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AN EXPERIMENTAL STUDY OF INTERNAL CHARACTERISTICS OF NUCLEATE POOL BOILING OF NANOFLUID R141b/TiO₂

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Numerous studies of different modes of boiling have been reported in the literature [1-5]. The correlations serve a useful purpose in their application to engineered systems. However, because of their limited range of applicability, they can rarely be applied with confidence to new situations. Mechanistic models based on basic principles can alleviate this problem. For this purpose, the effort has continued to be made by researchers to develop mechanistic models.

The V.I. Tolubinsky [5] equation (2) is the simplest to use in practice:

$$\frac{h}{k} = \sqrt{\frac{\sigma}{g(\rho' - \rho'')}} = 75 \left(\frac{q}{h_{vap} \rho'' \bar{w}''} \right)^{0.7} \left(\frac{\alpha}{\nu} \right)^{0.2} \quad (2)$$

where h is the heat transfer coefficient, $W \cdot m^{-2} \cdot K^{-1}$; k is the thermal conductivity, $W \cdot m^{-1} \cdot K^{-1}$; σ is the surface tension, $N \cdot m^{-1}$; ρ' and ρ'' are the density of liquid and vapor respectively, $kg \cdot m^{-3}$; q is the heat flux, $W \cdot m^{-2}$; h_{vap} is the latent heat of vaporization, $J \cdot kg^{-1}$; α is the thermal diffusivity, $m^2 \cdot s^{-1}$; ν is the kinematic viscosity, $m^2 \cdot s^{-1}$; \bar{w}'' is mean velocity of bubble growth, $m \cdot s^{-1}$, $\bar{w}'' = D_b \cdot f$, where D_b is mean bubble departure diameter, f is mean bubble departure frequency.

During the last decades, a number of attempts have been made to develop correlations or models for parameters D_b and f , but with limited success [1]. Therefore, information on the internal characteristics of the boiling process is necessary for predicting the heat transfer coefficients.

Therefore, the main purpose of this study was to evaluate the effect of surfactant and TiO₂ nanoparticles additives into the refrigerant R141b on the internal characteristics of the nucleate pool boiling process.

The experiments were carried out with the following substances: refrigerant R141b; solution R141b / surfactant Span-80 (0.1 % mass.) (CAS No. 1338-43-8, Sigma-Aldrich); nanofluid R141b / surfactant Span-80 (0.1 % mass.) / TiO₂ nanoparticles (0.1 % mass.). The size of TiO₂ nanoparticles (nanopowder) did not exceed 25 nm (CAS No. 1317-70-0, Sigma-Aldrich).

The internal boiling characteristics (bubble departure diameter, bubble departure frequency and mean velocity of bubble growth) were studied experimentally under atmospheric pressure and in the range of heat fluxes from 29 to 57 $kW \cdot m^{-2}$. The snapshots of the boiling process were taken using the camera and the stroboscope. The shining time of light source was 50 μs and the intervals between flashes were 3 ms. During the obtained images processing the number of bubbles was 80-140 to determine the mean bubble departure diameter \bar{d}_0 and 50-110 to determine the mean bubble departure frequency \bar{f} . The mean velocity of bubble growth $\bar{w}'' = \bar{d}_0 \cdot \bar{f}$ defined by mean values of \bar{d}_0 and \bar{f} .

Dependences of bubble departure diameter \bar{d}_0 , bubble departure frequency \bar{f} and mean velocity of bubble growth $\bar{w}'' = \bar{d}_0 \cdot \bar{f}$ from heat flux of pure R141b, R141b/Surf. and R141b/Surf./TiO₂ are shown in Fig. 1.

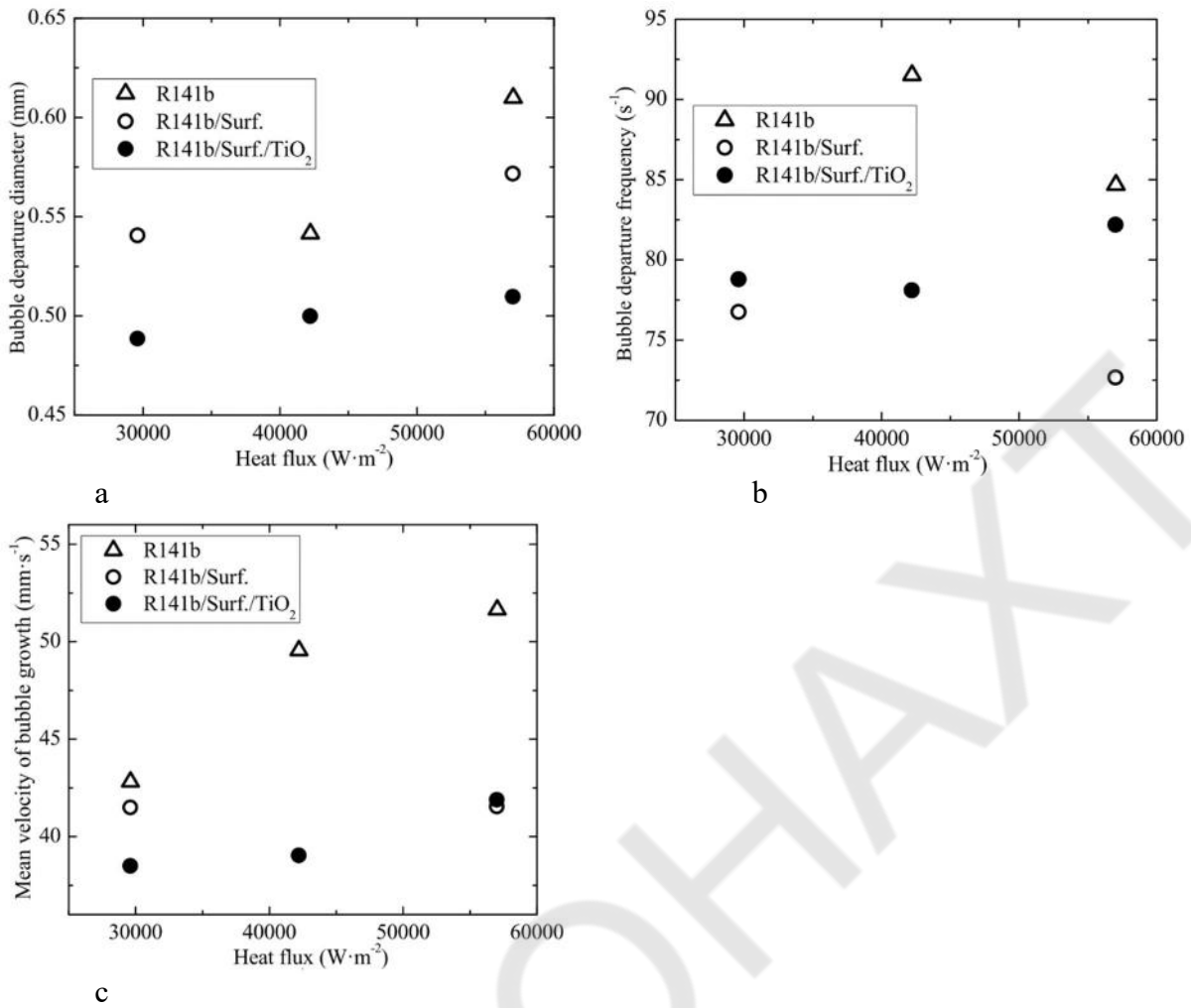


Fig. 1. Dependence of internal characteristics of nucleate pool boiling process from heat flux of pure R141b, R141b/Surf. and R141b/Surf./TiO₂: (a) departure vapor bubble diameter, (b) bubble departure frequency, (c) mean velocity of bubble growth

The experimental values of mean velocity of bubble growth can be used to calculate the heat transfer coefficient at nucleate pool boiling using the proposed by V.I. Tolubinsky [5] equation (2).

The experimental data on mean velocity of bubble growth \bar{w}'' were used in order to predict heat transfer coefficient by equation (2). To estimate the mean velocity of bubble growth at the pressures under which the experiments were performed the empirical equation (3) [5] was used.

$$\bar{w}''/\bar{w}''_{0.1} = (\rho''_{0.1}/\rho'')^{2.3+0.5lg\pi} \quad (3)$$

where $\bar{w}''_{0.1}$ and $\rho_{0.1}$ are the mean velocity of bubble growth and vapor density at $P=0.1013 \cdot \text{MPa}$ respectively; $\pi = P/P_C$ is the reduced pressure.

The properties of pure R141b were used to calculating the heat transfer coefficient by using the Eq. (2).

Calculated heat transfer coefficient values depending on heat flux at three pressure values are shown in Fig. 2.

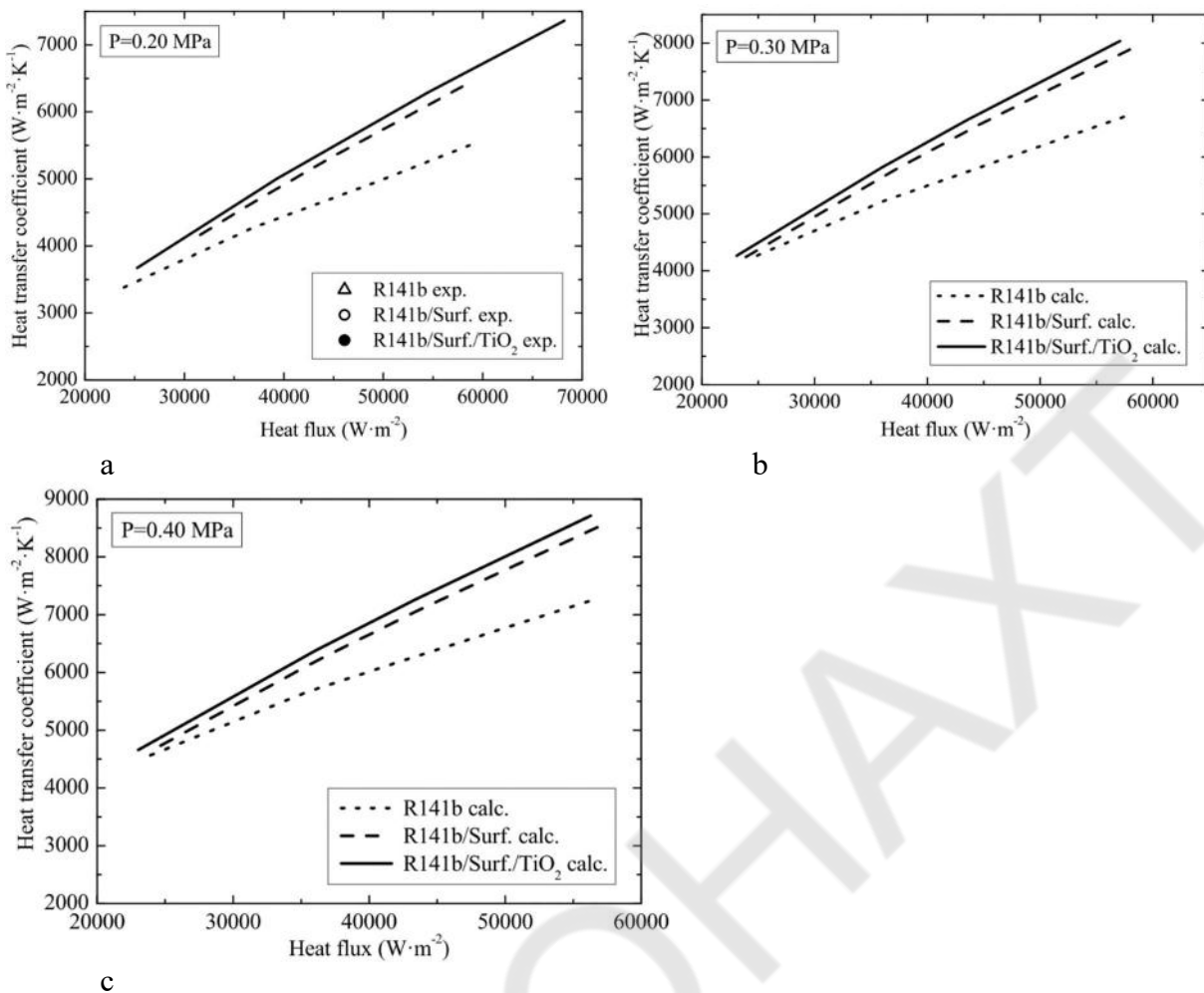


Fig. 2. Calculated heat transfer coefficient for R141b / surfactant and R141b / surfactant / TiO₂ solutions in contrast with R141b

The additives of surfactant and TiO₂ nanoparticles effect on the internal characteristics of nucleate pool boiling: departure bubble diameter, bubble departure frequency and mean velocity of bubble growth are decreased with surfactant and TiO₂ nanoparticles additives.

As follow from the calculated data, the pool boiling heat transfer coefficient of R141b / surfactant / TiO₂ nanofluid is higher in contrast with R141b, especially at high heat fluxes. Thus, it is expected the increase in the heat transfer coefficient with the addition of nanoparticles and surfactants to the refrigerants.

References

1. Dhir V. K. Mechanistic prediction of nucleate boiling heat transfer—achievable or a hopeless task? *Journal of Heat Transfer*. 2006. Vol. 128, Issue 1. P. 1-12.
2. Forster D. E., Greif R. Heat Transfer to a Boiling Liquid - Mechanism and Correlation. *ASME J. Heat Transfer*. 1959. Vol. 81. P. 43–53.
3. Mikic B. B., Rohsenow W. M. A New Correlation of Pool Boiling Data, Including the Effect of Heating Surface Characteristics. *ASME J. Heat Transfer*. 1969. Vol. 9. P. 245–250.
4. Judd R. L., Hwang K. S. A Comprehensive Model for Nucleate Boiling Heat Transfer, Including Microlayer Evaporation. *ASME J. Heat Transfer*. 1976. Vol. 98. P. 623–629.
5. Tolubinskiy V.I. Heat Transfer under Boiling (in Russian), Naukova Dumka, Kiev, 1980 (Chapters 4 and 5).

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