Where, Nu=Fully developed Nusselt number

[0284] K=Thermal conductivity of liquid, W/m-K

[0285] D_h=Hydraulic diameter, m

[0286] h_{liq}=Lqiuid heat transfer coefficient, W/m-K

[0287] Heat transfer coefficient for pure vapor can also be calculated in similar manner.

[0288] For 2-phase system, the heat transfer coefficient was assumed to be dependent upon vapor quality. The maximum heat transfer coefficient was assumed to be 3000W/m2 K. The 2-phase heat transfer coefficient increased linearly with vapor quality from pure liquid heat transfer coefficient to maximum heat transfer coefficient (3000 W/m^2 K) from vapor quality=0 to vapor quality=0.5 and then decreased linearly from maximum heat transfer coefficient (3000 W/m^2 K) to pure vapor heat transfer coefficient from vapor quality=0.5 to vapor quality=1.

[0289] **FIGS. 30** *a*) and *b*) shows the temperature profile in the vaporizer (wall and fluid temperature) from inlet to outlet of the channel for Case 1 and Case 2 respectively. For both cases, the outlet quality of vapor is the same. The small temperature difference between wall and the fluid helps prevents film boiling regime and prefers convective or nucleate boiling regime. Film boiling is generally marked by vigorous evaporation of the liquid which may lead to non-uniform and difficult to control process. On the other hand, convective boiling or nucleate boiling are easier to control and provides stable process in terms of temperature, pressure and quality variations. Thus micro-channel dimension vaporizer will provide more stable boiling than conventional macro-channel dimension vaporizer.

[0290] **FIGS. 31** *a*) and *b*) shows the vapor quality profile along the channel length for Case 1 and Case 2 respectively. For both cases the outlet vapor quality is same 0.73 but there is a difference between the rate of vaporization. Microchannel vaporizer has a smoother and gradual vaporization while macro-channel vaporizer has sudden and steep vaporization. These results may imply that micro-channel dimensions leads to stable vaporization as compared to macro-channel dimensions.

[0291] The Boiling number for Case 1 is 0.005 and the SR number for Case 1 is 5×10^{-6}. The boiling number and SR number for case 2 is 0.029 and 0.021 respectively.

EXAMPLE 8

Small Bubbles under High Shear Rate near the Heated Walls

[0292] The high shear rate observed in the micro-channel facilitates the detachment of vapor bubbles from the heated wall. Before detachment, the bubbles grow in size near the walls, and deform under the shear rate. The higher the shear rate, the more severe the deformation of the bubbles. The net effect is that the bubbles will detach at smaller radius. See **FIG. 32**. Dispersion of small bubbles in the continuous liquid phase has high inter-phase surface area per unit volume of fluid which improves the heat transfer. Also higher dispersion rate can be achieved with the small bubble size. The flow is more stable without the collision between bubbles which cause flow fluctuations.

[0293] Flow boiling heat transfer is optimized when the regime is nucleate boiling and the bubbles are detached from the surface formation sites while still very small since small bubbles maximize interphase heat and mass transfer. The effects of flow conditions on bubble detachment in slit microchannels have been studied experimentally. Generally, higher velocity gradients exist at the channel wall for microchannels as compared to their conventional counterparts. This in turn leads to larger values of wall shear stress which serves to "clip off" or detach the bubbles more rapidly during formation for given conditions (e.g., wall superheat, average heat flux, etc.). The studies (e.g., Journal of Colloid and Interface Science 241, 514-520 (2001)) show that the critical flow parameters for bubble detachment are a function of channel height as well as the bubble's contact diameter. The required average fluid velocity (the Capillary number) decreases for larger bubbles and the slope of this relationship was seen to decrease as channel height decreased. In general, less fluid velocity is required to detach similar-sized bubbles in a channel of smaller height (gap). Therefore, by virtue of their inherently small channel gap sizes, microchannels can generate smaller bubbles for the same flow and heat conditions.

EXAMPLE 9

Stable Bubbly Flows at High Dispersion

[0294] Under partial boiling conditions in the micro-channels, the vapor bubbles are generated on the super-heated surfaces, then they detach from the surfaces and migrate into the fluid body. There exists a section of micro-channel where bubbles are dispersed in the continuous liquid phase. The interaction between these bubbles has direct impact on the heat transfer performance and two phase flow stabilities. Within micro-channels the impact of the channel walls on the flow field is more dominate, and the shear rate across the channel width is at high level. This high level shear rate prevents the growth of the bubbles and deformation and eventually breakup occurs for the bubbles above critical size, with the critical bubble radius being a function of shear rate as well as interfacial tension and fluid viscosity. The high shear rate reduces the critical bubble radius. The micro-channel walls regulate the flow field in between. The streamline is dominantly parallel to the walls. The flow is dominantly laminar.

EXAMPLE 10

Wetting Enhancement Structures

[0295] The surface heat flux requirement for boiling can be reduced significantly if the thickness of liquid film on the heated surface can be reduced. Though micro-channels provides thin liquid films inside the channels, however the liquid film thickness can be further reduced by using structures such as fine meshes, screens etc. These structures help liquid spread out on larger surface area, thus reducing the thickness of liquid film on the surface. The thin liquid film will require small surface heat flux for vaporization, thus these structures can help achieve partial boiling with low surface heat fluxes. Some examples of these structures are but not limited to expanded metal foils, wire mesh screen, cotton cloth, sintered metals, metal foams, polymer fibers, grooved surfaces (Triangular grooves (i.e. Fresnel lens), rectangular grooves, circular grooves) or any wetting, porous material.