Effect of Nanofluid jet Impingement on its Heat Transfer Enhancement and Pumping Power

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Abstract— This paper present an experimental investigation on convective coefficient of Nanofluid in impingement of jet and its pumping power performance. In this investigation based solution is used is ethylene glycol andAl_2O_3as Nano Particle. With Different conc. (0%,0.2%,0.25% & 0.3%). It is found that Nanofluid enhances the heat transport rate in the cost of Pumping Power. The Presented data which is in terms of Reynolds Number at impingement diameter of jet can take into account on effects of impinging jet height and nozzle Diameter.

Keywords: **Heat Transfer Enhancement, Jet Impingement,NanofluidAl_2O_3-Ethylene Glycol**

I. INTRODUCTION

Heating or cooling in the industries like Electronics, Auto-sector and various manufacturing sector have the important challenging task related to heat transfer. Nano technology is the new emerging technology which helps conductivity rise in Ethylene glycol i.e. based fluid is rise by suspending nanoparticle in it. It possess high thermal conductive property of solid i.e. Nanoparticle increase the thermal conductive property of fluid. Impingement jet is modern developed technique which gives the more heat transport rate between the heating surface and impinged liquid. Impingement jet is mostly used where maximum possible heat transport rate desired. Likely Liquid jet can be used to cool the Turbine blades, Electronic Component and Combustion chamber wall and heat transport can be considered as important process in Thermal Power Stations.

The aim of this investigation is to examine effect ○f Nanofluid impingement of jet on heat transport performance under round free liquid impingement of jet on flat, constant input heat flux surface. Some important literature on enhancement about performance of heat transport coefficient under impinging jets with nanofluid is available. Liquid jet can also be classified like submerged or free surface. In submerged type jet, liquid discharged into same liquid medium. Where as in free surface type liquid jet discharged in to gas medium. For free type surface jet the impingement has clearly shows high cooling ability(Liu and Lienhard,1993).Review of previous papers on the investigations of nanofluid with impinging jet states that high heat transfer rates found at the exact stagnation point impinge of the jet because of very thinner boundary layer form near stagnation point. However after the jump region, the cooling rate goes slow i.e. half of the stagnation point cooling rate(Liu X,Lienhard,1993).

The foundation work of Watson in the era of jet impingement divided the flow field of an impinging jet on circular horizontal disk into two regions before hydraulic jump formation. First region near center jet assumed the boundary layer type and the second was free surface flow up until hydraulic jump position(Watson E, 1962).

Ishigaistudied heat transfer and flow related an impinging circular jet on horizontal type disk plate and compared experimental measurement of film thickness with Watsons theoretical work. Results were good between these two solutions near impinging center at jet,but as radial location increases, the difference becomes more (Ishigai S, 1977). Zhao and Masuokastudied the heat transport of jets 2 mm and0.9 mm and having 10 mm disk diameter(Zhao Y,Masuoka T,2002).

Maria Jose carried experimentation by adding Al_2O_3nanoparticle in Ethylene Glycol solution and stability and then dispersion of nanofluids analyzed at different concentrations max. 25% in the mass fraction. The viscosity and thermal conductivity were experimentally found out at temperatures ranging from 283.15 K to 323.15 K. It get clear that both viscosity ,thermal conductivity increase as increase in concentration of nanoparticle, whereas when temperature rises viscosity lowers and thermal conductivity get raised by considerable amount. Measured enhance in thermal conductivity maximum19% compared with available literature values (Maria Jose et.al.2003).

C. Nguyen et.al carried out experimentation to study, heat transport performance for water-Al_2O_3 (36nm particle size) nanofluid in liquid evacuated impinging jet system destined to the cool high-power electronic components. Data obtained for water and 5% particle concentration volume fraction, three particular heated surface to nozzle exit distances (2mm, 5mm and 10mm) and flow Reynold numbers ranging 1700 to nearly 20000.Their obtained results shown that surface heat transport coefficient increases considerably when mass flow rate is increased, but relatively not sensitive to the nozzle to heated surface distance. Found that use of nanofluid can give more heat transport enhancement of much as 72% when compared with water solely. Results from erosion tests shown that nanofluid have tendency to cause premature wear of mechanical components. (C.T.Nguyen et.al, 2008)

This paper shows the impact of using vertical type alumina-Ethylene Glycol Nanofluid jet with various concentrations on the cooling of horizontal heated circular disks in terms of dimensionless parameters. This paper shows effect of nanoparticle concentration on pumping power in impinging process.

2. EXPERIMENTAL DETAILS

For this experimental work test rig was such designed in order to find effect of flow rate, nozzle spacing from plate surface and for different nanofluid conc. to measure effects of mention parameters on heat transfer. Figure 1 shows the experimental set up for heater, cu plate,Mica sheet and wire thermocouples. Mica sheet plays role of electrical insulator. Heater plate sandwiched in betweenmica sheets to avoid hazards. Assembly is enclosed in thin metal sheet and Cu plate is placed above this. Eight wire j type thermocouples are brazed as shown in the figure to the plate from center to in radial direction with 20 mm distance apart. One end of thermocouple is brazed to Cu plate. Other end of wire is attached to the temperature indicator.

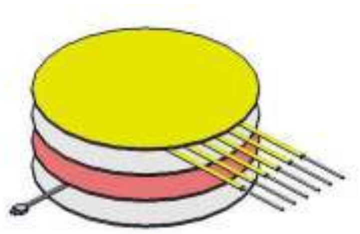

Fig. 1 Experimental Set-Up

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

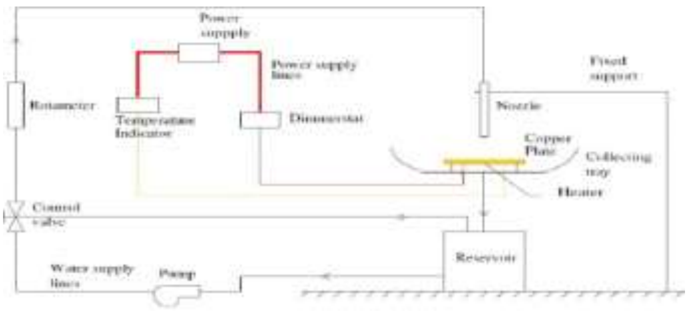

Fig.2 Schematic of the Experimental set up

A centrifugal pump is used for delivering nanofluid in the form of jet at the required flow rate. The flow rate was measured by rotameter which connected to 6 mm nozzle arrangement through the PVC piping. The circular tubes of internal diameter 6 mm are used as nozzles. The tubes have length to dia. ratio above 50, so as to ensure flow condition at exit is fully developed. Provisions are also made to get the vertical positions of nozzle. A Jet from nozzle fall on heated circular Cu plate of2 mm thickness and 300 mm diameter, mounted on fixed leveled surface. The jet impinging centered over flat horizontal Cu plate assembly spreads radially and falls freely into collecting tray of dimension 480 mm x 480 mm. The entire things are mounted on heavy frame structure so that no adverse effect of external vibrations. The setup fabricated such that local temperature of the plate is measured at 8 various locations. These temperatures can be recorded by operating temperature indicator. Dimmerstat is used for controlling current supplied to the heater. During the experimentation, Perfect horizontal arrangement of target plate was ensured all along with the aid of spirit level, in addition, free fall of the liquid was also observed to be uniform from all the edges of plate to ensure that no perceptible error because lacks flatness of target plate

2.1 Component selection

2.1.1 Cu Plate

Cu plate is to be placed on heater plate and assembly is enclosed in wooden box to avoid directly contact with water and heater plate. Silicone sealant is used to fix Cu plate on a wooden box.

2.1.2 Heater

Strips are used as heating element and local heating of surface is avoided. Assembly of mica sheets and heater is enclosed as one unit to avoid hazard.

2.1.3Nozzle

To obtain fully developed type flow and avoid effect of nozzle inlet on the exit of nozzle. Minimum nozzle height to dia. ratio required 50 so nozzle length is to be kept 40 cm.

2.1.4Nanoparticle Al_2O_3

Al_2O_3 nanoparticle is selected due to thermal stability in the ethylene glycol soln. also have good thermal conductivity, easy availability and low cost. two avoid pumping losses and early Seattle down period minimum grain size is selected.i.e.10-20nm.Nanoparticle is purchased from Sisco Laboratories Pvt Ltd.Mumbai.

Table No.1 Nanofluid Property

S.No	Parameters	Values
1	Quantity	100 gm
2	Property	Alpha
3	Purity	99.9%
4	Particle Size	10-20 nm

2.2 Estimation of nanoparticle by Volume Concentration

Amount of Al_2O_3 is calculated by using law of mixture formula. Nanofluid having concentrations of 0.2, 0.25 & 0.3% are prepared by using sonication and magnetic steering.

Table No.2 Nanoparticle Volume Concentration

S. No	Volume concentration φ (%)	Weight of Nano particles Al_2O_3 (Grams)	Ethylene Glycol (Liters)
1	0.20	32	5
2	0.25	40	5
3	0.30	48.15	5

2.3 Nanofluid Preparation

Normally agglomeration of nanoparticles takes place when nanoparticle suspended in Ethylene Glycol. Nanofluid subjected to magnetic stirring after ultrasonic vibration for 40 minutes. The ultrasonic vibration technique is most used technique to producing highly stable, uniformly dispersed Nano suspensions by two step process.

It is clear that the duration of ultrasonic vibration has significant effect on conductivity because it helps to reduce the clustering of nanoparticles.

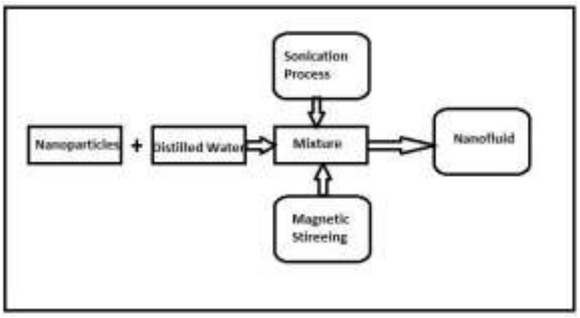

Fig.3 Block Diagram of Nanofluid Preparation

III. EXPERIMENTAL PROCEDURE

An experiment is carried for examine effect of Nanofluid concentrations and flow rate on circular horizontal disk with steady state cooling. Nanoparticle volume conc. is 0%,0.2%,0.25% and 0.3% in the pure ethylene glycol. Ethylene glycol used as based fluid as reference having 0 % conc. in the current investigations.

At the beginning of the experimentation, the rotameter use to establish the required flow rate through the nozzle. Then, the heater is turned on where the electric power is adjusted using the dimmerstat and recorded by voltmeter and ammeter. Then temp. Indicator collects thermocouple readings and noted manually.it should note that system reaches steady state in 45 min where temp is recorded .the experiments are done first for ethylene glycol sol. and then Nanofluid with different concentration.

IV. RESULT AND DISCUSSION

This part deals with the investigation of average heat transport coefficient for copper disc. Flow rate for fluid is varied form 2 LPM to 4 LPM. The vertical distance of nozzle exit from disc surface is also varied simultaneously. This distance is maintained at 24 mm, 18 mm and 12 mm. Initially, plain ethylene glycol has been impinged upon disc and temperature variation is recorded for flow rates mentioned earlier and vertical distance of nozzle exit from disc surface is also varied. Same operating parameters are maintained for nano fluid with volume proportion of nanoparticle of 0.2 %, 0.25 % and 0.3 % and temperature variation has been recorded. The power required for pumping to ethylene glycol sol. and three nanofluid conc. is also determined while carrying out experimentation.

The effect of nanoparticle proportion, ratio of nozzle height to nozzle diameter and nanofluid flow rate, over average convective heat transfer coefficient is analyzed.

Table No.3 Experimental Parameters

S.No	Mass flow rate (LPM)	Z/D ratio	Nanofluid proportion; (%)	Nozzle diameter (mm)
1	1	2	0 %	6
2	2	3	0 %	
3	3	4	0 %	
4	1	2	0.2 %	
5	2	3		
6	3	4		
7	1	2	0.25 %	
8	2	3		
9	3	4		
10	1	2	0.3 %	
11	2	3		
12	3	4		

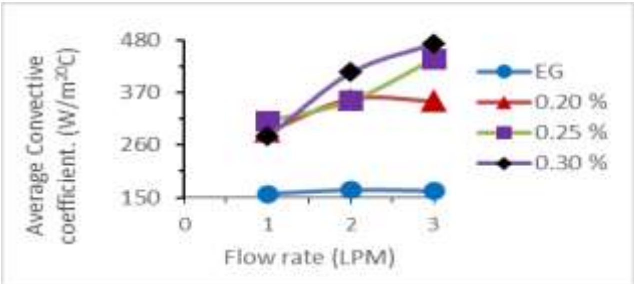

Fig.4 Effect of flow rate on Avg. Convective coefficient at Z/D ratio 2

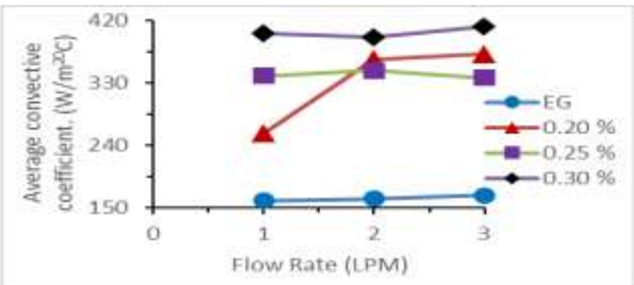

Fig.5 Effect of flow rate on Avg. Convective coefficient at Z/D ratio 3

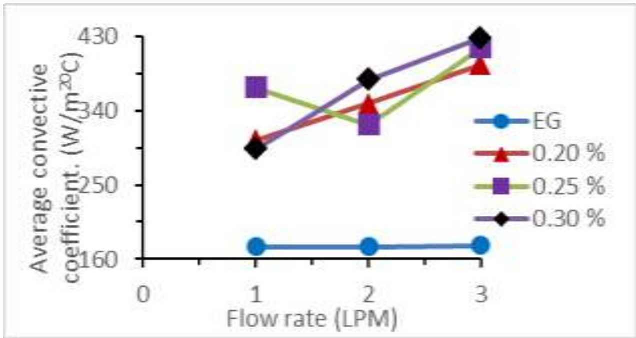

Fig.6 Effect of flow rate on Avg. Convective coefficient at Z/D ratio 4

4.1 Comparison of Experimental convective heat transport coefficient obtained from Nusselt Number correlations with experimental value.

There are few models available for the average Nusselt number In jet impingement along circular disk such models are those given by Zhao et al. They used integral analysis method to solve the flow in radial direction of circular disk. The film was divided into stagnation, near impingement point, boundary layer and similarity regions.

Equation proposed by Zao et.al.

$$Nu_j = 0.77212\,[2D_j/D]^{2*}Pr^{0.4}Re^{0.5}{}_j + 0.89[2D_{j/}D]^{2*}\{[D/2D_j]^{3/2} - 1\}*Pr^{1/3}Re^{0.5} \quad (1)$$

Empirical correlation for forced convection over flat plate

$$Nu = 0.663Re_j^{0.25} * Pr^{0.3} \quad (2)$$

In all of above two correlations Reynold's Number is calculated at jet exit from nozzle and subscript j represent jet exit conditions.

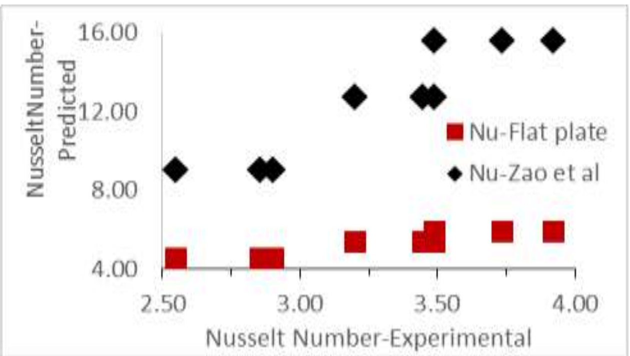

Fig.7 Comparison between Nusselt Number predicted an Experimental for Flat Plate for 0.20% Conc.

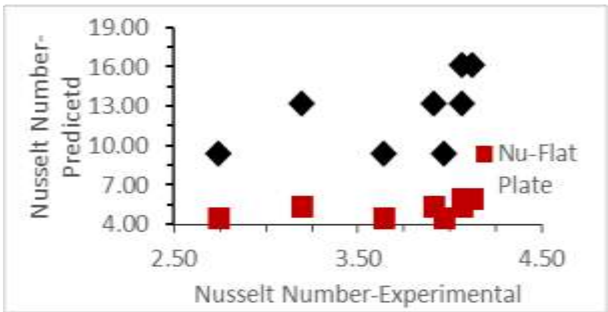

Fig.8 Comparison between Nusselt Number predicted an Experimental for Flat Plate for 0.25% Conc.

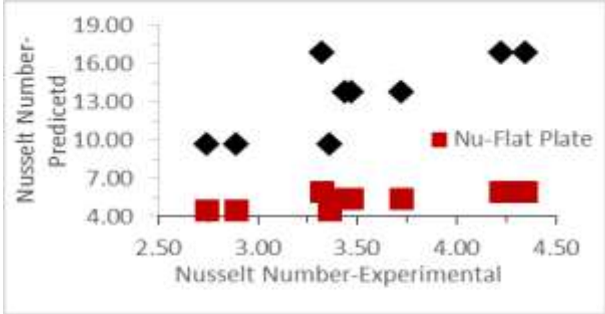

Fig.9 Comparison between Nusselt Number predicted an Experimental for Flat Plate for 0.30% Conc.

4.2 Pumping Power Requirement

Variation in pumping power is also an effective way to observe effect of nanoparticle in the Ethylene Glycol. Nanoparticles increases density and viscosity of nanofluid with increase in proportion. As these two properties are dominant in varying the pumping power the same effect observed in following graph.

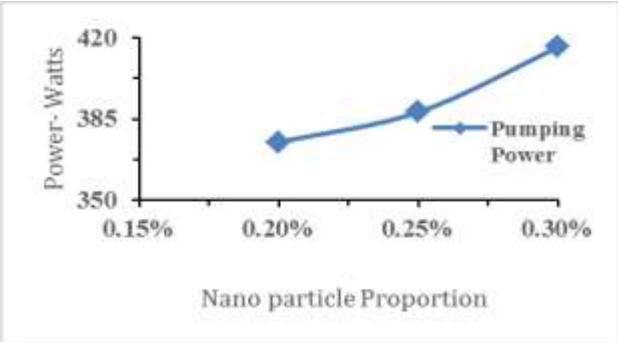

Fig. 10 Pumping power required for three concentrations of nanofluid.

As observed in above figure, the power required to pump and circulate the nanofluid has shown the increasing trend as proportion of nanoparticle increases. Increase in power is 13 Watts as proportion of nano particles increased from 0.2 % to 0.25 % and a power of additional 28 Watts has been required for the proportion of 0.3 %.

V. CONCLUSIONS

The following conclusions were drawn from the experimental study.

1) For 0.2, 0.25& 0.3% concentrations h increases by 24%, 33% & 44% than plain ethylene glycol respectively. Thus, as nanofluid concentration increases heat transport coefficient increases.
2) Distance from stagnation point increases local convective heat transport coefficient decreases and this variation is indicated by increase in temperature.
3) Effect of spacing on heat transport coefficient is predominant in Z/D = 2 to 4& as the spacing increases coefficient increases. Thus maximum heat transfer, spacing distance to diameter ratio should be 4.
4) As flow rate increases from 1 lpm to 3 lpm, increase in heat transport coefficient is 33 to 57%. Thus flow rate is important factor in heat transport coefficient enhancement.

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