Augmentation in Heat Transfer with the use of Turbulators in Solar Air Heater Duct– A Review

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***Abstract* -The use of turbulators in different forms of such as ribs, baffles, obstacles, rings and winglets are the effective technique in order to increment in the performance of heat exchangers and Solar air heater ducts. Investigators studied the effect of these turbulators to find heat transfer and friction characteristics in Solar air heaters ducts. In this paper a sensible attempt has been made to carry out a brief literature review of turbulators used by the researchers to investigate heat transfer augmentation and flow structure in Solar air heater ducts. The various turbulators with their effects reported by various researchers, is presented with diagram, for easiness to understand.**

Keywords- Turbulators, Solar air heater, Heat transfer, Friction factor, Roughness.

I. INTRODUCTION

Energy consumption is increasing with the development in the population of the world, with limited resources of energy such as crude oil, natural gas, coal and nuclear energy, etc. Incessant use of these resources would lead to dissipation. In view of earth's depleting fossil fuel reserves, researchers are encouraged to develop renewable energy available on earth. Solar energy is an epochal alternative as an unlimited source of energy which can fulfil the need of our daily life. To utilise solar energy it should be converted into thermal energy by using solar air heater and others equipment's. Solar air heater is simple in nature due to its simple design and low cost. The thermal efficiency of solar air heater is considered to be very low because of high thermal resistance or low heat transfer capability between absorber plate and flowing medium i.e. air in the duct. Various enhancement techniques are employed to make the solar air heater efficient. Enhancement techniques essentially reduce the thermal resistance in a conventional solar air heater by promoting higher convective heat transfer coefficient with or without increase in surface area. Number of techniques have been investigated and are available for increment the heat transfer rate in solar air heaters. Many investigators used fins, artificial roughness, and corrugated absorber plate to reduce the thermal resistance. Turbulators in the form of delta winglet, vortex generator, obstacles and perforated baffles, ribs, blocks have been used for enhancing the convective heat transfer coefficient by creating turbulence at heat transfer surface. In this paper, a brief attempt has been made to review the investigation carried out by various investigators for heat and flow characteristics in ducts provided with different types of turbulators viz. Delta shaped winglets, Rectangular shaped winglets, Rings, Twisted tapes, Cans etc.

II. CONCEPT OF TURBULATORS USING IN SOLAR AIR HEATER DUCTS

Turbulators create turbulence in flow of air in the dynamic flow field and improve the heat transfer exchange by convection. The presence of the turbulators in fluid flow results in enhancement of heat transfer from the absorber plate of Solar air heater with high punishment of pressure loss. The turbulators can create one or more combinations of the following conditions promising to heat transfer rate with minimal pressure penalty such as (i) Breaking the sub-laminar boundary layer, (ii) Increasing the turbulent intensity, (iii) Increase in heat transfer area, and (iv) Creating of vortex and/or secondary flows. Turbulators with Larger height are responsible for high heat transfer as well as high pressure drop. Due to recirculation of flow, hot zone is developed behind these elements leading to drop of heat transfer from these zones. Thus attempts have been made by the researchers in order to solve this problem by providing perforations in the ribs/block/baffles. The perforations enhance the heat transfer from these zones and reduce the pressure drop across the channel. The perforations in elements allow a part of the flow to pass through these perforations and mix with the main flow to create a higher level of mixing and turbulence.

III. OBSTACLES USED IN SOLAR AIR HEATER DUCT

The purpose of introducing obstacles in the Solar air heater duct is to create secondary flow, swirl or vortex turbulence, so as to increase the heat transfer coefficient as the performance of Solar air heater. Shapes, geometry and orientation of obstacles which are used by the researchers can be categorized as, (a) Delta shaped winglets (b) Rectangular shaped winglets (c) Cans (d) Rings (e) Twisted Tape

(A) Delta shaped winglets

Gentry et al. [1] using delta-wing vortex generators and reported improved in average heat from 50%–60% for flow over a flat plate at low Reynolds numbers. They used optimal delta-wing geometries for Reynolds numbers in the range of 600 - 1000. Torii et al. [2] reported two types of arrangement of delta winglet-type vortex generators that is staggered and in-line, in a fin-tube heat exchanger as shown in Fig. 1.

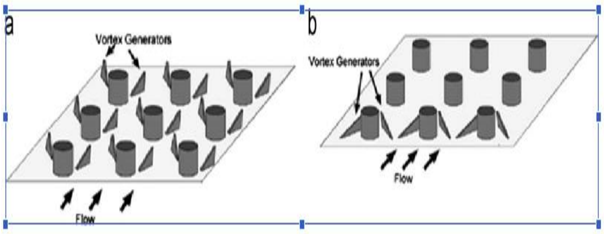

Fig. 1. Configuration of winglet type vortex on the surface-tube bank: (a) “common flow down” configuration; and (b) “common flow up” configuration [2].

The heat transfer augmented by 10%–30% with pressure loss 55%–34%, in case of staggered arrangement. But, in the case of in-line tube arrangement it was increased 10%–20% and 15%–8% reduction in pressure. Bekele et al. [8] investigated the effect of delta-shaped obstacles in solar air heater duct as shown in Fig. 2.

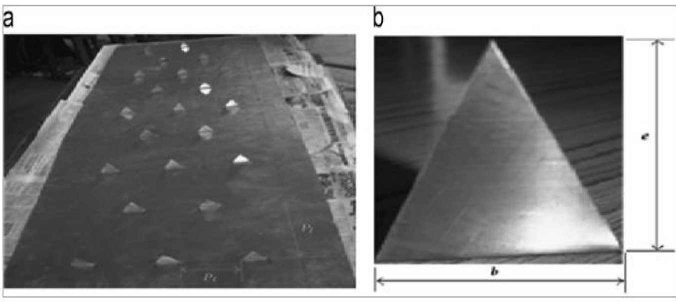

Fig. 2. Delta shaped obstacles mounted on plate [8].

The parameters was taken Longitudinal pitch (Pl/e) and relative obstacle height (e/H), varied from 3/2 to 11/2 and 0.25 to 0.75 respectively. The heat transfer enhancement reported by 3.6 times with respect to smooth duct under similar geometrical and flow conditions at Re =7276.82, Pl/e =3/2, and e/H = 0.75.

(B) Rectangular shaped winglets

Min et al. [3] investigated fluid flow and heat transfer characteristics of longitudinal vortex generator (LVG) attached in rectangular, which is shown in Fig. 3.

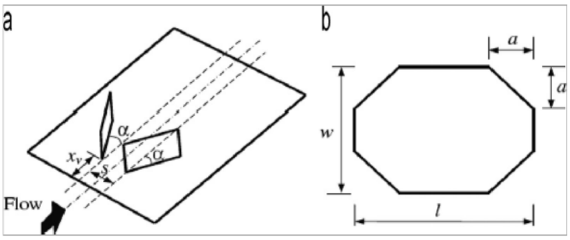

Fig. 3. Schematic view of present modified longitudinal vortex generator:

(a) Layout of common-flow-down wings and (b) Modified rectangular wing [3].

It was concluded that local heat transfer had been enhanced near the positions of z = ± 74 mm from the centerline of the Solar air heater plate. The down-sweep of the longitudinal vortices was beneficial to the heat transfer enhancement. Zhou and Ye [4] investigated the thermohaydraulic performance of curved trapezoidal winglet as shown in Fig. 4.

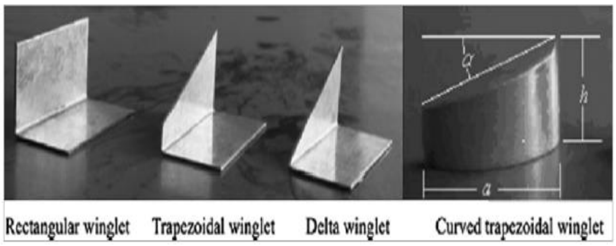

Fig. 4. Different Winglets (a) Rectangular (b) Trapezoidal (c) Delta (d) Curved trapezoidal [4]

They make comparison, between curved trapezoidal winglet with rectangular winglet, trapezoidal winglet and delta winglet. They found, curved trapezoidal winglet, delta winglet had the best thermohaydraulic performance in fully turbulent flow region. Kotcioglu et al. [5] investigated the second law of a cross-flow heat exchanger duct having winglets in the presence of a balance between the entropy generations and concluded that increase in the cross-flow fluid velocity improves the heat transfer rate and decreases the heat transfer irreversibility. The used winglets geometry are shown in Fig. 5.

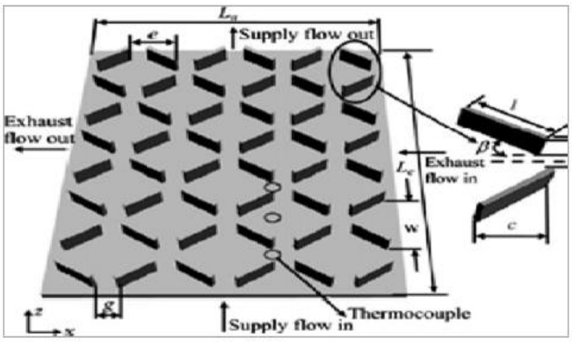

Fig. 5. Arrangement of winglets in Rectangular channel [5].

Promvonge et al. [6] studied the effects of combined ribs and delta-winglet type vortex generators (DWs) for turbulent airflow through Solar air heater duct as shown in Fig. 6

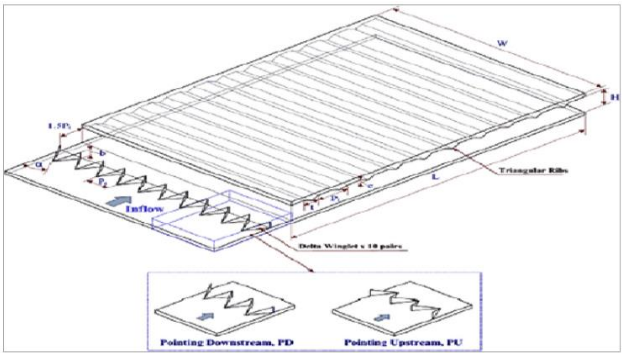

Fig. 6. Combined ribs and delta-winglet type vortex generators [6].

They tested on ten pairs of the DWs having roughness height 0.4 with transverse pitch ratio 1 and three attack angles of 60^0,45^0 and 30^0.Significant increment in Nusselt number and friction factor values are found. Chompookham et al. [7] also studied the effect of combined wedge ribs and winglet type vortex generators (WVGs) on heat transfer and friction loss characteristics. For this they arranged both wedge ribs and WVGs on the opposite channel walls and in-line arrays. Due to this, combined ribs and the WVGs, significant increment in heat transfer rate and friction loss over the smooth channel was observed. The used winglet geometry is shown in Fig. 7.

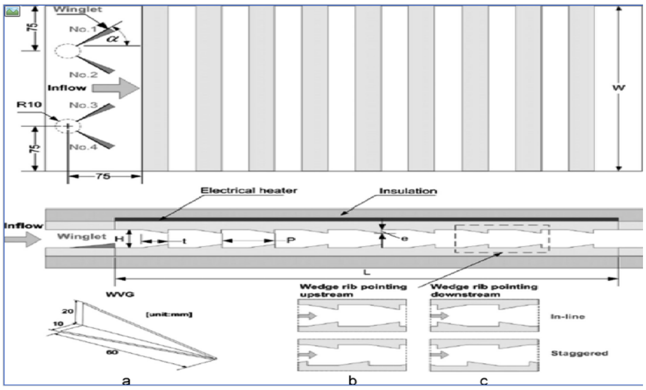

Fig. 7. Test section with (a) winglet geometry; (b) wedge rib pointing upstream; and (c) wedge rib pointing downstream [7].

Abene et al. [9] studied the effect of obstacles in solar air heater duct. The different shapes studied, were ogival transverse (OT), ogival inclined folded (OIF), waisted tube (WT), waisted delta lengthways (WDLs), waisted ogival lengthways (WOLs) and transverse longitudinal obstacles (TL) as shown in Fig. 8. They conclude that the form, dimensions, orientation and disposition of the obstacles strongly influences the collector efficiency.

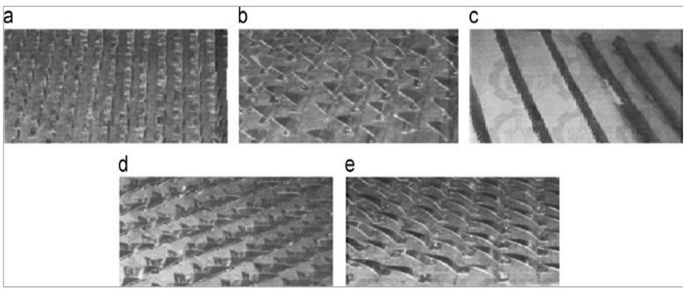

Fig. 8. Different obstacles geometry: (a) OT; (b) OIF1; (c) WT; (d) WDL1; and (e) WOL1 [9].

Esen [10] presented an experimental energy and exergy analysis for a Solar air heater with various obstacles and without obstacles. The results reveal that optimal values of efficiency were middle level of absorbing plate in flow channel duct and the double-flow collector supplied with obstacles appears significantly better than that without obstacles.

(C) Cans

Ozgen et al. [11] used obstacles in the form of aluminium cans in the double-pass channel of a flat plate Solar air heater. Two different arrangements made by cans for the experiment which is staggered and regular on absorber plates of Solar air heater. Staggered arrangement was found to be the best. Schematic arrangements of cans for experiment on the absorber plate are shown in Fig. 9.

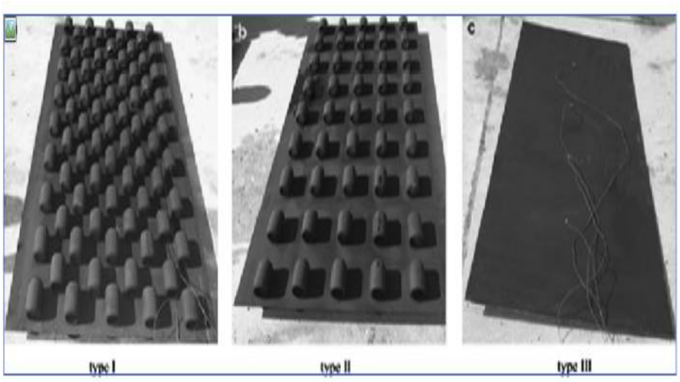

Fig. 9. Aluminums cans attached on absorber plate [11].

Numerically studied done by Nguyen et al. [12] for fluid flow and heat transfer in circular tubes within internal circumferential rib. It was reported that the ratio of thermal conductivity of wall to fluid affect the heat transfer enhancement .They were found enhancement for high Prandlt number (Pr) fluids in roughened tube.

(D) Rings

Gee and Webb [13] investigated the heat transfer and friction factor characteristics of helical-rib surface in circular tube. Three different helix angles (30^0,49^0 and 70^0). It was observed that helical-rib with helix angle of 49^0 provided the highest performance. Thianpong et al. [14] investigated heat transfer, friction factor and thermal performance characteristics of a tube equipped with twisted rings (TRs). Three distinct rings were tested as shown in Fig. 10.

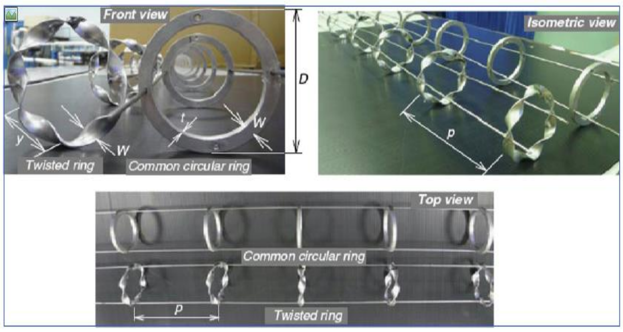

Fig. 10. Twisted ring studied by Thianpong [14].

It was concluded that in comparison to common circular rings (CRs), twisted rings (CRs) gave lower Nusselt number (Nu) and friction factor (f), except at the largest width ratio (W/D=0.15) and the smallest pitch ratio (p/D=1.0). Further, maximum thermal performance factor had been found corresponding to smaller value of width ratio and pitch ratio.

(E) Twisted tapes

Eiamsard et al. [15] performed experimental analysis to find out effects of the typical twisted tape (TT), oblique delta-winglet twisted tape (O-DWT) and straight delta-winglet twisted tape (SDWT) which is shown in Fig. 11.

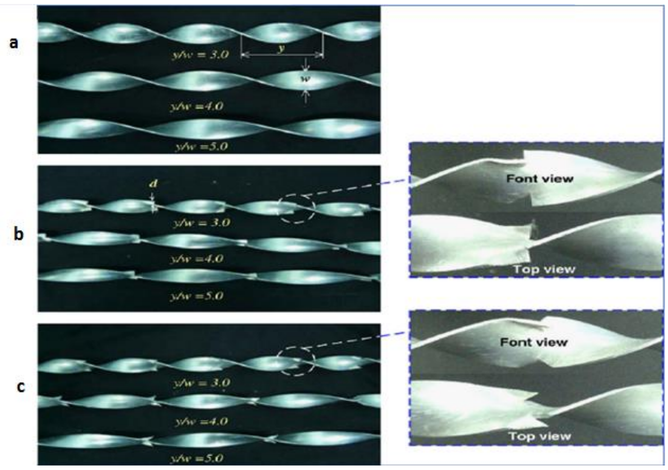

Fig. 11. Twisted tape vortex generator: (a) typical twisted type (TT); (b) straight-delta winglet twisted t types (S-DWT); and (c) oblique-delta winglet twisted (O-DWT) [15].

It was observed that Nusselt number, friction factor and thermal performance factor in a tube with the O-DWT were, respectively, 1.04–1.64, 1.09–1.95, and 1.05–1.13 times of those in the tube with TT. Smith et al. [16] investigated the effects of tandem wire coil elements in the form of turbulators on heat transfer and turbulent flow friction characteristics in a uniform heat-flux square duct. Full-length coil, 1D and 2D length coil elements were placed in tandem inside the duct with various free-space lengths to reduce the friction loss. Increment in Nusselt number and friction ratio of tandem wire coil elements with compare to the smooth air heater duct were found in the range of 1.7–2.45 and 4.5–9.5 respectively.

IV. CONCLUSIONS

An attempt has been made review about the heat transfer, friction factor enhancement in the Solar air heater ducts, provided with turbulators. Based on the literature it can be conclude that,

1) Turbulators in the form of winglets, rings, twisted rings, obstacles in Solar air heater ducts are most suitable and promising way to create turbulence in order to increase the heat transfer rate.
2) However, significant increment in pressure drop or pumping power has been also observed.

Therefore, the design of the vortex generator or turbulators is found to be a very acute task which needs attention to minimize the pressure drop through Solar air heater ducts. The various others combinations of turbulators can be used in future for investigating to enhance maximum heat transfer with minimum pressure drop or pumping power.

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