An Investigation for Thermo hydraulic Performance of Artificially Roughened Solar Air Heater

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Abstract- **In this work, the numerical analysis has been carried out for discrete multi V-shaped and staggered rib roughness surface absorber plate. The thermo hydraulic performance has been carried out by considering Fluid outlet temperature, heat flux, glass surface temperature, turbulence kinetic energy and thermal efficiency. The variables consider for the study are fluid inlet temperature and velocities. The highest thermal efficiency that can be achieved by the solar air heater is about 30%.**

Index Terms- Solar Air Heater, absorber plate, Artificial Roughened Surface, Thermal Efficiency, Heat flux.

INTRODUCTION

1.1 General

Vitality and new water are the two noteworthy products that outfit the basics of each human movement for a sensible and feasible personal satisfaction. Vitality is the fuel for development, a fundamental prerequisite for financial and social advancement. Sun based vitality is the most old source and the root for all fossil and sustainable writes. Uncommon gadgets have been utilized for profiting from the sunlight based and other sustainable power source writes since time immemorial.

Sun oriented radiation outflow from the sun into each edge of room shows up as electromagnetic waves that convey vitality at the speed of light. The sun based radiation is retained, reflected, or diffused by strong particles in any area of room and particularly by the earth, which relies upon its landing for some exercises, for example, climate, atmosphere, agribusiness, and financial development. Contingent upon the geometry of the earth, its separation from the sun, geological area of any point on the earth, galactic directions, and the creation of the climate, the approaching illumination at any given point takes diverse shapes. A critical part of the sun oriented radiation is retained and reflected once more into space through environmental occasions and therefore the sun oriented vitality adjust of the earth continues as before.

Sunlight based vitality authorities are extraordinary sorts of warmth exchangers that change sun powered radiation vitality to inside vitality of the vehicle medium. The real part of any nearby planetary group is the sun based gatherer. This is a gadget that ingests the approaching sun oriented radiation, changes over it into warmth, and exchanges the warmth to a liquid (typically air, water, or oil) coursing through the authority. The sun oriented vitality gathered is conveyed from the circling liquid either straightforwardly to the boiling water or space molding hardware or to a warm vitality stockpiling tank, from which it can be drawn for use during the evening or on shady days.

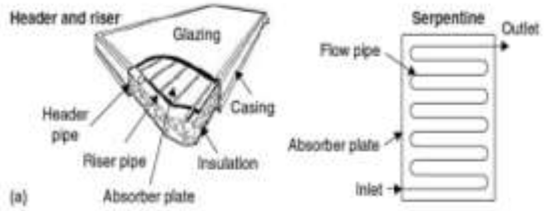


Figure 1.1 Typical flat-plate collector

II-LITERATURE REVIEW

The outcomes of an exploratory examination on warm trade and disintegration factor in a counter stream twofold pass sun arranged air hotter (DPSAH) channel with discrete multi V-shaped and shocked rib cruelty on two broad surfaces of the warmed plate have been investigated by Ravi Kant Ravi and R.P.Saini: 2017. The examination covers a broad assortment of Reynolds number (Re) from 2000 - 20000, relative paralyzed rib pitch (p'/p) from 0.2–0.8, relative astounded rib measure (r/e) from 1– 4 and relative offensiveness width (W/w) from 5-8. The perfect estimations of stream and geometrical parameters of offensiveness have been proficient and illuminated in detail. For the Nusselt number (Nu), the best addition of 4.52 times to the relating estimation of smooth twofold pass channel has been proficient, at any rate it has in like manner been seen that the disintegration factor (f) enhanced by 3.13 wrinkles when appeared differently in relation to smooth one. The rib parameters contrasting with most outrageous augmentation in Nu and f are r/e=3.5, p'/p=0.6 and W/w =7. Further, connections for Nu and f have in like manner been made in view of exploratory data.

A preliminary and numerical examination of turbulent convective warmth move in a sun-based air radiator channel with winglet-type vortex generators (WVGs) put on the protect plate is presented by Sompol Skullong et al: 2018. Air as the test fluid enters the pipe having a uniform divider warm movement associated on the upper divider or the protect plate with Reynolds number from 4100 to 25,500. Two sorts of WVGs are exhibited: rectangular (RWVG) and trapezoidal (TWVG) WVGs, with a particular true objective to make various vortex streams along the channel. The WVG parameters in the present examination consolidate two relative stature (BR=e/H=0.2 and 0.48), three longitudinal pitch extents (PR=Pl/H=1, 1.5 and 2) and a single strike edge, α=30°. The exploratory result reveals that the RWVG with BR=0.48 and PR=1 gives the most shocking warmth trade and disintegration factor at around 7.1 and 109.5 times over the level channel, independently while the TWVG with BR=0.2 and PR=1.5 yields the best warm execution around 1.84. By then, to upgrade the execution by diminishing the noteworthy weight mishap, both the WVGs with BR=0.48 and PR=1.5 are modified to be punctured rectangular and trapezoidal winglet-type vortex generators (P-RWVG and P-TWVG) with four unmistakable punched hole/pore estimations (d=1, 3, 5 and 7 mm) on their central zone. The examination shows that among the punctured WVGs, the P-RWVG at d=1mm yields the most shocking warmth trade and rubbing factor up to 6.78 and 84.32 times higher than the smooth pipe yet the best warm execution of around 2.01 is found for the P-TWVG with d=5 mm. To research the stream and warmth trade plan, a 3D numerical stream entertainment is performed and affirmed with open estimations where both the numerical and assessed comes are in awesome comprehension.

The examination exhibits that P-WVGs can make vortex-streams that can provoke impingement flies on the divider (shield plate), which progress speedier fluid mixing between the more smoking close divider fluid and the colder base divider fluid regions. The assistant stream or VI affect appears to block the point of confinement layer change. As needs be, unprecedented warmth trade change is refined with respect to the smooth pipe alone.

III-RESEARCH METHODOLOGY

3.1 Thermal and thermo-hydraulic performance of solar air heater

Frequency of valuable energy increase by air flowing through duct of solar air heater might be estimated in terms of mean plate temperature ‘T_{pm}’ by using the subsequent equation; the equation is described through *Hottel–Whillier–Bliss equation with* also described by *Duffie and Beckman*

$$Q_u = A_c\, F_R\, [\, I\,(\tau\alpha)_e - U_L(T_i - T_a)] \qquad (3.1)$$

Where Ac is the surface area of absorber plate (m^2) F_R is the Heat removal factor, I is the turbulence intensity/intensity of solar radiation (W/m^2), $(\tau\alpha)_e$ is the effective transmittance absorptance product, U_L is the overall heat loss coefficient ($W/m^2/K$), Ti fluid inlet temperature (K) and Ta ambient temperature (K).

The three outline factors, FR, (τα)e, and UL, are occasions of warm execution and syndicate to yield finish collector productivity as far as the working factors of temperature and insolation. The three variables can be utilized to distinguish highlights which would upgrade execution with the most astounding money saving advantage. Then again, factors that are not financially reasonable in enhancing execution might be dispensed with to lessen costs.

Heat removal factor is given by,

$$Heat\ Removal\ factor\ F_R = \frac{Usefull\ Energy}{Using\ Energy} = \frac{T_i - T_a}{T_{pm} - T_a}$$

The rate of valuable energy gain by flowing air in the duct of a solar air heater can also be calculated from the following equation

$$Q_u = mC_p(T_0 - T_i) = hA_c(T_{pm} - T_{am}) \qquad (3.2)$$

The transmittance $\tau(\theta)$ of a glass cover for solar radiation depends on the angle of incidence θ. Typical values for clear glass are given in Table 3.1.

Table 3.1 Transmittance of a Glass Cover.

θ	0°	60°	70°	80°	90°
$\tau(\theta)$	0.9	0.8	0.65	0.35	0

The absorptance $\alpha(\theta)$ of the black plate for solar radiation also depends on the angle of incidence θ. Table 3.2 shows typical values for $\alpha(\theta)$ and the product $\tau(\theta).\alpha(\theta)$.

Table 3.2 Absorptance of a Black Plate

θ	0°	60°	70°	80°	90°
$\alpha(\theta)$	0.92	0.85	0.75	0.60	0
$\tau(\theta).\alpha(\theta)$	0.83	0.68	0.49	0.21	0

Hydraulic performance of a solar air heater disquiets with pressure drop (ΔP) in the duct. Pressure drop totals for energy consumption by blower to propel air concluded the duct. The pressure drop for completely established turbulent flow through duct with Re 50,000 is given as follows equation:

$$\Delta P = \frac{2f\rho l v^2}{D} \qquad (3.9)$$

$$f = 0.079\ Re^{-0.25} \qquad (3.10)$$

Where v is the velocity of air in the duct (m/s), f is the friction factor, ρ is the density of air (kg/m^3), D is the equivalent or hydraulic diameter of duct (m) and l is the length of the duct.

Geometry

The absorber plate design has been consider for the study is adopted from Ravi Kant Ravi, R.P. Saini; 2017. Figure 3.1 shows the geometry of the solar air heater. While figure 3.2 and 3.3 shows the drafting of solar air heater asembly and absorber plate respectively.

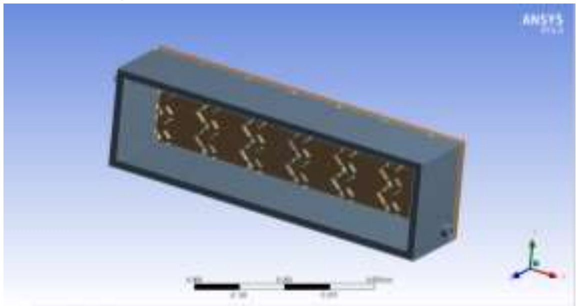


Figure 3.1(a) Geometry of the Solar Air Heater

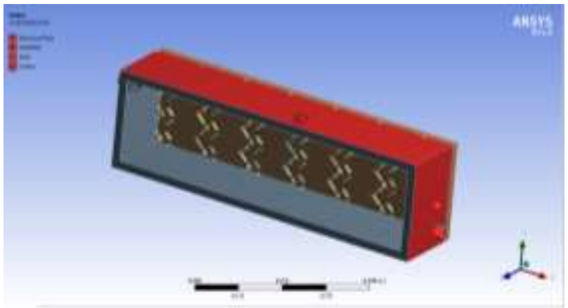


Figure 3.1(b) Parts of the Solar Air Heater

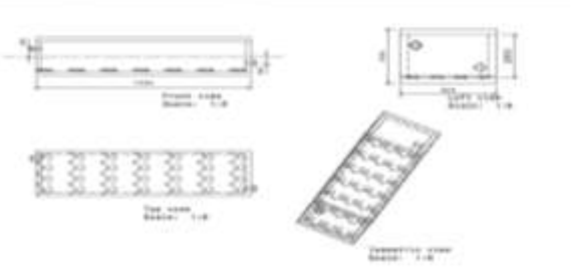


Figure 3.2 Drafting of assembly design of solar air heater

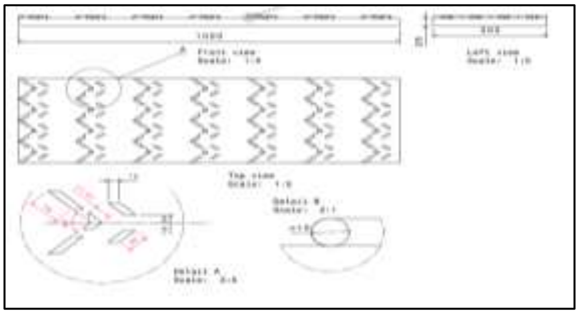


Figure 3.3 Drafting of absorber plate design of solar air heater

IV-RESULT ANALYSIS

The two basic variables i.e. inlet velocity and inlet air temperature considered as the base parameters for the study. For velocity 0.5m/s, 1.5 m/s and 2.5 m/s, the different air inlet temperature 283, 293 and 303K are considered for the study.

4.1 Results for inlet air velocity 0.5 m/s inlet air temp 283 K

Figure 4.1, 4.2, 4.3 and 4.4 shws the Heat flux generated, Outlet air temperature, Glass surface temperature and Turbulence Kinetic Energy respectively for the condition when the inlet air velocity is considered as 0.5 m/s and the air inlet temperature considered as 283K.

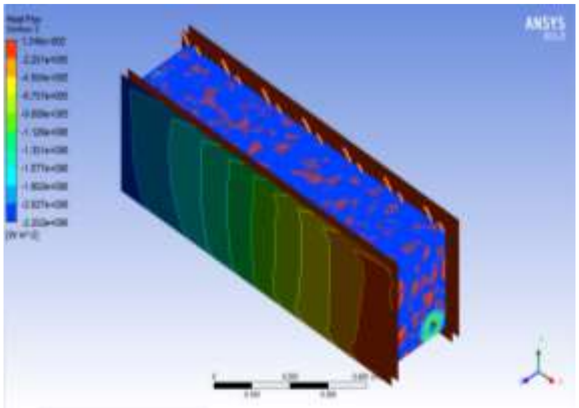


Figure 4.1 Heat flux generated considering inlet air velocity 0.5 m/s inlet air temp 283K

4.2 Results for inlet air velocity 1.5 m/s inlet air temp 283 K

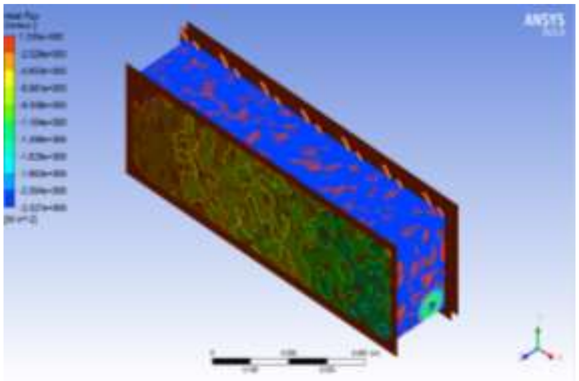


Figure 4.2 Heat flux generated considering inlet air velocity 1.5 m/s inlet air temp 283K

4.3 Results for inlet air velocity 2.5 m/s inlet air temp 283 K

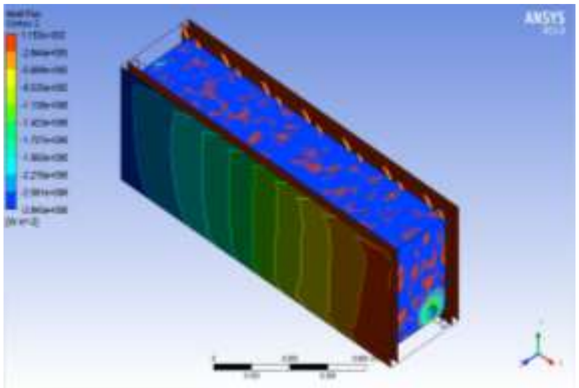


Figure 4.3 Heat flux generated considering inlet air velocity 2.5 m/s inlet air temp 283K

4.4 Results for inlet air velocity 0.5 m/s inlet air temp 293 K

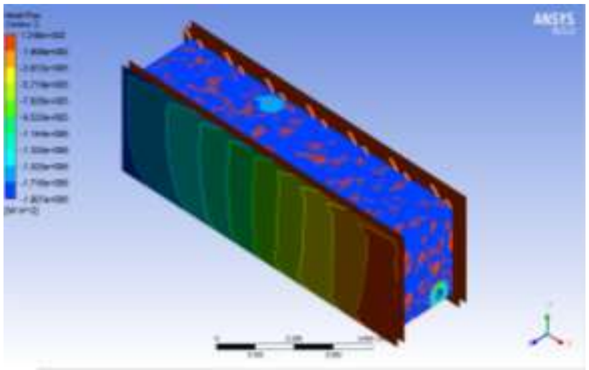


Figure 4.4 Heat flux generated considering inlet air velocity 0.5 m/s inlet air temp 293K

4.5 Results for inlet air velocity 1.5 m/s inlet air temp 293 K

Figure 4.17,4.18, 4.19 and 4.20 shows the Heat flux generated, Outlet air temperature, Glass surface temperature and Turbulence Kinetic Energy respectively for the condition when the inlet air velocity is considered as 1.5 m/s and the air inlet temperature considered as 293K.

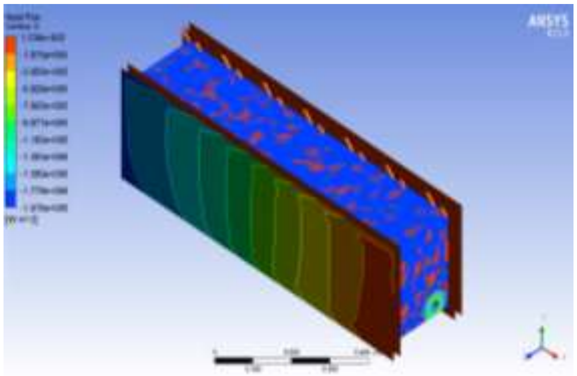


Figure 4.5 Heat flux generated considering inlet air velocity 1.5 m/s inlet air temp 293K

4.6 Results for inlet air velocity 2.5 m/s inlet air temp 293 K

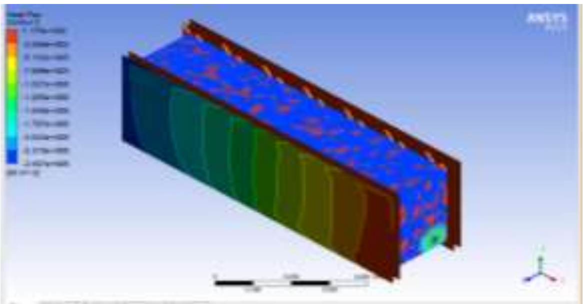


Figure 4.6 Heat flux generated considering inlet air velocity 2.5 m/s inlet air temp 293K

4.7 Results for inlet air velocity 0.5 m/s inlet air temp 303 K

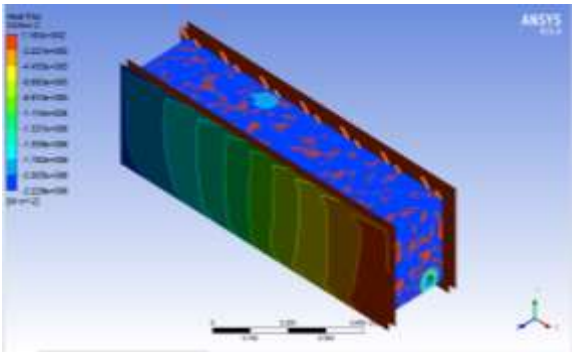
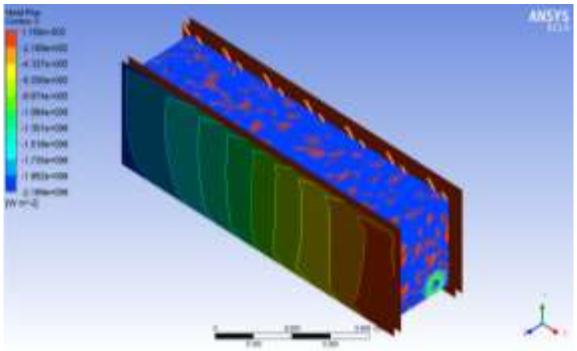


Figure 4.7 Heat flux generated considering inlet air velocity 0.5 m/s inlet air temp 303K

4.8 Results for inlet air velocity 1.5 m/s inlet air temp 303 K



4.8 Results for inlet air velocity 2.5 m/s inlet air temp 303 K

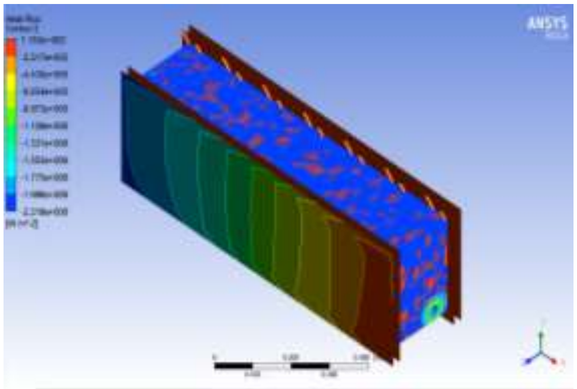


Figure 4.9 Heat flux generated considering inlet air velocity 2.5 m/s inlet air temp 303K

4.10 Discussion

4.10.1 Fluid Outlet Temperature

Fluid i.e. air outlet temperature is the basic requirement of any passive solar heating device which can be applied for any households etc.

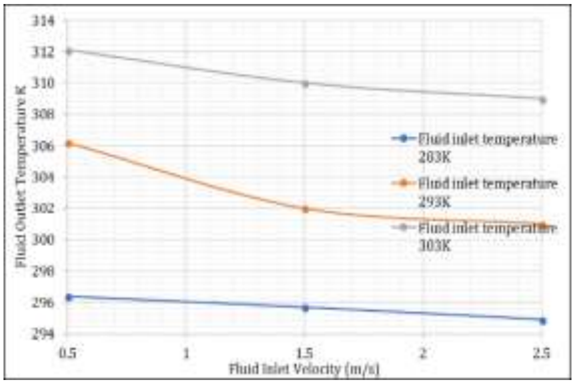


Figure 4.10 Fluid outlet temperature with respect to Fluid inlet velocity at different inlet temperature.

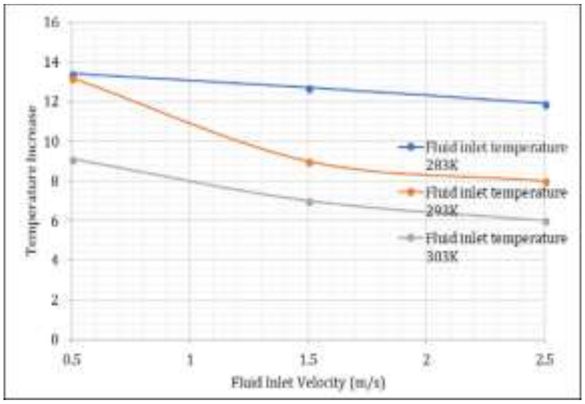


Figure 4.11 Temperature increase of fluid with respect to Fluid inlet velocity at different inlet temperature.

Figure 4.11 shows the variation in Fluid outlet temperature with respect to Fluid inlet velocity at different inlet temperature i.e. 283, 293 and 303 K respectively and the figure 4.38 shows the Temperature increase of fluid with respect to Fluid inlet velocity at different inlet temperature.

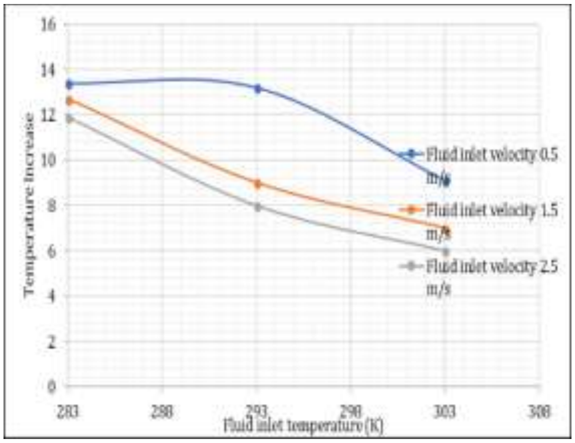


Figure 4.12 Temperature increase of fluid with respect to Fluid inlet Temperature at different inlet velocity.

4.10.2 Heat Flux

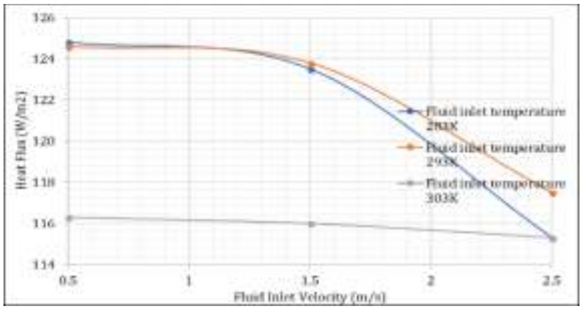


Figure 4.13 Heat Flux with respect to Fluid inlet velocity at different inlet temperature.

4.10.3 Glass Surface Temperature

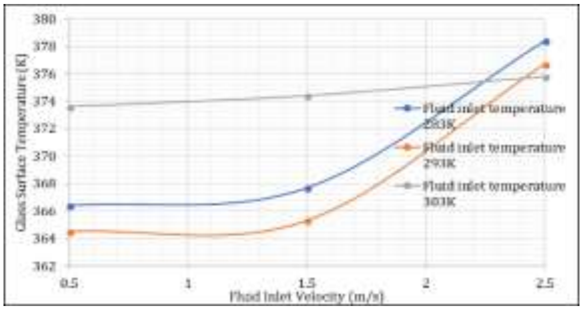


Figure 4.14 Glass Surface Temperature with respect to Fluid inlet velocity at different inlet temperature.

4.10.4 Turbulence Kinetic Energy

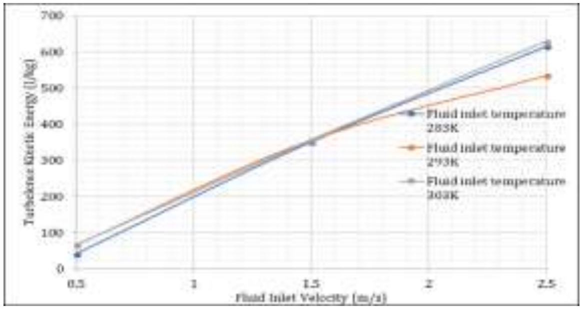


Figure 4.15 Turbulence Kinetic Energy with respect to Fluid inlet velocity at different inlet temperature.

4.10.5 Thermal Performance

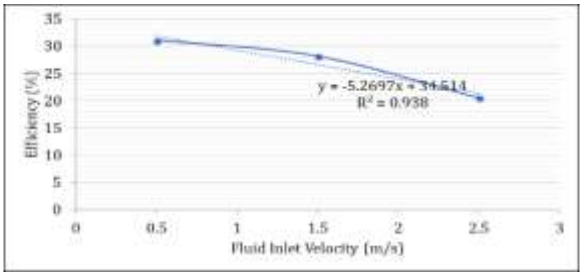


Figure 4.16 Thermal Efficiency with respect to Fluid inlet velocity.

V-CONCLUSION

5.1 Conclusion

Solar energy collectors in general are a special kind of heat exchanger that transforms solar radiation energy into internal energy of the transport medium. The major component of any solar system is the solar collector. This is a device which absorbs the incoming solar radiation, converts it into heat, and transfers this heat to a fluid flowing through the collector. The solar energy thus collected is carried from the circulating fluid either directly to the hot water or space conditioning equipment or to a thermal energy storage tank from which it can be drawn for use at night and/or on cloudy days.

In this work, thermal and thermohydraulic performance of artificially roughened solar air heater has been investigated with the help of a mathematical model as well as Finite element analysis. Absorber plate of solar air heater is assumed to be roughened with formation of protrusions. Fluid outlet temperature, heat flux, glass surface temperature, turbulence kinetic energy and thermal efficiency have been used as measures for assessing thermal and thermohydraulic performance of solar air heater. The following observations have been made after the study.

1. The Temperature of fluid increase with respect to Fluid inlet velocity at different inlet temperature.
2. At low inlet velocity the highest temperature can be achieved and it is decreases when the fluid inlet velocity increases this due to the fact that high fluid velocity decreases the heat transfer time thus less heat transfer occurs.
3. If the fluid inlet temperature increases while keeping the constant inlet velocity the temperature difference achieved is less
4. It can be observed that at lower inlet temperature the high difference of temperature is achieved with maximum outlet temperature at each velocity.
5. the heat flux is highest at low fluid inlet velocity and lowest at high fluid velocity. There is rapid decrease in heat flux generation at increment of velocity.
6. There is increment in glass surface temperature as fluid inlet velocity increases.
7. Turbulence kinetic energy increases with the increment of fluid inlet velocity.

8. The highest thermal efficiency about 31.1% can be obtained from the solar air heater consider for the study. The thermal efficiency reduces as the fluid inlet velocity increases.

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