# EXPERIMENTAL INVESTIGATION OF A DIMPLED PLATE BY NATURAL CONVECTION HEAT TRANSFER

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***Abstract** - Heat transfer describes the exchange of thermal energy, between physical systems depending on the temperature and pressure, by dissipating heat. The fundamental modes of heat transfer are conduction or diffusion, convection and radiation. The exchange of kinetic energy of particles through the boundary between two systems which are at different temperatures from each other or from their surroundings. Heat transfer always occurs from a region of high temperature to another region of lower temperature. Heat transfer changes the internal energy of both systems involved according to the First Law of Thermodynamics. Natural convection is a mechanism, or type of heat transport, in which the fluid motion is not generated by any external source (like a pump, fan, suction device, etc.) but only by density differences in the fluid occurring due to temperature gradients. In natural convection, fluid surrounding a heat source receives heat, becomes less dense and rises. The surrounding, cooler fluid then moves to replace it.*

***Keywords** – Heat Transfer, Natural Convection, Dimpled Plates.*

## I. INTRODUCTION

Convective heat transfer, or convection, is the transfer of heat from one place to another by the movement of fluids, a process that is essentially the transfer of heat via mass transfer. Bulk motion of fluid enhances heat transfer in many physical situations, such as (for example) between a solid surface and the fluid. Convection is usually the dominant form of heat transfer in liquids and gases. Although sometimes discussed as a third method of heat transfer, convection is usually used to describe the combined effects of heat conduction within the fluid (diffusion) and heat transference by bulk fluid flow streaming.

Natural convection is a mechanism, or type of heat transport, in which the fluid motion is not generated by any external source (like a pump, fan, suction device, etc.) but only by density differences in the fluid occurring due to temperature gradients. In natural convection, fluid surrounding a heat source receives heat, becomes less dense and rises. The surrounding, cooler fluid then moves to replace it. This cooler fluid is then heated and the process continues, forming a convection current; this process transfers heat energy from the bottom of the convection cell to top. The driving force for natural convection is buoyancy, a result of differences in fluid density. Because of this, the presence of a proper acceleration such as arises from resistance to gravity, or an equivalent force (arising from acceleration, centrifugal force or Coriolis effect), is essential for natural convection. For example, natural convection essentially does not operate in free-fall (inertial) environments, such as that of the orbiting International Space Station, where other heat transfer mechanisms are required to prevent electronic components from overheating.

## II. LITERATURE REVIEW

Many studies have focused on cooling through natural convective heat transfer in many books and many previous researchers investigated natural convection from the extended surfaces. These studies are motivated by the fact that the heat transfer rate from the extended surfaces differs greatly that from the base surfaces. Relevant literature pertaining to enhancement of heat transfer by introducing protrusions mounted on the heat transfer surfaces, reviewed from different points. A number of heat transfer studies from Russia utilize dimples. A variety of experimental, analytical and computational research works has been carried out on enhancement of heart transfer.

**Kuethe et al.[1**] was the first suggest the use of dimple surface for heat transfer enhancement. Surface dimples are expected to promote turbulent mixing in the flow and enhance the heat transfer, as they behave as a vortex generator.

**M.A.Dafedar et.al.[2]** studied experimentally the heat transfer augmentation through various geometries of dimpled surfaces in longitudinal and lateral directions. In his paper horizontal rectangular plates of copper and aluminum with different dimpled geometries (like square, circular and triangular) for in-line arrangements were studied in natural convection with steady laminar external flow condition.

The various parameters considered for study are Nusselt number, heat transfer coefficient and heat transfer rate for a constant Prandtl number (0.7) and Grashof number (104 -107 ).It has been found that the heat transfer coefficient and heat transfer rate increases for various dimpled surfaces as compared to plane surface. It has been also found that the heat transfer coefficient and heat transfer rate increases along longitudinal direction as compared to lateral direction. And it is seen that heat transfer rate is maximum for triangular shape dimple when the apex of triangle is faced towards inlet of air flow Finally it is concluded that heat transfer enhancement takes place along the dimpled surface.

**Iftikarahamad H. Patel et.al.[3]** presented the computational investigation of convective heat transfer in turbulised flow past a dimpled surface. A parametric study is performed with k-ε turbulence model to determine the effects of Reynolds number, dimple depth and Nusselt number on heat transfer enhancement. In this paper we have computed heat transfer coefficients in a channel with one side dimpled surface. The sphere type dimple geometry was considered with diameter (D) 10 mm and the depth (δ) 4 mm, to obtain δ/D ratio as 0.4 and it was increased later to 5 mm to increase δ/D ratio to 0.5. The Reynolds number based on the channel hydraulic diameter was varied from 200000 to 360000.The results showed that more heat transfer was occurred downstream of the dimples due to flow reattachment. Due to the flow recirculation on the upstream side in the dimple, the heat transfer coefficient was very low. As the Reynolds number increased, the overall heat transfer coefficient was also increased.

**Faheem Akthar et.al.[4]** experimental investigated the natural convection heat transfer over circular dimpled surfaces is carried out. The various heat transfer parameters considered for study are Nusselt number, heat transfer coefficient and heat transfer rate. From the obtained results, it can be concluded that large amount of heat transfer enhancement does takes place for the dimpled surfaces.

**Saurabh R Verma et.al [5]** studied Heat Transfer enhancement using dimples are based on the principle of scrubbing action of cooling fluid taking place inside the dimple and phenomenon of intensifying the delay of flow separation over the surface. Spherical indentations or dimples have shown good heat transfer characteristics when used as surface roughness. The technology using dimples recently attracted interest due to the substantial heat transfer augmentations it induces, with pressure drop penalties smaller than with other types of heat augmentation. From all the research work studied the researchers have used various dimple shaped geometries such as triangular, ellipsoidal, circular, square out of which ellipsoidal shape gives better results due to prior vortex formation then other shapes

**Amjad Khan et.al.[6]** studied the fluid flow and heat transfer characteristics of spherical dimples at different angle of orientation from the centre with apex facing the inlet were investigated. The experiment was carried out for laminar Natural convection conditions with air as a working fluid. The overall Nusselt numbers and heat transfer coefficient at different orientation angle of dimples were obtained. From the obtained results, it was observed that the Nusselt numbers and heat transfer coefficient increases with decrease in the orientation angle of dimples.

**Burgess et al.[7]** experimentally analyzed the effect of dimple depth on the surface within a channel with the ratio of dimple depth to dimple printed diameter, equal to $\delta/D$, 0.1, 0.2, and 0.3. The data showed that the local Nusselt number increased as the dimple depth increased due to an increased strength and intensity of vortices and three dimensional (3D) turbulent productions.

**Ligrani et al.[8]**experimentally showed the influence of dimple aspect ratio, temperature ratio, Reynolds number and flow structures in a dimpled channel at Re = 600 to 11,000 and air inlet stagnation temperature ratio of 0.78 to 0.94 with H/D =0.20, 0.25, 0.5, 1.00. The results indicated that the vortex pairs which are periodically shed from the dimples become stronger and local Nusselt number increase as channel height decreases. As the temperature ratio Toi/Tw decreases, the local Nusselt number also increased.

**Mahmood et al.[9]** studied the flow and heat transfer characteristics over staggered arrays of dimples with $\delta/D=0.2$. For the globally average Nusselt number, there were small changes with Reynolds number. He studied the effect of dimpled protrusions (bumps) on the opposite wall of the dimpled surface.

**S. D. Hwang et al.[10]** in present study, heat transfer and thermal performance of a periodically dimple protrusion patterned surface have been investigated to enhance energy-efficiency in compact heat exchangers. The local heat transfer coefficients on the dimple/protrusion walls are derived using a transient TLC (Thermo chromic Liquid Crystal) technique at low Reynolds number. The periodically patterned surface is applied to the bottom wall only or both the bottom and top walls in the test duct. On the single-side patterned walls, various secondary flows generated from the dimple/protrusion coexist. The vortices induced from the upstream affect strongly on the downstream pattern. For the double-side patterned wall case, vortex interaction affected by the opposite wall enhances highly the heat transfer. The heat transfer augmentation is higher in the lower Reynolds number due to the effective vortex interactions. Therefore, the performance factor considering both heat transfer enhancement and pressure loss increases with decreasing the Reynolds number.

**Moon et al.[11]** shows that heat transfer is enhanced and pressure loss is reduced for dimpled surfaces. Some practical applications dimpled surfaces in internal passages include macro-and micro-scale heat exchangers, electronics cooling, combustion chamber liners, passages for internal cooling of turbine blades in gas turbine engines, biomedical devices, etc.

**Sane et al.[12]** was carried out experiment to study heat transfer and friction coefficient by dimpled surface with the aspect ratio of rectangular channel is kept 4:1 and Reynolds number based on hydraulic diameter is varied from 10000 to 40000. They were observed that at all Reynolds number as depth increases from0.2 to 0.3, the number and thermal performance increases and then after when depth increase from 0.3 to 0.4 normalized Nusselt number and thermal performance decreases.

## III. SUMMARY OF REVIEW

The above mentioned researchers investigated natural convection from the extended surfaces and very few have worked on Dimpled Plates concept. From the present study the following conclusion are found out -

- Due to dimples heat transfer enhancement characteristics and lesser pressure loss penalties, their use for thermal management application has attracted many researchers.
- It is concluded that the maximum heat transfer rate will takes place in largest diameter of the circular dimpled surface.
- The vortices formed inside the dimples results in thinning and to disturb the thermal boundary layer formed over the surface during coolant flow and serve ultimately to bring about enhancement of heat transfer between the fluid and its neighboring surface at the price of less increase in pressure.
- Introducing the dimples on the surface not only increase the surface area available for heat transfer but also reduces the hydrodynamic resistance for the fluid flow over the surface, resulting in less pressure drop.
- Heat transfer coefficients for dimpled surfaces are better than smooth surface for staggered arrangement.

## IV OBJECTIVES

The objectives of the above study are as follows -

1. To study natural convection from vertically heated dimpled plate with variation in dimple diameter and dimple shape for inline and staggered arrangement under steady state..
2. To study the effect on heat transfer performance with variation in the heat input for above mentioned dimple geometry.
3. To study the effect on heat transfer from dimpled plate by maintaining the dimple area constant and varying the dimple shape.

## V PROPOSED WORK

From the existing literature it is found that most of the work has been carried out for dimpled tube under forced convection but very limited literature is available for vertical heated dimpled plate under natural convection.

Hence the proposed work is concerned with the experimental investigation of the natural convection heat transfer over the vertical heated dimpled plate. From the previous studies it has been observed that performance of the vertically heated plate can be further improved by providing the dimples on the surface of the plate. This is due to the reason that the dimpled surfaces gives heat transfer enhancement characteristics and lesser pressure loss penalties. Therefore, we can expect the thermal performance of the vertically oriented heated plates can be further enhanced by replacing the plate with dimpled plate.

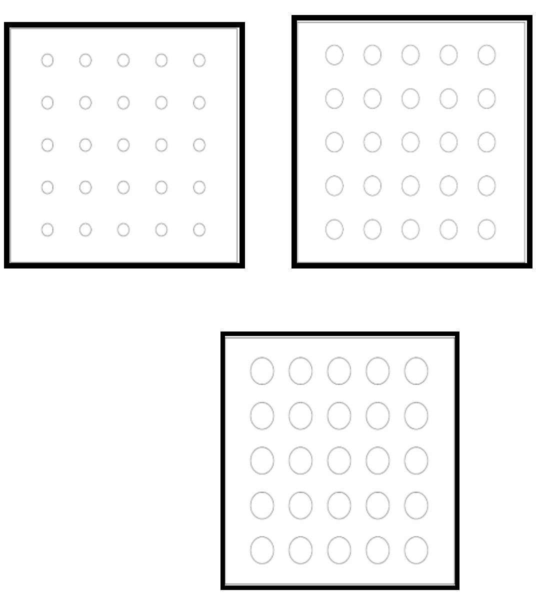

**Fig.No.1:-** Proposed dimpled plates with variation in diameter of dimples

(In-line arrangement)

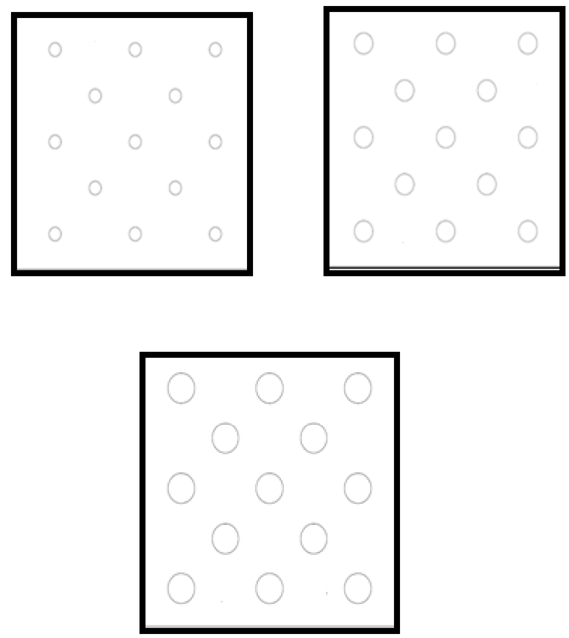

**Fig.No.2:-** Proposed dimpled plates with variation in diameter of dimples

(Staggered arrangement)

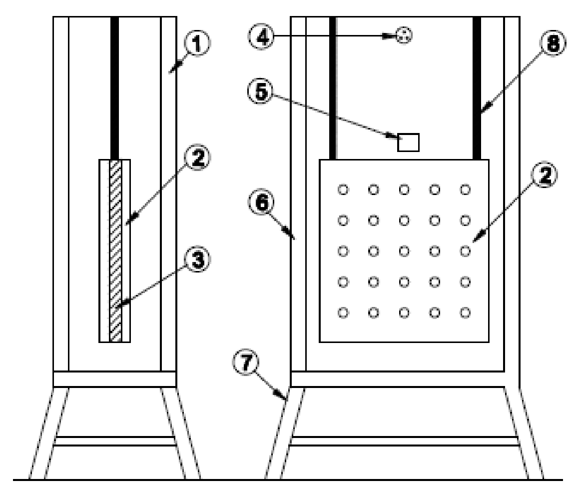


Fig.No.3 :- Schematic diagram of natural convection apparatus

1) Duct, 2) Heated Plate, 3) Heater, 4) Heater Socket 5) Thermocouple Socket
6) Acrylic Sheet, 7) Stand, 8) Hanger

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