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Review

Review of pool boiling enhancement by surface modification

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ABSTRACT

This paper provides a comprehensive review of published articles addressing passive enhancement of pool boiling using surface modification techniques. They include macroscale, microscale, and nanoscale surfaces, as well as multiscale (hybrid-scale), and hybrid-wettability techniques. Different enhancement methods are assessed in terms of underlying fluid routing mechanisms and ability to achieve three distinct heat transfer goals: eliminating incipient boiling hysteresis, increasing nucleate boiling heat transfer coefficient, and ameliorating critical heat flux (CHF), especially for inert dielectric coolants that are both highly wetting and possess relatively poor thermophysical properties. While different enhancement scales are shown to provide different degrees of success in achieving the three goals, it is shown that both microscale and nanoscale surface features are susceptible to blockage, resulting in deterioration of the enhancement over time. This review also points to scarcity of sufficiently sized databases for a given enhancement scheme in terms of fluid type, surface material, size, and orientation, enhancement shape, pattern, and scale, and operating pressure. This renders available findings less-than-adequate tools for design of practical cooling systems.

Contents

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Nomenclature

A	area
A^+	area fraction
B	dimensionless parameter
C	compensating factor
d	diameter
g	gravitational acceleration
H	channel height
h	heat transfer coefficient
h_{fg}	latent heat of vaporization
K	fitting factor
k	thermal conductivity
k_m	thermal conductivity of porous matrix
P_r	reduced pressure
q''	surface heat flux
r	bubble radius; pore radius
r^+	non-dimensional roughness
R_a	average surface roughness
S	area factor
S_m	mean spacing between surface peaks
T	temperature
ΔT_i	superheat at boiling incipience, $T_i - T_{sat}$
ΔT_{sat}	surface superheat, $T_w - T_{sat}$
u_c	capillary velocity
V''	wicked volume flux
v_{fg}	specific volume difference
W	wicking coefficient
Wi	wicking number

Greek symbols

α	contact angle
α_m	modified contact angle
α_{rec}	receding contact angle
β	geometrical factor
δ	gap width; coating thickness
ε	volumetric porosity
θ	cavity cone angle; surface orientation angle
λ_c	critical wavelength
μ	viscosity
φ	solid fraction
ρ	density
σ	surface tension

Subscripts

b	boiling
CHF	critical heat flux
f	liquid
g	vapor
i	incipience
nc	natural convection
p	particle
sat	saturation
$unconf$	unconfined
w	surface