Heat Transfer Enhancement Of Staggered Dimples With Different Shape On Plate

Dhruv N. Desai, Sanjay N Havaldar

Abstract: Nowadays the most common approach for heat transfer enhancement involves the use of rough surface. A surface can be created rough in number of paths like by using pins, inserting ribs or creating dimples on the surface. With air as working fluid the experiment will be carried out for laminar forced convection conditions. The motive behind the experiment is to find out the rate of heat transfer and air flow distribution on triangle and circular dimples plate with straggled and inline arrangements, and found outcomes are evaluated with flat surface. Dimples 0.64 cm in diameter and 0.30 cm deep on the flat surfaces to enhance the heat transfer rate. Outcomes shows that the rate of heat transfer for triangle dimple shape surface with staggered arrangement seems to have maximum value than the smooth and inline plate.

Index Terms: Dimples, Enhancement, Staggered and Inline arrangement, Rate of heat transfer.

1 Introduction

Compact heat exchangers are used broadly within the trade as radiators to cut back the surplus thermal energy. Improved effectiveness of compact heat exchanger will permit smaller radiators resulting in smaller frontal area and so will result in substantial fuel saving. Recently the surface heat transfer enhancement using dimples got an interest due to its low-pressure loss characteristics with the comparison of others. Air characteristic resistance to heat transfer in compact heat exchangers contains between 70-80 % of the total resistance and thereby any improvement within the effectiveness of a compact heat exchangers is targeted on the augmenting the air characteristic convective heat transfer. Microelectronic cooling, mostly in central process units, gas turbine internal air foil cooling, fuel elements of atomic energy plants, macro and small-scale heat exchangers, and bio medical devices, all these appliances have a better worth of heat transfer. A massive quantity of effort has been dedicated to developing new strategies to extend heat transfer from fined surface to the encircling flowing fluid. Rib turbulators, a collection of pin fins, and dimples are useful for this determination. In case of the industry, because of the demand for lesser and additional powerful product, power densities of electronics elements enhanced. The extreme temperature of the element is one of the core aspects that regulator the consistency of electronic crops. Thermal management has forever been one amongst the most problems within the industry, and its importance can grow in returning decades. the utilization of heat sinks is that the most typical application for thermal management in electronic packaging. Nowadays the most common approach for heat transfer enhancement involves the use of rough surface. A surface can be made rough in number of ways like by using pins, inserting ribs or making dimples on the surface. Ribbed or a pinned surface under an impinging jet are mainly used because of their roughened surface that helped to enhance heat transfer coefficient. A dimpled surface may behave completely differently than the other two surfaces under an impinging jet.

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Because of these ups and downs of the flow field they can produce different heat transfer coefficients in dimple surface that may agitate the cross flow. A recent study by Chyu et al.13 may support this phenomenon. They dealt with concavity-type dimples with convection and showed that dimples can enhance heat transfer, while the pressure losses were nearly one-half of the protruding elements. They used different dimple geometry from our studied dimple case. Schukin et al.14 provided limited data downstream of the single concavity in a diffuser channel. Afnasyev et al.15 experimentally studied the friction and heat transfer in a dimpled channel and reported a 30–40% heat transfer enhancement without any appreciable effect on the hydrodynamic damage. An amount of heat transfer learned from Russia applies dimples. Although the concept of using depression for heat transfer augmentation dates back to early 1970’s, the heat transfer data on dimpled surface are very limited and most of the earlier lessons are directed in Russia. Outward dimples are expected to push turbulent joining within the movement and rise the heat transfer, as they accomplish as a vortex generator.

2 Research study on Dehumidifiers

Many researchers published in the past on this topic are discussed in brief in this chapter. Gm.S.Azad et al. [1] In this paper, Jet impingement heat transfer quantities are finished an array of inline air jets striking orthogonally on mark target surfaces. The Nusselt numbers for a dimpled surface and a smooth surface are about the same. Nevertheless, a mark surface gives a developed heat transfer because of enhanced area (circumferential area), that is regarding 34 and 9.5% for our many-dimples and less-dimples cases, separately. P. V. Lutade et al. [2] In this paper, Jet impingement could be a freezing method, wide used wherever the high rate of heat transfer is needed. It's terribly comforts to execute. Dimples have easy geometry, light weight, low-slung maintenance, truncated pressure penalty and it endorses turbulent combination owed to that the boundary layer get weak and moderately breakdowns that leads to heat transfer growths. Sharp edges of rectangular cavity trapped the flow preventing the passage for exit of spent air. Thus, incoming air has no room to touch the surface of plate which leads to poor heat transfer rate. Nat vorayos et al. [3] In the present study, heat transfer investigation of dimply surfaces of outside movement was examined. A whole of 14 kinds of dimply surfaces are considered. The effect of hollow pitch was inspected. Ashif Ramjan Shekh et al. [4] In this paper, the reputation of heat transfer improvement has increased better worth in such parts as microelectronic cooling, particularly in fundamental dispensation elements, vapor turbine internal air foil cooling, fuel elements of atomic power plants, and bio medical plans. Occurrence of mixture of aforesaid designed dimples can be investigated and associated. Trial plate material can be altered such as copper and operation are likened with another material mixtures. Hemant C. Pisal et al. [5] the significance of heat transfer improvement has gained larger worth in such zones as electronics cooling, particularly in central process elements, macro and small-scale heat exchangers, turbine internal air foil cooling, fuel components of nuclear energy plants, and bio medical policies. For round and elliptical dimples, heat transfer improvements (comparative to a smooth plate) were finalized for Reynolds range differ from 650 to 2100. Wilfred V. Patrick et. al. [6] three-dimensional flow construction and understand its impact on the heat transfer during a channel with depressed indentations on one wall. Altogether cases the thermal efficiency exploitation dimples was found to be considerably larger than different heat transfer augmentation techniques presently utilized.

3 Experimental Study

This fig shows a layout of experimental work which is carried out. For the taking reading plate dimension is 1000mm with MS material plate. For this experiment used a K-Type thermocouple for temperature measurement. And for changing a manometer reading used a butterfly valve.

A. Experiment Set up

Experimental setup consists of a blower, test plate, Butterfly valve, U-tube manometer etc. Also, it contains planning of K-Type thermocouples, heater is needed.

Fig.2 *Experiment Setup*

B. Testing Procedure

- Switch on electrical values supply to heater and allow rise in temperature of plate.
- Now start the blower and adjust the air flow with valve.
- Adjust height level difference in U-tube manometer.
- Measure Temperature at thermocouple at 8 different places in plates.

C. Thermocouple

A thermocouple could be a temperature detecting tool containing of two different metals combined with at one end. This formation generates a voltage proportional to the distinction among the temperature at the detecting end of the thermocouple and an orientation temperature. Thermocouples are one in every of the widest used temperature sensors obtainable. Type K thermocouple temperature ranges from -270 to 1260°c.

Fig. 3 *K-Type Thermocouple*

D. Blower

By operating pneumatic valve Reynolds number & mass flow rate requirement is achieved. Blower specification as follows: MOTOR RATING: 0.24 HP, single Phase.

E. Heater

Heater is attached at side of rectangular channel and having thickness of 5mm. Heater is having a capacity of 500 watt and power supply of 230 V AC. Its length is having a 500mm and width of 80 mm with 2-meter cable.

Fig. 4 *Heater*

F. Butterfly Valve

In this experiment use of this valve is to vary the manometer readings. A butterfly valve, a Quarter-turn revolving controller that is employed to stop, begin and control the flow. it's simple and quick to exposed. The knob with a 90° revolution gives a whole gap or closing of the valve. Generally, the big kind of butterfly valves is supplied with casing, wherever the needle wheel by gears is linked to the stem. It simplifies the valve's operation with the speed expense.

G. Test Plate

Test Plate is of MS sheet of thickness 2 mm and having a dimension as 1000mm*210mm. The dimple produced on the test plate is of 0.65 cm diameter and 0.30cm depth. For rectangular pattern arrangement for inline, total 13 rows are employed in the stream wise direction & 3 rows are in span wise direction. For Staggered arrangement total 36 rows are employed in the stream wise direction & 6 rows are in span wise direction.

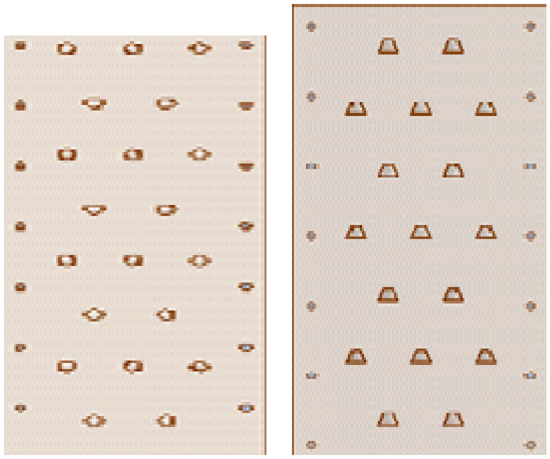

Fig. 5 *Staggered Arrangement*

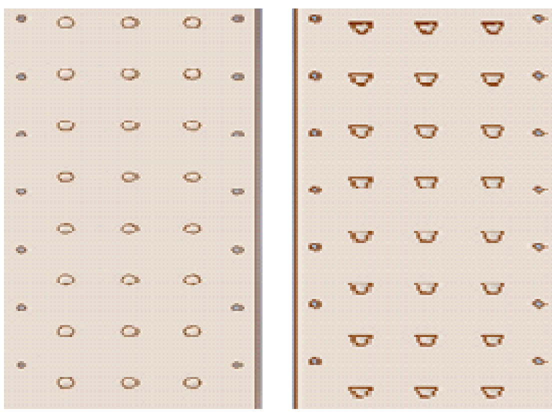

Fig. 6 *Inline Arrangement*

H. Design of plate

Mild steel contains a carbon 0.16 to 0.18%, Manganese 0.70 to 0.90%, Silicon maximum 0.40%, Sulphur maximum 0.04%, Phosphorous maximum 0.04%.

I. Dimensions of test plate

Selecting a 2 mm thick MS Plate. With a dimension of 1000mm*210mm with 5 Nos. of plates. One plate has a flat plate and other 4 plate have a different arrangement like inline and staggered with circular and triangle dimples.

J. Rectangular Channel with Square & Round Flange

This rectangular channel made of MS material with 1000mm length and 210 mm width. In this square duct have a 150 mm width and 100 mm height. And circular flange with 175 mm OD and 130mm ID. In this fig below the rectangular channel we put a 5 Nos. of MS plate with turn by turn. Fist we check with the flat plate without dimples and then took a reading with 4 nos. of different dimples shape & arrangements.

K. Dimension of set up

Circular Flange OD	175 mm
Inside Diameter	130 mm
PCD of circular flange	160 mm
Length of Rectangular channel	1000 mm
Square Flange length	100 mm
Square Flange Width	210 mm
4 Nos of Dimples plate and 1 Flat Plate (lxb)	1000x210mm

4 Data Reduction

Steady state value of the plate and air temperature in the channel, at various locations for given manometer reading is used to find values of performance parameters. The Volume flow rate of air is determined from the pressure drop across the orifice meter, using the following relations:

$$Q = Cd\ (\pi/4)\ dp2\ d02\ \sqrt{2gH} / \sqrt{(dp^4-do^4)} \quad \text{in (m3/sec)}$$

The useful heat gain of the air is calculated as:

$$q = \dot{m}*Cp*(T0 - Ti) \quad \text{in (J/s)}$$

The heat transfer coefficient for the test section is calculated by Newton's law of cooling which says that 'the amount of convection heat transfer is relative proportional to the temperature variance between surfaces of test section and fluid.'

$$q = h*As*(Ts-T\infty)$$

The convective heat transfer coefficient h can be defined as the rate of heat transfer between a solid surface and a fluid per unit area per unit temperature difference. The Nusselt number as,

$$Nu = h*Dh/k$$

Now For friction factor analysis,

$$\text{Pressure drop } (\Delta p) = \rho *g(l*\sin\Theta)$$

Angle (8°) for ordinary water

$$\text{Friction factor } (f) = \Delta p*Dh / 2* \rho\, air*L*V2air$$

Friction Factor For a smooth rectangular duct is given by modified Blasius equation is given by,

$$f = 0.0084 * Re-0.25$$

From the friction factor analysis and normalized Nusselt number ratio (Nu/Nu0) we can calculate the thermal performance.

Thermal performance= (Nu/Nu0) / (f/f0)1/3

5 Results

Using the data found from experiments, Rate of heat transfer, heat transfer coefficient, Nusselt number and ratio of Nusselt number to base line Nusselt number for different manometric head are discussed in the following subsections.

A. Reynolds number Vs. Rate of heat supplied

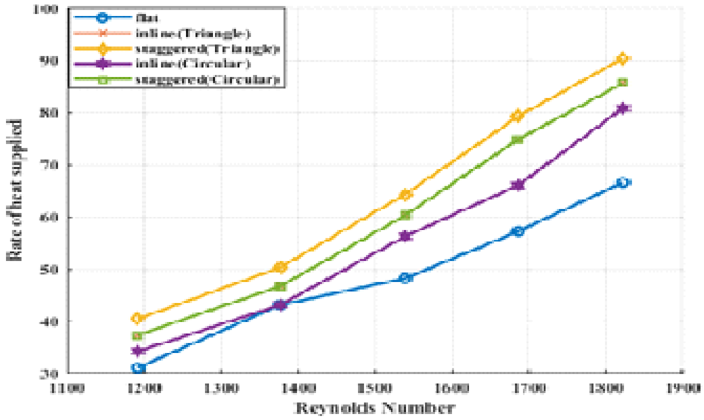

Fig. 8 *Re vs. Rate of heat supplied*

For Reynolds number 1200, heat transfer coefficient is 7.79 for the flat plate which is increase to 11.6 for Triangle plate. While at higher Reynolds number 1800, the heat transfer coefficient is 20.63 for Flat plate which is increase to 35.68 for the Triangle plate.

B. Effect of Dimple Shape and Reynolds number on thermal performance

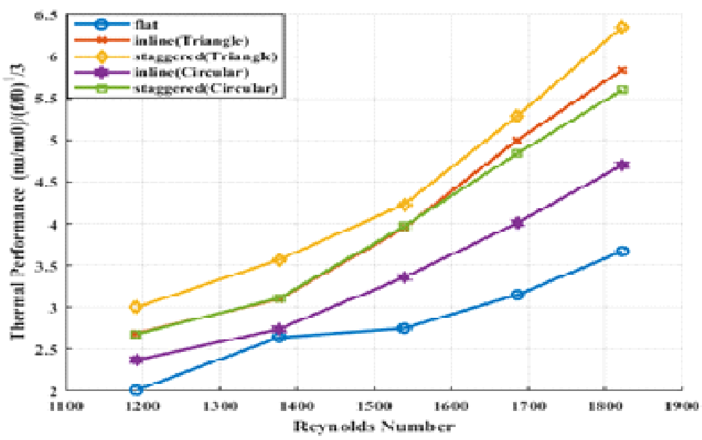

Fig. 9 *Thermal performance vs Reynolds number for different Shape*

It has been observed that in both the cases presented above the with an increase in mass flow rate thermal performance factor increases.

6 Conclusion

In this experiment see that Reynolds number rises with rise in Nusselt number. And mass flow rate rise with rise in Nusselt number. For the Circular dimpled plate, the thermal performance factor raised from 0.69 to 1.87. And for the triangle dimpled plate with staggered arrangement the thermal performance factor is raised from 0.88 to 2.12.

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