IJESRT: 9(11), November, 2020 ISSN: 2277-9655

International Journal of Engineering Sciences & Research Technology

(A Peer Reviewed Online Journal)
Impact Factor: 5.164

IJESRT

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IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

ANALYSIS THE PERFORMANCE AND EFFECTS OF ARTIFICIAL ROUGHNESS WITH VARIOUS RIBS ARRANGEMENT ON THE ABSORBER PLATE OF SOLAR AIR HEATER

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DOI: https://doi.org/10.29121/ijesrt.v9.i11.2020.4

ABSTRACT

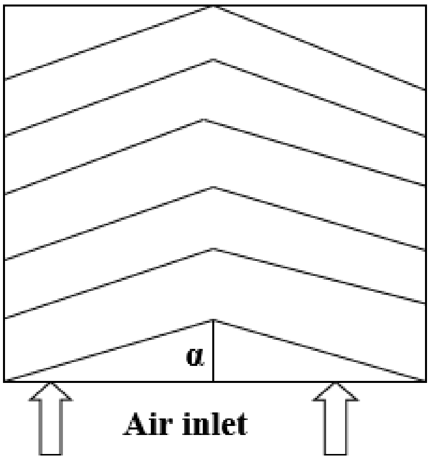
Energy requirement is very important in our life. Today, every country draws its energy needs from a variety of sources. we can broadly categorize these sources as comercial and noncommercial. The commercial sources include the fossil fuels like coal, oil and natural gas, while the noncommercial sources include wood, animal wastes and agricultural wastes. In past few years, it has become obvious that fossil fuel resources are fast depleting and the fossil fuel era is gradually coming to an end. This is particularly true for oil and natural gas. Energy expenditue is constantly increasing all over the world, and we have very little source of energy. So in such a situation, we need to find alternate source of energy. Till this time, it would not be wrong to say that the sun was supplying all the energy needs of man either directly or indirectly. As we know the energy resources available on the earth are in various forms like sunlight, fossil fuels, hydraulic energy, wind energy, tidal energy, geothermal energy and nuclear energy etc. we are having basically two types of energy resources i.e. conventional and non-conventional energy resources. From the point of view of energy saving and fulfill of present and future demand, the best option is renewable energy. We know that Sun is the ultimate source of energy and it is easilly available on the earth in free of cost. Solar energy is used in many areas for different purposes like heat and cool buildings, to heat water, to operate engines etc. So we have best option for provide heat for various purposes is Solar Air Heater. Artificial roughness, which is mounted on the absorber plate, play important role for enhancement of heat transfer rate in order to improve the thermal performance of solar air heater. In this paper our aim is to increase the thermal performance of solar air heater using artificial roughness with different shape of ribs arrangement roughness.

KEYWORDS: Heat transfer, artificial roughness, Thermal performance.

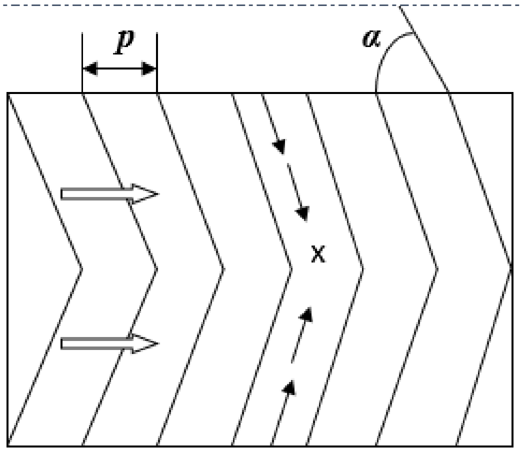
1. INTRODUCTION

Solar air heaters are being used for many applications requiring low to medium grade thermal energy, like space heating and cooling, agricultural drying, timber seasoning, mainly due to their low manufacturing cost, simple design, low operating and maintenance cost. Their use limited because of lower thermal efficiencies primarily as a result of lower convective heat transfer coefficient between the absorber plate and air leading to higher plate temperature and greater thermal losses. Various artificial roughness in the form of different geometry like ribs, baffles, wire mesh, dimple shape roughness etc. for the enhancement of heat transfer coefficient and improvement of thermal performance of solar air heaters have been proposed and investigated by a number of investigators. Such roughness geometries includes different rib arrangements like continuous, discrete, transverse, and angled, in v- pattern for ribs of different shapes (circular, square, chamfered, wedge, etc.).[1]. The artificial roughness has been used as an effective means for improvement of thermal performance of solar air heaters. However, this results in increase of friction factor for flowing fluid. In case of v-shape ribs the maximum heat transfer occurred at relative roughness height of 0.034 and at an angle of attack of 60° [2]. In case of v- down ribs, two contradictory effects occurs: the secondary flow is towards the central axis where it interacts with the axial flow (at x in fig.2) creates additional turbulence leadind to the increase in the heat transfer rate [3].

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7



1. V-shape ribs



2. V- down continiuos ribs

⇨ Primary flow

→ Secondary flow

X Mixing of primary and secondary flows

Nomenclature:
Collector area, m^2k
Thermal conductivity of air, W/m K
B solar air heater duct height,
M, mass flow rate of air, kg/s
Cp, specific heat of air at constant pressure,
J/kg K,Nusselt number
Ų, hydraulic diameter of solar air heater duct,
M, averageNusselt number
E, roughness height, *m* Nusselt number for smooth duct
E+, roughness Reynolds number4, Heat transfer enhancement factor
E/Ų, relative roughness height p pitch of roughness element, *m*
F, friction factor P/E relative roughness pitch
FS, friction factor for smooth duct Re flow Reynolds number
Fr, friction factor for four sided rough duct *To*outlet temperature of air,℃
Average friction factor *Ti* inlet temperature of air,℃
Friction enhancement factor average plate temperature,℃
Friction enhancement factor average air temperature,℃
H convective heat transfer coefficient, W/m2K

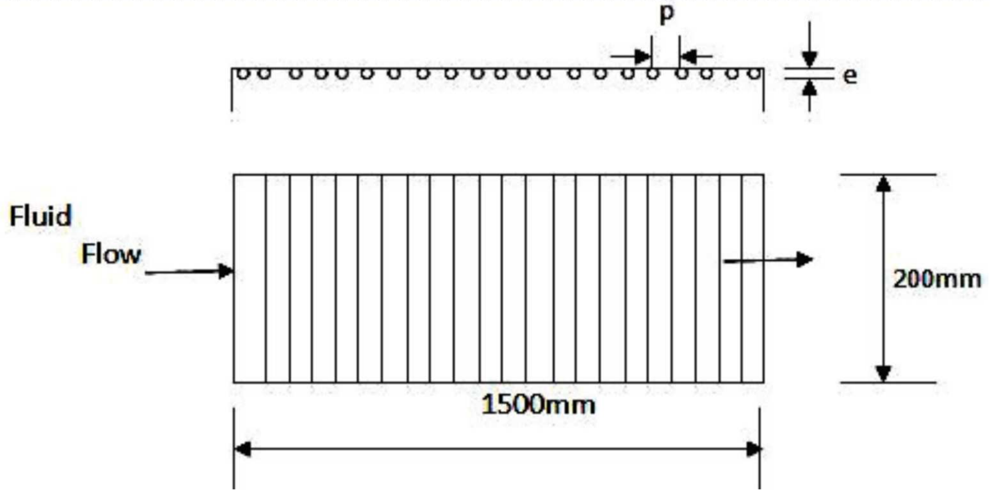


Figure2. Schematic diagram of Roughness

Table 1.Relative roughness pitch (p/e) for a maximum value of a heat transfer coefficient for different types of artificial roughness.

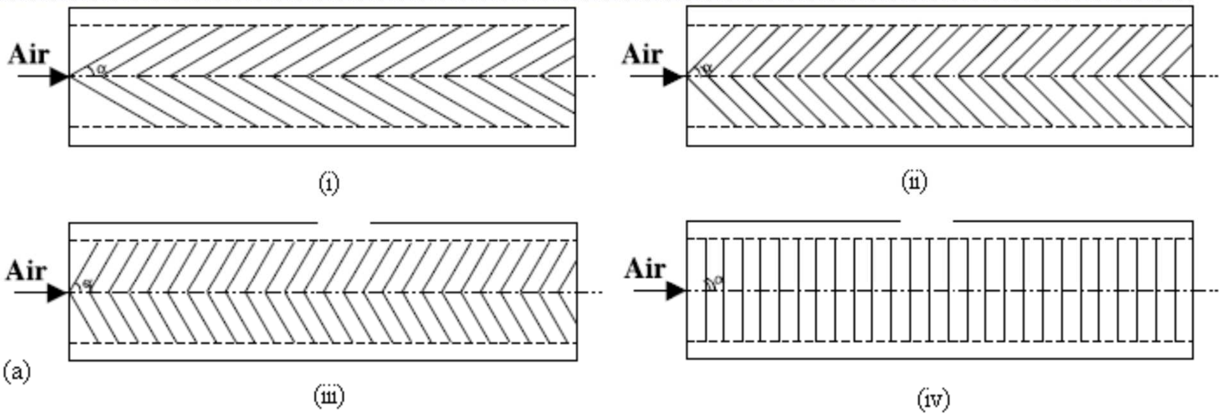
Investigators	**Roughness Geometry**	**Value of (p/e) for maximum heat transfer coefficient**
Abdul–Malik Ebrahimmomin, J.S.Saini,S.C. Solanki (2001)	V shaped rib roughness	10
RajendraKarwa, S.C.Solanki,J.S.Saini (2000)	Integral chamfered rib	7.9
J.L.Bhagoria, J.S.Saini,S.C. Solanki (2001)	Transverse wedge shape	7.52
M.K.Paswan et al	Wire mess Transverse &logitudial	9
M.M.Sahu, J.L.Bhagoria (2005)	90˚ broken transverse rib	20
A.R.Jaurker,J.S.Saini (2005)	Rib-grooved	6
Varun,R.P.Saini,S.K.Singal(2007)	Combination of inclined & transverse ribs	8
K.R.Aharwal, B.K.Gandhi, J.S.Saini (2007)	Gap in inclined continuous rib	10
S.V.Krmare, A.N.Tikekar (2008)	Metal rib grits roughness	17.5
ApurbaLayek, J.S.Saini,S.C. Solanki (2008)	Transverse chamfered rib-groove	10
S.K.Saini,R.P. Saini (2008)	Arc shaped wire	10
Thakur Sanjay Kumar,Vijay Mittal, N.S. Thakur, AnoopGautum (2011)	60°inclined continuous discrete rib	12
Sachin Choudhary, Varun, Manish Kumar Chouhan (2012)	Continuous M shaped ribs turbulators	25
A.M.Lanjewar, J.L.Bhagoria, R.M.Sarviya (2012)	W-Shaped	10
Pankaj Kumar & M.K.Paswan	Rhombus shape	16

Table 2.Relative roughness height (e/D) for a maximum value of heat transfer coefficient

Investigators	Roughness Geometry	Value of (e/d) for maximum heat transfer coefficient
Abdul–MalikEbrahimmomin, J.S.Saini,S.C. Solanki (2001)	V shaped rib roughness	0.034
RajendraKarwa, S.C.Solanki,J.S.Saini (2000)	Integral chamfered rib	0.041
J.L.Bhagoria, J.S.Saini,S.C.Solanki (2001)	Transverse wedge shape	0.033
M.M.Sahu, J.L.Bhagoria (2005)	90˚ broken tranvers rib	0.0338
M.K.Paswan & S.P .Sharma	Wire mess	0.0330
A.R.Jaurker,J.S.Saini (2005)	Rib-grooved	0.0363
Varun,R.P.Saini,S.K.Singal(2007)	Combination of inclined & transverse ribs	0.030
K.R.Aharwal, B.K.Gandhi, J.S.Saini (2007)	Gap in inclined continuous rib	0.0377
S.V.Krmare, A.N.Tikekar (2008)	Metal rib grits roughness	0.044
ApurbaLayek, J.S.Saini,S.C. Solanki (2008)	Transverse chamfered rib-groove	0.03
S.K.Saini,R.P. Saini (2008)	Arc shaped wire	0.0422
Sanjay Kumar,Vijay Mittal, N.S. Thakur, AnoopGautum (2011)	60°inclined continuous discrete rib	0.0498
Sachin Choudhary, Varun, Manish Kumar Chouhan (2012)	Continuous M shaped ribs turbulators	0.0777
A.M.Lanjewar, J.L.Bhagoria, R.M.Sarviya (2012)	W-Shaped	0.018
Pankaj Kumar & M.K.Paswan(2016)	Rhombus Shape	0.011

Table 3.Angle of attack (α) for a maximum value of a heat transfer coefficient for different types of artificial roughness

Investigators	Roughness Geometry	Value of (α) for maximum heat transfer coefficient
Abdul–MalikEbrahimmomin, J.S.Saini,S.C. Solanki (2001)	V shaped rib roughness	60°
J.L.Bhagoria, J.S.Saini,S.C. Solanki (2001)	Transverse wedge shape	90°
M.K.Paswan & S.P. Sharma	Wire mess	90^0
M.M.Sahu, J.L.Bhagoria (2005)	90˚ broken tranverse rib	90°
K.R.Aharwal, B.K.Gandhi, J.S.Saini (2007)	Gap in inclined continuous rib	60°
S.V.Krmare, A.N.Tikekar (2008)	Metal rib grits roughness	60°
ApurbaLayek, J.S.Saini,S.C. Solanki (2008)	Transverse chamfered rib-groove	60°
S.K.Saini,R.P. Saini (2008)	Arc shaped wire	($\alpha/90 = 0.3333$)
Thakur Sanjay Kumar,Vijay Mittal, N.S. Thakur, AnoopGautum (2011)	60°inclined continuous discrete rib	60°
Sachin Choudhary, Varun, Manish Kumar Chouhan (2012)	Continuous M shaped ribs turbulators	60°
A.M.Lanjewar, J.L.Bhagoria, R.M.Sarviya (2012)	W-Shaped	60°
Pankaj Kumar & M.K.Paswan	Rhombus Shape	90^0


Air
α
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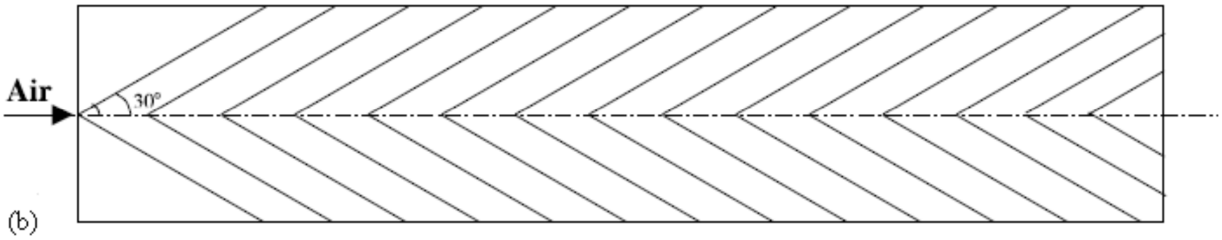
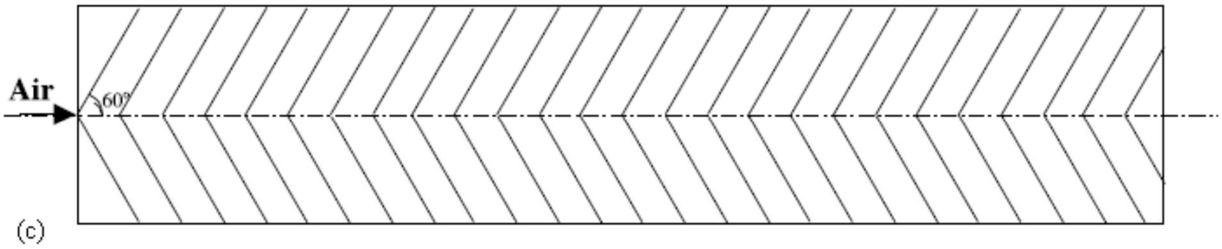
Air
α
(ii)
Air
α
(iii)
Air
α
(iv)

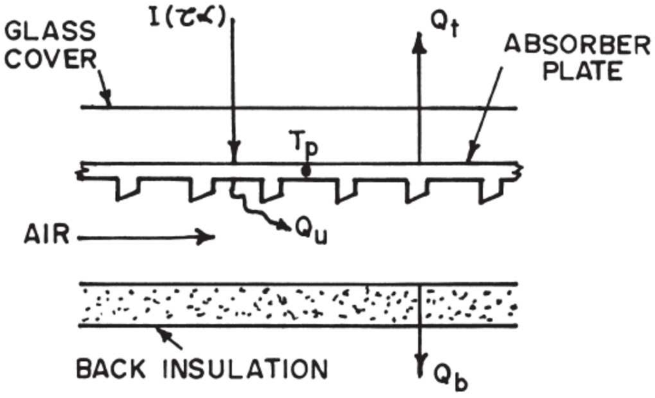
(a)


Air
30°

(b)


Air
60°

(c)


GLASS COVER
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ABSORBER PLATE
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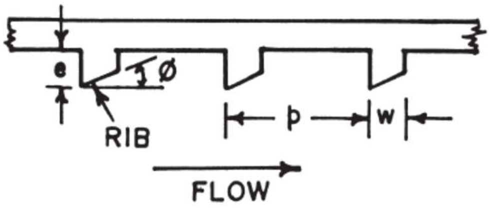
BACK INSULATION
Q_b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ISSN: 2277-9655
Impact Factor: 5.164
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Table 4.Correlations developed for heat transfer and friction factor for different roughness geometries

Momin,Saini,Solanki (2001)	V-Shaped rib roughness	Re –2500 –18000, (e/Dh)=0.02-0.034, α =30 – 90 ° ,pitch-10.	Nur = 0.067×(Re)0.888×(e/Dh)0.424 ×(α/60°)-0.077×exp[-0.782×(lnα/60°)2] Fr = 6.266×(Re)-0.425×(e/Dh)0.565 ×(α/60°)-0.093×exp[-0.719×(lnα/60°)2]
Karwa,Solanki,Saini (2000)	Integral chamfered rib	Pitch –4.58 –7.09,duct depths 21.8,21.5,16 mm,Re -3750-16350	For 7≤e+ <20 R=1.66e-0.0078φ(W/H)-0.4(p/e)2.695exp [-0.762{ln(p/e)}2](e+)-0.075 WhenW/H>7.75 use W/H=7.75 g= 103.77e-0.006φ(W/H)0.5(p/e)-2.56exp [0.7343{ln(p/e)}2](e+)-0.31 WhenW/H>10 use W/H=10 For 20≤e+≤60
M.K.Paswan & S.P Sharma (2002)	Wire mesh	Pitch- 1.5 -6.25,duct depth-20 mm, Re-3000-20000	R=1.325e-0.0078φ(W/H)-0.4(p/e)2.695exp [-0.762{ln(p/e)}2] WhenW/H>7.75 use W/H=7.75 g= 32.26e-0.006φ(W/H)0.5(p/e)-2.56exp [0.7343{ln(p/e)}2](e+)0.08
Bhagoria,Saini,Solanki (2001)	Transverse wedge shape	Re –3000-18000 , roughness height 0.075 –0.033 rib	Nur=1.89×10-4(Re)1.21(e/Dh)0.426(p/e)2.94 [exp{-0.71(ln(p/e))2}](φ/10)-0.018 [exp{-1.50(ln(φ/10))2}]
Varun,Saini,Singal (2007)	Combination of inclined & transverse ribs	Re-2000-14000,Pitch-5-13mm,W/H-10	Nu/Re1.213=0.0006×(p/e)0.0104 and Nu=0.0006×Re1.213×(p/e)0.0104 f/Re-0.3685=1.0858×(p/e)0.0114 and f=1.0858×Re-0.3685×(p/e)0.0104
Karmare&Tikekar (2008)	Metal rib grit roughness	Re-3600-17000,Pitch-15-17.5, e/Dh- 0.035-0.044	f=15.55×(Re)-0.26×(e/Dh)0.91×(l/s)-0.27 ×(p/e)-0.51for 3600 < Re < 17000 Nu=2.4×0-3×(Re)1.3×(e/Dh)0.42×(l/s)-0.146

			×(p/e)-0.27for 3600 < Re < 17000
Saini&Saini (2008)	Arc shaped wire	Re-2000-17000,Pitch-10,α/90-0.3333-0.6666,W/H-12	Nu=0.001047Re1.3186(e/d) 0.3772 (α/90)-0.1198 f=0.14408Re-0.17103(e/d)0.1765 (α/90)0.1185
Thakur Sanjay Kumar et al. (2011)	Continuous M shaped ribs turbulators	Re-3000-22000, Pitch-12.5-75, α-30-60°, e/D-0.037-0.0776	Nu=3×10-5 (Re)0.947(e/D)0.290(p/e)5.885 (d/w)0.115×exp[-1.237(ln(p/e))2] f=0.014Re-0.23(e/D)0.804(d/w)0.097 (p/e)4.516×exp(-
Pankaj Kumar & M.K.Paswan (2016)	Rhombus shape	Re-3000-18000,Pitch-18mm,duct depth-20 mm	

2. CONCLUSION

- This Paper reviews the investigation carried out by various investigators in order to enhance the heat transfer by use of artificial roughness.
- Use of artificially roughened surfaces with different type of roughness geometries of different shapes,sizes and orientation is found to be the most effective technique to enhance the heat transfer rate with little penalty of friction.
- Roughness in the form of ribs and wire matrix were mainly suggested by different investigators to achieve better thermal performance. Among all, rib roughness was found the best performer as far as thermal performance is concerned.
- Correlations developed for heat transfer and friction factor for solar air heater ducts having artificial roughness of different geometries for different investigators are also shown in tabular form. These correlations can be used to predict the thermal efficiency, effective efficiency and then hydraulic performance of artificial roughened.

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