다단 조작장치의 동특성에 관한 연구

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A Dynamic Study in a Rushton Extractor

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Abstract

The residence time distribution of a Rushton Extractor was determined by using a dye pulse and electrolyte pulse trace techniques. The system under investigation employed an organic solution as a dispersed phase and ? water as a continuous phase of the system.

The flow patter of the system can be described by a modified mixing cell model. The experimental result demonstrated that the proposed model can represent the system and may be able to explain other similar processes.

Introduction

The dynamic characteristics in a flow system has been analysed by a dispersion model and a mixing cell model.

Taylor[1] used the dispersion model for the tubular flow. Aris[2] used the method for the dispersion model in a two phase system with transfer between phases, for the dispersion in the flow through a tube with stagnant pockets[3], and for the flow with a pulsating velocity[4].

Bischoff and Levenspiel[5] extended Aris theory to include a linear rate process, and used the result to construct Comprehensive correlation of the dispersion coefficient.

The theory of the longitudinal dispersion applied to chemical reactors was studied by Rao and Corrigan[6].

Mixing cell model has been discussed by many au-

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thors. The more general case of unequal-sized tanks in series was discussed by Mason and Piret[7]. A quantitative approach to the nonideality of mixing was introduced by Cholette and Cloutier[8, 9]

When the gross flow pattern of the fluid deviates greatly from the uniformly dispersed tubular flow, however, the dispersion modle can not satisfactorily characterize the nature of the flow. On the other hand, a simple mixing cell modle fails to characterize the flow pattern of the system of tanks in series where each mixing cell can be hardly recognized as an independent one but there is a considerable amount of flow exchanging between adjacent mixing cells. In this paper, the mixing cells in series model with intermix flow is proposed and the theoretical model is compared with the experimental results, the concentraion impulse response in a Rushton extractor. The extractor was considered as a system where both the dispersion and the mixing cells in series model fails.

The proposed model, the mixing cells with intermix

flow, could interpret well the experimental residence time distribution curves of the continuous phase but, for the drop phase, the proposed model could not give a good fit in the range of this investigation.

Theoretical

In this investgation, the mixing cells in series with intermix flow model is proposed. The model is assumed to consist of a series of perfectly mixed cells of a equal volume with intermix flow between adjacent cells.
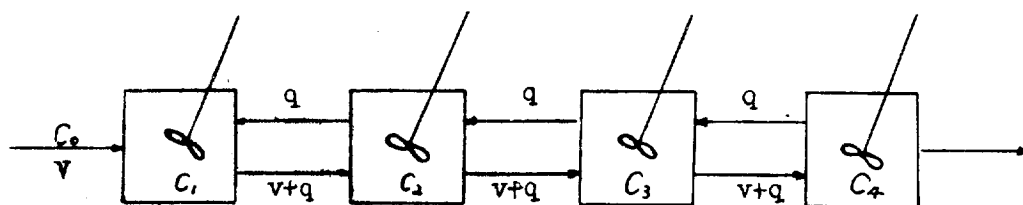
and

$$(1+r) C_3 - (1+r) C_4 = \frac{1}{4} \frac{d C_4}{d\theta} \tag{8}$$

When an unit impulse is given to the incoming flow, the initial conditions of the above equaitons are

$$C_0(\theta) = \delta(\theta)$$

and

$$C_1(0) = C_2(0) = C_3(0) = C_4(0) = 0$$

$C_4(\theta)$ in the equations obtained with the above initial conditions is the residence time distribution,

Fig. 1 Theoretical model

Fig. 1 shows a four stage mixing cells in series with intermix flow. The material balance equations are.

$$v C_0 - (v+q) C_1 + q C_2 = \frac{V}{4} \frac{d C_1}{dt} \tag{1}$$

$$(v+q) C_1 - (v+2q) C_2 + q C_3 = \frac{V}{4} \frac{dC_2}{dt} \tag{2}$$

$$(v+q) C_2 - (v+2q) C_3 + q C_4 = \frac{V}{4} \frac{dC_3}{dt} \tag{3}$$

and

$$(v+q) C_3 - (v+q) C_4 = \frac{V}{4} \frac{d C_4}{dt} \tag{4}$$

Let $r = \dfrac{q}{v}$, $\tau = \dfrac{V}{v}$ and $\theta = \dfrac{t}{\tau}$

then the above equations become

$$C_0 - (1+r) C_1 + r C_2 = \frac{1}{4} \frac{d C_1}{d\theta} \tag{5}$$

$$(1+r) C_1 - (1+2r) C_2 + rC_3 = \frac{1}{4} \frac{dC_2}{d\theta} \tag{6}$$

$$(1+r) C_2 - (1+2r) C_3 + r C_4 = \frac{1}{4} \frac{dC_3}{d\theta} \tag{7}$$

$f(\theta)$, of the system illustrated in Fig. 1. The residence time distribution function could be calculated by a digital computation based on a Runge-Kutta metohd with r as a parameter and the results are shown in Fig. 2.
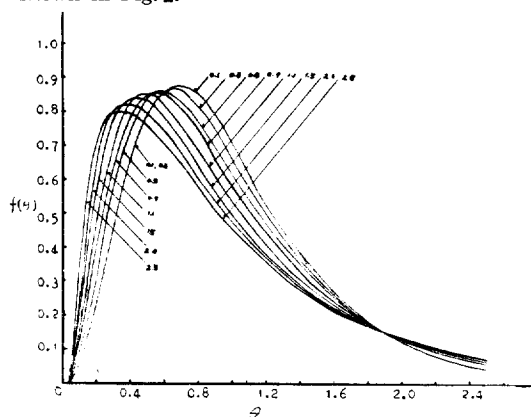

Fig. 2 Theoretical curve

Tabel 1. Dimensions of extraction colum

Diameter of column	;2 inch
Length of column	;15 inch
Number of impeller	;4
Distance between two impellers	;3 inch

Width of impeller blade	; $\frac{1}{4} \times \frac{1}{4}$ inch
Width of baffle	; $\frac{1}{6}$ inch

Particular attention is given to the fact that the feed jet velocity must be small enough to avoid the jet mixing. Also, each outlet was a bugle type to minimize the wake effect and to keep smaller hold up of the fluid before it reaches the monitering device. The inlet as well as the outlet is detailed in Fig. 4.
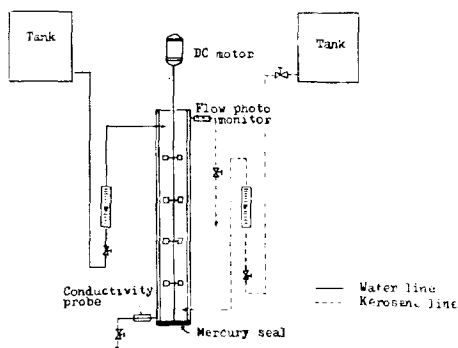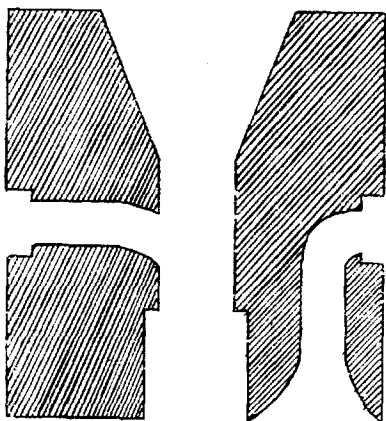

Fig. 3 Extraction equipment

Fig. 4 Detail of the inlet and outlet

Steday flows of both water and Kerosene were maintained by a constant head tanks, and flow rates were measured with calibrated rotameters. The rotational speed of agitator driven by a D.C. motor was

controlled with a powerstat. The agitation speed was measured by a stroboscope.

The continuous phase was distilled water containing constant specific resistance, 100,000 Ωcm and the dispersed phase Kerosene (at 25°C, density 0.78 g/cc and viscosity 2.2 c.p.).

In order to minimize the effects of the surface activity, fresh water and fresh Kerosene were used for each run and the column was often flushed.

The flow rate of water as well as Kerosene was 120 ml/min. and either water or Kerosene was chosen as a dispersed or a continuous phase.

Conductivity method

The electrolyte tracer, 0.1 ml of 30 % Nacl solution, was injected by a syringe inserted through a self sealing rubber plug end of the water inlet and the conductivity of the outlet flow was measured. The conductivity probe was consisted of two parallel 4 m/m square stainless steel plates 4 m/m apart and was held by a 9 m/m glass tube. All the exposed metallic surfaces, i.e. the outer surfaces of the probe and cupper wire, except the innersurfaces of the probe, were coated with nonconducting plastic material.

The probe was connected as one leg of the bridge circuit (see Fig. 5.) within a Dynamic strain amplifier, TOA DPM-6 CT.
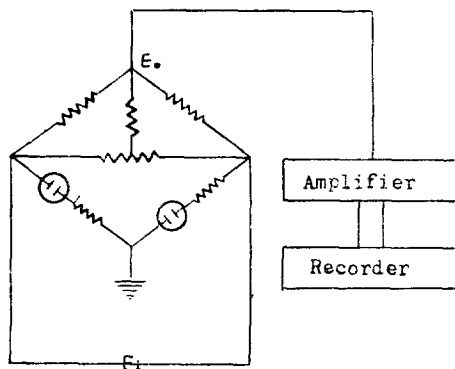

Fig. 5 Schematic circuit diagram for conductivity

The outlet voltage from the balanced bridge was amplified by the amplifer and Continuousely recorded by the Electronic polyrecorder, TOA EPR 2 TC.

Calorimetric method

The tracer used in the Kerosene phase was a portion of Kerosene with Dupont Red, insoluble in water. The tracer solution was injected into the Kerosene feed line, just below the mixing section as shown in Fig. 3.

The outlet concentration of the red color in Kerosene was measured with Flow photomonitor shown in Fig. 6. and continuously recorded on the polycorder, TOA EPR 2 TC.
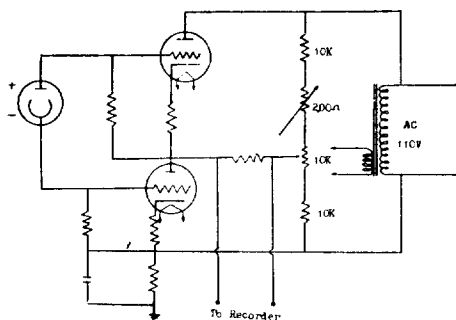

Fig. 6 Schematic circuit for flow photo monitor

Experimental Result and Discussions

continuous phase

Fig. 7a and Fig. 7b are the experimental residence time distributions for the continuous phases of water and Kersosene obtained with the conductivity probe and the photo-monitor, respectively. As shown in the figures, the distributions become skewed more to the left as the agitator speed increases.
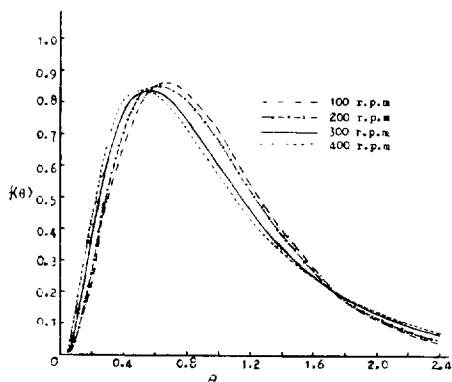

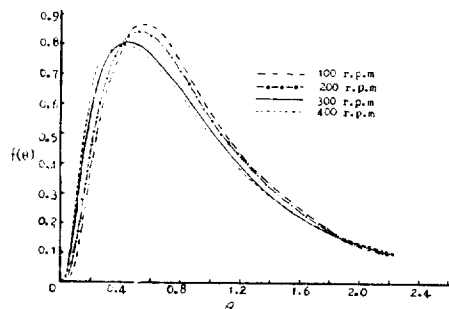Fig. 7a Residence time distribution for continuous phase (water)

Fig. 7b Residence time distribution for continuous phase (Kerosene)

This tendency agrees well with that of the theroretical one since it may be reasonable to consider that the intermix flow to the adjacent mixing cell increases with the agitator rotation.

Fig. 8a and Fig. 8b are the comparisons of the experimental results with the theoretical model. The theoretical curve is chosen to have the same time of maximum $f(\theta)$ as the experimental one.
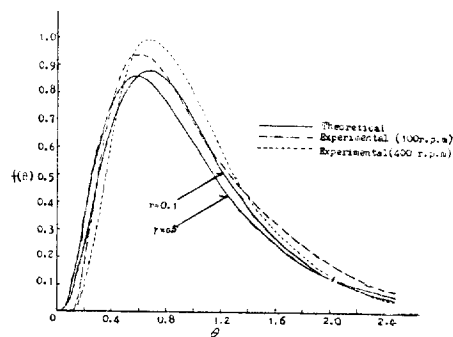

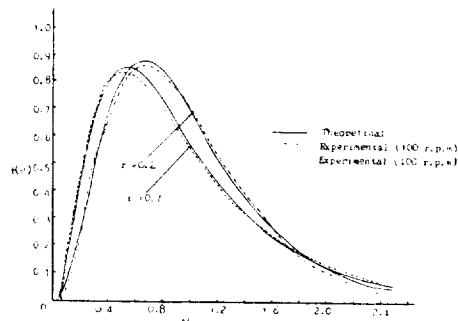Fig. 8a Residence time distribution for continuous phase (water)

Fig. 8b Residence time distribution for continuous phase (Kerosene)

The figure shows that the residence time distribution of the continuous phases are fairly close to that of the proposed theoretical model.

Dispersed phase

The experimental residence time distribution functions obtained for the dispersed phase are shown in Fig. 9a for water and in Fig. 9b for Kerosene.
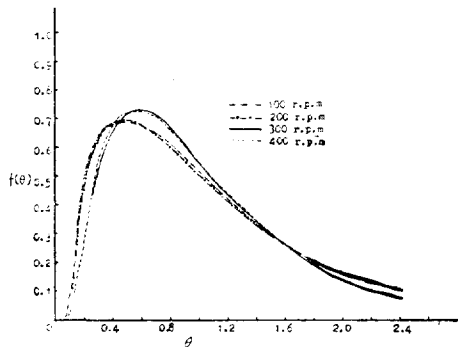
that the proposed model no longer fits to the dispersed phase at the lower impeller rotation.

Fig. 10a and Fig. 10b are the comparisons of the experimental results with the theoretical model for the dispersed phases of water and Korosene respectively. The corresponding theoretical curve is to have the same time of maximum $f(\theta)$ as the experimental one.

Fig. 9a Residence time distribution for dispersed phase (water)

Fig. 10a Residene time distribution for dispersed phase (water)

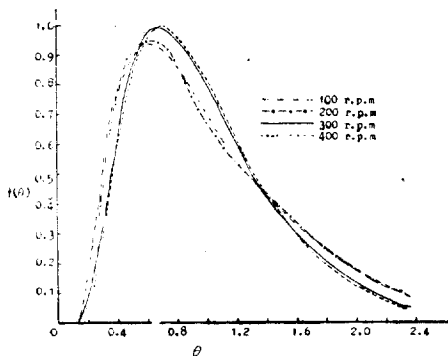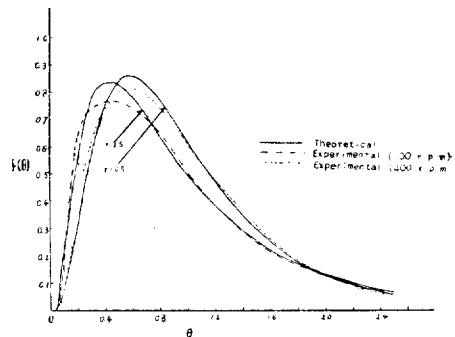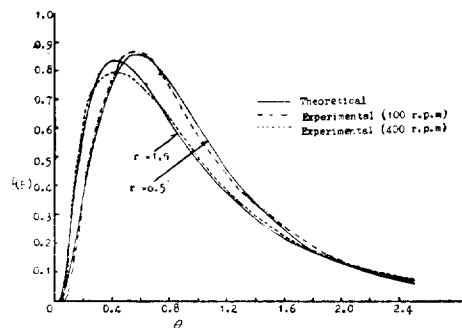**Fig. 9b** Residence time distribution for dispersed phase (Kerosene)

Fig. 10b Residence time distribution for dispersed phase (Kerosene)

As shown in the figures, the tendency of the skewness of the curves is reverse from that the continuous phase. Actually, no intermix flow was observed for the dispersed phase at the lower agitation speed (100 and 200 r. p. m) and only the spiral motion toward the direction of the flow of the dispersed phase was observed at the lower agitation speed. This implies

From the figures, it could be observed that the theoretical model is no longer appropriate for the dispersed phase in the range of this investigation. However, it could be suggested that the model would be applied even for the dispersed phase at much higher impeller rotation.

Conclusions

1. The mixing cells in series with intermix flow model is proposed and the theoretical residence time distribution function based on the model is calculated.

2. The experimental method adopted in this investigation is the concentration impulse technique by employing the electric conductivity probe for the aqueous phase and the photo monitering device for the organic phase. The method gave a sufficient degree of accuracy throughout the experiments.

3. The experimental residence time distribution obtained in a Rushton extractor is compared with the theoretical model. For the continuous phase, the model could be fairly well suited to the experimental results but, for the dispersed phase, the model is no longer applicable especially in the region of the lower impeller rotation.

Nomenclature

V; Total volume of the extractor
r; Backflow ratio of backflow rate to forward flow
C_0; Initial concentration of impulse
v; Volume flow rate
q; Backflow rate
C; Concentration
τ; Mean residence time
θ; Dimensionless time
$f(\theta)$; Residence time distribution function

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