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"ENHANCEMENT OF HEAT TRANFER IN SOLAR AIR HEATER PROVIDING WITH DIFFERENT TURBULATORS USING CFD ANALYSIS"

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Abstract: The Performance of Solar Air Heater found to be low due to Low Heat Transfer Coefficient between Absorber Plate and Air. When Air Passes through Solar Air Heater Duct, Laminar Sub Layer is created on Absorber Plate, Which Reduce Heat Transfer between Absorber Plate and Air.so It is require to break this Laminar Sub layer by Providing Different Turbulators viz. Ellipse, Rectangular, Semi-Circle, and NACA Profile on Absorber Plate. But due to use of Turbulators or roughness surface frictional coefficient is increase. So requirement of fan power is increase ultimately, over all power consumption of the heater is also increase due to increase in roughness. We are try to find the most suitable shape of the Turbulators that destroyed the sub-laminar layer near to plate that increase the heat transfer with minimum losses of the power due to friction. Computational fluid Dynamic (CFD) Analysis of Solar Air Heater has been carried out in wide Range of Reynolds number between 6000 to 18000.The effect of Different Turbulators on Heat transfer and friction factor were investigated. The Results Obtained in terms of Nusselt Number and Friction Factor were Compared with Analytical Results.

Keyword: solar air heater, heat transfer, Artificial roughness, turbulence, friction

1. Introduction

1.1 Energy

Due to increasing use of fossil fuels and environmental concern and rapid depletion of natural resources have led to development of alternative source of energy which are renewable and environment friendly , Fossil fuels are being depleted quickly. World has started running out of oil and it is estimated that 80% of world's supply will be consumed in our lifetimes. So we are forced to look for nonconventional energy sources such as geothermal, ocean tides, wind, solar. [1]

Solar energy is the prime free source of in exhaustible energy available to all. India is one of the best recipients of solar energy due to its favourable location in the solar belt (40° S to 40° N). The solar energy potential in India is immense due to its convenient location near the Equator. [2]

1.2 Solar collector

This equipment absorbs the incoming solar radiant energy and converting it into thermal energy at the absorbing surface and transferring this energy to a fluid flowing through the collector plate. Solar collectors are special kind of heat exchanger which converts solar energy (radiation) to internal energy of the transport medium. [3]

1.2.1 Stationary collector

In this type of collector, the solar absorbing surface is flat plate for no means for concentrating (focus) the incoming solar radiation. In this case solar collecting area is same as the solar energy absorbing area. The Stationary collector or flat plate collector absorbs both beams as well as diffused radiation which is shown in figure.1.1, Construction of solar flat plate collector is simple and it does not require any sun tracking system. Therefore it can be properly mounted on rigid platform and hence becomes mechanically stronger than that of collector having tracking system. Maintains of flat plate collector is also less .The main disadvantages of at plate collector is that large heat loss area because of the absence of optical concentration and hence it cannot attained high temperatures. [3]

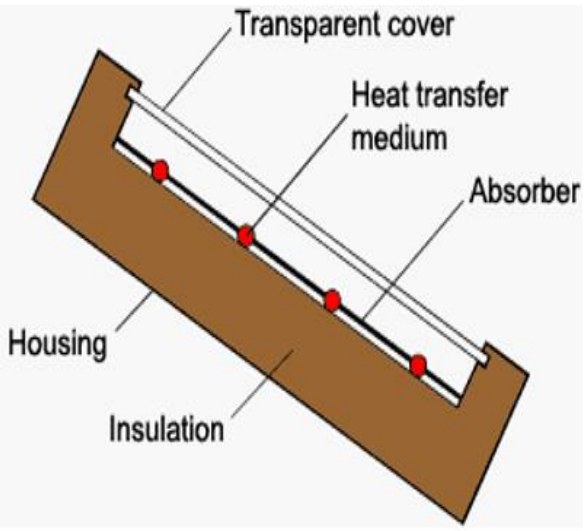

Figure 1:-Solar Flat plate collector

1.2.2 Concentrating type solar collectors:

Concentrating type collector is shown in figure1.2 which consists of reflectors to concentrate the solar radiation energy falling on collecting large surface area to a smaller absorbing surface area.in this type, the solar radiation is converged from a large area into smaller area using optical means or reflectors. The concentrating type solar collector collects mostly beam radiation and very little diffuse radiation this is due to radiation has no unique direction like beam radiation and so diffused radiation does not obey optical principles, the main advantage of this collector is that High temperature can be achieved due to concentration of radiation. [3]

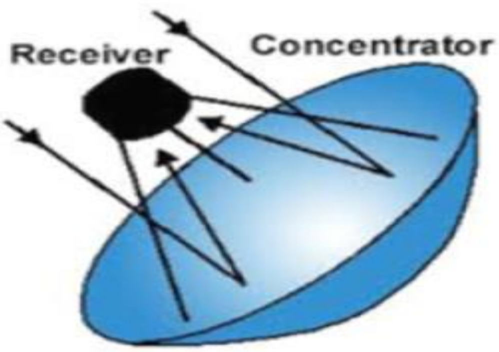

Figure 2:- concentrating type solar Collectors.

2. Details of solar air heater consideration

As par ASHRE 93-77, recommendation, the system and operating parameter have been consider for the present investigation the most important part of the system considered was the duct. the duct consider was having inner cross section dimensions of 300mm*25mm as shown in fig.1.the aspect ratio has been kept 12in this study as many investigator have established this aspect ratio for such study. The flow system consists of 900mm long entry section, 1000mm long test section and 500mm long exit section. Entery and exit length of the flow have been kept to reduce the end effects on the test section considering the recommendation provided in ASHRAE standard 93-77. A consist heat flux of 1000 W-m2 was considered to be supply by having a heater plate placed over the absorb Plate

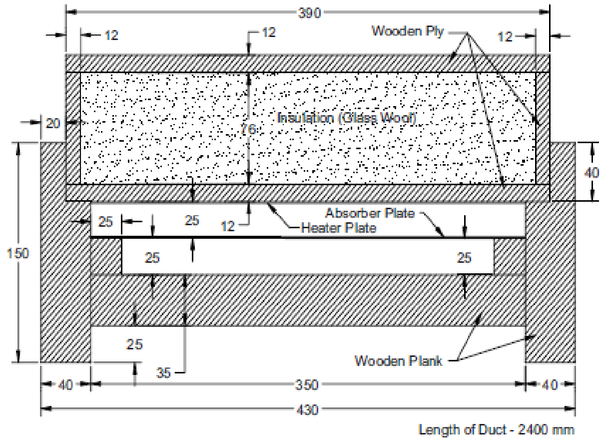

Figure 3:- sectional view of solar air heater duct.

3. Analysis

3.1 Solution domain:-

The arrangement of roughness elements in the form of semi-circle shaped ribs and flat duct fixed on the inner side of the absorber plate has been considered the solution domain used for CFD analysis has been generated as shown in Fig. 4. The duct used for CFD analysis having the height (H) of 25 mm and width (W) of 300 mm. Thickness of the absorber plate has been considered as 0.5 mm. A 28 mm thick wooden plank was considered for the sides of the duct and 40 mm thick wooden plank as bottom of the duct. A uniform heat flux of 1000 W/m2 was considered for analysis. Roughness was considered at the underside of the top of the duct to have roughened surface while other three sides were considered as smooth surfaces.

3.2 Grid

The chosen geometry is such that secondary flows are bound to occur. Thus possibility of using 2-D solution domain and gird is ruled out. Thus 3-D solution domain and grid were selected. In order to examine the flow and heat transfer critically in the inter rib regions; liner meshing at these locations has been done. In other regions coarser mesh has been used. For the present work, meshing has been done using commercially available software ANSYS 16.2.

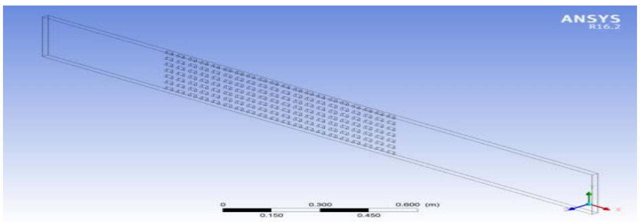

Figure 4:- arrangement of block in flow channel

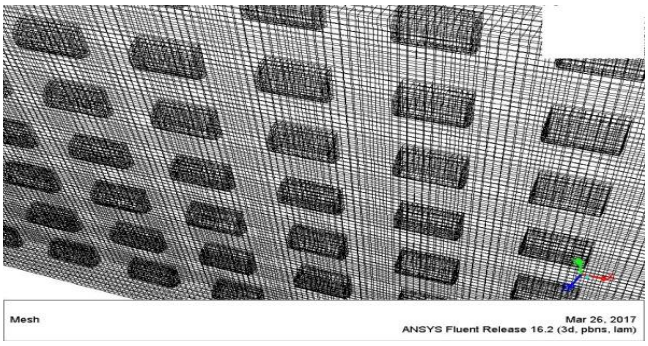

Figure 5:- meshing of duct

4. Result

The analysis of the model with enclosure was done in ANSYS FLUENT 16.2. For this at first the mesh was checked and after the approval of mesh various analysis parameters like models, materials and boundary conditions were set.

4.1 Models

The results obtained with different turbulence models were compared with the experimental results of Alam et al. as well as Dittus-Boelter empirical correlation for Nusselt number (Nu) and Modified Blasius equation for Friction factor (f).
$Nu = 0.023\ Re^{0.8}\ Pr^{0.4}$
The model used for analysis was RNG K-epsilon and energy.

4.2 Boundary condition

Table 1:- boundary condition

Inlet type	Velocity inlet
Outlet type	Pressure outlet
Duct bottom	Heat flux
Sides and top surface	wall
velocity	Varies with Reynolds number
Heat flux	1000 w/m^2

5. RESULTS AND DISCUSSIONS

In our research we had target to complete analysis at two geometry and seven velocity magnitude so whole procedure we cannot present here and we presented limited and important results.
Using ANSYS we complete analysis in two parts,
(1) Analysis of duct without turbulence at various velocities.
(2) Analysis of duct using semi-circle block at various velocity.

5.1 Graph

The line graph illustrate is Reynolds number Vs friction factor graph. Red line depict with-out turbulence provide in a flat plate. However, blue line depicts semi -circular provided in test section of flat plate. For taking a 6000 to 18000 Reynolds number so we get a various Nusselt number for each and every inlet velocity (figure-6)

The line graph illustrates Reynolds number vs friction factor graph. Hear we get a minimum friction factor at a maximum Reynolds number but obvious at that point we take a maximum inlet velocity. (Figure-7) Results obtained with semi-circular observed maximum compared to other roughness. Since the laminar sub layer region is thick at the low Reynolds number, thus the roughness height of the order of laminar sub layer thickness at lowest operational Reynolds number is suitable to attain higher heat transfer enhancement at the cost of moderate friction.

Comparison of all turbulence likes rectangle, ellipse, half-circle and mixed profile's relation between Reynolds number, friction factor and Nusselt number shown in figure8 and figure9. All the shape is solved in RNG K-epsilon model. In details in viscous heating
With temperature variation.

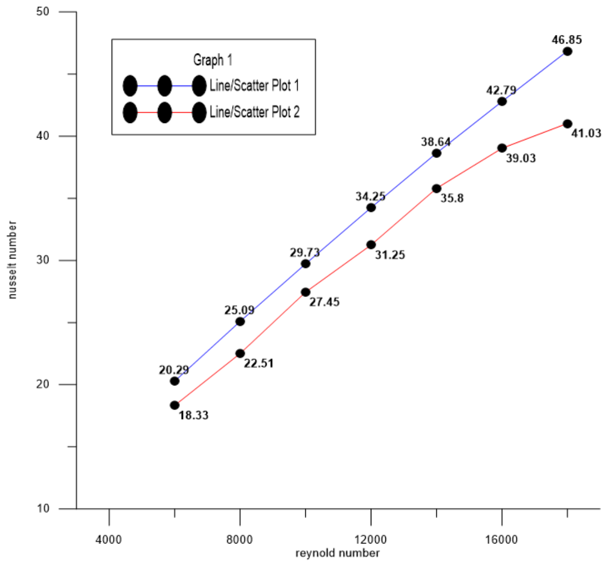

Figure 6:- Reynolds number vs Nusselt number

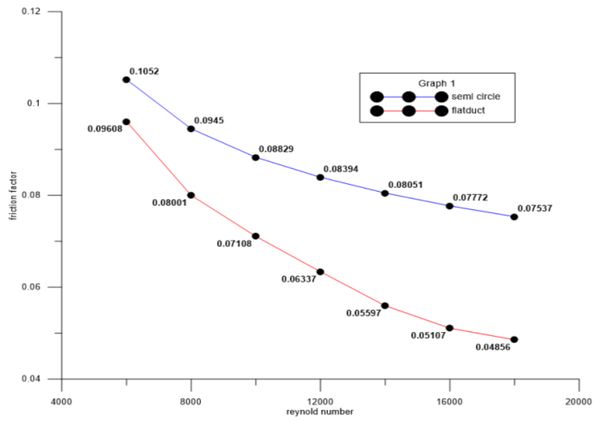

Figure 7:- Reynolds number vs friction factor

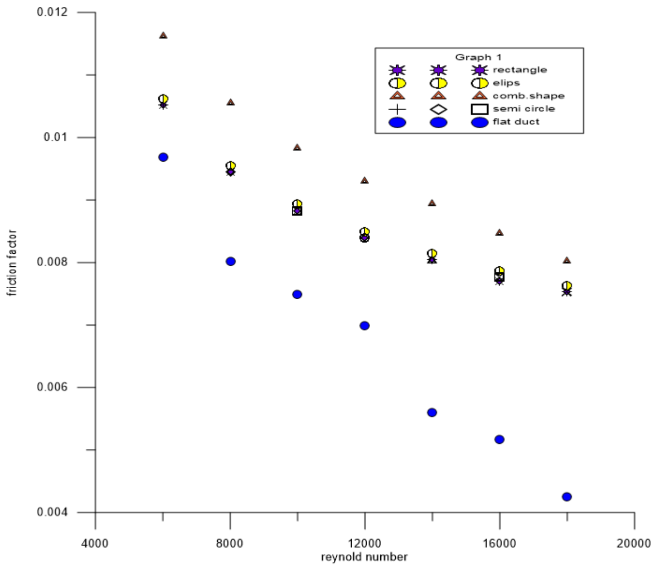

Figure 8:- Reynolds number vs friction factor

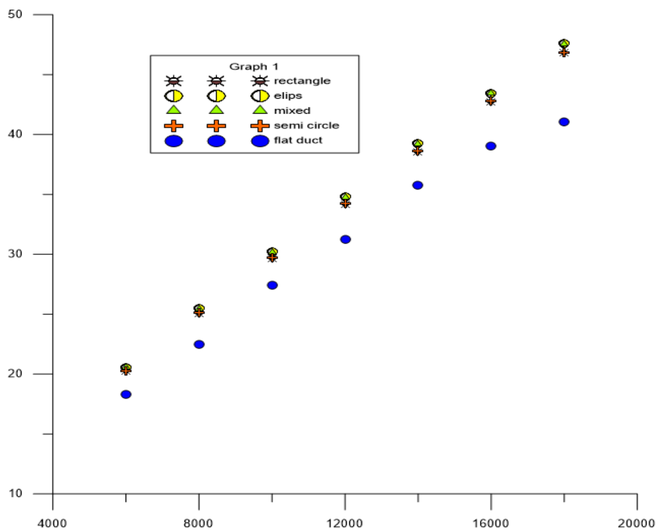

Figure 9:- Reynolds number vs Nusselt number

5.2 Contours

As we applying the velocity at inlet and after all at outlet velocity decrease due to friction. Velocity varies with distance as shown in figure 10.

Temperature varies with the bottom surface to top surface. It will be maximum at bottom surface. Temperature variation counter shown in figure 11.
Kinetic energy will disturb at wall solid particle. It increase it's energy shown in figure 12.

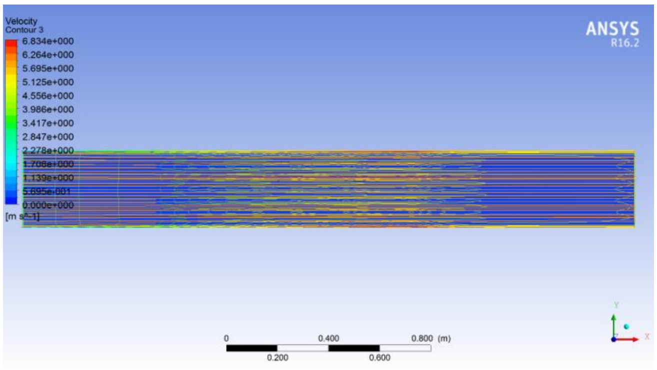

Figure 10:- velocity counter

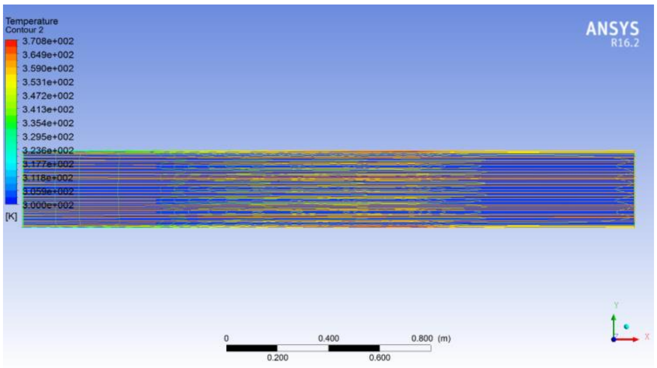

Figure 11:- static temperature

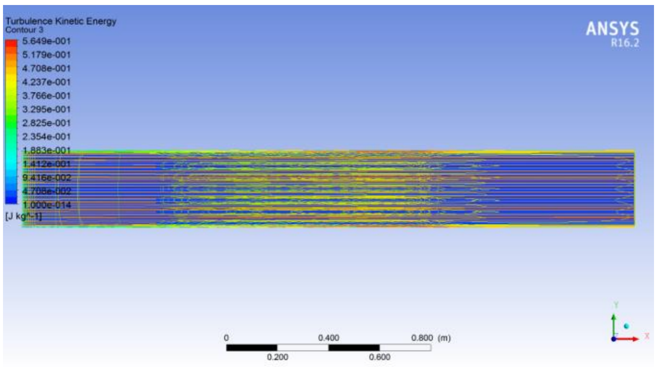

Figure 12:- kinetic energy

6. CONCLUSION

In our research we had lots of analysis about 30-40. So it becomes very complex to conclude best optimise shape at various velocities. So that analysis should be very exact. At some particular flow is not fully developed and it leads to decrease efficiency.in semi-circle block friction factor is increase compare to flat duct, but also increasing Nusselt number so as per linearity of graph Reynolds number also increase. As per equation of Reynolds number flow become turbulence and desire output is more compare to flat plat duct.
Our main aim is to achieving optimum shape with friction factor leads to less power consumption.

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