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Letter to the Editors

This letter provides discussion of the previously published paper, Yi-Ye Yan and Tsing-Fa Lin, "Evaporation heat transfer and pressure drop of refrigerant 134A in a small pipe", *Int. J. Heat Mass Transfer*, Vol. 41, pp. 4183–4194, 1998 [1]

Yan and Lin provide their measured evaporation coefficients and two-phase friction factor for R-134A flowing inside a 2.0 mm inside diameter tube. They also provide correlations they developed to predict their data. This work is important, because it provides the first and only published correlation for the evaporation coefficient for two-phase forced convection regime in such small diameter tubes. However, another correlation [2] has been published for friction pressure drop that applies to small diameter tubes.

The evaporation coefficient correlation (Yan and Lin Eq. (17)) is based on a variant of the Kandlikar [3] correlation for forced convection vaporization inside tubes. It varies from the Kandlikar correlation in the empirically determined coefficients and exponents. Yan and Lin "more than 80% their evaporation data fall within ±15% of their correlation". The Yan and Lin correlation for the two-phase friction pressure drop (their Eq. (22)) is given as an empirical power law correlation for the two-phase friction factor (f_{tp}) as a function of the "equivalent all-liquid Reynolds number". They state that the "average deviation of the friction correlation is 17%".

In working with this correlation, the present authors have found that both of the Yan and Lin correlations show extremely poor ability to predict the Yan and Lin data. The data points were read from the publication figures. Fig. 1 shows the ability of Yan and Lin's Eq. (17) to predict the Yan and Lin R-134A evaporation coefficient data. Fig. 1 shows that the predicted data fall far below the correlation. Fig. 2 shows the results of using Yan and Lin's Eq. (22) to predict the two-phase friction factor (f_{tp}) as a function of the equivalent all-liquid Reynolds number (Re_{eq}). Fig. 2 shows that the predicted friction data also fall far below the correlation. The present authors communicated with Dr. Yan [4] to determine if typographical errors exist in their Eqs. (17) and (22). They responded that they were not aware of any typographical errors in either equation. We will appreciate the efforts of authors Yan and Lin to provide directions on the proper use of their correlation—or of errors in the published version.

It is noted that the test section used in this work, consists of 28 parallel tubes, 200 mm long in a plane array having 100 mm heated length. Such a geometry is possibly susceptible to flow mal-distribution. The authors provide no detailed description of the inlet and exit

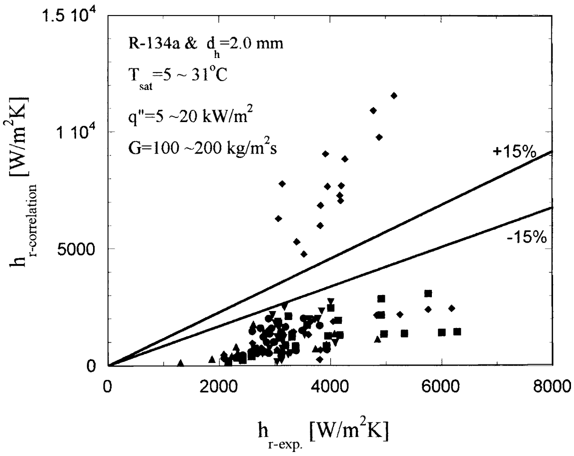

Fig. 1. Use of Yan and Lin [1] Eq. (17) correlation to predict R-134A evaporation coefficient data of Yan and Lin [1].

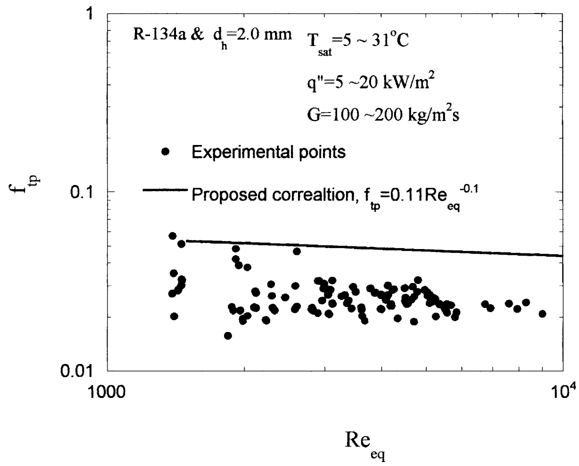

Fig. 2. Use of Yan and Lin [1] Eq. (17) correlation to predict R-134A two-phase friction factor data of Yan and Lin [1].

manifold designs, which will affect the flow distribution in the channels. Explanation on this will be welcomed.

The present authors have used the Shah correlation [5] to predict the Yan and Lin data for $T_{sat} = 31$ °C, $q'' = 5$ kW/m^2, and 100 and 200 kg/s m^2 mass velocity (G). This comparison shows that the Yan and Lin data for $G = 100$ kg/s m^2 and $x = 0.2$ are approximately five times that predicted by the Shah equation. However, at 0.8 vapor quality, the predicted values for both mass velocities are approximately equal and are 25% above the Shah correlation prediction. One may expect nucleate boiling to influence the evaporation coefficient at low vapor quality. However, the $q'' = 5$ kW/m^2 is sufficiently small that one would not expect significant nucleate boiling enhancement at this heat flux. The authors explanation of this will be appreciated.

References

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Reply to Prof. R.L. Webb's and Dr. J.W. Paek's comments

Dr. Yan and I examine the comments from Prof. Webb and Dr. Paek carefully. Here is our response. We appreciate their comments to point out our mistakes.

(1) By checking all the measured raw data and the data reduction procedures leading to the evaporation heat transfer coefficient h_r and friction coefficient f_{tp} with extreme care, the results presented in Figs. 13 and 14 of the article for the comparison between the correlations proposed by Yan and Lin (1998) and the measured data are noted to be in mistake. More specifically, the error in f_{tp} ($\equiv -\Delta P_f/(2G^2 v_m L/D_i)$) is due to the incorrect evaluation of the specific volume v_m for the two-phase R-134a liquid–vapor mixture. The measured data for the frictional pressure drop ΔP_f, however, are correct, so are the heat transfer coefficient h_r. Moreover, the correlation for h_r given in the article of Yan and Lin (1998) is also incorrect. This correlation is too complicate to use conveniently and there are 36 values of the empirical constants involved in the equation. Some mistakes were made in the curve-fitting procedures in missing the final step to bring the data well above and well below the correlation together.

(2) A new and simpler correlation for h_r is proposed here. For $X_m \leqq 0.7$

$$h_r = 4.36\frac{k_l}{D_i}Pr_l^{1/3}(1-X_m)^{-0.5}(C_1 \cdot Re_{eq} + C_2)(C_3 \cdot Bo + C_4) \tag{1}$$

and for $X_m > 0.7$

$$h_r = 4.36\frac{k_l}{D_i}Pr_l^{1/3}(1-X_m)^{-0.5}(C_1 \cdot Re_{eq} + C_2) \tag{2}$$

Here the coefficients C_1 to C_4 are expressed as

$$C_1 = -0.0124G^{-0.368} \tag{3}$$

$$C_2 = 1.49G^{0.514} \tag{4}$$

$$C_3 = -1166X_m + 1028 \tag{5}$$

$$C_4 = 0.53\,e^{0.931X_m} \tag{6}$$

Note that the unit for the mass flux of R-134a G is kg/m^2 s, and Re_{eq} and Bo are respectively the equivalent Reynolds number and Boiling number, which have been defined in the article. Meanwhile, a new correlation is provided here for the friction factor as

$$f_{tp} = 0.127Re_{eq}^{-0.1925} \tag{7}$$

The comparison of the above correlations with the correct measured data for h_r and f_{tp} is shown in Figs. 1 and 2. The results show that the root-mean-square deviations between the above correlations and measured data are 18% for the heat transfer coefficient h_r and 22% for the friction factor f_{tp}.

(3) The refrigerant R-134a is sent into the 28 small pipes in a row by an upstream plenum, which is a horizontal large cylindrical container with two openings of 84 mm wide and 2 mm high to allow the refrigerant to