Experimental Analysis of Natural Convection Heat Transfer in Staggered Dimpled Plates

Mr. Vaibhav Warke[1] Mr. Rohit Bhide[2] Mr. Shubham Kulkarni[3] Mr. Saikiran Chavare[4] Mr. Kartik Dhumal[5]
[1,2,3,4,5]U.G. Student,
Department of Mechanical Engineering,
Padmabhooshan Vasantraodada Patil Institute of Technology,
Budhgaon, Sangli, India.

Abstract: 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 and heat transference by bulk fluid flow streaming. Convective heat transfer 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 between a solid surface and the fluid. This paper refers to the convective heat transfer from a staggered dimple plate of dimple diameter 6mm and another plate with 10mm dimple diameter.

Key words: Heat Transfer, Natural Convection, Dimpled Plates, Heat Transfer Coefficient.

1. Introduction:

According to the modern or dynamical theory of heat-Heat is a form of energy. The molecules are in parallel motion. The mean kinetic energy per molecule of the substance is proportional to its absolute temperature.

Free or natural, convection occurs when bulk fluid motions streams and currents are caused by buoyancy forces that result from density variations due to variations of temperature in the fluid. Forced convection is a term used when the streams and currents in the fluid are induced by external means such as fans, stirrers, and pumps creating an artificially induced convection current. Natural or free convection is observed as a result of the motion of the fluid due to density changes arising from the heating and cooling process. Natural convection represents an inherently reliable cooling process. Further, this mode of heat transfer is often designed as a backup in the event of the failure of forced convection due to fan break down.

2. Literature Review

Kuethe et al.[1] was the first one to 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 aluminium with different dimpled geometries 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.

Iftikarahamad H. Patel et.al.[3] presented the computational investigation of convective heat transfer in tubulised 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] experimentally 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.

Mahmood et al.[7] studied the flow and heat transfer characteristics over staggered arrays of dimples with δ/D=0.2. For the globally average Nusselt number, there were small changes with Reynolds number. He studied the effect of dimpled protrusions on the opposite wall of the dimpled surface.

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 increases.

Burgess et al.[9] 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 δ/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 turbulent productions.

3. Experimental setup

3.1 Setup for experiment:

Fig. 3.1 Actual setup

Fig. 3.2 Power Pack

The below images are of experimental setup. The power system contains the wattmeter, dimmerstat for heat supply and temperature indicator with selectors. Besides the power box, the duct or enclosure is provided for natural convection purpose. The overall dimension of the enclosure is 1m x 1m x 1m. A gap of 70mm is kept open at the bottom side for air intake. The heater plate will be sandwiched between the vertical plates and will be attached to the hook provided at the top end of the enclosure. One end of enclosure side is covered with a transparent acrylic sheet, to visualize the total system while other three ends are covered with white acrylic sheet.

3.2 Plates used for experiment:

I. Plane plate

Fig. 3.3

Material: Aluminium Material Grade: 324
Area of Plate: 0.045 m^2 Thickness: 1.8mm

II. Staggered Dimple Plate ϕ6 mm

Fig. 3.4

Area of Plate: 0.0486 m^2
Distance between two dimples: 17.75mm
Dimple Depth: 2mm
No of Dimples: 64

III. Staggered Dimple Plate ϕ10 mm

Fig. 3.5

Area of Plate: 0.0486 m^2
Distance between two dimples: 33.75mm
Dimple Depth: 3mm
No of Dimples: 24

4. Result and discussion

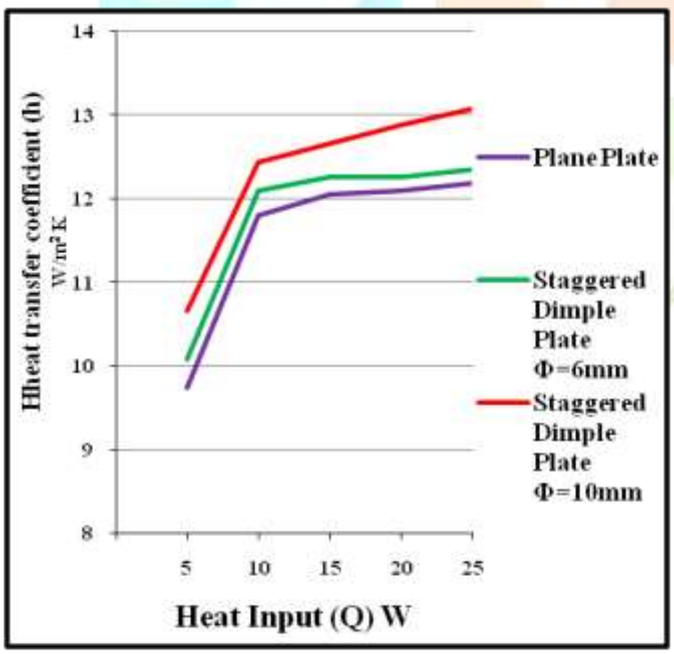

Fig. 4.1

From fig 4.1, it has been observed that with increase in the heater input the heat transfer coefficient also goes on increasing proportionally. And the heat transfer coefficient is to be found high for the staggered circular dimple plate of aluminium with 10 mm diameter compared with the geometry of 6mm diameter and plane plate.

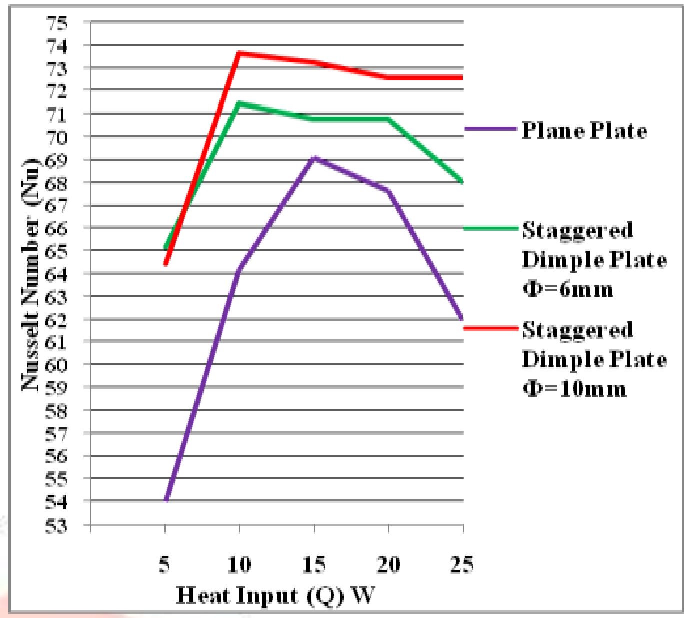

Fig. 4.2

From above fig, it has been observed that with increase in the heater input the nusselt number also goes on increasing. It is found that nusselt number is high for staggered dimpled plate of 10mm diameter than other geometry.

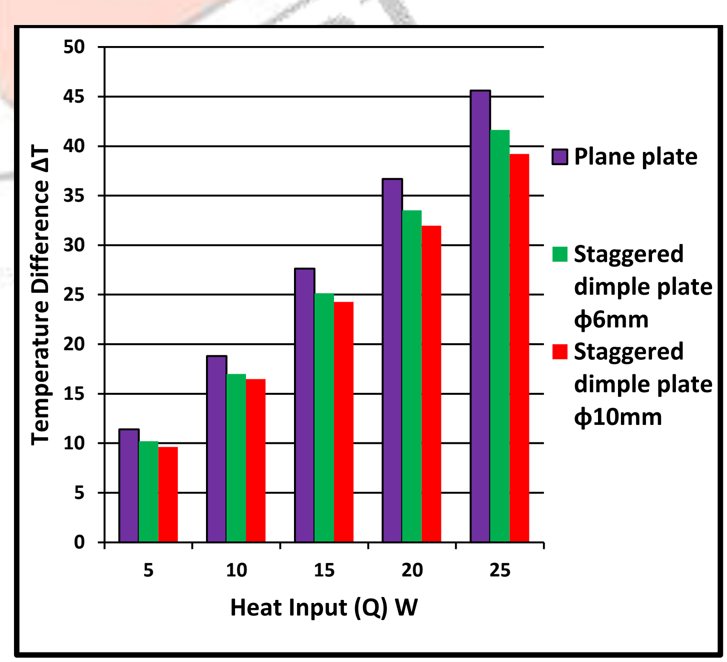

Fig. 4.3

From above graph, it has been observed that with increase in heater input the temperature difference also goes on increasing. Temperature difference is low for the staggered dimpled plate of 10 mm diameter.

5. Conclusion:

The Vertical Plate with staggered 10mm circular dimple arrangement has good heat transfer performance than Vertical Plate with staggered 6mm circular dimple and plain vertical plate because it acts as a flow disturber to heat flow over the plate.

6. Reference

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