Study And Experimental Investigation On Heat Transfer Enhancement Using Nanofluid Jet Impingement

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Abstract*- Jet impingement cooling is a vital technique for thermal management of electronic devices of high heat flux by impinging fluid on a heater surface due to its high local heat transfer rate. In this paper Experimental investigation to study the heat transfer between a vertical alumina-water nanofluid jet and a horizontal circular round surface is to be carried out at different jet flow rates, jet nozzle diameters and various nanoparticles concentrations. The aim of experiment is to find whether using nanofluid as a heat transfer carrier can enhance the heat transfer process. The results for the experiment are to be expressed in terms of different Reynolds number with change in Nusselt number for different concentration of nanofluid. The different parameters to figure out heat transfer enhancement are Reynolds number at impingement jet diameter, jet heights and nozzle diameter. Final results as general heat transfer correlation verses Nusselt numbers using nanoparticle concentrations will be plotted.*

Keywords*-* heat flux, heat transfer enhancement, jet impingement cooling, nanofluid, nanoparticles concentration.

I. INTRODUCTION

Impinging liquid jet is an established technique to provide high local heat transfer coefficients between the impinged liquid and a surface. Jet impingement cooling already used to cooling purpose in numerous applications.

1.1 Need of liquid impingement jet cooling technology:

1. In the modern world giving challenge for micro-scale heat transfer and cooling.
2. In day to day rapidly increasing heat generation rates.
3. In system components are in continuous working its heat generation rates increases but heat removal rates are very less.
4. Because of company using new technology components sizes reduces and small components high heat flux generated.

A high velocity cold liquid is directed from a vertically hole onto the component surface to be cooled. As the cooling liquid jet hits the surface it is diverted in all direction parallel to the impingement surface. The cooling effect is high, but decreases continuously as distance from the impingement point increases. To ensure efficient impingement cooling of larger areas a large number of such holes must be arranged in on row or several rows. Jet impingement is an attractive cooling mechanism due to the capability of achieving high heat transfer rates.

The heat transfer between a vertical round alumina-water nanofluid jet and a horizontal circular round surface is carried out. The experiment is focused on the verification of the jet effect on the distribution of local heat transfer coefficient on the impinged target surface. The effect of flow in jet to test plate distance are also examined at various intersect spacing (Z/D). And it is found that the convective heat transfer coefficient is maximum in the stagnation region but gets decreases in wall jet region.

II. LITERATURE REVIEW

Obida Zeitoun and Mohamed Ali carried out heat transfer between a vertical round alumina-water nanofluid jet and a horizontal circular round surface. The parameters studied were different jet flow rates, jet nozzle diameters, various circular disk diameters and three nanoparticle concentrations of aluminum oxide (0, 6.6 and 10%, respectively). Their experimental results reinstated that using nanofluid as a heat transfer carrier can enhance the heat transfer process. They also found that the Nusselt number (upto 100 % in some higher concentrations) increases with increase in the nanoparticle concentration for the same Reynolds number.

Jun-Bo Huang et. al. A numerical simulation on confined impinging circular jet working with a mixture of water and Al2O3 nanoparticles is investigated. The flow is turbulent and a constant heat flux is applied on the heated plate. Different nozzle-to-plate distance, nanoparticle volume concentrations and Reynolds number have been considered to study the thermal performances of the system in terms of local, average and stagnation point Nusselt number.

A.M. Sharifi et. al. They used numerical simulation and experimental investigation for the study of laminar forced convective heat transfer of Al2O3-water nanofluid. The results of experiments and computer-aided simulation using MATLAB indicated remarkable enhancement of convective heat transfer of base fluid, by adding small amounts of Al2O3 nanoparticles. However, increasing ethylene glycol in the base fluid composition resulted in decreasing of heat transfer coefficient.

R.Shanthi.et.al. discussed the preparation of nanofluids based on different nanoparticles and base fluid. They have mentioned that nanofluids are colloidal mixtures of nanometric metallic or ceramic particles in a base fluid, such as water, ethylene glycol or oil and nanofluids possess immense potential to enhance the heat transfer character of the original fluid due to improved thermal transport properties.

M. A. Teamah and S. Farahat carried out the heat transfer and fluid flow due to the impingement of vertical circular single jet on a horizontal heated surface is investigated numerically and experimentally. A mathematical model is driven and executed by a computer program, which is prepared for that purpose. The numerical results are presented for a range of Reynolds number between 1000 and 40000, showing the variation of segment and average segment Nusselt number as well as the velocity and temperature distribution in the film region.

III. EXPERIMENTAL SETUP

In general, experimental results are required for supplementing the analysis by providing certain basic data or parameters that cannot be predicted precisely, for verifying the analytical/numerical predictions and also for evaluating the overall performance of a system configuration so as to check effects of various parameters. For this work an experimental test rig was designed in order to find the effect of flow rate, nozzle spacing from plate surface and different nanofluid concentrations to measure the effects of these parameters on heat transfer. Figure 1 shows the experimental set up for plate, heater & mica sheet and thermocouples. Mica sheets act as an electrical insulator. Heater plate is sandwiched between two mica sheets to avoid hazards. This whole assembly is enclosed in thin metal sheet and Cu plate is placed above this. Five thermocouples are attached as shown in the figure to the Cu plate from center and at equal distance between them. One side of thermocouple wire is brazed to Cu plate. Other side of thermocouple wire is attached to the temperature indicator.

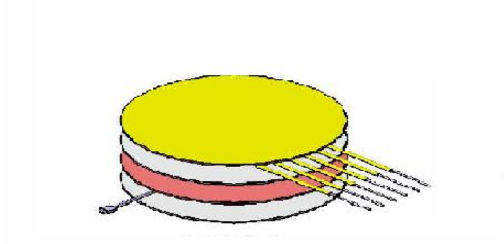

Fig. 1: Cu plate, Heater and Mica sheet assembly

Experiments were performed for characterization of heat transfer and effect of various parameters on local convective heat transfer coefficient. A schematic of the experimental setup is shown in figure 2. The setup was implemented with a suitable instrument control and measure the different variable affecting phenomena.

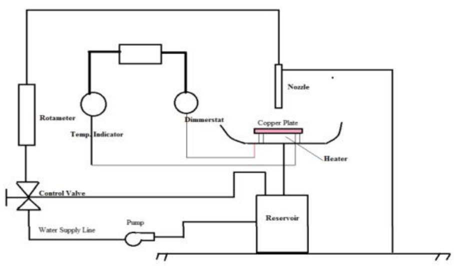

Fig. 2: Schematic diagram of Experimental Setup

Experimental setup consists of following components and their specifications are given below:

1. Copper plate
   - Thickness - 2 mm
   - Diameter -104 mm

2. Heater
   - Temp. Required - 65°C
   - Type -Circular heater plate
   - Thickness – 2mm
   - Diameter – 96 mm
   - Range - 1000watt

3. Thermocouple & Temperature Indicator
   - Type- J type
   - Temp. range – 0 to 1200 °C
   - Indicator Display -6 point indicator
   - Supply - 230 volt

4. Pump
    Power – 0.5HP
    Discharge – 1 to 5 lpm
5. Rotameter
    Range – 0 to 5 lpm

6. Reservoir and Collecting Tray
    Reservoir material - M.S. Plate
    Reservoir size – 40*30*30cm
    Tray material – M.S. sheet

7. Nozzle
    Material - Stainless steel
    Diameter – 4,6,8 mm
    Length – 180 mm

8. Nanoparticles Al2O3
    Density – 3.95g/cm^3
    Thermal Conductivity – 35w/mk
    Quantity -100 gm
    Purity - 99.9 %
    Particle Size - 25 nm

IV. NANOFLUID PREPARATION

Preparation of nanofluids is an important stage and nanofluids should be prepared in a systematic and careful manner. A stable nanofluid with uniform particle dispersion is required and the same is used for measuring the thermo physical properties of nanofluids. In the present work, water is taken as the base fluid for preparation ofAl2O3 nanofluids. Nanofluid is prepared by different methods. We are using a two-step method because it is easy and convenient due to availability of nanoparticles. Two-step preparation process is extensively used in the synthesis of nanofluids by mixing base fluids with commercially available nanopowders obtained from different mechanical, physical and chemical routes such as milling, grinding methods.

Thus by using nanoparticles and distilled water nanofluid can be prepared by the following method as shown in figure 3. Normally agglomeration of nanoparticles takes place when nanoparticles are suspended in the base fluid. All the test samples of Al2O3 nanofluids used subsequently for estimation of their properties were subjected to magnetic stirring process followed by ultrasonic vibration for about 30 minutes. The ultrasonic vibration technique is the most commonly used technique for producing highly stable, uniformly dispersed nano suspensions by two step process.

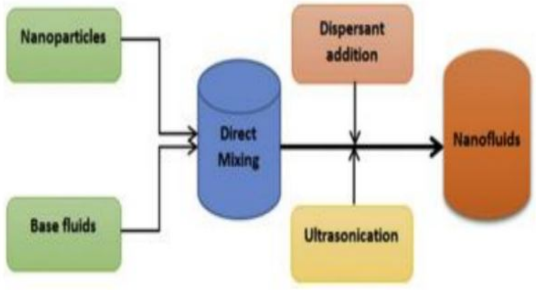

Fig. 3: Nanofluid preparation using two step method

V. EXPERIMENTAL PROCEDURE

The present study is carried out to examine the effect of nanofluid flow rates and concentrations on cooling of horizontal circular disks. Water is used as liquid reference in the current investigation since it is the base fluid of the used nanofluid. Three nozzles are used to examine jet size effect on heat transfer from hot disks. At the beginning of the experiment, the control valve is used to establish the required flow rate through the nozzle. Then, the heater is turned on where the electric power is adjusted using the dimmer stat and recorded. The experiments are done first for pure water only, then for nanofluid. Water from collecting tank is passed through pump. From this pump through control valve it reaches to flow meter. From the flow meter it reaches to the nozzle and from that nozzle it impinges on a flat horizontal plate. This plate is heated by the heater plate. And mica is used here as an electrical insulator. Thus by using liquid jet impingement we can achieve cooling of the plate. Temperature of the plate is measured by a set of thermocouples which are connected to temperature indicator. By varying the above mentioned parameters and by using the nanofluid we can enhance the heat transfer. Thus different readings are taken and optimum parameters can be obtained for obtaining maximum heat transfer from plate.

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