The Effects of Mass Transfer on Drop Breakage in Rotating Disc Contactors

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ABSTRACT

Breakage of single drops of solvent in water is examined in a 300 mm diameter RDC. Correlations for drop size distribution and scale-up effects obtained from breakage without mass transfer are used to find apparent interfacial tensions for breakage with mass transfer occuring.

INTRODUCTION

This work was intended to obtain more fundamental correlations for drop size distribution and scale-up from the breakage probability of single drops in the presence of mass transfer for a 300 mm RDC. The data obtained are to be compared with the correlations obtained by Bahmanyar et al. (1989) A simple system of no mass transfer breakage was first examined from which the correlations were then applied to that of mass transfer using apparent interfacial tensions.

EXPERIMENTAL DETAILS

The experimental work involved was divided into:

a) single drop breakage without mass transfer

b) single drop breakage with mass transfer

c) estimation of apparent interfacial tension for mass transfer systems from the correlation for critical conditions obtained for no mass transfer systems.

The systems under study show high, medium and low interfacial tensions, an important property which affects drop breakage.

Results

(a) Breakage Phenomenon

It is difficult to predict drop size if mass transfer takes place because of the changes in the physical properties of the dispersed phase and the continuous phase. The change of the interfacial tension between the two phases greatly affects the drop size.

In this work, the data obtained are for the non-turbulent region ($Re_D < 6 \times 10^4$). The mechanism of breakage was taken into consideration in deriving the correlation for the critical drop size (drop size above which breakage will occur) thus making it more fundamental.

(b) Breakage Without Mass Transfer

The behaviour of a swarm of drops in the rotating field of RDC is found to be adequately represented in most respects by single-drop dynamics. (Strand et al., 1962)

The coalescence process was neglected as the breakage experiments were conducted at a dispersed phase hold-up less than 1%.

The effect of drop breakage at various rotor speed was examined. It was observed that as the rotor speed increased, the drop formation rate at the capillary increases and the drop size decreases.

It was observed as the rotor speed increased, drop breakage increases. However at very high speed, the breakage reduces. Also, at high speed drops drifted away from the rotor edge towards the column wall. Bigger drops show higher breakage probabilities than smaller drops.

The critical rotor speed was taken by extrapolation of the best fit straight line at zero breakage fraction. The critical rotor speed increases as the drop diameter decreases.Figure 1 gives the data from the 300 mm RDC together with the data and correlation of Bahmanyar et al. (1989). The interfacial tensions used for the calculation of the modified Weber number were the equilibrium values and the critical rotor speeds were taken from the plot of breakage percentage vs rotor speed at zero breakage.

(c) Breakage With Mass Transfer

In this work, the breakage fractions are measured for the systems with mass transfer in both directions for solvent or aqueous.The correlations obtained from breakage without mass transfer were examined for systems undergoing mass transfer.

The critical rotor speed was then used to find the apparent interfacial tension. Using the calculated interfacial tension and the critical rotor speed, the modified Weber number was then calculated and plotted against the breakage fraction (figure 2).

DISCUSSION

Bahmanyar et al. (1989) examined the breakage probabilities for the systems Cumene/isobutyric acid/water and Cumene/acetic acid/water in the non-turbulent region ($Re_D < 6 \times 10^4$) for RDC of 152, 300 and 600 mm in diameter. They found empirical correlations obtained for systems without mass transfer could be used for systems undergoing mass transfer with calculated effective interfacial tensions. They demonstrated that the mass transfer process and direction of mass transfer do not affect breakage other than via interfacial tension forces.

The general empirical correlation relating a critical drop size as a function of Weber and Reynold numbers at zero breakage obtained is

$$d_{CR}/H_C = 7.6 \times 10^{-4} (\acute{A}_{app}/\mu_C N_{CR} D_R)$$

$$= 7.6 \times 10^{-4} Re_D/We_D \quad (1)$$

with a standard relative error of ± 0.004.

Drop breakage fractions were found to be dependent on column sizes and the equation given for correlating breakage fraction and modified Weber number (the ratio of kinetic energy to drop surface energy) is

$$p/(1-p) = 0.011 \ We_M^{1.1} \quad (2)$$

with a lower boundary (when drop contacts the rotor) of

$$p/(1-p) = 6 \times 10^{-3} \ We_M \quad (3)$$

and an upper boundary (when drop misses the rotor) of

$$p/(1-p) = 15.4 \times 10^{-3} \ We_M^{1.35} \quad (4)$$

Equation (1) is used for estimating the apparent interfacial tension associated with mass transfer.

The breakage probabilities increase rapidly as the rotor speed is increased above the critical rotor speed up to a maximum value beyond which the breakage probabilities decrease as the rotor speed is increased.

The dependence of the breakage process on modified Weber number (We_M) as plotted in figures 1 and 2 show good agreement for data obtained from the 300 mm

RDC within experimental uncertainties (standard deviations are ±26.72 and 16.43). Thus it can be deduced that the simple system for no mass transfer can be used to obtain correlation for drop size distribution for systems undergoing mass transfer.

CONCLUSION

The conclusions arrived at from this work are :

(1) it is possible to conduct inexpensive, simple and quick breakage experiments by just using eyes without any expensive technical/electronic devices.

(2) critical rotor speed (below which no breakage occurs) can be determined by linear extrapolation of breakage probabilities against rotor speed

(3) correlations given by Bahmanyar et al. (1989) can be used for determining drop size distribution and scale-up effects for mass transfer systems in a 300 mm diameter RDC. The direction of mass transfer is found to have little influence in drop size distribution and scale-up

(4) apparent interfacial tensions can be calculated using the critical conditions for the three columns studied.

NOMENCLATURE

d	drop diameter	m
d_{CR}	critical drop diameter	m
D_R	rotor diameter	m
H_C	height of compartment	m
N	rotor speed	s^{-1}
N_{CR}	critical rotor speed	s^{-1}
p	breakage probability	
Re_D	disc Reynold number	
We_D	disc Weber number	
We_M	modified Weber number	
Greek		
μ_C	viscosity of the continuous phase	kg/m.s
$Á_{app}$	apparent interfacial tension	N/m
e	hold-up of dispersed phase	

REFERENCES

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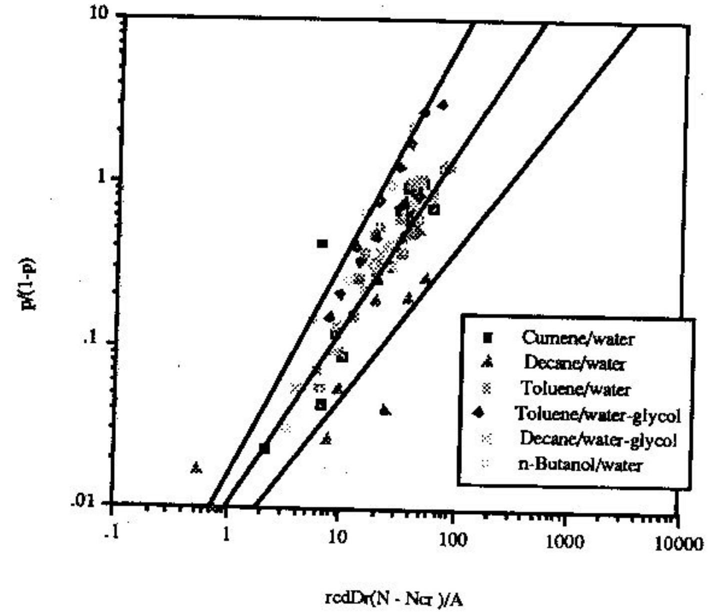

Figure 1 : Correlation of breakage for systems without mass transfer

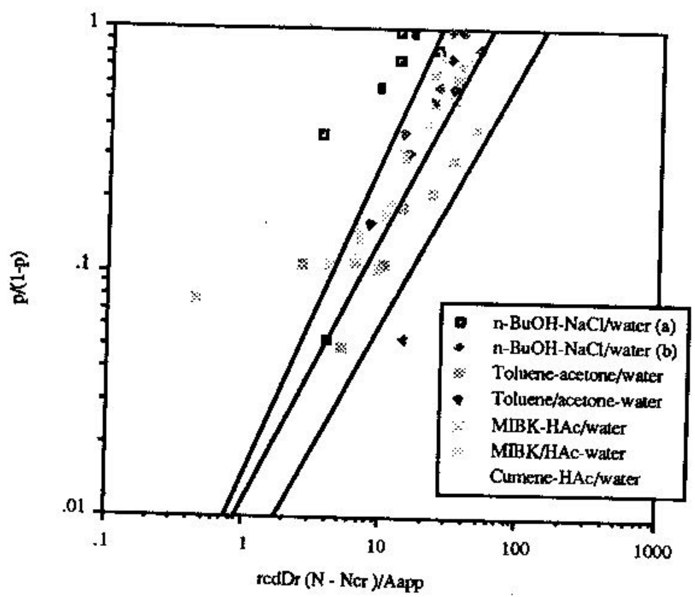

Figure 2 : Correlation of breakage for systems undergoing mass transfer