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Letter to the Editors

Comment on the paper W.W. Lin, J.C. Yang, D.J. Lee, "Metastable pin fin boiling", IJHMT 43 (9) (2000) 1629–1635

In paper [1] experimental and theoretical investigation of conditions of transition from metastable regime to stable one is carried out at boiling on a horizontal fin. The interest to a method of intensification of boiling heat transfer with the help of finned surfaces was stimulated by [2]. Similar works were carried out in the Institute for High Temperatures of the Russian Academy of Sciences (IHT RAS), Moscow, since the end of sixties. Results of these investigations have been published in Soviet (Russian) journal Teplofizica Vysokikh Temperatur translated into English as High Temperatures, International Journal of Heat and Mass Transfer, Heat Transfer – Soviet Research as well as proceedings of a lot of International conferences. Therefore it is more than strange to read in paper [1], published in 2000, that "this work has, for the first time, numerically and experimentally proved the existence of metastable regimes in fin boiling process". In IHT RAS the experimental researches of heat transfer were carried out at boiling on fins, finned surfaces and in inter-fin spaces [3,4]. The original investigation technique of local boiling heat transfer on a nonisothermal surface was developed [5]. The methods of prediction of boiling heat transfer on fins were developed [6].

Special attention was given to questions of stability of boiling heat transfer. This direction of investigations was begun by works [7,8], in which the concept of an equilibrium heat flux delimiting regions of stable and metastable boiling regimes was formulated. The method of an estimation of stability with the help of Lyapunov's functional [9,10] is developed. In these works the stability of heat transfer is investigated at boiling on a rod with uniformly distributed heat sources, that is a more general case, than the one considered in [1]. It is shown that stable temperature profile corresponds minimum value of functional:

$$J = \int_0^L \left\{ \frac{1}{2}\left(\frac{\mathrm{d}(\Delta T)}{\mathrm{d}x}\right)^2 + \frac{u}{fk}\int_0^{\Delta T} q(\Delta T)\,\mathrm{d}(\Delta T)\right\}\mathrm{d}x \quad (1)$$

if the temperature is given at fin base ($T_b = \text{const}$), and

$$J = \int_0^L \left\{ \frac{1}{2}\left(\frac{\mathrm{d}(\Delta T)}{\mathrm{d}x}\right)^2 + \frac{u}{fk}\int_0^{\Delta T} q(\Delta T)\,\mathrm{d}(\Delta T)\right\}\mathrm{d}x + \frac{q''_b}{k}\delta(\Delta T_b) \quad (2)$$

if the heat flux is given at the fin base ($q''_b = \text{const}$). Here $q(\Delta T)$ is a boiling curve.

The dependencies $q''_b(\Delta T_b)$, $J(\Delta T_b)$ and $J(q''_b/k)$ are shown in Figs. 1–3 (taken from [9]). In Fig. 1 the branches of curve CD and KL correspond to minimum value of functional. It is the stable boiling regime. Branch of curve FG corresponds to maximum value of functional and regimes. DF and KG correspond to metastable regimes. The point of crossing D (K) determines an equilibrium temperature head at a fin base ΔT_{eq}. In Fig. 3 the dependence $J(q''_b/k)$ is presented. Here equilibrium of stable regimes AB and MN are observed in point B(M) at equilibrium heat flux $q''_b = q_{eq}$. In [8] analytical estimates of equilibrium due to correlation (1) were compared with numerical calculation. In paper [9] the approached graphic method of definition ΔT_{eq} delimiting regions of metastable and stable regimes on equality dashed areas in Fig. 1 is offered, $S_1 = S_2$

In [1] the boundary between stable and metastable regimes was defined by equal critical temperature disturbances. It is very difficult to accord with their statement because it was not justified by theoretical way. The authors hold that line P–P′ is neutral stability line in Fig. 2 [1]. It is strange, why the line P–P′ does not cut from curve $q''_b(\Delta T_b)$ the equal areas S_1 and S_2 as shown in Fig. 1. It means that methods [1] allow to define the position of line P–P′ with large error.

Let us consider the transition from metastable regime to stable one. In Fig. 1 from [1] transition from

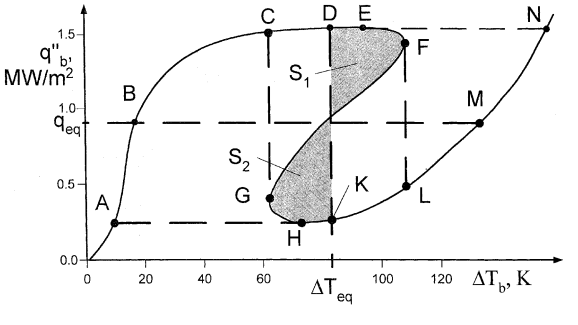

Fig. 1. Dependence of the heat flux q''_b in the heated rod end ($x = 0$) on the local excess temperature ΔT_b.

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Nomenclature

D	fin diameter, m
f	cross-section, m^2
J	functional, K^2/m
k	thermal conductivity, W/m K
L	fin length, m
q''_b	base heat flux, W/m^2
S	dashed area, m^2
T	temperature, K
T_b	base temperature, K
T_s	saturation temperature, K
ΔT_b	base superheat, K
ΔT_{eq}	equilibrium superheat, K
u	perimeter, m
x	axial position, m

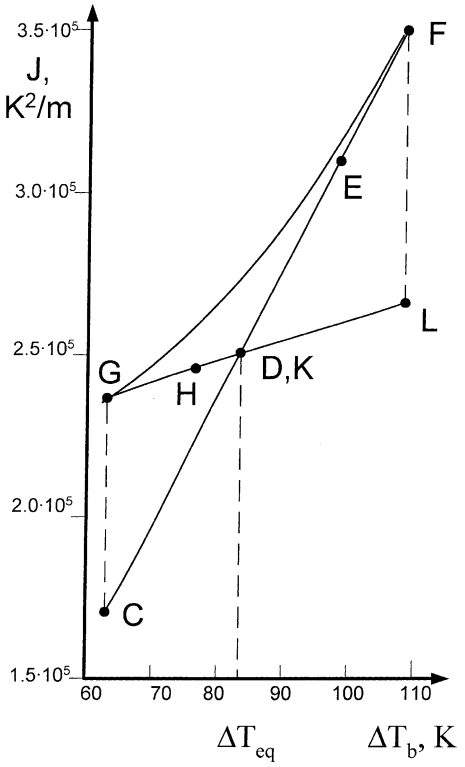

Fig. 2. Stationary values of the functional J (1) depending on ΔT_b (the first kind boundary condition).

metastable regime to stable one (points a–a' and b–b') follows to vertical line. It means that calculations were carried out for case $\Delta T_b = \text{const}$. In experiments of (Fig. 5 from [1]) transition from metastable regimes to stable one followed to horizontal line (points U_2–U'_2 and L_1–L'_1). It means that the experiments were carried out for case $q''_b = \text{const}$. In the first case equilibrium of regimes should be observed at $\Delta T_b = \Delta T_{eq}$ and was described by correlation (1). In the second case equilibrium of regimes should be observed at $q''_b = q_{eq}$ and was described by correlation (2). It follows that authors [1] erroneously compared calculations and experiments for quite different boundary conditions.

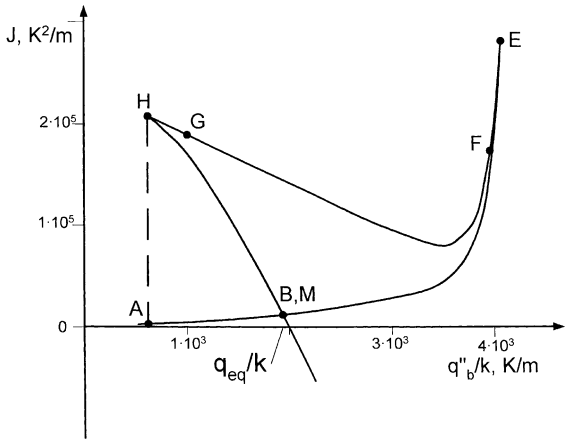

Fig. 3. Stationary values of the functional J (2) depending on q''_b/k (the second kind boundary condition).

Finally, the mentioned mistakes may be avoided if the authors [1] would pay attention to references mentioned above.

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