SIMPLIFIED EQUATION TO PREDICT MINIMUM WETTING RATE

Dear Sir:

In a previous paper²⁾, a correlating equation to predict the minimum wetting rate in a wetted-wall column was proposed as follows:

$$Ky^{2/3} + By^{5/3} = Ax^{1/3} \quad (1)$$

where $y = \Gamma/\mu$, $x = \rho\sigma^3/\mu^4g$, $B = 2 \cdot 3^{5/3}/15$ and A and K are numerical constants evaluated experimentally, which vary depending on the wetted-wall surface properties and liquid distribution manner. Eq. (1) can be used in a wide range of x , i. e. $10^{-2} < x < 10^{11}$, but the prediction of minimum wetting rate, Γ , with Eq. (1) contains a trial and error procedure. So it is convenient for practical use to transform Eq. (1) to an explicit function with respect to y .

At both extremes Eq. (1) has the asymptotic equations respectively as follows:

$$y = (A/K)^{3/2} x^{1/2} \quad \text{for } x \rightarrow 0$$

$$y = (A/B)^{3/5} x^{1/5} \quad \text{for } x \rightarrow \infty$$

According to the procedure proposed by Churchill and Usagi¹⁾, under these conditions the expression

$$y = \{[(A/K)^{3/2} x^{1/2}]^{-n} + [(A/B)^{3/5} x^{1/5}]^{-n}\}^{-1/n} \quad (2)$$

is suitable for approximation.

Rearranging the above equation, we obtain:

$$Y = [1 + Z^n]^{1/n} \quad (3)$$

where

$$Y = (A/B)^{3/5} x^{1/5} / y \quad (4)$$

and

$$Z = (A/B)^{3/5} / \{(A/K)^{3/2} x^{3/10}\} \quad (5)$$

The exponent n in Eq. (2) can be, in this case, evaluated analytically by the following procedure. When $Z=1$, i. e. when $x = (A/B)^2 / (A/K)^5$, $n = \ln 2 / \ln Y_{Z=1}$.

Substitution of the value of x at $Z=1$ to Eq. (4) gives $Y_{Z=1} = K / (B y_{Z=1})$ and $y_{Z=1}$ can be obtained by substituting x at $Z=1$ to Eq. (1) as follows:

$$\begin{aligned} K y_{Z=1}^{2/3} + B y_{Z=1}^{5/3} &= A(A/B)^{2/3} / (A/K)^{5/3} \\ &= K^{5/3} / B^{2/3} \end{aligned} \quad (6)$$

When $y_{Z=1} = CK/B$, Eq. (6) reduces to

$$C^{2/3} + C^{5/3} = 1$$

and this equation gives $C = 0.529$.

Hence

$$Y_{Z=1} = 1/C$$

and then

$$n = \ln 2 / \ln(1/C) = 1.09$$

The above description shows that the exponent n in Eq. (2) can be decided independently of A and K so long as it is evaluated by use of the values of x and y at $Z=1$ where x has the value of the intersection of the two asymptotic equations.

When the values of A and K evaluated experimentally in the previous work are used, the equation of the following final form

$$y = \{[(A/K)^{3/2} x^{1/2}]^{-1.09} + [(A/B)^{3/5} x^{1/5}]^{-1.09}\}^{-1/1.09}$$

can be used to predict a minimum wetting rate, the deviation from Eq. (1) being less than 6.6% over the entire range.

Nomenclature

A, B, C, K	= numerical constant	[—]
g	= acceleration due to gravity	[cm/sec ²]
n	= exponent defined in Eq. (2)	[—]
x	= $\rho\sigma^3/\mu^4g$	[—]
Y	= $(A/B)^{3/5} x^{1/5} / y$	[—]
y	= Γ/μ	[—]
Z	= $(A/B)^{3/5} / \{(A/K)^{3/2} x^{3/10}\}$	[—]
Γ	= minimum wetting rate	[g/cm·sec]
μ	= viscosity of liquid	[g/cm·sec]
ρ	= density of liquid	[g/cm ³]
σ	= surface tension of liquid	[dyne/cm]

Literature Cited

- 1) Churchill, S. W. and R. Usagi: *AIChE J.*, **18**, 1121 (1972).
- 2) Munakata, T., K. Watanabe and K. Miyashita: *J. Chem. Eng. Japan*, **8**, 440 (1975).

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