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# Investigations of Concrete Solar Collector: An Experimental Approach in Solar Passive Energy

S. R.Patil[1], A. A. Keste[2]

[1](,Department of Mechanical Engineering, Mewar University, Chittorgarh, Rajasthan, India)
[2](Department of Mechanical Engineering, M. E. S. College of Engineering, S. P. Pune University, Pune, India)

***Abstract :*** *Solar Energy is abundantly available non-conventional source of energy. Hot water needed to bath can thus use this non-conventional source. Current solar water heaters use Copper absorber plate which increases the cost of heater. When copper pipes are induced in concrete slab it reduces the space as well as the cost. Also serpentine arrangement which is more efficient than parallel tube riser is used. To increase the efficiency we will introduce dimples on the copper pipes. Circular Dimples may be formed in an infinite variation of geometries which results in various heats transfer and friction characteristics. Spherical indentations or dimples have shown good heat transfer characteristics when used as rough surface. 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. The proposed work is concerned with experimental set up for enhancement of the forced convection heat transfer over the circular dimpled surface and flow structure analysis within a dimple and its impact on concrete collector.*

***Keywords –*** *Circular Dimples, Solar Flat Plate Collector, Concrete*

## I. INTRODUCTION

Solar energy is one of the best alternatives over fossil fuels which are exhaustible, costly and polluting in nature. The proposal is to integrate the concrete absorber plate into the roof. Roof is that part of infrastructure of a building which has maximum exposure to sunlight throughout the day. This large amount of unused roof area is used for water heating purposes [11]. Hot water at moderate temperature (upto 54°C) can be obtained in buildings during the daytime in winter by using reinforced cement concrete slabs or by slightly modifying the roof structure and laying down a network of copper pipes over it which can offer a low cost passive solar water heating system in the building itself. Inbuilt cement concrete solar water heating system (i.e. integrated cement concrete system with roof) can also be made during the construction of the building. This passive solar water heating technique is easy to fabricate and the mason or skilled person can do this type of job after a little training for it. Solar collector with dimple surface can be used for the further enhancement in heat transfer rate.

Now in this constructed flat plate solar water collector if dimples are introduced it can enhance the efficiency of concrete flat plate solar water collector. Thus by varying the distances between the dimples, the pattern of dimples on the copper tubes we will be studying its enhancement on the obtained outlet temperature.

## II. LITERATURE REVIEW

A wooden box as shown in Fig. 1 with inner dimensions 2m x 1m is fabricated which corresponds to the size of conventional collector available in the market. Approximately 20 Kg of cement and 80 Kg of sand is used to construct the slab. This mixture is then poured into the wooden box at a height of 2cm from the bottom. Wire mesh is embedded at a height of 1.11cm which provides reinforcement for the concrete slab. The Cu tubes with dimpled surfaces are tied to the wire mesh and are arranged in such a manner that 50% of its portion along its length, remains inside the concrete slab while 50% remains exposed directly to the sunlight.

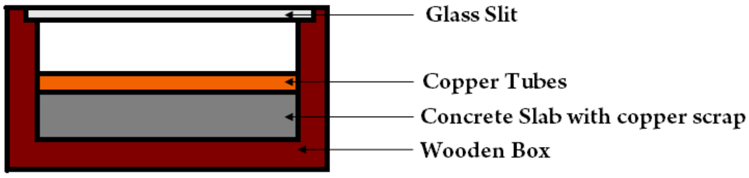


Fig.1 Schematic Diagram of Apparatus

Vincente, et al. [1] mentioned that in dimpled tubes there is increase in friction factor coefficient from 150% to 350% and upto 250% in Nusselt number. Reduced height h/d showed highest influence in both Faning friction factor and Nusselt number but relatively less effect of dimple density. The deeper the dimple better the performance. The study shows that the performance of dimpled tubes is suitable for Reynolds number ranging from 2000 to 40,000. The heat transfer rate increases from 20% to 110% as compared to smooth tubes. Dafedar, et al. [2] found that The maximum heat transfer rate will takes place in triangular dimpled surface with apex facing towards inlet of air flow in both plates. It is found that the Nusselt number is high for circular dimpled surface in copper plate and triangular dimpled surface (hypotenuse facing towards air flow) in aluminum plate. The heat transfer coefficient is maximum for both aluminum and copper plate in triangular dimpled surface with apex facing towards air flow. Ping Li [3] showed f/f0 and Nu/Nu0 and TP of dimple/protrusion aligned arrangement is lower than that of staggered arrangement, especially in the dimpled + protrusioned microchannel. f/f0 and Nu/Nu0 and TP reach the maximum. In the dimpled microchannel, f/f0 of groups with S/D = 2.5 is larger than that of S/D = 1.5 when inlet velocity is small, but the later is larger than the former as inlet velocity increases to a critical value, and the critical reverse velocity gets larger when nanoparticle volume fraction increases. Tay, et al. [4] Dye flow visualization was conducted with a number of dimples of various dimple depths, with round edges and sharp edges over a range of Reynolds numbers. ReD is varied from 1000 to 28000. Six different stages in flow development of the large scale structures within the dimple were observed in their experiments as shown in figure 2. In the stage I, the flow over the dimples is fully attached and streamlines curve towards the centerline as fluid flows into the dimples and curve away from the centerline as fluid flows out of the dimples. Increasing the Reynolds number leads to the stage II where a small separated flow region forms in the upstream half of the dimple, which then develops to the stage III where a pair of counter-rotating vortices connected by a vortex line to form a horseshoe vortex are observed within the dimple. In the stage IV, one of the vortices increases in size and dominates the flow. Like the vortices in the previous third stage the axis of the dominating vortex is also tilted from the vertical towards downstream and span wise direction, but the rotational direction of this dominating vortex is fixed and does not change with time. Increasing the Reynolds number results in stage V where the axis of the single vortex becomes vertical. At this stage, the vortex is unstable and may switch its direction of rotation randomly and continually. These flow changes may be traced to the reorientation of the vortex line in the various flow development stages. The sixth and final stage occurs when the single vortex responsible for asymmetric flow is broken down and the symmetry about the centerline is again regained in the flow. For dimples with d/D greater than 10%, a pair of counter-rotating vortices is also observed within the chaotic flow of the terminating stage VI. During the development process, fluid masses are also regularly ejected from within the dimple. Increasing the Reynolds number results in increasing the frequency of mass ejections. Not all dimples display all the five development flow stages before the termination stage. As d/D decreases, the termination stage sets in sooner, so that fewer of the stages are observed for dimples with low d/D.

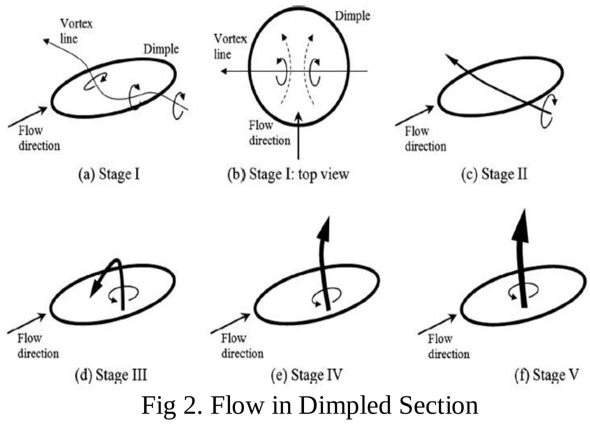


Fig 2. Flow in Dimpled Section

Johann et al. [5] found that the dimple package with the depth h to diameter D ratio of h/D = 0.26 provides the highest heat transfer and thermo-hydraulic performance. At h/D smaller than 0.26 the vortices arising in the cavity are not strong enough to mix the hot and cold fluid effectively, what results in a weak heat transfer enhancement. When h/D is larger than 0.26 a relatively stable recirculation zone arises in the dimple. Chang, et al. [6] mentioned the performances of Nu/Nu1, f/f1 and g for four types of hexagonal straight ducts with (I) smooth wall, (II) concave–concave, (III) convex–convex, (VI) concave–convex dimpled walls. The laminar and turbulent Nu/Nu1 for the entire dimpled hexagonal test ducts respectively increase and decrease as Re increases. With 900 6 Re 6 30,000, the accompanying pressure drop penalties of such HTE performances raise the laminar and turbulent f/f1 to the ranges of 2–6.7 and 2.5–3.6 As the separated flows tripped by the convex dimples promote the higher degrees of HTE impacts than the vertical structures induced by the concave dimples, the Nu follow the order of convex–convex > concave–convex (convex) > concave–convex (concave) > concave–concave among the tested dimple configurations at each Re tested.

## III. PROPOSED EXPERIMENTAL SETUP

In the experimental set up a flat plate collector of concrete slab with copper scrap is present in the wooden box. In this slab, dimpled copper tube of inner diameter 5.5 mm is placed in it. The experimental setup is shown below. The number of tubes bent and formed serpentine pattern with 20 individual tubes having dimples over it on the 700cm of the total 1m length of the tube. The solar radiations fall on the dimpled tubes and the water flowing with mass flow rate of 25 kg/hr heats up. As the copper pipe has dimples the turbulence increases and so the heat transfer rate increases with it increasing the rise in outlet temperature compared to the smooth tubes.The preliminary design calculations are made based on an approximate method following the analysis of ordinary liquid flat plate collector under steady state condition.The problem is then reduced to find out the effect of various parameters on the useful heat gain of collector. As a sample figure 3&4 shows the effect of variation in tube spacing and tube diameter.

The design parameters selected are

U1 = 10 $W/m^2 K$

- K = 4 W/mK (MFRC)
- (m) = 25 kg /hr = $6.94*10^{-3}$ kg/sec
- $h_f$ = 384.3 $W/m^2K$
- W = 0.08m
- $\delta$ = 0.03m

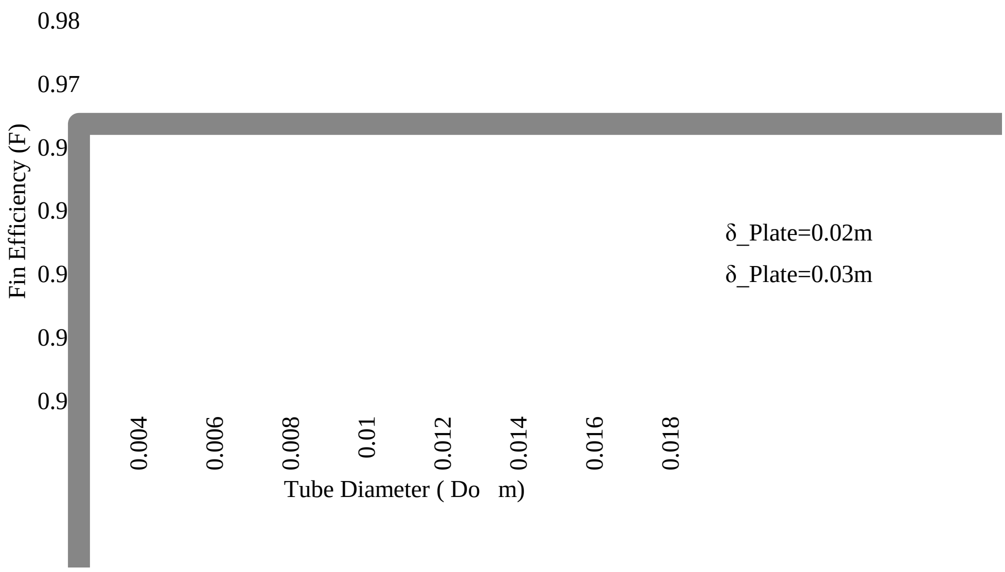


Fig. 3 Tube Diameter Selection

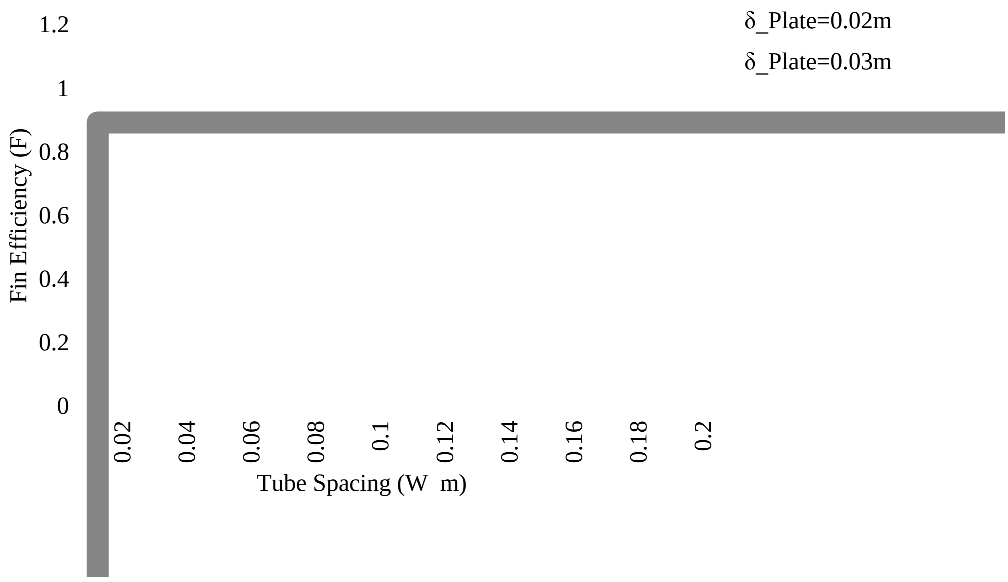


Fig. 4 Tube Spacing Selection

## IV. PROPOSED DIMPLES DESIGN

The parametric study will be carried for i) mass flow rate of air ii) dimple depth to dimple diameter ratio (δ/D) iii) dimple arrangement on the plate i.e. staggered and inline arrangement iv) heat input v)and dimple density on the plate. v) Dimple density on the plate.

Heat transfer performance in the circular and dimples tube is amplified by suspension of water. The convective heat transfer coefficient increases with increasing Reynolds number and increasing volume concentrate in plain tube, and increases further with a dimpled tube. The volume concentration, shape, dimensions, and properties of the water affect the thermal conductivity. Hence the selected dimensions of dimple diameter will be 2.5 mm and the depth of dimple will be 1mm. The helical pattern of dimples is selected with horizontal dimple spacing (p) as 1.4 cm and vertical dimple spacing as 3 cm.

The density of dimples over the length of tube will be $\frac{d^2}{pl}$ = 0. 288. This means that the number of dimples on every tube will be about 158. With reference to Sukhatme the designed Copper tube of outer diameter D = 0.075 cm was selected. In order to increase the Nusselt Number and the Heat Transfer in Copper tubes Dimples are proposed to be embossed in helical staggered manner. The shape of dimple chosen in circular since the Nu obtained in copper tube is maximum as compared to triangular / Square [3]. The serpentine structure of the Copper tube will be induced inside the MRFC slab. Hence the length of the tube available across for dimples will be 70 cm including the side clearances inside the box and the curved serpentine sides. The depth by diameter ratio of the dimple is assumed to be 50% as the distribution of flow as follows for h/d = 50% [1]. $\frac{h}{d}$ = 0. When d is assumed to be 0.5 and h = 0.25. For the depth to diameter ratio 0.5 dimple with blunt edege the flow structure obtained will be as follows.

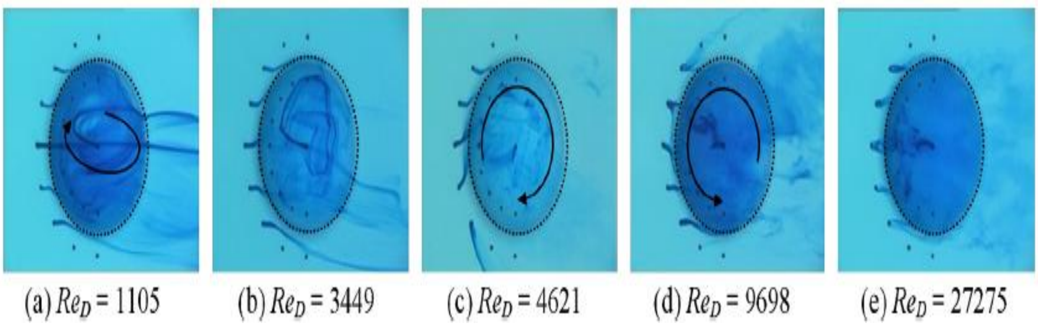


Fig 5. Dye Jet Showing Flow In Dimpled Section

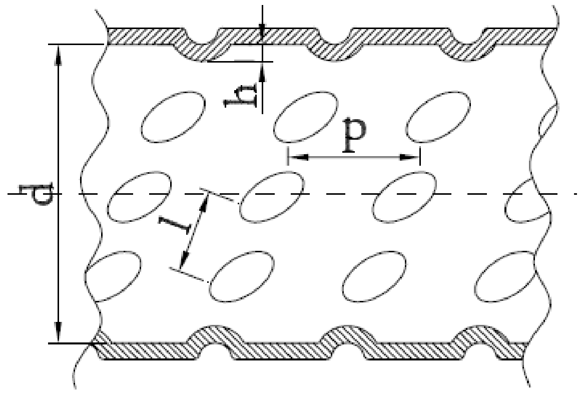


Fig 6. Dimple Spacing

The density of dimples on the tube is assumed to be 0.12. Then $\frac{d^2}{pl}$ = 0. 12.

So the overall structure of pipe with designed dimples will be having p = 1.4 cm l= 3 cm.
Total Surface Area of single tube = $2\pi RL$

= 165 $cm^2$

Number of dimples on one tube = 54.928 = 55 (approx)

## V. CONCLUSIONS

Solar energy can be tapped by using concrete collector as it is low cost passive water heating system. Copper tubes in concrete solar collector are promising as heat transfer rate increases and outlet temperature increases compared to conventional method. A forced convection flow in serpentine tubes having dimple surface for concrete solar collector is proposed to enhance heat transfer rate so as to increase the outlet temperature of water.

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