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POOL BOILING CORRELATIONS FOR STRUCTURED FIN TUBES

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ABSTRACT

Since the 1950s, many researchers have investigated boiling on enhanced surfaces. Tubes with enhanced boiling surfaces are now widely used in commercial applications. Refrigeration, hydrocarbon processing, and other industries benefit from enhanced boiling, and many studies of the phenomena have been published. Heat Transfer Research, Inc. (HTRI) conducted a comprehensive literature review and compiled available experimental data on structured fin tubes that are commercially available. This paper describes the data trends and discusses the development of generalized correlations for predicting pool boiling heat transfer coefficients for structured fin tubes.

The structured fin tubes discussed in this paper include the GEWA-SE, GEWA-T, GEWA-TX, GEWA-TX19, GEWA-TWX, GEWA-YX26, GEWA-B, GEWA-PB, and GEWA-B5 by Wieland Thermal Solutions; the Turbo-B®, Turbo-BII LP®, Turbo-BII HP®, and Turbo-B5® by Wolverine Tube, Inc.; and the Thermoexcel-E by Hitachi [1-13]. The test fluids include refrigerants, such as R11, R12, R22, R113, R123, R236fa, and R134a, as well as hydrocarbons like isopropyl alcohol, propane, pentane, and p-xylene. The data cover reduced pressures ranging from 0.011 to 0.222 and heat fluxes from 0.13 to 446.5 kW/m^2. A total of seven hundred data points are included in the correlation development.

The enhanced boiling data are divided into two groups, based on the evolution of structured fins and the heat flux dependence:

- Group One: for which the pool boiling heat transfer coefficient increases as heat flux increases, similar to that on plain tubes. These data were mostly taken using earlier commercial enhanced tubes, like GEWA-T and Turbo-B.
- Group Two: for which the pool boiling heat transfer coefficient does not significantly vary with heat flux, instead staying constant or decreasing slightly with heat flux. These data were collected on more recent commercial enhanced tubes, like GEWA-B5 and Turbo-B5.

Figure 1 illustrates the heat flux dependence for the two groups of data. Unlike the Group Two data, the Group One data show a definite trend that boiling coefficient increases as heat flux increases. Fin structure improvements over time enhance the boiling coefficient, especially at low heat fluxes or temperature differences. Therefore, the boiling coefficients for Group Two are typically higher than those of Group One and provide an upper limit for those of Group One.

The enhanced boiling coefficient also depends on many other parameters, like physical properties and dimensions of the fin structure. Fin density and fin tip gap significantly impact the enhancement. The enhanced boiling coefficient is higher for a higher fin density (or a smaller fin pitch) and a narrower fin tip gap. Based on the available data, we developed two correlations for calculating pool boiling coefficients of pure components for the structured fin tubes:

Group One:
$$h_{nb1} = 180\left(\frac{k_\ell}{D^*}\right)\left(\frac{qD^*}{k_\ell T_{sa}}\right)^{0.36}\left(\frac{\rho_v}{\rho_\ell}\right)^{0.3}\left(\frac{P_{fin}}{D^*}\right)^{-0.2}\left(\frac{\delta_{gap}}{D^*}\right)^{-0.5} \tag{1}$$

Group Two:
$$h_{nb1} = 0.35\left(\frac{k_\ell}{D^*}\right)\left(\frac{qD^*}{k_\ell T_{sa}}\right)^{-0.05}\left(\frac{\lambda\left(D^*\right)^2}{\alpha_\ell^2}\right)^{0.2}\left(\frac{\rho_v}{\rho_\ell}\right)^{0.3}\left(\frac{P_{fin}}{D^*}\right)^{-0.2}\left(\frac{\delta_{gap}}{D^*}\right)^{-0.5} \tag{2}$$

Overall, both correlations predict most of the compiled data within ±25%, as shown in Figure 2, and work better at higher heat fluxes. The prediction uncertainties are higher for Group One at low heat fluxes, at which nucleate boiling is not likely to be completely activated. In addition, measurement uncertainties are typically higher at low heat fluxes due to the measuring of very low temperature differences.

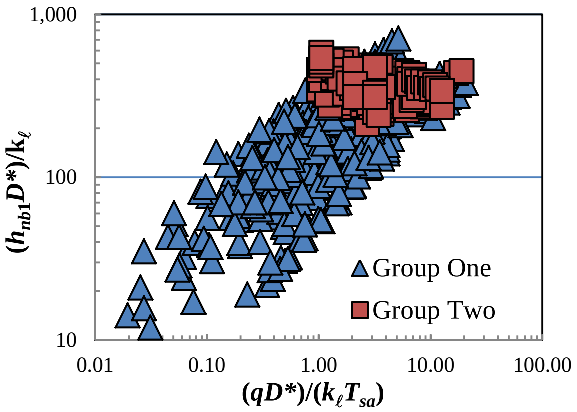

Figure 1. Boiling coefficient verse heat flux

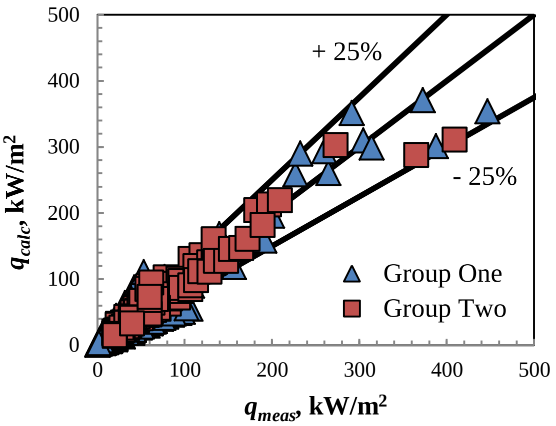

Figure 2. Heat flux predictions of boiling data

NOMENCLATURE

D^*	Length scale, $=\left[\dfrac{2\sigma}{g(\rho_\ell-\rho_v)}\right]^{0.5}$, m
h_{nb1}	Single component pool boiling heat transfer coefficient, W/m^2 K
k_ℓ	Liquid thermal conductivity, W/m K
P_{fin}	Fin pitch, m
q	Heat flux, W/m^2
T_{sa}	Absolute saturation temperature, K
α_ℓ	Liquid thermal diffusivity, m^2/s
δ_{gap}	Gap between fin tips, m
λ	Latent heat, J/kg
ρ	Liquid density, kg/m^3

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