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A NOTE ON THE LOCKHART–MARTINELLI CORRELATION IN THE TURBULENT–TURBULENT CASE

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NOMENCLATURE

b, Blasius exponent;
K, dimensionless parameter, equation (5);
m, dimensionless parameter to be fitted to the experimental data;
X_{TT}, Lockhart–Martinelli parameter for the turbulent–turbulent case.

Greek symbols
α, void fraction;
γ, slip ratio;
μ_g, vapor viscosity;
μ_l, liquid viscosity;
ρ_g, vapor density;
ρ_l, liquid density;
ϕ_L, parameter related to the void fraction α by equation (2);
χ, vapor quality.

FOR TWO phase turbulent–turbulent flow in pipes, the void fraction α depends on the vapor quality, χ, on the vapor and liquid densities ρ_g, ρ_l on the vapor and liquid viscosities μ_g, μ_l. That α actually only depends on the parameter X_{TT} is the physical content of the Lockhart–Martinelli correlation [1], X_{TT} being defined by

$$X_{TT} = [(1-\chi)/\chi]^{(2-b)/2} (\rho_g/\rho_l)^{1/2} (\mu_l/\mu_g)^{(b/2)} \quad (1)$$

where b denotes the Blasius exponent.

The curve $\alpha\,(X_{TT})$ is usually fitted by the equations

$$\alpha = 1 - (1/\phi_L), \qquad \phi_L^2 = 1 + 21/X_{TT} + 1/X_{TT}^2. \quad (2)$$

Using such a fit is rather troublesome when performing analytical calculations. Moreover equation (2) yields an unphysical singularity for $\partial\alpha/\partial\chi$ as $\chi \to 0$. As a substitute for equation (2) we propose the relation

$$\alpha = 1 - (m/2)\,X_{TT}^{2/(2-b)} - \{[1 + (m/2)\,X_{TT}^{2/(2-b)}]^2 - 1\}^{1/2} \quad (3)$$

where m denotes a dimensionless parameter to be fitted to the experimental data.

A comparison of the fit of equations (2) and (3) is given in Table 1, with $m = 0.054$. The agreement is quite good, except for $\chi \to 0$, since equation (3) does not generate any unphysical singularity.

$\alpha(\chi)$, as defined by equation (3), only depends on X_{TT}, according to the Lockhart–Martinelli correlation. This is the only case of equation (3) which can be turned into the simple analytical relation

$$\chi = (\alpha m K)/[(1-\alpha)^2 + \alpha m K] \quad (4)$$

where K is defined by

$$K = [(\rho_g/\rho_l)^{1/2} (\mu_l/\mu_g)^{b/2}]^{2/(2-b)}. \quad (5)$$

Let us now consider the slip ratio γ, which is known to satisfy the identity

$$\gamma = (\rho_l/\rho_g)\,[(1-\alpha)/\alpha]\,[\chi/(1-\chi)]. \quad (6)$$

Using equation (4), this simplifies to

$$\gamma = (\rho_l/\rho_g)\,[mK/(1-\alpha)]. \quad (7)$$

Some properties of the correlations, equations (4) and (7) are:

(1) From the numerical point of view, the agreement with the usual correlation, equation (2), is quite good.
(2) They do not yield unphysical singularities as $\chi \to 0$.
(3) Their analytical form is very simple.
(4) They only depend on the parameter m, which must be

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Table 1. Comparison of the correlations equations (2) and (3)

X_{TT}	χ	α[equation (2)]	α[equation (3)]
55.21	2×10^{-4}	0.149	0.137
30.20	4×10^{-4}	0.232	0.223
21.22	6×10^{-4}	0.291	0.284
13.52	8×10^{-4}	0.337	0.330
16.60	1×10^{-3}	0.374	0.368
7.436	2×10^{-3}	0.490	0.487
5.221	3×10^{-3}	0.555	0.553
4.062	4×10^{-3}	0.599	0.598
3.342	5×10^{-3}	0.632	0.631
2.849	6×10^{-3}	0.657	0.656
2.489	7×10^{-3}	0.677	0.677
2.214	8×10^{-3}	0.694	0.694
1.997	9×10^{-3}	0.708	0.709
1.821	1×10^{-2}	0.721	0.721
0.9873	2×10^{-2}	0.793	0.794
0.6877	3×10^{-2}	0.828	0.829
0.5306	4×10^{-2}	0.849	0.851
0.4330	5×10^{-2}	0.865	0.866
0.3661	6×10^{-2}	0.877	0.878
0.3172	7×10^{-2}	0.886	0.887
0.2798	8×10^{-2}	0.894	0.894
0.2501	9×10^{-2}	0.900	0.901
0.2260	1×10^{-1}	0.906	0.906
0.08691	0.25	0.948	0.945
0.03342	0.50	0.974	0.968
0	1	1	1

In order to relate the vapor quality χ and the parameter X_{TT} the following parameters have been used (corresponding to sodium): $\rho_l = 0{,}7217\,\mathrm{g\,cm^{-3}}$, $\rho_g = 0{,}48.10^{-3}\,\mathrm{g\,cm^{-3}}$, $\mu_l = 0{,}1475$ centipoises, $\mu_g = 0{,}02009$ centipoises, $b = 0{,}26$. In equation (3) the parameter m has been fitted to $m = 0.054$.

fitted to the experimental results. The usual correlation, equation (2), could be adjusted either by modifying the coefficients of the series in $1/X_{TT}$ or by adding to it further terms.

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