Enhancement of Heat Transfer Co-Efficient of Artificially Roughened Absorber Plate of Solar Air Heater With Symmetrical Right Angle Geometry

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Abstract: In present day the world's depleting available fossil fuel, which provide the major source of energy, the development of non-conventional renewable energy sources has received an impetus. Solar energy is most important among renewable energy resources due to its availability, free of cost and non-pollute. The thermal performance of a conventional solar air heater is poor because of relatively low heat transfer coefficient between absorber plate and the flowing fluid (air). Use of artificial roughness on the absorber plate has been found to be an effective method of increasing heat transfer between absorber plate and flowing fluid. Artificial roughness is provided to increase turbulence for flowing fluid (air). The artificial roughness should be in such a way that increase heat transfer and reduce friction factor. In this study, circular shaped copper wire is used in symmetrical right angle geometry to provide artificial roughness.

Keywords: -Symmetrical right anglegeometry, friction factor, force convection, Reynolds number, Nusselt number, pressure drop.

I. INTRODUCTION

All the physical activity in this world, whether by human being or by nature, is caused due to the flow of energy in one form or the other. Energy is required to do any kind of work. The word 'energy' itself is derived from the Greek word 'en-ergon', which means 'in-work' or 'work content'. The work output depends on the energy input. The capability to do work depends on the amount of energy one can control and utilize. Energy has become an important and one of the basic infrastructures required for the economic development of a country. Energy security is imperative for sustained growth of economy.

Energy is the capability to produce motion, force and change in shape. Energy is the basic ingredient of the fabric life. Energy action in the universe is an expression of energy in one form or the other. The living standard can be directly related to per capita energy consumption. Presently major portion of our energy demand is met by crude oil which supplies nearly 39 % natural gas about 20 % and coal about 33 %. The present energy sources ace exhaustible and are depleting fast. The present energy consumption is about 0.3 to 0.5 Q/year (1Q = 10^{10} KJ) where as availability in the form conventional energy resources such as coal, oil and natural gas is 35Q. Conventional energy sources are not sufficient to meet the energy demands for very long.

A systematic study of various forms of energy and energy transformations, involving human experience and observations is called energy science. The applied part of energy science useful to human society, nation and individual is called energy technology.

II. LITERATURE SURVEY

Amongst all available methods of enhancing turbulence in convective heat transfer, artificial roughness is believed to be an efficient method. In order to attain higher heat transfer coefficient, it is desirable that the flow at the heat transferring surface is to be made turbulent. However, excessive turbulence leads to increase power requirement and such power is obtained from the fan or blower to make the air flow through the duct. It is therefore desirable that the turbulence must be created only in the region very close to the heat transferring surface i.e. laminar sub layer only. To minimize the friction losses, height of the roughness element should be kept small in comparison with the duct dimensions.

Anil Singh Yadav, J.L. Bhagoria[1] investidated that to augment and improve heat transfer active and passive methods used in absorber surface in solar air heater ,heat exchanger and gas turbines blade. They also investigate that the pressure drop in the form of friction factors , Reynolds number ,Nusselt number and prandtl number.It was obserbed that the use of cathode ray tube caused a substantial increase the friction factor over the plane tube.It can explaned that flow fluid with the regulators instead inside the tube prevented and increase contact surface area as compare to the plane tube.Increased contact surfaces caused both belonges resident time of the flow and dynamics of the fluids.

Table 2.1: Roughness geometries and their parameters

Authors	Roughness geometry	Range of parameters	Result
Anil Singh Yadav ,and J.L. Bhagoria [1]	Eqilateral Triangle Geometry	Re no =3800 – 18000,e/D=.021-.042,P/e=7.14-35.71,α=58°-80^0	As increase of Reynolds number friction factor decreases.
Adem acir ,Ismail ,Mehmet Emin[2]	Circular ring turbulators	Re no =3000 – 20000,Pitch ratio(L/D)=2-3.5, No of hole(N)=2-4-6	The highest efficiency were found about 1.83 and 1.41 with PR=2 and N=2 of the Re no=3000-7500
Anil Kumar Patil[3]	V-down Discrete	Re no =3000 – 17000,e/D =0.043,P/e=10,α=60°	Creating gap in V-shaped rib is found to enhance the heat transfer rate by breaking the secondry flow and producing higher level of turbulence in the fluid downstream of the rib.
Hans V.S., Saini R.P., Saini J.S[5]	Multi V-shaped rib roughness	Re no=2000-20000 ,P/e=6-12 , α=30° - 75°	6 and 5 times enhancement Nusselt number and friction factor respectively were reported over smooth duct.
Prasad and saini[6]	Continuous transverse ribs	Re no =5000 – 32000,e/D =0.02 0.033,P/e=10-20	At P/e=7.5 , maximum heat transfer occurs.
Kumar and Bhagoria[7]	Discrete W- shaped	Re no =3000 – 15000,e/D =0.0168 – 0.0338,P/e=10,α=30° - 75°	Downward W – shaped pattern gives better performance.
Bopche and tandale[8]	U- shaped ribs	Re no =3800 – 18000,e/D =0.0186 – 0.039,P/e=6.67 – 57.14	Re no at near about 14000 gives best result.
Sahu and bhagoria[9]	90° broken rib roughness	Re no=3000-12000 ,p=10,20,30 ,W/H=8	1.25-1.4 time enhancement in heat transfer coefficient was reported over smooth duct.
Momin AME ,Saini J.S. ,Solanki S.C[10]	Continuous V-rib roughness	Re no =2500 – 18000,e/D =0.02 – 0.034,P/e=10 , α=30° - 90°	At Maximum Reynolds no ,friction factor is at minimum value.
Verma and Prasad[13]	Continuous transverse rib roughness	Re no =5000 – 20000,e/D =0.01-0.03,P/e=10-40	Transverse rib roughness produce max Q enhance while the P/e lies b/w 8-10 times than that of the roughness height.
Muluwork K.B. et al.[12]	Discrete V-rib roughness	Re no =2000 – 15500,e/D =0.02 ,P/e=3-9 , α=60°	If value of P/e reach more than 9 then friction factor increases.

Anil kumar patil et al. [3] experimentally investigated the heat transfer coefficient and friction characteristics of a rectangular duct of a solar air heater provided V-shaped ribs on absorber plate as shown in Figure 2.4. This investigation covered several parameters i.e. Reynolds number (Re) in the range of 2500-18000, relative roughness height (e/D_h) range of 0.02-0.034 and arc angle range of 30 -90 for a fixed relative roughness pitch (p/e) of 10. The maximum enhancement of Nusselt number and friction factor as a result of providing artificial roughness had been found out to be 2.30 and 2.83 times respectively over the smooth duct for an arc angle value of 60° . Correlations for heat transfer and friction factor were also developed.

Anil singh yadav and J.L.Bhagoria[4] Explained that Artificial roughness is well known methods to increase heat transfer and reduce the friction factor from a surface to roughened the surface either randomly with a sand grain or by used on regular geometry roughness eliment on the surface. Many investigators have studied this problem in an attempt to developed to accurate prediction of the behaviour of a given roughness geometry and to define a geometry which give the best performance a given flow friction.

Lanjewar et al. [5] had carried out experimental investigation of heat transfer and friction factor characteristics of rectangular duct roughened with W-shaped ribs on its underside on one broad wall arranged at an inclination with respect to flow direction as shown in Figure 2.26. The parameters investigated for this study were relative roughness pitch (p/e) of 10, relative roughness height (e/D_h) 0.018-0.03375 and arc angle of flow 30 -75. Air flow rate corresponds to Reynolds number in the range of 2300-14000. The maximum enhancement of Nusselt number and friction factor has been found to be respectively 2.36 and 2.01 times that of smooth duct for arc angle of 60°. Correlations were also developed for heat transfer coefficient and friction factor for roughened duct.

Hans et al. [6] had carried out an experimental study to see the effect of multiple V-rib roughness on heat transfer coefficient and friction factor in an artificially roughened solar air heater duct as shown in Figure 2.24. The experiment encompassed Reynolds number (Re) from 2000 to 20000, relative roughness height (e/D_h) ranges from 0.019–0.043, relative roughness pitch (p/e) in the range of 6–12, arc angle ranges from 30 –75 and relative roughness width (W/w) varies from 1–10.The maximum heat transfer enhancement has been found to occur for a relative roughness width (W/w) value of 6 while friction factor attains maximum value for relative roughness width (W/w) value of 10.Using these experimental data, correlations for Nusselt number and friction factor in terms of roughness geometry and flow parameters had been developed.

Kumar and Bhagoria [7] experimentally investigated the heat transfer and friction characteristics of a solar air heater having discrete W-shaped roughness provided on one broad wall of rectangular channel as shown in Figure 2.23.The investigation has been carried out for relative roughness height (e/D_h) range of 0.0168 - 0.0338, relative roughness pitch (p/e) range of 12.5–36, arc angle range of 30 -75 , for fixed relative roughness pitch (p/e) value of 10 and Reynolds number varies from 3000 – 15,000.It was reported that maximum enhancement of Nusselt number and friction factor in comparison to smooth duct was of order of 2.16 and 2.75 times respectively for an arc angle of 60^o. Correlations for Nusselt number and friction factor were also developed.

Bopche and Tandale [8] have carried out an experimental investigation to study the heat transfer coefficient and friction factor of a rectangular duct roughened artificially with U-shaped tabulator. The parameters investigated were Reynolds number (Re), relative roughness height (e/D_h) and relative roughness pitch (p/e) varying from 1800-3800, 0.0186–0.03986 and 6.67-57.14 respectively. Arc angle (α) is kept constant at 90 for the study. The U-shaped roughness geometry shows appreciable heat transfer enhancement even when Reynolds number value is less than 5000 where ribs are generally inefficient. The maximum enhancement in Nusselt number and friction factor are reported to be 2.388 and 2.50 times respectively. Correlations for Nusselt number and friction factor were also developed.

Sahu and Bhagoria [9] investigated the effect of 90 broken ribs on the enhancement of the thermal performance of solar air heaters for fixed roughness height (e) value of 1.5 mm, duct aspect ratio (W/H) value of 8, pitch ranging from 10-30 mm and Reynolds number in the range of 3000-12000. The investigated roughness geometry has been shown in Figure 2.18. Roughened absorber plate increases the heat transfer coefficient by 1.25-1.4 times as compared to smooth rectangular duct under similar operating conditions. Corresponding to roughness pitch value of 20 mm, maximum value of Nusselt number was obtained which decreases on the either side of this value of pitch. The correlations were also developed for heat transfer coefficient and friction factor.

Mulluwork et al. [10] compared the thermal performance of staggered discrete V-up and V-down ribs as shown in Figure 2.16. They had studied the effect of relative roughness length ratio (B/S), relative roughness segment ratio (S'/S), relative roughness staggering ratio (P'/P) and arc angle on heat transfer and friction factor. Nusselt number for V-down discrete ribs was found to be higher than the corresponding V-up and transverse discrete roughened surfaces. Nusselt number increases with the increase in relative roughness staggering ratio (P'/P) and attained a maximum value of Nusselt number for relative roughness staggering ratio value of 0.6. Correlations for Nusselt number and friction factor were also developed.

III. CONCLUSIONS AND LITERATURE REVIEW

The use of artificial roughness is established as an effective method of enhancement of thermal performance for solar air heaters. Artificial roughness elements have been designed in such a way that the height of roughness should be in the range of the order of laminar sub-layer so as not to create disproportionate rise in pumping power while enhancing the thermal gain of the collectors. It is this elegance of this method which makes it thermo-hydraulically superior to other methods like use of fins and other substantially large protrusions. Extensive experimentations have been carried out in part, employing artificial roughness viz. transverse rib, angled rib, inclined rib with gap, v-shaped rib, discrete or broken v-shaped rib, discrete v-shaped rib with pieces, w-shaped rib, wedge or chamfered shaped rib, dimpled shaped rib, rib-groove, Multi v-shaped rib and z-shaped rib, for heat transfer enhancement in rectangular ducts.

Majority of experimental investigations involving artificial roughness in rectangular ducts have been conducted to improve heat transfer rate in nuclear reactor, gas turbine, blade cooling and heat exchanger. However, in the last two decades, several investigators have proposed the use of artificial roughness in solar air heaters and reported substantial improvement in thermal performance of solar air heaters at the expense of frictional losses.

In order to determine the optimum roughness geometry, that maximizes heat transfer enhancement for a minimum pressure drop penalty, a number of roughness geometries having different shapes, form and orientations have been employed in solar air heaters. Out of the several geometries investigated, it has been reported that V-shaped ribs are capable of yielding better thermal gain results as compared to that of inclined (angled) ribs as well as transverse ribs of equivalent relative roughness height and pitch. Heat transfer augmentation study in solar air heaters on dimples and protrusions were also carried out but very few studies have been reported so far. Providing protrusions on the absorber plate is quite simple in comparison to pasting ribs over the surface and also have less pumping penalty.

IV. REFERENCES

[1] Anil Singh Yadav, J.L. Bhagoria ,Renewable energy 91(2016) 484-500[2016].

[2] Adem acir ,Ismail ,Mehmet Emin ,Investigation of effect of the circular ring turbulators on heat transfer augmentation and fluid flow characteristic of solar air heater ,Gazi university, institute of science and technology , Ankara ,Turkey [2016].

[3] Anil Kumar Patil, Department of Mechanical Engineering, D.I.T., Dehradun 248009, U.A., India , [2015].

[4] Lanjewar A., Bhagoria J.L., Sarviya R.M., Heat transfer and friction in solar air heater duct with W-shaped rib roughness on absorber plate, Energy, Vol. 36, 4531-4541, [2011].

[5] Hans V.S., Saini R.P., Saini J.S., Heat transfer and friction factor correlations for a solar air heater duct roughened artificially with multiple V-ribs, Solar Energy, Vol. 84, 898-911, [2010].

[6] Prasad S.B., Saini J.S., Singh K.M., Investigation of heat transfer and friction characteristics of packed bed solar air heater using wire mesh as packing material, Solar Energy, Vol. 83 (5), 773-783, [2009].

[7] Kumar A., Bhagoria J.L., Heat transfer and friction factor correlations for artificially roughened solar air heater duct with discrete W-shaped ribs, Energy Conversion and Management, Vol. 50(8), 2106-2117, [2009].

[8] Bopche S.B., Tandale M.S., Experimental investigations on heat transfer and friction characteristics of a turbulator roughened solar air heater, International Journal of Heat and Mass Transfer, Vol. 52 (11-12), 2834-2848 ,[2009].

[9] Sahu M.M., Bhagoria J.L., Augmentation of heat transfer coefficient by using 90 broken transverse ribs on absorber plate of solar air heater, Renewable Energy, Vol. 30, 2057-2063, [2005].

[10] Momin AME ,Saini J.S. ,Solanki S.C.,Heat transfer and friction factor correlation for solar air heater duct with V-shaped rib roughness on absorber plate. Int J heat mass transfer[2002].

[11] S.P. Sukhatme"Solar Energy: Principal of Thermal Collections and Storage", Tata McGraw-Hill , New Delhi [2015].