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Oscillating heat pipe simulation considering bubble generation Part II: Effects of fitting and design parameters

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ABSTRACT

In the part I, the OHP simulations with and without the TS bubble generation have been performed. In those simulations, four fitting and six design parameters were used. In this paper, the effects of both design and fitting parameters are investigated in the simulations with and without the TS bubble generation. The fitting parameters are the coefficient of phase change (α), evaporation coefficient on the TS bubble (α_b), initial length of the TS bubble (L_b) and degree of superheat (ΔT_{sup}). The design parameters are the nucleation site (NS) configurations, NS positions, number of NSs, temperature of heating section, number of liquid slugs and vapor plugs, and number of turns. The results show that both the fitting and design parameters influence the motions of liquid slugs and vapor plugs, pressure difference between two vapor plugs (driving force) and heat transfer rates of an OHP. The effects of the combinations of design parameters are also investigated. The results show that the motions of liquid slugs and vapor plugs becomes complex (unsteady oscillating motions) due to the random TS bubbles generation. The profile of heat transfer rates also becomes random due to the complex motions.

1. Effects of fitting parameters

1.1. Coefficient of phase change (α)

In the part I, we simplified the Hertz–Knudsen equation (Eq. (1)) to calculate the rate of phase changes. We obtain the simplified one (Eq. (2)) by using the fitting parameter α. In this paper, the effects of α are investigated by changing its value to be five times bigger, 10 times bigger and five times smaller than the value of α in the part I (5.4×10^{-14} kg/(Pa s)).

Fig. 1 shows the motions of liquid slug-vapor plug interfaces in the simulation with the TS bubble generation, between $\alpha = 5.4 \times 10^{-14}$ kg/(Pa s), red curve[1], and $\alpha = 27 \times 10^{-14}$ kg/(Pa s), blue curve. Fig. 1(a) and (b) show that as the value of α increases, the frequency of the TS bubble generation and the pressure difference between the vapor plugs (driving force) increase. The oscillating amplitude decreases because the length of the short liquid slug, when the TS bubble is generated, becomes smaller, then the period of TS bubble growth decreases. The rate of latent heat increases due to the increasing of phase changes, as the value of α increases (Fig. 1(c) and (d)). The rate of sensible heat decreases because the oscillating amplitude of liquid slugs and vapor plugs decreases (Fig. 1(e) and (f)). The average values of oscillating amplitude, oscillating frequency and heat transfer rates of the simulation results in Fig. 1 are shown in Table 1. The results show that as the value of α increases, the heat transfer in the OHP is more dominated by latent heat than sensible heat, which agrees with the previous report [1].

Figs. 2 and 3 show the motions of liquid slug-vapor plug interfaces and the pressure of vapor plugs in the simulation with $\alpha = 5.4 \times 10^{-13}$ kg/(Pa s) and $\alpha = 1.08 \times 10^{-14}$ kg/(Pa s). Fig. 2 shows that the TS bubble generation does not occur stably. The third TS bubble generation (at NS1 and $t = 0.479$ s) cannot growth stably because the pressures of TS bubble and vapor plug 1 become almost the same. The pressures of vapor plugs 1 and 2 become almost the same ($t = 0.528$ s) and finally, both liquid slugs cannot reach the NS, as shown in Fig. 2(b). When the value of α equals 1.08×10^{-14} kg/(Pa s), the TS bubble generation also does not occur stably (only three times, once in the NS1 and twice in the NS2) because the driving force is not enough to push both liquid slugs pass through the NS. Finally, the motions of liquid slugs and vapor plugs become a simple sinusoidal oscillating. From these results, it seems that the proper values of α for the stable TS bubbles generation are between 5.4×10^{-14} and 27.0×10^{-14} kg/(Pa s).

Fig. 4 shows the simulation results without the TS bubble generation with $\alpha = 1.08 \times 10^{-14}$ kg/(Pa s), $\alpha = 5.4 \times 10^{-14}$ kg/(Pa s) and $\alpha = 27 \times 10^{-14}$ kg/(Pa s). It shows that the increasing of α value

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[1] For interpretation of color in Figs. 1,4,7,12,16, the reader is referred to the web version of this article.

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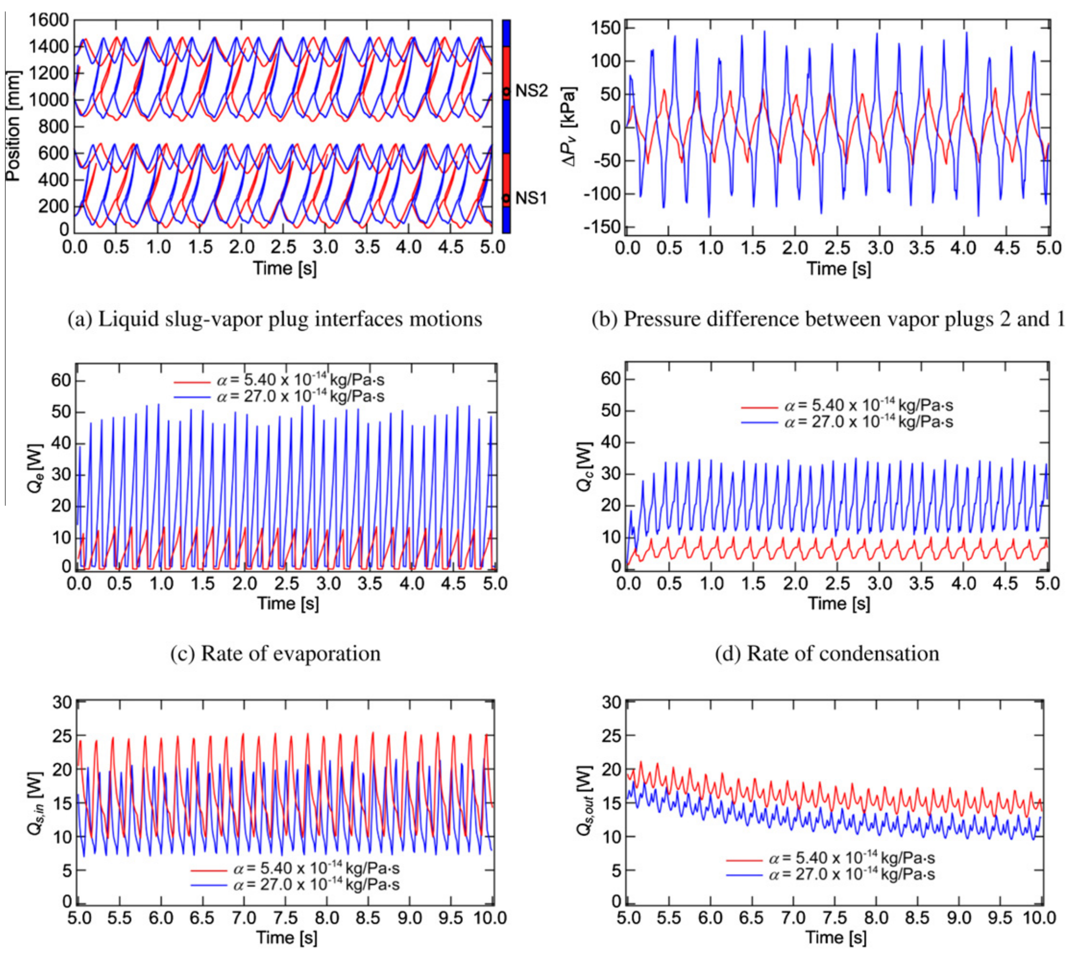
Nomenclature

L	length m
P	pressure Pa
Q	heat transfer rate W
Q″	heat flux W/m^2
T	temperature K
Greek letter	
α	phase change coefficient kg· Pa^{-1} s^{-1}
Subscripts	
b	TS bubble
c	condensation
e	evaporation
l	liquid
lat	latent
s	sensible
v	vapor
w	wall
Abbreviations	
am	amplitude
CS	cooling section
fr	frequency
HS	heating section
in	input
NS	nucleation site
os	oscillating
out	output
TS	tube-size

slightly decreases the oscillating amplitude but increases the oscillating frequency and driving force. The average values of oscillating amplitude in Fig. 4(a) are 54, 42 and 38 mm (black, red and blue curves). These results are similar with the results in the simulation with the TS bubble generation.

1.2. Evaporation coefficient on the TS bubble (α_b)

In the part I, the simulation with the TS bubble generation assumed that the value of α_b is 10 times bigger than the value of α_v, then the value of $\alpha_b = 5.4 \times 10^{-13}$ kg/(Pa s) for $\alpha_v = 5.4 \times 10^{-14}$ kg/(Pa s). Fig. 5 shows the effects of α_b by comparing the simula-



(a) Liquid slug-vapor plug interfaces motions (b) Pressure difference between vapor plugs 2 and 1

(c) Rate of evaporation (d) Rate of condensation

(e) Rate of sensible heat in (f) Rate of sensible heat out

Fig. 1. Effects of α in the simulation with the TS bubble generation.