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Flow Boiling Heat Transfer in Small Diameter Channels Using Nano Fluids: A Review

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Abstract: Boiling is a convective heat transfer process that involves a phase change from liquid to vapour. Two phase flow boiling heat transfer is attractive over a single phase because of heat transfer coefficient. Researchers have investigated the forced convection of fluids, both experimentally and numerically. A good understanding of characteristics of nano fluid flow has thoroughly been investigated in these studies. In recent years, many researchers have tried to fill the gaps on this subject in the literature. This paper reports on most of the forced convective heat transfer literature occurring both in-tubes and in-channels regarding the use of nano fluids.

Keywords: Flow boiling, nanoparticles, heat transfer.

I. INTRODUCTION

1.1. BOILING

A liquid to vapor phase change process just like evaporation but there is significant differences between two liquid to vapor phase change process. It called evaporation if it is happens at a liquid vapor interface and boiling. If it occur at a solid liquid interfacing. Boiling on the other hand happens at the solid liquid interfacing when a liquid is bringing into contacting with a surface at a temperature above the saturation temperature of the liquid. The boiling process is characterize by the rapid formation of vapor bubbles at the solid liquid interfacing that separated from the surface when they reach a certain sized and effort to rise the free surface of the liquid. Boiling is a complicate phenomenon because of the large number of variable involve in the process and the complex fluid motion pattern caused by the bubble formation and increment.Boiling is classified as pool boiling or flow boiling it is depending on the presence of bulk fluid motion.Boiling is called pool boiling in the absence of bulk fluid flow when the flow boiling in the Presence of it.

1.2. FLOW BOILING

Flow boiling is consider more complicated than pool boiling because of boiling heat transfer processes. Sequence of two-phase and boiling heat transfer regimes takes place along the heated channels during flow boiling.The boiling and heat transfer regimes in a uniformly heated horizontal pipe when the heat and mass fluxes are both moderated.

1.3. NEED FOR SMALL CHANNEL FOR FLOW BOILING

A channel serves with finish two objectives: achieve An liquid under close contact with the channel dividers What's more bring new liquid of the dividers Also uproot liquid away from those dividers Likewise the transport procedure is finished. Those rate of the transport methodology relies on the surface area, which varies for those breadth d for a hardware tube, inasmuch as those stream rate relies on the cross-sectional area, which varies linearly for D2. Thus, those tube surface zone to volume proportion varies similarly as 1/D. Clearly, concerning illustration the breadth decreases, surface range with volume proportion expands [1].

Channel order In light of water powered breadth may be proposed on serve concerning illustration and basic aide to passing on those dimensional range under thought. Those purpose behind utilizing 2 mm breadth channel will be that discovered the middle of the edge limit of the order from claiming channel. The benefit of nano fluid used for laminar and turbulent flow where heat transfer coefficient and thermal conductivity increased compare to base fluid. We consider the flow regimes in single-phase flow, where laminar, transition, and turbulent are the main flow regimes.

1.4. Application of Flow Boiling Heat Transfer

Steam production in steam and nuclear power plants. Heat absorption in refrigeration and air conditioning system**.** Distillation and refining of liquids. Refineries and sugar mills (Heat exchangers)**,** Melting of metal in furnaces. Cooling the machines like nuclear reactors where the large quantities of heat are released in relatively small volume.

1.5. Fundamental nanofluid

Nanofluids is a fluid mixing nanometer size particles called nanoparticles. The fluids engineered colloid of nanoparticles in a base fluid. Nanoparticles which are commonly used in nanofluids is made from numerous materials

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such as oxide ceramics, nitride ceramics, carbide ceramics and metals semiconductors , carbon nanotubes and composite materials such as alloyed nanoparticles or nanoparticle core-polymer shell composites. In addition nonmetallic, metallic, and other materials for nanoparticles, completely new materials and structures may also have desirable characteristics. Common base fluids include water (H2O), ethylene glycol (EG), engine oil (EO), pump oil and glycerol have been used in a nanofluids. Enhancing thermal conductivity of liquids concepts of nanofluids modeling on suspensions is the most recent approaching in more than a century of works. The low thermal conductivity of conventional heat transfer fluids is a serious constraint in improving the performance and compactness of engineering equipments. Particles which can convert from millimeter to micrometer sized in the late 19th century become a part of the modern adventure into the new kingdom of the very small world of nanoparticles. Particularly, nanofluids are a new lord class of nanotechnology based heat transfer fluids that is stable suspended a small amount one volume percentage or less of particles with lengths on the order of in traditional heat transfer fluids. In 1990s, Choi had anticipated the impression of the emergence of novel class of fluid and the term ‘nanofluid. The working together of two things to produce an effect greater than the sum of their individual effects that is the key of nanofluids success.

II. LITERATURE REVIEW BASED ON NUMERICAL INVESTIGATION

MasoudSaberia, Mansour Kalbasia, [1]in this study, laminar forced convective heat transfer of nanofluids consisted of alumina/water and zirconia/water through a vertical tube under constant heat flux boundary condition was investigated numerically. Single phase and two phase mixture models were used for analyzing thermal behavior of nanofluids. Furthermore, effects of Reynolds number, nanoparticle types and nanoparticles volume fraction on the convective heat transfer coefficient were studied. The results of single phase and mixture models were compared with the experimental data.

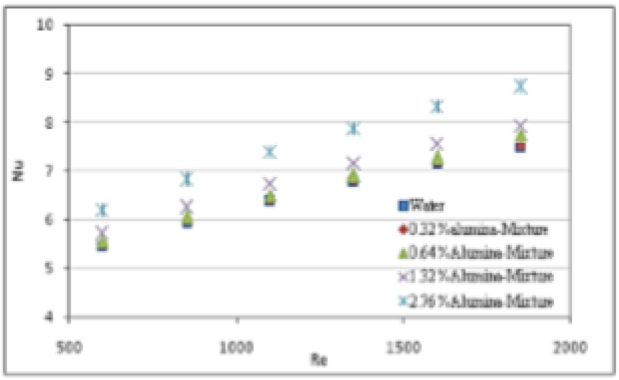

Figure 1: Local Nusselt number at x=0.3 versus Reynolds number for water and alumina/water nanofluid.

The results of the mixture model for prediction of the convective heat transfer coefficient showed better agreement with the experimental data, while the prediction of nanofluid mean bulk temperature distribution inside the tube by the single phase model was better than the mixture model compared to the experimental data. In addition, according to the results of numerical data, the convective heat transfer of nanofluids is higher than that of water similar to the experimental data. The average relative error for predicting convective heat transfer coefficient between experimental data and single-phase model was 13% and 8% for alumina/water and zirconia/water nanofluids, respectively while for mixture model was 8% and 5%.

Ningbo Zhao, ShuyingLi [2]this paper presents a numerical study on laminar flow and convective heat transfer of nanofluids in a circular tube under constant wall heat flux boundary condition. Single phase model is used for simulating the heat transfer and flow behaviors of three different nanofluids. The effects of nanoparticle concentrations, nanoparticle diameter, nanoparticle material and Reynolds number on the Nusselt number and wall shear stress of nanofluids are determined and discussed in details. The comparison of Nusselt number of CuO-EG/water, SiO2-EG/water and Al2O3-EG/water nanofluids are presented. The results show that Nusselt number clearly increases with an increase in the nanoparticle concentration and flow Reynolds number, while the nanoparticle diameter has an opposite effect on the Nusselt number. Compared to SiO2-EG/water and Al2O3-EG/water nanofluids, CuO-EG/water nanofluids give higher Nusselt number with the same nanoparticle concentrations. The results also show that wall shear stress increases with increasing nanoparticle volume concentration.

S. ZeinaliHeris, M. Nasr Esfahan [3] Laminar-flow convective heat transfer of nanofluid in a circular tube with constant wall temperature boundary condition is investigated numerically. A dispersion model is used to account for the presence of nanoparticles. Numerical predictions are in agreement with experimental results obtained in our laboratory for different particles in different sizes. Results clearly show that addition of nanoparticles to base liquid

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produces considerable enhancement of heat transfer. Heat transfer coefficients increase with nanoparticle concentration. Decreasing nanoparticles size at a specific concentration increases heat transfer coefficients.

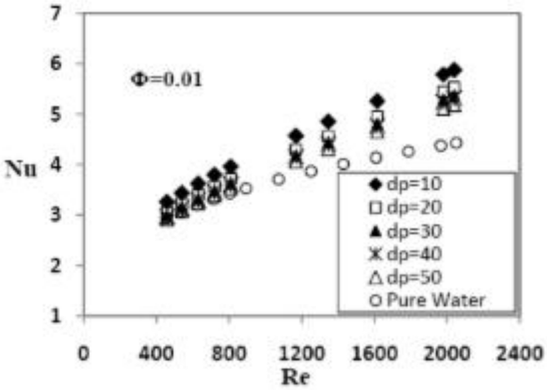

Figure2 :Nusselt number vs. Reynolds number for Al2O3/water nanofluid with nanoparticles diameters (dp) at volume fractions of nanoparticles; (a) 1.0% volume fraction.

Saeed Zeinali Heris, Seyyed Hossein Noie [4] in this article, laminar flow-forced convective heat transfer of Al2O3/water nanofluid in a triangular duct under constant wall temperature condition is investigated numerically. In this investigation, the effects of parameters, such as nanoparticles diameter, concentration, and Reynolds number on the enhancement of nanofluids heat transfer is studied. Besides, the comparison between nanofluid and pure fluid heat transfer is achieved in this article. Sometimes, because of pressure drop limitations, the need for non-circular ducts arises in many heat transfer applications. The low heat transfer rate of non-circular ducts is one the limitations of these systems, and utilization of nanofluid instead of pure fluid because of its potential to increase heat transfer of system can compensate this problem. In this article, for considering the presence of nanoparticl: es, the dispersion model is used. Numerical results represent an enhancement of heat transfer of fluid associated with changing to the suspension of nanometersized particles in the triangular duct. The results of the present model indicate that the nanofluidNusselt number increases with increasing concentration of nanoparticles and decreasing diameter. Also, the enhancement of the fluid heat transfer becomes better at high Re in laminar flow with the addition of nanoparticles.

Mohammadian et al. [5] investigated experimentally forced convective heat transfer from a vertical circular tube conveying deionized (DI) water or very dilute Ag-DI water nanofluids (less than 0.02% volume fraction) in a cross flow of air.They performed some experiments in a wind tunnel and heat transfer characteristics such as thermal conductance, effectiveness, and external Nusselt number had been measured at different air speeds, liquid flow rates, and nanoparticle concentrations. The cross flow of air over the tube and the liquid flow in the tube were turbulent in all cases.They compared the experimental results and it had been found that suspending Ag nanoparticles in the base fluid increased thermal conductance, external Nusselt number, and effectiveness. Furthermore, they observed by increasing the external Reynolds number, the external Nusselt number, effectiveness, and thermal conductance increase. Also,they found by increasing internal Reynolds number, the thermal conductance and external Nusselt number enhance while the effectiveness decreases.

Naphon et al. [6] studied the heat transfer characteristics of nanofluids cooling in the minirectangular fin heat sink. They fabricated the heat sinks with three different channel heights from the aluminum by the wire electrical discharge machine with the length, width and base thickness of 110, 60, and 2 mm, respectively. The nanofluids were the mixture of de-ionized water and nanoscale TiO2 particles. They compared the results obtained from the nanofluids cooling in mini-rectangular fin heat sink with those from the de-ionized water cooling method.They considered the effects of the inlet temperature of nanofluids, nanofluid Reynolds number, and heat flux on the heat transfer characteristics of mini-rectangular fin heat sink. It was found that average heat transfer rates for nanofluids as coolant are higher than those for the de-ionized water as coolant. The results of this study were of technological importance for the efficient design of cooling systems of electronic devices to enhance cooling performance.

Rabeti et al. [7] analyzed numerically forced convection heat transfer of nanofluids over a horizontal flat plate embedded in a porous medium saturated with a nanofluid. In the boundary layer, heat can be generated or absorbed. It was assumed that the nanoparticles were uniformly in the base fluid. A similarity approach was used to reduce the governing partial differential equation to an ordinary differential equation. The resulting ordinary differential equation was numerically solved for a type of porous medium, sand, and three types of nanoparticles, namely, alumina (Al2O3), copper (Cu), and titanium dioxide (TiO2). They investigated theoretically effect of heat generation/absorption as well as volume fraction of nanoparticles on the heat transfer enhancement of nanofluids;

Saberi et al. [8] investigated numerically, laminar forced convective heat transfer of nanofluids consisted of alumina/water and zirconia/water through a vertical tube under constant heat flux boundary condition. They used single phase and two phase mixture models for analyzing thermal behavior of nanofluids. Furthermore, they studied effects of Reynolds number, nanoparticle types and nanoparticles volume fraction on the convective heat transfer coefficient. They compared the results of single phase and mixture models with the experimental data. The results of the mixture model for prediction of the convective heat transfer coefficient showed better agreement with the experimental data, while the prediction of nanofluid mean bulk temperature distribution inside the tube by the single phase model was better than the mixture model compared to the experimental data. In addition, according to the results of numerical data, the convective heat transfer of nanofluids was higher than that of water similar to the experimental data. The average relative error for predicting convective heat transfer coefficient between experimental data and single-phase model was 13% and 8% for alumina/water and zirconia/water nanofluids, respectively while for mixture model was 8% and 5%.

Sohel et al. [9] discussed analytically, the thermal performance of a circular shaped copper microchannel heat sink by using three types of nanofluids. Al2O3 Water, TiO2water and CuO water nanofluids used in this analysis and the comparative thermal performance of these three nanofluids also discussed. The hydraulic diameter of the circular channel was 400 mm and the total block dimension was 10 mm 10 mm 4 mm. A steady, laminar and incompressible flow with constant heat flux was assumed in the circular channel. The analyses were done at various volume fractions ranging from 0.5 vol. % to 4 vol. % and at a constant inlet velocity of 1.5 m/s. The results showed that the thermal performance can be increased significantly by using CuO water nanofluid as a coolant for cooling of electronic heat sink when Al2O3water and TiO2water nanofluids showed less improvement. Compared to pure water, the highest improvement (13.15%) in the heat flux occurred for 4 vol. % CuOwaternanofluid when Al2O3water and TiO2water nanofluids showed 6.80% and 6.20% improvements respectively. They found this improvement in heat flux was calculated without considering the additional required pumping power due to the increased viscosity of nanofluids. Therefore, CuOwaternanofluid can be recommended to obtain maximum heat transfer performance in a circular microchannel heat sink.

SyamSundar et al. [10] reported experimental investigations and theoretical determination of effective thermal conductivity and viscosity of magnetic Fe3O4/water nanofluid. They prepared the nanofluid by synthesizing Fe3O4 nanoparticles using the chemical precipitation method, and then dispersed in distilled water using a sonicator. Both experiments were conducted in the

III. CONCLUSION

The representative results and the review of the findings from the literature on convective heat transfer of nanofluids demonstrated that nanofluids exhibit an enhanced heat transfer coefficient compared to its base fluid and it increases significantly with increasing concentration of nanoparticles as well as Reynolds number. From the review of available results for boiling heat transfer, it can be conferred there is undisputed substantial increase in the boiling critical heat flux of nanofluids. However, reported data are still limited to clearly understand the underlying mechanisms and trend of boiling heat transfer performance of nanofluids. There are only a few results for CHF enhancement observed during flow boiling with nanofluids.We need nanofluids that maintain their stability over increased operating times. Much research has done with and very few research done with other type of nanofluids.

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