"A Review on Effect of Nano-fluids on Liquid Jet Impingement on Heat Transfer Enhancement"

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***Abstract*- Jet impingement has been an attractive cooling option in a number of industries over the past few decades. Over the past 25 years, jet impingement has been explored as a cooling option in microelectronics. Recently, interest has been expressed by the automotive industry in exploring jet impingement for cooling power electronics components. Jet impingement cooling has broad application, such as controlled cooling of metals or non-metals in manufacturing processes, as a result of its easy implementation and high efficiency.**

Many investigations have dealt with convective heat transfer by submerged jet impingement(gas jets in gases or liquid jets in liquids), but studies of free liquid jets(travelling through gases) are much less common, particularly those presenting theoretical analyses of the heat transfer by liquid jets. The reason may be the complexity of the local phenomena. Heat transfer is a basic thermal process which is part of thousands of natural and manmade processes. The attempts of increasing heat transfer of a device or processes by providing external aid are known as heat transfer enhancement.

***Key words* – Liqud jet impingement, Heat transfer, Nano-fluids.**

I. INTRODUCTION

Nanofluids are potential heat transfer fluids with enhanced thermo physical properties and heat transfer performance can be applied in many devices for better performances (i.e. energy, heat transfer and other performances). Evaluating the heat transfer enhancement due to the use of nanofluids has recently become the center of interest for many researchers. This newly introduced category of cooling fluids containing ultrafine nanoparticles (1–100 nm) has displayed fascinating behavior during experiments including increased thermal conductivity and augmented heat transfer coefficient compared to a pure fluid.

Tis study consider the impingement of a circular nano fluid liquid jet on a surface of uniform heat flux. In this work effect of nanofluid and increasing concentration of nano particles in the fluid on the heat transfer abilities of the liquid jet impingement will be investigated experimentally. Results of this study will be studied and analyzed to draw the conclusions. This study will also works to explore the effect of change in nozzle diameter, through which liquid jet is created and variation in the flow rate of nano fluid/ water on the heat transfer.

McMurray et al.(1966) [1] studied convective heat transfer to impinging plane jets from uniform heat flux walls. They observed the heat transfer to be subdivided into an impingement zone and a zone of correlations on the stagnation flow in the impingement zone and on the flat boundary layer in the uniform parallel flow zone.

Gradeck et al. (2006) [2] carried out experimental and numerical investigations on hydraulic jumps due to normal impingement of circular liquid jets on a moving surface, for various jet and plate velocities, as well as for various nozzle diameters and drop heights (drop height is the distance of the nozzle tip from the plate). In their study, a power correlation has been derived for predicting the radial location of the hydraulic jump, as a function of the pertinent dimensionless groups. Numerical simulations have also been carried out for predicting the radial locations of the hydraulic jump.

Wang et al. (2007) [3] explained the theory of "Heat transfer characteristics of Nanofluids: a review" the thermal conductivities of fluids containing suspended solid metallic or non-metallic (metallic oxide) particles would be expected to be significantly higher than those of conventional heat transfer fluids. Nanoparticles are also suitable for use in micro systems because they are many orders of magnitude smaller than the micro systems.

Kate et al. (2008) [4] in their experimentation, hydrodynamics of non circular shaped hydraulic jump phenomenon have been investigated. At higher angles of jet inclination, the jumps are bounded by a smooth curve. However, at lower angles of jet inclination, typical jump profiles with corners have been observed. Effect of jet inclination angle on jump the profile and jump area has been investigated. Measurements of stagnation pressure and film thickness for different jet inclination angles and volume flow rates of liquid are reported.

Kate et al. (2009) [5] investigated effects of jet obliquity on hydraulic jumps formed by impinging circular liquid jets on a moving horizontal plate. Special cases of a circular hydraulic jump when the target plate is stationary and the impinging jet is vertical, and elliptic hydraulic jumps when the target plate is stationary and the impinging jet is obliquely inclined, are also discussed. It is conjectured that flow due to impinging jets on a horizontal moving plate can be modeled as an equivalent flow due to an inclined impinging jet on stationary horizontal flat plates, with appropriate alterations in the jet velocity and the jet inclination angles. The theoretical predictions were to be found in good agreement with experimental results.

Peyghambarzadeh et al. (2011) [6]conducted experiment on forced convective heat transfer in a water based nanofluids, has been experimentally compared to that of pure water in an automobile radiator with different concentrations of nanofluids. Additionally, the effect of fluid inlet temperature to the radiator on heat transfer coefficient has also been analyzed by varying the temperature. Results demonstrate that increasing the fluid circulating rate can improve the heat transfer performance while the fluid inlet temperature to the radiator has trivial effects. Meanwhile, application of nanofluid with low concentrations can enhance heat transfer efficiency up to 45% in comparison with pure water.

Javadi et al. (2013) [7]have reported improving heat exchanger's performance by increasing the overall heat transfer as well as minimizing pressure drop. Nanofluids with higher thermal conductivity and better thermophysical properties can be applied in heat exchanger to increase the heat transfer rate. . In his study SiO_2, TiO_2 and Al_2O_3 are applied in a plate heat exchanger and the effects on thermophysical properties and heat transfer characteristics are compared with the base fluid. Since it is desired to minimize the pressure drop, the influence of nanofluid application on pressure drop and entropy generation is investigated. It is concluded that the thermal conductivity, heat transfer coefficient and heat transfer rate of the fluid increase by adding the nanoparticles and TiO_2 and Al_2O_3 result in higher thermophysical properties in comparison with SiO_2. The highest overall heat transfer coefficient was achieved by Al_2O_3 nanofluid, which was 308.69 $W/m^2.K$ in 0.2% nanoparticle concentration. The related heat transfer rate was improved around 30% compared to SiO_2 nanofluid. In terms of pressure drop, SiO_2 shows the lowest pressure drop, and it was around 50% smaller than the pressure drop in case of using TiO_2 and Al_2O_3.

Husam Abdulrasool Hasan et. al [8] studied the effect of nanoparticles (SiC, TiO2 and SiO2) with water as its base fluid on the electrical and thermal performance of a photovoltaic thermal (PVT) collector equipped with jet impingement have been investigated. A PVT collector was tested indoor at set levels of solar irradiances and mass flow rates. The system consists of four parallel tubes and 36 nozzles that directly injects the fluid to the back of the PVT collector. The electrical performance of the PVT collector was determined based on the mean temperature of the PVT absorber plate. The SiC/water nanofluid system reported the highest electrical and thermal efficiency. The electrical, thermal, and combined photovoltaic thermal efficiencies were 12.75%, 85%, and 97.75%, respectively, at a solar irradiance of 1000 W/m2 and flow rate of 0.167 kg/s and ambient temperature of about 30 _C. Moreover, the Pmax of PVT with SiC nanofluid increased by 62.5% compared to the conventional PV module.

Yu Hang Peng ,Wen Long Cheng(2017) [9]Studied Vacuum spray flash evaporation cooling (VSFEC) experiments were carried out to study the effect of heat transfer enhancementof a nanofluid comprising distilled water and Al2O3 particles with a diameter of 30 nm. The tests are performed with a flat heatedsurface using a nozzle with an orifice diameter of 0.5 mm and a nozzle-to-heated surface distance of 7 mm. The spray volumeflux is varied in the range of 1.7 L/h-5.0 L/h, while the concentration is specified as 0ppm, 100ppm, 200ppm, 300ppm or 500ppm.The experiment results show that a more uniform surface temperature cand be obtained however, due to the difference of heat transfer mechanism, the effect of heat transfer enhancement is also different using AL_2O_3-Water nanofluid.

Mohamed A. Teamah a,b et al. [10] studied Numerical and experimental studies have been conducted to investigate flow structure and heat transfer of nanofluid jet normally impinging on a flat plate. Al2O3-water is used as working fluid. The governing equations are numerically solved using finite volume approach together with SIMPLER algorithm. A wide spectrum of experimental and numerical simulations has been done. The results covered wide ranges of Reynolds number, Re, from 3000 to 32000, nanofluid volume fraction, ϕ, from 0 to10%. The dimensionless distance from jet nozzle to the horizontal plate was kept constant at 3. An experimental apparatus was constructed to measure the film thickness distribution, wall temperature and temperature of flowing fluid. The effects of Re and ϕ are investigated on the film thickness distribution, isothermal contours, and both local and average Nusselt numbers. A good agreement was found between the numerical and experimental results as well as the previous cited results. The results showed that the increasing of nanoparticle percent increases the convective heat transfer coefficient compared with the pure water. At ϕ =10.0% and Re=24000 the heat transfer coefficient increases by 62% compared with the pure water. The effect of nanofluid type (Al2O3-TiO2-CuO) is studied numerically. It has been observed that the CuO nanofluid increases the heat transfer by 8.9% and 12% compared to aluminum and titanium nanofluid respectively.

A.M. Tiara [11] studied The cooling rate of steel strips on a Run-out Table (ROT) in a hot strip mill affects both the metallurgical microstructure and mechanical properties. The current study focuses on the enhancement of heat transfer rate of an AISI 304 steel plate in both transition and nucleate boiling regimes by jet impingement methodology. The heat transfer studies during jet impingement have been carried out in the case of a steel plate (100 mm _ 100 mm _ 6 mm) from an initial temperature of around 900 _C at the surface. Nanofluid is used along with the base fluid in order to improve the thermal properties which affect the rate of heat transfer. The nanofluid employed here is Cu–Al layered double hydroxide (LDH) at 120 ppm along with different additives at their optimized concentrations,. The nanofluid based additives have been characterized based on the thermo physical properties. The maximum rate of cooling was attained in the case of Cu–Al LDH/ Tween 20 nanofluid, as supported by the enhancement of thermal conductivity and reduction in surface tension.

A.M. Tiaraa [12] studied Enhancement of thermal conductivity by the addition of nanofluid is found to improve the rate of cooling of a steel plate. In the present research work, alumina nanofluid at the previously optimized concentration of 10 ppm along with a non–ionic surfactant is employed for jet impingement cooling. The steel plate (100 ×100 ×6 mm) is cooled from an initial surface temperature of 900 °C. The concentration of non-ionic surfactant polyoxyethylene (20) sorbitan monolaurate (Tween 20) is optimized, and the surfactant is characterized based on its thermal properties. A maximum thermal conductivity enhancement of 21% and a minimum contact angle of 40.48° were exhibited by surfactant added nanofluid at 55 ppm. Inverse heat conduction method was employed to estimate the heat flux and temperature at the plate surface based on the internal thermocouple data. A maximum heat transfer rate of 139 °C/s with a critical heat flux (CHF) of 2.93 MW/m2 was attained at a surfactant concentration of 55 ppm. SEM and EDAX analysis of the plate surface after jet impingement confirmed the presence of the nanoparticles.

W. Wu et. al.[13] studied An experimental study was performed to investigate jet impingement heat transfer of HFE7100 dielectric liquid with metallic phase change materials (Field's alloy) in nanometer particulate form (nano PCM). Asimple method was used to prevent the precipitation of Field's alloy nanoparticles in a HFE7100 suspension by surface modification with silane monolayers. The optical transmittance of the nanoparticle suspension was monitored by a portable spectrometer and there was no significant change in optical transmittance over time. The nano PCM particle suspension impinges on a heated surface and absorbs heat by phase change process from solid to liquid phase coupled with the evaporation of HFE7100. The present study shows that the mass fraction of nanoparticles plays an insignificant role in pressure drop but an important role on heat transfer performance. The high-heat-flux removal capability has been demonstrated by repeated closed loop test. Our results show that slurries with 30% particle mass fraction can improve the average heat transfer coefficient by 70% when compared to pure HFE7100 in the temperature range of 62–66 ^{0}C.

II. CONCLUSION

It is concluded that the thermal conductivity, heat transfer coefficient and heat transfer rate of the fluid increase by adding the nanoparticles and TiO_2 and Al_2O_3 result in higher thermo physical properties in comparison with SiO_2. The highest overall heat transfer coefficient was achieved by Al_2O_3 nanofluid, which was 308.69 W/m^2.K in 0.2% nanoparticle concentration. The related heat transfer rate was improved around 30% compared to SiO_2 nanofluid. In terms of pressure drop, SiO_2 shows the lowest pressure drop, and it was around 50% smaller than the pressure drop in case of using TiO_2 and Al_2O_3. The application of nano fluid with low concentrations can enhance heat transfer efficiency up to 45% in comparison with pure water.

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