IMPACT OF VARIOUS PARAMETERS IN LIQUID JET IMPINGEMENT: A REVIEW

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ABSTRACT
Liquid jet impingement is an efficient technique for various industrial applications like Turbine blade cooling, Metal annealing, Textile drying, Electronic equipment. Thus study of various parameters to enhance heat transfer in liquid jet impingement becomes important. Heat transfer rate in liquid jet impingement can be enhanced by changing different parameters like jet inclination angle, nozzle to spacing distance, flow rate, use of multiple jet impingement, changing surface roughness and by using fluid which is having high thermal conductivity. Nanofluids are fluid having high thermal conductivity compared to conventional fluids like water. Effects of these parameters on heat transfer rate are discussed in detail in this paper from various researches going on.

***KEYWORDS**: Liquid jet impingement, Heat transfer rate, Nanofluids, Applications of Liquid jet impingement.*

1. INTRODUCTION
Recent technological developments in the various fields need efficient cooling techniques. The heat transfer process can be improved by means of active and passive techniques. Active techniques are mechanical agitating, rotating, vibration and use of electrostatic or magnetic fields. These techniques required external energy input is costly. In critical operations it is inconvenient. Passive techniques include methods to modify the fluid properties, surface shape, roughness or external attachments to increase the surface area, and make the flow turbulent. Impinging of liquid jet on a surface to remove heat from surface is an effective method for high heat flux heat transfer. In recent years, the use of jet impingement as a high performance technique for local heating or cooling a surface has become a well-established method because of its high heat transfer rates and its simplicity in application to a variety of industries. The applications of the impingement technique are numerous which include drying of paper, textiles, annealing of metals, tempering of glass, cooling of electronic equipment and freezing of tissue in cryosurgery. Due to broad industrial uses of the impinge jets extensive research has been conducted to investigate the hydrodynamic and thermal characteristic of such jets. Heat transfer rate in liquid jet impingement can be enhanced by using different passive techniques changing are discussed in this paper. Liquid jet on a surface can be widely classified into two configurations, namely submerged and free surface jet. A submerged jet is discharged into fluid of the same type. On the other

hand, a free surface jet is that jet which moves in a medium different from that of the jet. A water jet discharged in air is a free jet while air jet discharged in air is a submerged jet.

When jet of water falls on horizontal plate it spreads in the form of thin film. At the some distance from the stagnation point its depth increases suddenly. This is called as hydraulic jump. Depth is observed much larger at outside of jump compared to inside. This is because Froude no outside the jump is small compared to inside jump. Maximum heat transfer rate is obtained within inside area. So that in practical application we have to obtain such a flow conditions that we can obtain maximum area before hydraulic jump. Parameters which affect this area bounded are flow rate and jet inclination angle are discussed in this paper. Other parameters like surface roughness jet to nozzle spacing are also discussed.

2. EFFECT OF PARAMETERS ON LIQUID JET IMPINGEMENT

Mohamed A. Teamah et al [1] carried out experimentation to determine the effect of flow rate on hydraulic jump profile. Water flow rate is varied from 2 to 5 lpm. Nozzle to target spacing is kept constant i.e. 30 mm. nozzle is having circular shape and 5.5 mm in diameter. Jet is impinging on horizontal surface vertically. The experimentation shows that area bounded by hydraulic jump profile is of circular shape. As the water flow rate increases from 2 to 5 lpm, the hydraulic jump radius increases 230%.

R.P Kate et al [2] carried out experimentation with inclined jet with various jet angles. This inclined jet with varying jet angles form non-circular hydraulic jump profiles. Further study shows that these jump profiles can be grouped into two categories. Jump with jet inclination angle in range of (25°<Ø≤ 90°) and another jump with jet inclination angle (≤ 25°). From flow visualization experiments this is observed that when (Ø≤ 25°) jumps with corners are formed & when 25° < Ø< 90°) jumps with elliptical shape are formed. Circular jumps are form when jet is vertical. Thus jet inclination angle has significant effect on hydraulic jump profile.

Chitranjan Agarwal et al [3] investigated effect of nozzle exit to surface spacing on the cooling of electrically heated surface with jet impingement. Experimentation consists of water jet impingement on stainless steel surface of 800℃. Varying surface temperature is recorded at stagnation point with respect to time. D=diameter of jet=2.5 mm. Temperature of jet water is 22±1 ℃. Flow rate is to be kept 2.75 lpm. Spacing between jet exit & surface (Z) is varied in the range of Z/D=4-16. Reynolds no is also kept constant=24000. Results obtained shows that at Z/D=4, time required for plate to obtain 100℃ from 800℃ is 4.6 sec. While at Z/D=8-12, time required for plate to obtain 100℃ from 800℃ is 4.45 sec. Further when Z/D=8-12 time required for plate to obtain 500℃ from 800℃ is 1 Sec. While at Z/D=4 time required for plate to obtain 500℃ from 800℃ is 1.15 Sec. Thus at high surface temperature at Z/D=4 cooling is delayed by 15% as compared to higher nozzle exit to surface spacing.

J.H lienhard V and J. Hadeler [4] carried out study to determine the effectiveness of jet array on flux cooling in liquid jet impingement. High speed water jets are effective to remove fluxes as high as 400 MW/m^2 over small areas. If large area is considered then jet arrays have proven to be useful. This experimentation consists of array of fourteen, 2.87 mm ID nozzles on 10 mm centers to produce 47 m/s water jets impinging on an area of $10cm^2$. Results of experimentation shows that jet array removed fluxes up to 17 MW/m^2 only by forced convection. The associated heat transfer coefficients was to be measured 220 kW/m^2.

Gabour and Linhard [5] measured the effect of varying wall roughness on stagnation point Nusselts number. Here jet is fully developed turbulent cold water jet. Experimentation consists of mild steel surface having cross hatch pattern. Roughness depth K is $4.7 \leq K \leq 28.2$ um. Nozzles used are having diameter D=4.4, 6.0, 9.0 mm and Reynolds no from 20000 to 84000. The Prandtl number is held between 8.2 and 9.1. Graph is plotted Reynolds number against Nusselts number. Nusselts number is greatly affected by Reynolds number and dimensionless roughness K*=K/D. For higher value of K* Nusselts number is higher and for lower value of K* Nusselts number is smaller. Results show that roughness of 28 um rms height could raises the Nusselts number by up to 50%.

Since different research teams used different particle sizes and conducted their studies under various conditions, it is difficult to determine the effect of molecular materials just on the improvement of heat conductivity. It is evident from Wang et al [6] researchers.

It is possible to produce high heat flux transmission by impinging a fluid jet onto a material to remove heat. Due to its high rate of heat transmission and simplicity of application across numerous industries, boundary layer flow has recently gained substantial favour as a high-performing approach for local central heating of a material. Impingement techniques can be used for a variety of operations, including the chilling of electronic equipment, the annealing of metals, the drying of paper, the tempering of glass and textiles, and the chilling of tissue during cryosurgery [7].

Mostafa Jalal et al. conducted an experimental test to determine the effect of a CuO/water nano-fluid alone on convective heating of a heat sink inside the laminar regime. They found that the heat transfer coefficient also grew when the volume proportion of nanoparticles rose [8].

Consequently, understanding the causes of and magnitude of splash is a key component of the design of the jet cooling system (Lienhard et al., 1992). When impinging jets are employed in clean-room settings (such as silicon chip production) to remove post-etching debris, spilled liquid can cause airborne contamination that results in faults on the chip surface. The splattered drops from the usage of toxic chemicals to form metal can produce a hazardous aerosol, making its regulation expensive [9].

The two parts of the process are indicated by the name; the first stage involves the production of the nanoparticles, and the second stage entails their scattering in the base Fluid. Depending on the kind of nanoparticles to be used, the first phase is typically carried out using material fume testimonies and passive gas accumulation [9]. This technology is less expensive to transmit nanofluids due to the proactive rise in company nano-powder manufacture in the latter contact [10].

3. CONCLUSION

From the above review, the following conclusions can be drawn.

1. As the flow rate increases hydraulic jump radius increases.
2. As the flow rate increases film thickness decreases.
3. Profile of jump is of circular shape when

jet inclination angle is 90˚and it becomes elliptical when jet inclination angle < 90˚.

4. Nozzle to surface spacing distance is not that much considerable when surface temperature drop is larger but it affects when there is small surface temperature drop.
5. To remove heat fluxes from large surface area, Jet array is an effective technique.
6. Heat transfer characteristics of surface are affected by surface roughness.

REFERENCES

[1] Mohamed A. Teamah, M. Khalil Ibrahim, Mohamed M. Khairat Dawood, EI-Sayed Abdel Aleem, "Experimental Inveastigation for Hydrodynamic Flow Due to Obliquely Free circular Water Jet Impinging on Horizontal Flat Plate", European Journal of Scientific Research. 83(2012) pp.60-75.

[2] R.P. Kate, P.K. Das, Suman Chakraborty, "An investigation on non-circular hydraulic jumps formed due to obliquely impinging circular liquid jets", Experimental Thermal and Fluid Science. 32(2008) pp.1429–1439.

[3] Chitranjan Agarwal, J.K. Maherchandani, Mukesh Sahi, Faghri A, "Effect of Nozzle to surface spacing on the cooling of Electrically Heated surface with Jet Impingement", International Journal of Advanced research in Electrical, Electronics and Instrumentation Engineering. 1(2012) pp.73-76.

[4] J.H. Linhard V and J. Hadler, "High Heat Flux Cooling by Liquid Jet Array Module", Chem. Engnrg. & Tech. 22(1999) pp.967-970.

[5] L.A. Gablour and J.H. Lienhard V, "Wall Roughness Effects on Stagnation Point Heat Transfer Beaneath an Impinging Liquid Jet", J. Heat Transfer. 116(1994) pp.81-87.

[6] Nguyen, C. T., Galanis, N., Polidori, G., Fohanno, S., Popa, C. V. and Le Bechec, A., An experimental study of a confined and submerged impinging jet heat transfer using Al2O3-water nanofluid. International Journal of Thermal Sciences, vol. 48, pp. 401-411 (2009).

[7] Chitranjan Agarwal, J.K. Maherchandani, MukeshSahi, Faghri A, "Effect of Nozzle to surface spacing on the cooling of Electrically Heated surface with Jet Impingement", International Journal of Advanced research in Electrical, Electronics and Instrumentation Engineering. (2012) 1 pp.73-76.

[8] Xin Liu, L. A. Gabour, J. H. Lienhard V, "Stagnation Point heat transfer during impingement of laminar liquid jet: Analysis incluiding surface tension", Journal of heat transfer (1993) 115 pp.99-105.

[9] Sourav K. Bhunia John H. Lienhard V, "Surface Disturbance Evolution and the Splattering of Turbulent Liquid jet", Journal of Fluids Engineering, (1994) 116 / 721.

[10] Vadiraj Katti, S.V. Prabhu, "Experimental study and theoretical analysis of local heat transfer distribution between smooth flat surface and impinging air jet from a circular straight pipe nozzle", Department of Mechanical Engineering, Indian Institute of Technology, Bombay, Powai, Mumbai 400 076, India.

[11] Praveen Barmavatu, Mihir Kumar Das, Rathod Subhash, Banoth Sravanthi, Radhamanohar Aepuru, R Venkat reddy, Yalagandala akshay kumar "Designing an Effective Plate Fin Heat Exchanger and Prediction of Thermal Performance Operated Under Different Water Blends Using Machine Learning", Journal of Thermal Sciences and Engineering Applications, ASME Publications, Manuscript id: TSEA-21-1662, Accepted, 2022. https://doi.org/10.1115/1.4055653

[12] Barmavatu Praveen & scg "CFD approach for different fluids varients in compact heat exchanger at different parametric conditions" International journal of scientific & technological research ISSN 2277-8616/vol-8/issue-12/pp:2288-2296/December 2019.

[13] Barmavatu Praveen & scg "fabrication of compact heat exchanger with composite alloys" International journal of innovative technology and exploring engineering ISSN 2278-3075/vol-8/issue-6s4/pp:717-721/april 2019.

[14] Saikesh Erramshetty, Barmavatu Praveen, Venkata Manikanta Ankem,, Yesu Raju Uppea "Enhancement of vapour compression refrigeration system (VCR) performance using greenhouse gas mixtures", International Journal of Computational Engineering Research (IJCER), ISSN 2250 – 3005/vol-10/issue-09/pp:01-10/ September 2020.

[15] Barmavatu Praveen & scg "An apporach in finding overall heat transfer coefficeint of compact heat exchanger using different fluids" International journal of research, ISSN 2236-6124/vol-8/issue-6/pp:229-238/june 2019.

[16] Barmavatu Praveen & scg "Performance evaluation of a compact heat exchanger with Varying

different properties" Journal of applied science and computations ISSN 1076-5131/vol-6/issue-6/pp: 192-199/june 2019

[17] Barmavatu Praveen, Sai pranay r.p "fabrication of portable solar thermo electric refrigerator by liquid cooling" International journal of scientific research in science and technology ISSN 2395-6011/vol-4/issue-7/pp:248-255/april 2018.

[18] Barmavatu et al "An empherical apporach on fabrication of compact heat exchanger" International journal of management, technology and Engineering ISSN 2249-7455/vol-9/issue-6/pp: 183-189/june 2019.