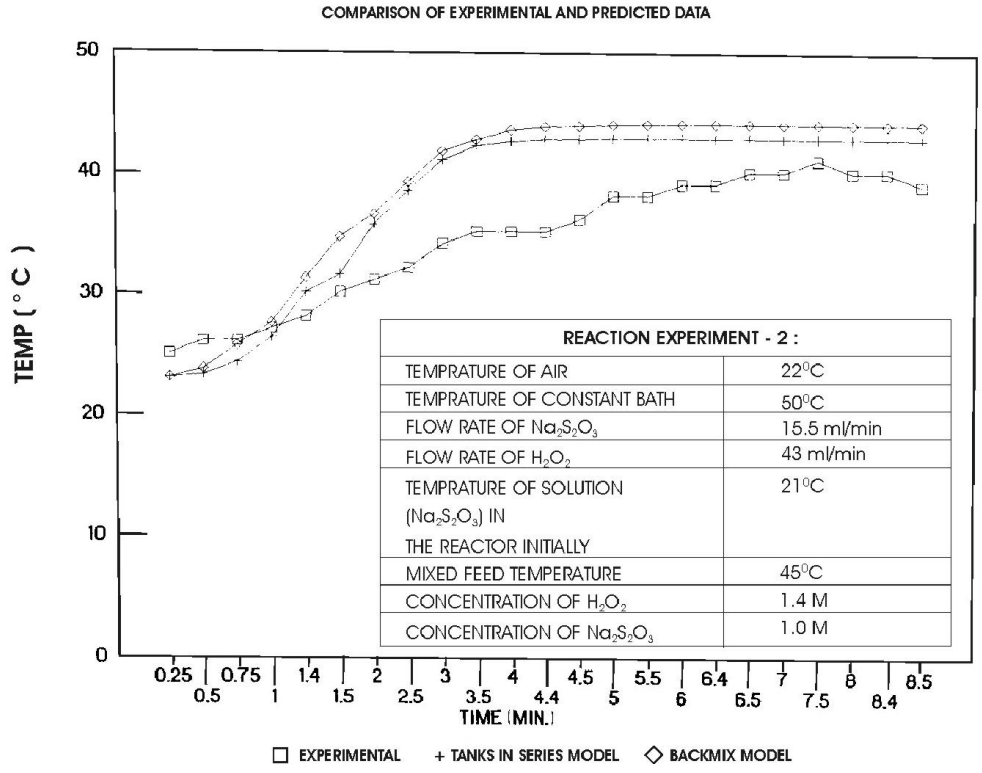
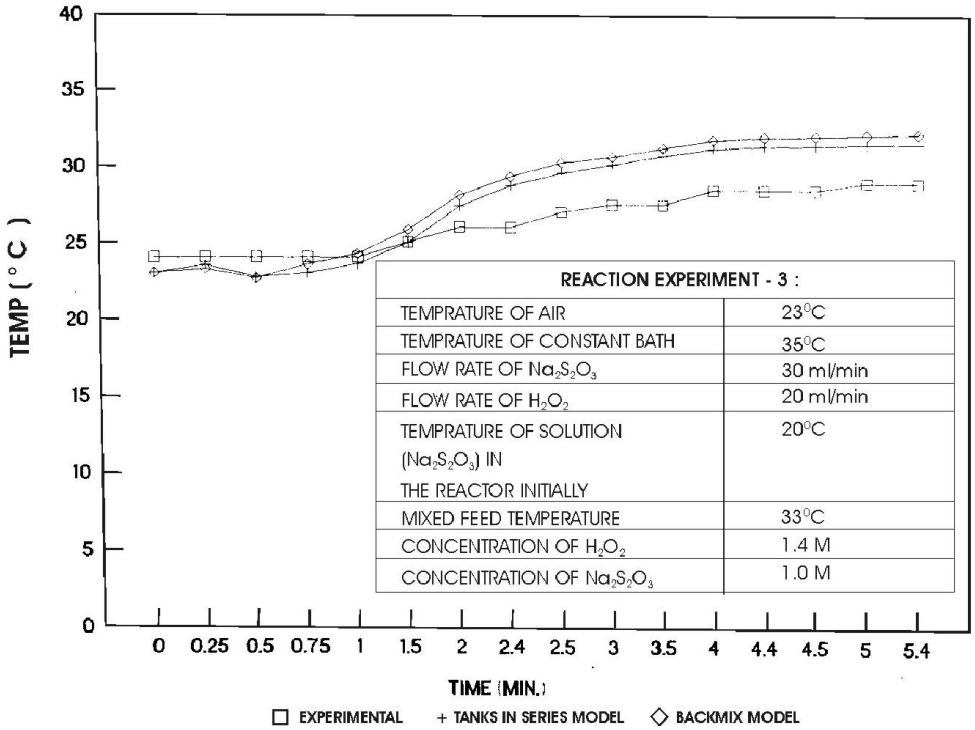


Figure - 7



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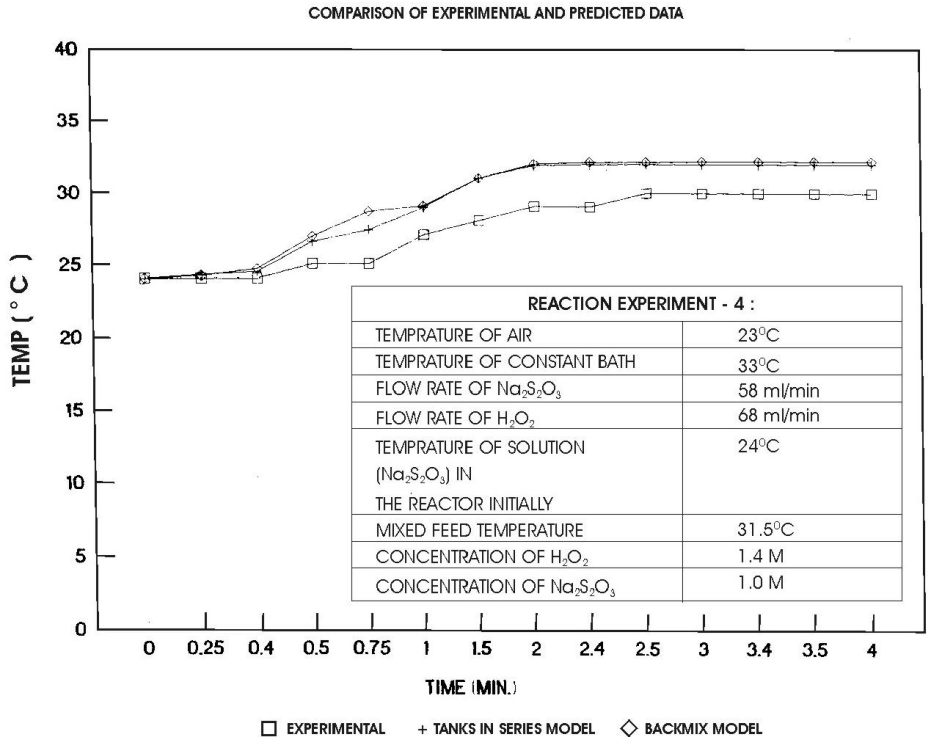

EXPERIMENTAL SET UP

1. Inlet of reactor.
2. Packed bed reactor
3. Outlet of reactor
4. Packing
5. Sodium Thiosulphate storage tank with constant head overflow
6. Hydrogen peroxide shortage tank with constant head overflow
7. Coils
8. Thermostate
9. Thermometers

Procedure

In one storage tank specific concentration of sodium thiosulphate and in another tank specific concentration of H_2O_2 were taken. Level of both the tanks were maintained.

RTD study was carried out to study flow pattern in the reactor using saturated solution of KCL at different flow rates. Concentration tracer was measured using conductivity meter and results obtained all given in the Fig. 2, 3, 4. The parametric sensitivity study was carried out at diff. temperature using thermostate. Results are reported in Fig. 5, 6, 7.

RESULTS AND DISCUSSION

RTD

Pulse input given to the reactor and the output obtained by the analysis of the exit stream by conductivity meter shows non ideal behaviour of the flow which is evident from fig. 2, 3, 4. This is quite obvious as the reactor is packed with steel balls which at higher flow rate will lead to axial and radial dispersion and consequently change the flow pattern from plug flow to back mix flow as flow rate increases from 70 ml / min. (Fig. 2) to 120 ml / min. (Fig. 4)

By using Runge Kutta and Mid point average method the experimental results were analysed and it is observed that the present reactor system can be described with a Tanks in series model with N=4 compartments.

Parametric Sensitivity

The results of the parametric sensitivity studying over the range of temperature considered during the experiments and the predicted values of the temperature as a function of time are as shown in Fig. 5,6,7. The initial period gives an excellent match between experimental and predicted values for both Tanks in series model and Back mix model. However small deviation is observed in the letter part of each experiments. The system shows steady state parameter values after a period of about 1.5 to 4 min. depending on the other operating conditions. The systems shows the single steady state over the period of study.

Conclusion

The following conclusions have been drawn from the present study:

1. The reaction between sodium thiosulphate and hydrogen peroxide has been employed to study, the dynamic characteristic for packed bed. In order to represent the packed bed, with mathematical models stimulation response studies (RTD) have been carried out. The RTD experiments were carried out at three different flow rates by giving reactor a pulse input.
2. The reactor was approximated to CSTR in series model.
3. The predicted temperature profile at dimensionless distance at 0.2, 0.6, 0.8 and 1.0 was compared with experimental temperature means used at these points. The predicted temperature was satisfactorily in agreement with the experimental data.

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