"Experimental Analysis To Enhance The Heat Transfer By Using Dimpled (Cashew And Capsule) Surface"

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ABSTRACT

Dimples play a very important role in heat transfer enhancement of electronic cooling systems, heat exchangers etc. This work mainly deals with the experimental investigation of forced convection heat transfer over circular shaped dimples (i.e. 1) Cashew dimples, and 2) Capsule dimples) of different diameters on a flat copper plate under external laminar flow conditions. Experimental measurements on heat transfer characteristics of air (with various inlet flow rates) on a flat plate with dimples were conducted. From the obtained results, it was observed that the heat transfer coefficient and Nusselt number were high for the copper plate in which the diameter of dimples increases centrally in the direction of flow.

Keywords: - *Heat Transfer, Circular Shape, Laminar Flow, Dimples Shape (Cashew & Capsule)*

1. INTRODUCTION

The maximum temperature of the component is one of the main factors that control the reliability of electronic products. Thermal management has always been one of the main issues in the electronics industry, and its importance will grow in coming decades. The use of heat sinks is the most common application for thermal management in electronic packaging. Heat sink performance can be evaluated by several factors: material, surface area, flatness of contact surfaces, configuration, and fan requirements. Although there are a few investigations for the use of dimples under laminar airflow conditions, there exist no experimental data with respect to the use of different dimple shapes for heat sink applications. Therefore, this study evaluated the heat transfer characteristics using two different dimple shapes on a heat sink fin by experimental methods: 1) Cashew dimples, and 2) Capsule dimples.

The conventional heat transfer enhancement approaches to increase either the heat transfer rate or the turbulence of fluid stream, in general, it involves the incorporation of fins, baffles, turbulizers and etc. Although, these approaches are the effective method to improve the heat transfer performance; however, the increasing of fluid stream pressure drop should be concerned. The dimpled surface is one of the effective methods to improve the heat transfer rates without the significant pressure drop. Normally, the dimpled surface generates the vortex flow within its hole and the augmentation of heat transfer is obtained. [1]

Enhancement techniques can be separated into two categories: Active and Passive.

A. Active Method

This method involves some external power input for the enhancement of heat transfer. Some examples of active methods include mechanicals aids, surface vibration, fluid vibration, electro-static fields, suction or injection and jet impingement requires an external activator/power supply to bring about the enhancement

B. Passive Method

This method generally uses surface or geometrical modifications to the flow channel by incorporating inserts or additional devices. For example, inserts extra component, swirl flow devices, treated surface, rough surfaces, extended surfaces, displaced enhancement devices, coiled tubes, surface tension devices and additives for fluids

C. Compound Method

If two or more techniques can be utilised simultaneously to produce an enhancement larger than that produced by only one Technique than it can be said as Compound Method. A compound method is a hybrid method in which both active and passive methods are used in combination. The compound method involves complex design and hence has limited applications.

2. VORTEX HEAT TRANSFER TECHNIQUE

Each dimple acts as a “Vortex Generator” which provides an intensive and stable heat and mass transfer between the dimpled surface and gaseous heating/ cooling media. Taking advantages of vortex heat transfer enhancement (VHTE), as

a) Higher heat transfer coefficient
b) Negligible pressure drop penalty
c) Potential for fouling rate reduction
d) Simplicity in design and fabrication
e) Compactness and/or lower cost

This method is potentially used in heat transfer enhancement in convective passages for industrial boilers, process heaters, furnaces , heat exchangers and variety for other industries like automotive (radiators, oil coolers etc.),heat treating(recuperater), aerospace ,military, food processors etc.

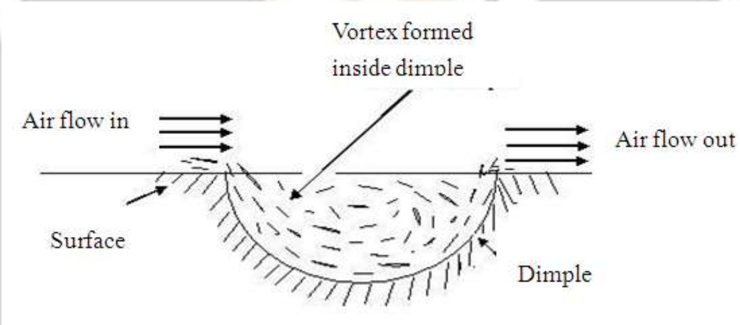


Fig.No. 1

3. LITERATURE REVIEW

3.1 Saurabh R Verma, P. M. Khanwalkar, V. N. Kapatkar , [2]

This paper presented is a review on Heat transfer augmentation for various dimpled geometries. Heat transfer enhancement over surface Results from the depression forming recesses rather than projections. Such features are known as dimples, and may be formed in an infinite variation of geometries which results in various heats transfer and friction characteristics. 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

3.2 Prof.S.A.Wani, Prof.N.V.Hargude, Mrs.S.P.Mane, Prof.K.S.Kamble ,[3]

This paper presented is a review on Experimental investigation of an inline dimpled plate by natural convection heat transfer. 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.

3.3 Ashif Ramjan Shekh, Prashant D Nikam, Siddhant B Bhagwat, Sanket S Satpute,[4]

This paper presented is on Heat transfer enhancement using dimpled surface. The importance of heat transfer enhancement has gained greater significance in such areas as microelectronic cooling, especially in central processing units, macro and micro scale heat exchangers, gas turbine internal airfoil cooling, fuel elements of nuclear power plants, and bio medical devices. A tremendous amount of effort has been devoted to developing new methods to increase heat transfer from fined surface to the surrounding flowing fluid. The experiment will be carried out for laminar forced convection conditions with air as working fluid.

The objective of the experiment is to find out the heat transfer and air flow distribution on dimpled surfaces and all the results obtained are compared with those from a flat surface.

3.4 Sagar R Kulkarni, Dr. R.G.Tikotkar,[5]

This paper presented is on Experimental Investigation of Heat Transfer Enhancement over the Dimple Surface under Forced Convection .An experimental study has been conducted to study heat transfer over the dimpled plates under forced convection. The Reynolds number is varied in the range of 10000 to 30000 based on hydraulic diameter. The dimpled depth is varied from 0.2 to 0.4 keeping 0.1 frequency and keeping the dimple density constant in both the arrangements. The dimple print diameter is kept as 10mm where dimple depths are 2mm,3mm,4mm.A constant heat of 0.5 amperes was given. It is noticed that, heat transfer is augmented for a depth of 0..3 in both the arrangements.0.4 depth plate shown very least augmentation. The maximum thermal performance is for staggered arrangement and for 0.3 depth. The maximum thermal performance for inline arrangement is lowest value of thermal performance of staggered plate.

3.5 IftikarAhemad H. Patel et al. [6]

Investigated heat transfer enhancement over the dimpled surface. The main objective of his experiment ware to find out the heat transfer and air flow distribution on dimpled surfaces and all the results obtained are compared with those from a flat surface. For obtaining the results, the spherical type dimples were fabricated, and the diameter and the depth of dimple were 6 mm and 3 mm respectively. Channel height was 25.4mm, two dimple configurations were tested. The Reynolds number based on the channel hydraulic diameter was varied from 5000 to 15000. From experimentation it was observed that thermal performance is increasing with increase in Reynolds number. But the thermal performance of inline dimples arrangement is poor as compared to the plate with staggered dimple arrangement.

3.6 M. A. Saleh, H.E.Abdel-Hameed [7],

Studied the flow and heat transfer performance of a parallel/ counter flow heat exchanger, when the heat transfer surface is provided with dimples on one or both sides i.e. on cold fluid side and hot fluid side. The experimental set up consists of two parallel identically and geometrically passages: one for the hot fluid and the other for the cold fluid. The average duct height is 10 mm and duct width is 110 mm The Results consist of flow characteristics (mainly pressure distributions) and heat transfer characteristics (Nusselt number distributions) comparison against the non-dimpled case (smooth surface) was held. Authors also studied that the cases with various dimples depths (d/D= 0.2, 0.3 and 0.4) and arrangements (in line and staggered) were tested over a range of Reynolds number (50 to 3000). It was found that the overall heat transfer rates was 2.5 times greater for the dimpled surface compared to a smooth surface and the pressure drop penalties in the range of 1.5-2.0 over smooth surfaces.

3.7 Nopparat Katkhaw and Nat Vorayos [8]

Flat surface with ellipsoidal dimple of external flow was investigated in this study.10 types of dimple arrangements and dimple intervals are studied. The stream of air flow solver the heated surface with dimples. The velocity of the air stream varies from 1to5m/s. The temperature and velocity of air stream and temperature of dimpled surfaces were measured. The heat transfer of dimpled surfaces was determined and compared with the result of smooth surface. For the staggered arrangement, the results show that the highest heat transfer coefficients for dimpled surfaces are about 15.8% better than smooth surface as dimple pitch of ST/D min or¼ 3.125 and SL/D min or¼ 1.875 yield the highest the at transfer coefficient values. And for the inline arrangement ,the results show that the heat transfer coefficients for dimples surfaces are about 21.7% better than smooth surfaces dimple pitch of ST/D min or¼ 1.875 and SL/D min or¼ 1.875 yield the highest heat transfer coefficient values.

3.8 Nopparat Katkhaw and Nat Vorayos [9]

In the present study, heat transfer analysis of dimpled surfaces of external flow was investigated. A total of 14 types of dimpled surfaces are studied. The effect of dimple pitch was examined. The experiments were carried out with air stream flows over the heated surface with dimples. The temperature and velocity of air stream and temperature of dimpled surfaces were measured. The heat transfer of dimpled surfaces was investigated and compared with the result of smooth surface. For the staggered arrangement, the computed results show that the maximum Nusselt number for dimpled surfaces are about 26% better than smooth surface. And for the inline arrangement, the results show that the maximum Nusselt number for dimples surfaces are about 25% better than smooth surface.

4. EXPERIMENTAL SETUP

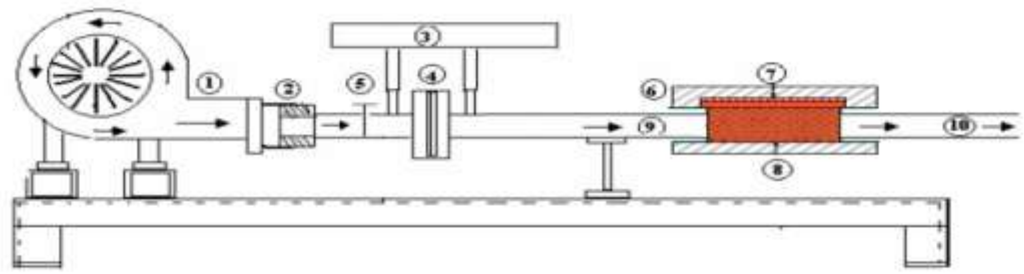


Fig.No. 2

A schematic diagram of the experimental setup is shown in the figure, It consists of an open loop flow circuit. The main components of the test apparatus are sequentially a blower (1), adapter (2), pressure measurement with manometer (3), orifice Flow Meter (4), open-close valve (5), insulation of asbestos rope or silica wool (6), Test plate (7), electric heater (8), air inlet (9), and air outlet (10). The channel inner cross section dimensions are 23cm (wide) 18 cm height. The channel was constructed with 3 mm thick epoxy resin material with which has the temperature range of 150 0C to 200 0C.

5. TEST PLATE

The test plate is of aluminium test plate of having dimension (10.16 X 15.24 X 1) Cm. The dimples produced on the test plate of having dimension for capsule (L=2.6 cm , H=1.5 cm , a=1.0 cm , r = 0.8 cm) (ST =3 cm & SL=2 cm) and for cashew (L=2.6 cm & W=1.5 cm) (ST =3 cm & SL=2 cm) both shape depth on plate is 1 cm . For rectangular pattern arrangement total number of rows are employed in the streamwise direction similarly, ribs are in spanwise direction with some offset. shows different types of combinations of test plates

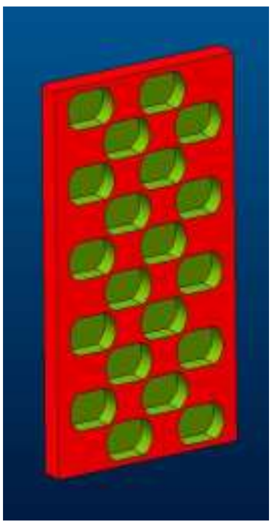
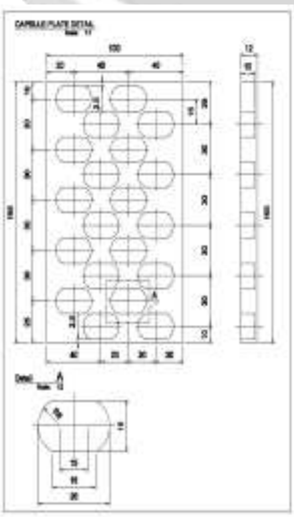


Fig.No. 3



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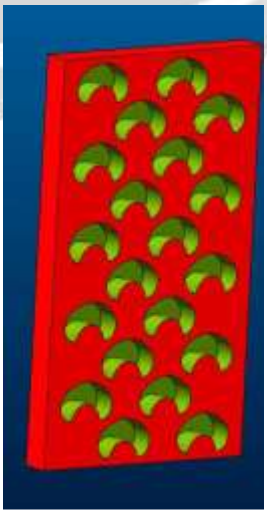

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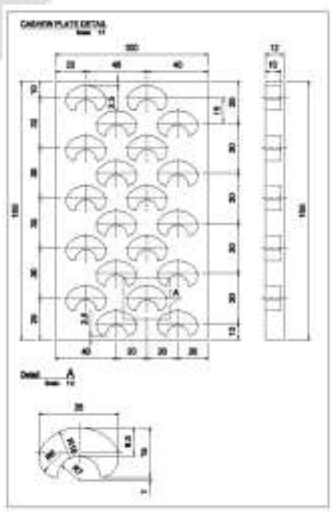

Fig.No. 6

6. ASSEMBLY PROCEDURE

1. Attach the blower to the test section by pipe having orifice arrangement
2. Connect the U-tube manometer across the orifice meter to measure manometric height differences.
3. At the bottom of test section layer of glass wool is kept to avoid heat losses. Above gloss wool, heater & test plate which are bolted together are placed.
4. To measure temperature at different location on test surface one end of thermocouple is screwed to test surface & other is to temperature indicator display.
5. Thermocouples are also attached at the inlet & outlet for measuring inlet air temperature & outlet air temperature of test section.
6. Bottom section of test section is made up of wood and can be easily screwed and unscrewed for replacement of test plates to be tested.

7. TESTING PROCEDURE

1. Switch on electric supply to heater and allow rise in temperature of plate up to 50-60°C.
2. Now start blower.
3. Measure height level difference in U-tube manometer.
4. Wait for steady state conditions of voltage and current supplied to heater and measure all the temperature at different locations of test surface (T5, T6, T7, T8) and also measure inlet air temperature ($T_i=T_1$) and outlet air temperature ($T_o=T_2$) at the test section by rotating knob on temperature indicator display.
5. Stop heater supply. Remove bottom plate of test section & let the test plate be cool.
6. After 15 to 20 minutes remove the test plate from test section, put fresh glass wool and repeat the procedure for another plate at same voltage and current supply to heater.

8. CALCULATIONS

The heat transfer coefficien fo nd o by sing New on‟s law of cooling, which states that the heat flux from surface to fluid is proportional to the temperature difference between surface and fluid.

q =h x A x (Ts - Ta)

Where,

Q = heat transfer rate = heat carried by air through test section (Watts)

Q = ma x Cpa x (Tao – Tai)

A = heat transfer area (m²)

H = heat transfer coefficient (W/m²K)

Ts= average surface temperature

= (T5 + T6 + T7 + T8)/4

Tbm= mean bulk temperature

= (Tout + Tin)/2

Nusselt number based on test plate length is defined as

Nu= (h x l)/K

For change in temp of air (ΔT),

ΔT=Tout -Tin , where Tout=T2 & Tin=T1

Also for average surface temperature of plate (Ts) :

Ts=(T5 + T6 + T7 + T8)/4 from

1) For bulk mean temperature of air ,

Tbm=(Tout + Tin)/2

Tbm=(T2+T1)/2

From bulk mean temperature, Thermo physical properties of air is calculated,

(From Heat and Mass Transfer Data Book Page.No.33 by C.P.Kothandaraman)

P=[kg/m3]

Cp = [j/kgk]

K= [w/m.k]

μ=[N-s/m2]

Pr

dh=hydraulic diameter

dh=4A/p = 2ab/a+b

2) Manometric head in terms of air column is calculated as,

ha=(ρw/ρa)*hw

Now discharge is given by,

Q=Cd*a1*√2gha

Cd = Coefficient of discharge

a1= orifice plate area = (π/4*d2)

Mass flow rate of air

Ma=Q* ρa (kg/sec)

3) Reynolds number is calculated as ,

Re= (ρ*v*dh/μ)

Where, dh=hydraulic diameter

4) Heat Transfer Coefficient

Q=h*As*ΔT=m*Cp*ΔT

Where As=surface area

h=(m* Cp* ΔT)/(As*ΔT) (w/m2k)

5) Nusselt number is calculated as ,

Nu=(h*dh)/(k)

6) Heat transfer rate

Q=ma*cp*(Tout-Tin) (W)

7) Coefficient of friction

Cf = 0.0592 Re-0.2 (5x105 < Re <107)

From the figure 7,8,9 we can see the graph plotted again the heat transfer coefficient vs different dimpled shape is show. As we can from the figures the heat transfer coefficient decreases with decrease in Air flow rate. As we can see from figure 7 heat transfer coefficient is maximum as compared with the figure 8 and 9 and maximum in case of copper.

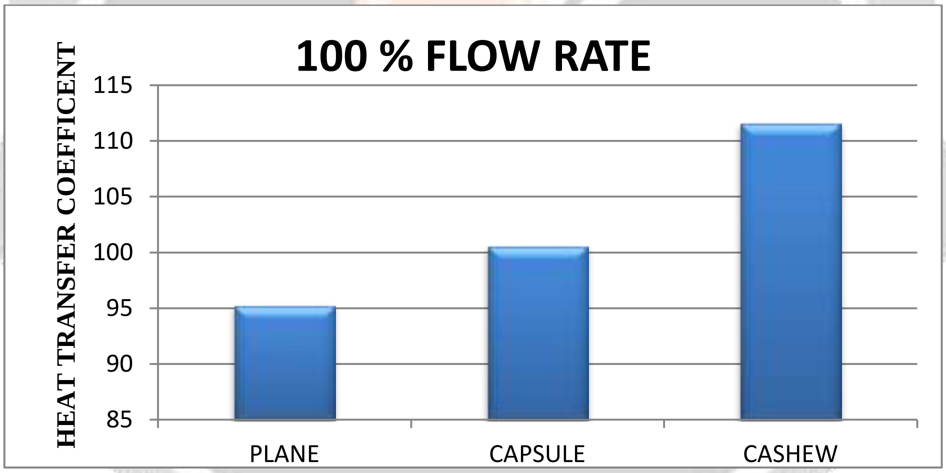

Figure 7: Heat Transfer Coefficient Vs Different Dimpled Shape

If we compare the figure 8 with figure 7 the heat transfer coefficient decreases but the heat transfer coefficient is greater in Copper as it is compared with Aluminium plate.

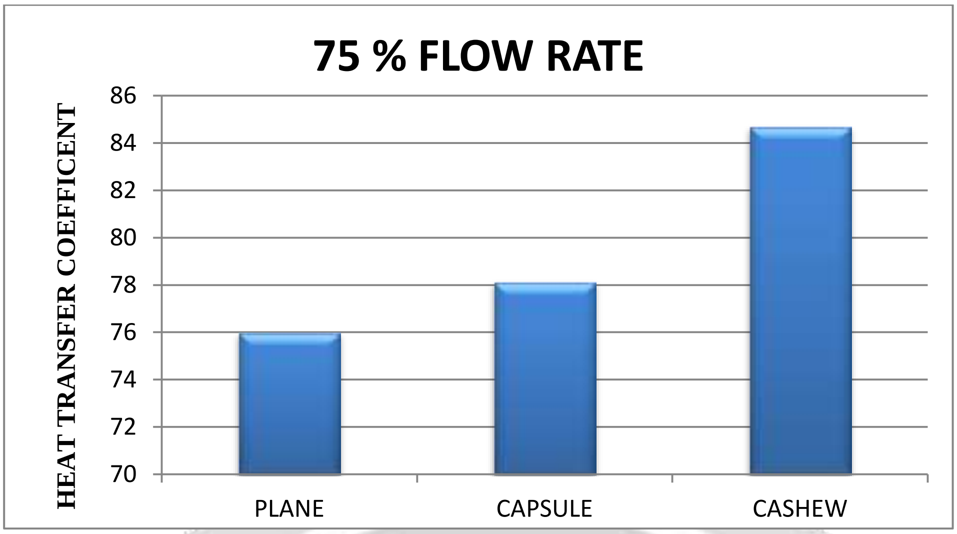

Figure 8: Heat Transfer Coefficient Vs Different Dimpled Shape

From the figure 9 we can notice that heat transfer rate is minimum at 50% flow rate because due to decrease in air flow rate heat transfer rate decreases.

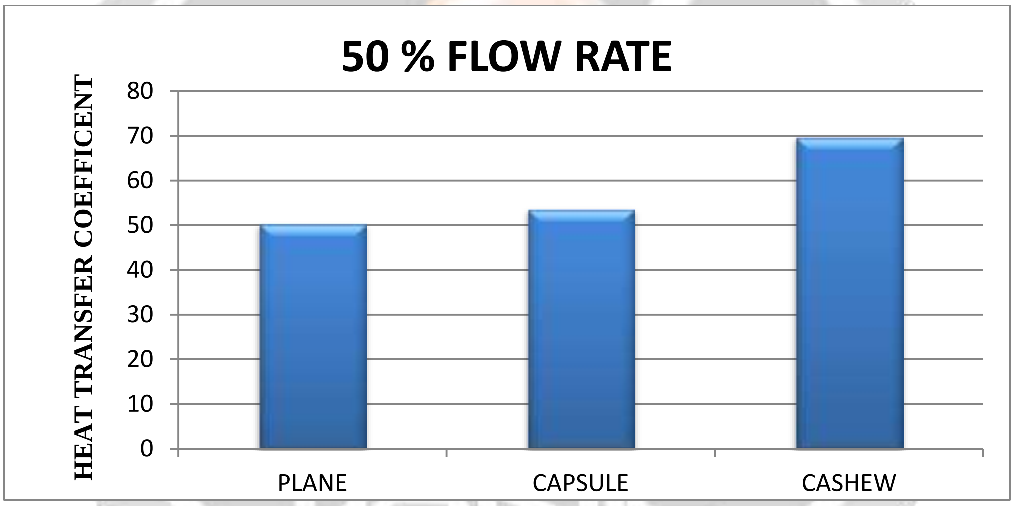

Figure 9: Heat Transfer Coefficient Vs Different Dimpled Shape

Heat transfer coefficient is observed in the range of 95-50 w/m^2°C

From the figure 10,11,12 we can see the graph plotted against coefficient of friction vs different dimpled shape. As we can see from the above figure that co-efficient of friction increases with decrease in air flow rate

From the figure 10 we can see that the coefficient of friction is low as it is compared with the figure 11 and 12. Co-efficient of friction increases with decrease in air flow rate.

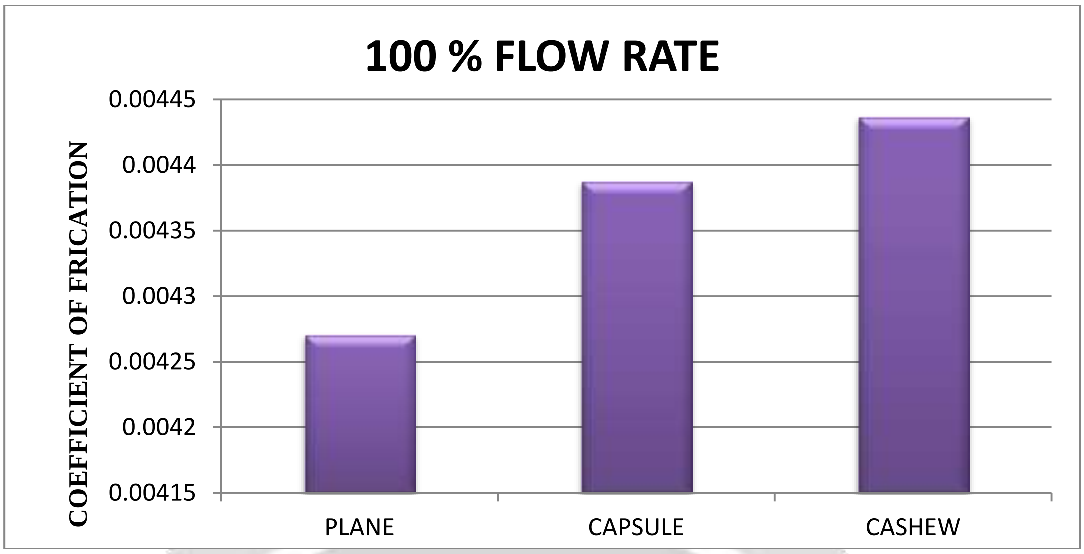

Figure 10: Coefficient Of Friction Vs Different Dimpled Shape.

From figure 11 we can see that co-efficient of friction increases if it is compared with the figure 10. Here the co-efficient of friction is maximum in case of Capsule and Cashew due to its surface roughness.

From the figure 12 we can see the maximum co-efficient friction. Due to decrease in air flow rate co-efficient of friction increase and is greater in case of Cashew shape as it is compared with Capsule shape.

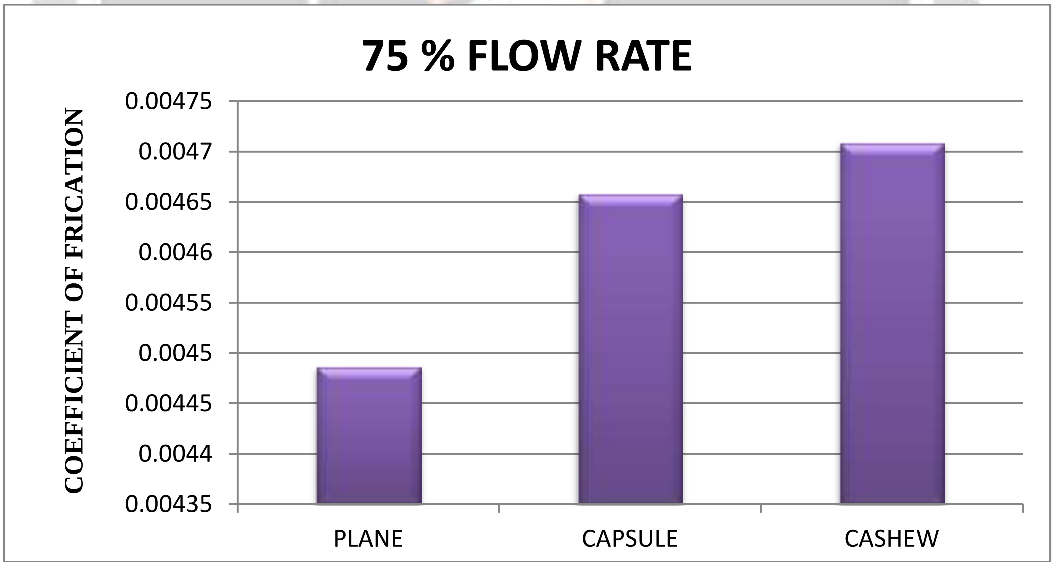

Figure 11: Coefficient Of Friction Vs Different Dimpled Shap

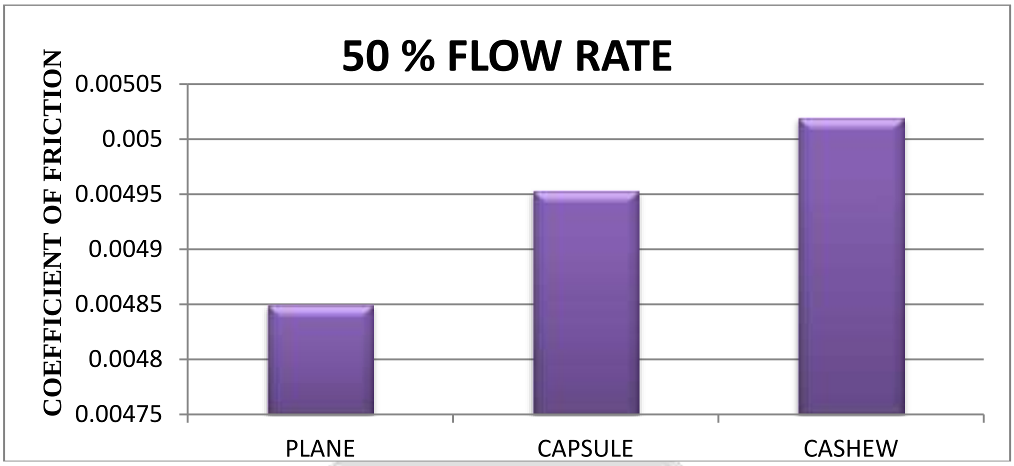

Figure 12: Coefficient Of Friction Vs Different Dimpled Shape

Co-efficient of friction is observed in the range of 0.004271-0.005020 C_f

From the fig 13.14,15 we can see the graph plotted again Nusselt number VS different dimpled shape is shown. As we can that the Nusselt number decreases with decrease in Air flow rate

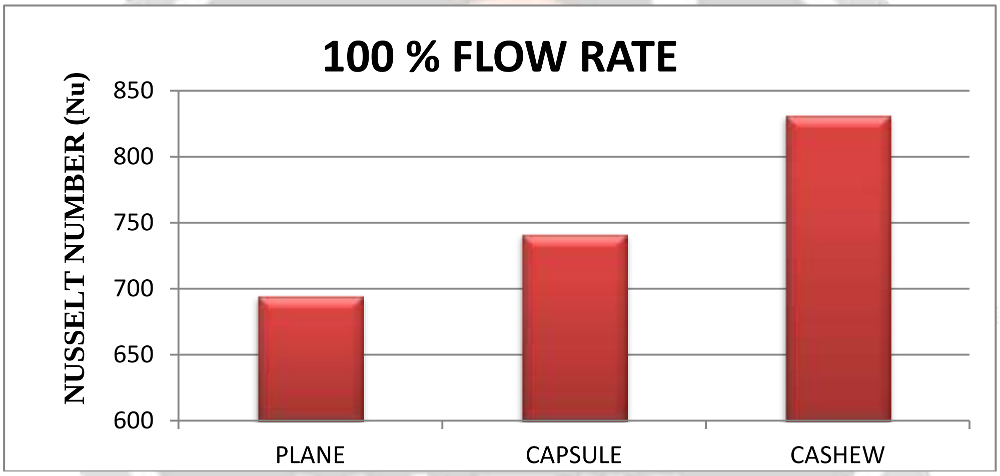

Figure 13: Nusselt Number VS Different Dimpled Shape

From 13 we can see that the nusselt is at its highest peak as it is compared with the other two graph.

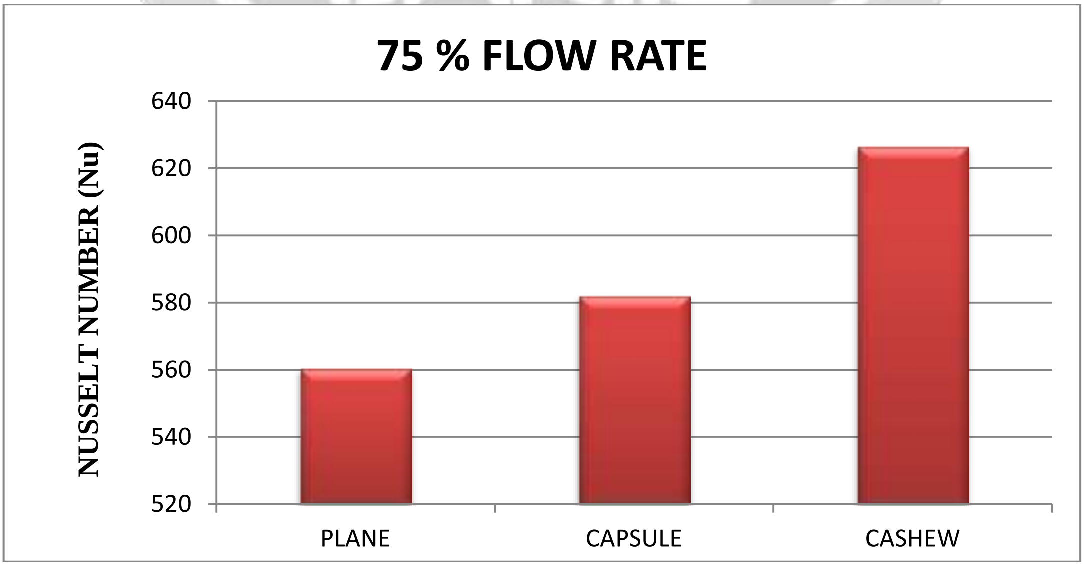

Figure 14: Nusselt Number VS Different Dimpled Shape

From the figure 14 we can see that the nusselt number decreases with decrease in Air flow rate as it is compared with the figure 13.

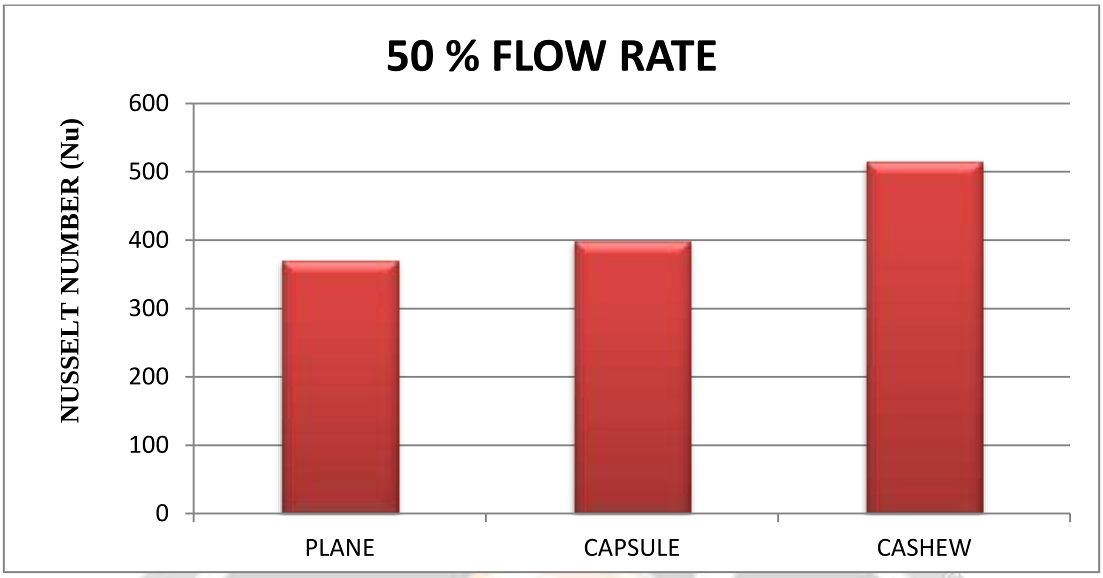

Figure 15: Nusselt Number VS Different Dimpled Shape

From figure 15 we can see that the Nusselt number is minimum as it is compared with the figure 13 and 14 The Nusselt number obtained is in between the range of 832 - 372Nu.

9. CONCLUSIONS

Experimental investigations have been carried out in the rectangular duct to study the effect of various shape of dimpled on heat transfer enhancement. From the graph plotted, following conclusions are made:
The heat transfer coefficient on three test plates i.e.
(1) Simple plate without dimple
(2) Dimpled plate with staggered arrangement. (Capsule Shape)
(3) Dimpled plate with staggered arrangement. (Cashew Shape)
Results shows that the heat transfer coefficient for dimpled surface is more than the simple plate without dimple due to vortex formed inside the dimple causes scrubbing action of flowing fluid inside the dimple.

1) It is found that the heat transfer is more for dimpled surfaced plate when compared with plane plate.
2) It is concluded that the maximum heat transfer rate will takes place in Cashew shape dimpled surface.
3) It is found that the Nusselt number decreases with decrease in air flow rate.
4) The Nusselt number is maximum for Cashew shape and Capsule as it is compared with Plane.
5) Nusselt number is directly proportional to the Heat transfer rate hence we can say that heat transfer rate is maximum in Cashew shape and Capsule shape as it is compared with the Plane plate.
6) Co-efficient of friction is inversely proportional to Reynolds number and the Co-efficient of friction increases with reduction in air flow rate and co-efficient of friction is greater for Cashew.
7) The heat transfer coefficient is more for Cashew as it is compared with Capsule.
8) As it also concluded that heat transfer rate (Q) is maximum in Cashew shape plates as compared with Capsule shape and Plane plate.
9) Heat transfer rate is directly proportional to Reynolds number as the Reynolds number increases heat transfer rate also increases.
10) The Reynolds number obtained is in between the ranges of 511110 to 228000 no.

10. RECOMMENDATIONS FOR FUTURE WORKS

Heat transfer enhancement techniques (active, passive and compound) are used in many applications based area such as internal cooling channels of turbine blades, heating, and cooling in evaporators, thermal power plant, air-conditioning equipment, process industries, refrigerators, radiators for space vehicles, automobile radiators, etc. To have better mixing as well as for better heat transfer performance, different shape of dimpled are used in the rectangular duct. There is a lot of scope for advancement in the experimentations.

Different shapes like rectangular, triangular, teardrop, square, flat oval, stermline body, round or circular shapes of dimples can be used instead of Capsule and Cashew dimples on the test surface. The performance of a combination of above mentioned shaped dimples can be experimented and compared. Test plate material can be change (which is the very good conductor of heat) and performance is compared with different material combinations.

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