Indian Journal of Agriculture Engineering (IJAE)
ISSN: 2582-9319 (Online), Volume-2 Issue-1, May 2022

Efficient Solar Air Heater Absorber Plate for Crop Drying Application

Gyaneshwar Sanodiya

Abstract*: Solar air heaters are commonly placed on farms to provide heat during the drying of croplands. This practice has been studied to see if solar air heaters can provide adequate heat to support the harvesting and drying of crops. The study revealed that solar air heaters can provide sufficient heat to support the drying of croplands and the harvesting of grain. However, solar air heaters are more efficient when their air flow and thermal capacity are equal. To be more economical, they should be designed with more efficient components such as reflectors and ducting systems. The air flow and the thermal capacity of the solar air are also affected by the duct system's low heat transfer coefficient. This can be increased by taking advantage of the air's restricted thermal capacity. Active and passive approaches can also be used to increase the HT coefficient of solar air heaters. In most cases, this method is more cost-effective than using an absorber plate. In most cases, the use of an active or passive approach can increase the air flow and the HT coefficient of solar air heaters. This CFD study focused on the link between the roughness element for solar air heater ducts and the HT capacity of the system.

***Keywords*: Solar Air Heater, Crop Drying, Solar Energy, Heat Transfer.**

I. INTRODUCTION

Due to the depletion of fossil fuel reserves, it is now more important than ever to explore and use alternate forms of energy. Solar energy is a promising long-term solution that can meet the world's energy needs. Due to the depletion of fossil fuel reserves, it is essential that we explore and use energy-related solutions as soon as possible. Solar energy is a promising long-term solution. Solar energy is a free and abundant source of energy that can provide clean and pollution-free electricity. It is also a renewable resource. Solar energy is an indigenous resource that can be used for various applications. Its conversion into thermal energy is the most efficient and simple method of using solar power. A solar air heater is the most commonly used collector device due to its simplicity. They are also the least expensive. Aside from solar power, solar air heaters are also used for various applications such as heating. Due to their simplicity, solar air heaters are commonly used for the heating of various areas [1-17]. They can also be used to provide heat to spaces with low temperatures. To make solar air heaters more financially feasible in the long run, their thermal efficiency must be enhanced. This step involves increasing the air flow through the duct system and the plate to improve the thermal efficiency of the device. An increase in the HT between the air flow and the plate can help boost the device's thermal efficiency. HT coefficients can be divided into two categories. Fig. 1 shows an ordinary flat solar collector. If solar radiation goes directly over the darkened protective surface of the highly absorbent, a large part of the vitality is absorbed and replaced in liquid tubes into the vehicle medium for capacity diversion or utilization. The underside of the safety board and both sides are covered from diminishing conduction [18-44].

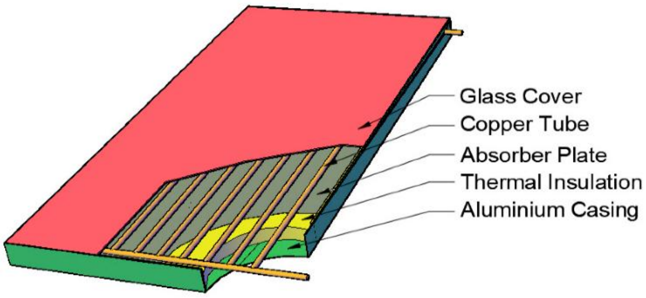

Fig. 1 Solar Air Heater

The active force techniques that are commonly used involve an acoustic field, a surface vibration, or an electric field. The use of a fluid field to improve a HT system has been around for over 80 years. These techniques are known to improve a HT system by using a combination of factors, such as an acoustic field and an electric field. The use of a fluid field and electric field to achieve this goal has been the subject of extensive research. Aside from physical surfaces, the techniques used for swirling flow involve adding fluid additives and using a variety of devices such as twisted tap inserts. To produce a swirling flow, the active methods need to have specific surface geometries. For over 140 years, researchers have been studying the various techniques that were used to improve a HT system (Fig. 2) [45-71].

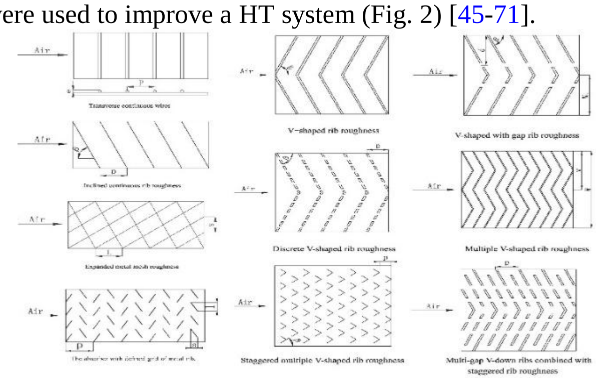

Fig. 2 Various ribs

An artificial roughness enhancement can be commonly used in forced convection HT to improve the turbulence near the HT surface.

Manuscript received on 28 March 2022 | Revised Manuscript received on 09 April 2022 | Manuscript Accepted on 15 May 2022 | Manuscript published on 30, May 2022.
***** Correspondence Author
Gyaneshwar Sanodiya*, Department of Mechanical Engineering, Oriental College of Technology, Bhopal (M.P), India. Email: gyan.sanodiya1@gmail.com

However, this method requires too much electricity to effectively move the air through the duct. In most cases, the use of artificial roughness has been widely adopted to improve the turbulence near the HT surface. However, this method usually consumes a high amount of electricity and requires a low power consumption to get done [72-76].

II. METHODOLOGY

If the solar air heater is designed to have a uniform air velocity, this can be achieved by introducing a pressure outlet condition that has a set pressure of 1.013×10^5 Pa. The temperature of the air in the duct is generally assumed to be 300 K. The design of the duct walls has been decided to apply the no-slip wall requirements and the impermeable boundary. It is necessary to provide a continuous flux of 1000W to the bottom wall in order to maintain the adiabatic wall conditions. The RNG k- model is used in the calculations. A finite volume approach is used to discretize the various governing equations of a given model. The solution is then segregated using the FV methodology. A second order upwind-biased scheme is then used to discretize the various governing equations. A commercial CFD software such as ANSYS FLUENT is used to complete the solution. The SIMPLE approach was chosen because it allows the user to combine the velocity and pressure in order to calculate incompressible flow. The dependent variable convergence conditions are 0.001. The ease of using the SIMPLE approach was also a reason why it was chosen. If the convergence criteria are not met, the solution is initiated using a first order upwind discretization scheme and then switched to a second order up wind discretization scheme. When the inlet air supply and the outlet air supply are connected, a uniform air velocity is produced. The adiabatic boundary condition is also observed. A uniform air velocity is also produced for an inlet air supply and a fixed outlet condition is established for a different outlet air supply.

III. RESULT AND DISCUSSION

A numerical study is carried out by, in order to obtain the results numerically. The selection of a turbulence model is critical for any kind of simulation. It is critical to conduct a thorough investigation of the heat transfer and flow characteristics. The optimum turbulence model for the simulation is chosen on the basis of this information. Two equation models and six turbulence models were investigated for the current simulation study, which included two equation-based models (Fig. 3).

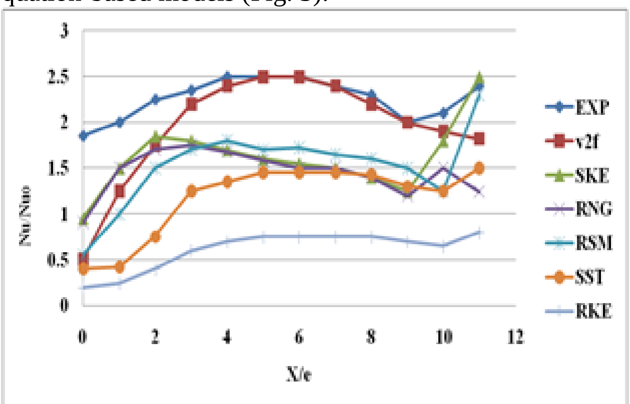

Fig. 3 Turbulence mode selection

Calculating the average Nu number involves looking at the whole test section, while calculating the pressure drop involves looking at the pressure drop at the inlet and outlet sections over the full length of the channel. According to the simulation results, as compared to a smooth duct without rib, both the heat transmission and the friction factor increase in a positive manner. The normalized *Nu* number, on the other hand, drops when the *Re* number increases (Fig. 4).

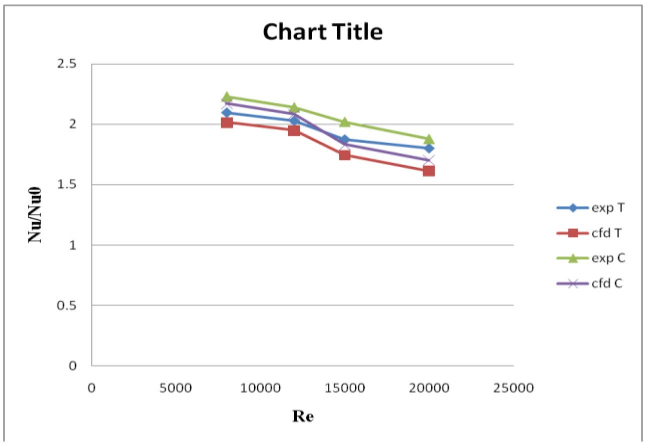

Fig. 4 Nu ratio for ribbed wall

It has been shown that when the Re number grows, the normalized friction factor (f/f_0) for both ribs increase as well. In contrast to former ribs, later ribs experience less of a rise in f/f_0, which makes them more suitable for applications where a reduced friction factor is needed at the expense of overall thermo hydraulic performance. According to the findings of the Nu/Nu_0 experiments and the CFD simulations, the maximum variation between the two is 10 percent for both ribs.

IV. CONCLUSION

In the article about solar air heater roughness, the conclusion is:

1) Artificial roughness on an air heater's surface enhances HT and overall thermal efficiency compared to a smooth surface.
2) Artificial roughness geometry of various forms, sizes, and orientations may be used to increase performance in many applications.
3) The researchers observed that artificial roughness increased the amount of pumping force needed. To improve thermal efficiency while reducing pumping power, ribbed solar air heaters must be constructed.
4) When applied to the solar air heater, the Renormalization-group K–model produces the best two-dimensional flow results, according to the findings of the calculations.
5) According to the simulation results, as compared to a smooth duct without rib, both the heat transmission and the friction factor increase in a positive manner.
6) The normalized *Nu* number, drops when the *Re* number increases.

Retrieval Number:100.1/ijae.C1507051322
DOI:10.54105/ijae.C1507.051322
Journal Website: www.ijae.latticescipub.com

Published By:
Lattice Science Publication

REFERENCES

1. Webb RL, Eckert ERG. Application of rough surfaces to heat exchanger design. International Journal of Heat and Mass Transfer. 1972;15(9):1647-58. [CrossRef]
2. Webb RL, Eckert ERG, Goldstein RJ. Generalized heat transfer and friction correlations for tubes with repeated-rib roughness. International Journal of Heat and Mass Transfer. 1972;15(1):180-4. [CrossRef]
3. Lewis MJ. Optimising the thermohydraulic performance of rough surfaces. International Journal of Heat and Mass Transfer. 1975;18(11):1243-8. [CrossRef]
4. Duffie JA, Beckman WA. Solar Engineering of Thermal Processes. New York: Wiley, 1980.
5. Patankar S. Numerical heat transfer and fluid flow. Boca Raton: CRC Press, 1980.
6. Webb RL. Performance evaluation criteria for use of enhanced heat transfer surfaces in heat exchanger design. International Journal of Heat and Mass Transfer. 1981;24(4):715-26. [CrossRef]
7. Prasad K, Mullick SC. Heat transfer characteristics of a solar air heater used for drying purposes. Applied Energy. 1983;13(2):83-93. [CrossRef]
8. Prasad BN, Saini JS. Effect of artificial roughness on heat transfer and friction factor in a solar air heater. Solar Energy. 1988;41(6):555-60. [CrossRef]
9. Cortés A, Piacentini R. Improvement of the efficiency of a bare solar collector by means of turbulence promoters. Applied Energy. 1990;36(4):253-61. [CrossRef]
10. Yadav AS, Shukla OP, Sharma A, Khan IA. CFD analysis of heat transfer performance of ribbed solar air heater. Materials Today: Proceedings. 2022;In press. [CrossRef]
11. Yadav AS, Shukla OP, Bhadoria RS. Recent advances in modeling and simulation techniques used in analysis of solar air heater having ribs. Materials Today: Proceedings. 2022;In press.
12. Yadav AS, Gattani A. Revisiting the influence of artificial roughness shapes on heat transfer enhancement. Materials Today: Proceedings. 2022;In press. [CrossRef]
13. Yadav AS, Dwivedi MK, Sharma A, Chouksey VK. CFD based heat transfer correlation for ribbed solar air heater. Materials Today: Proceedings. 2022;In press. [CrossRef]
14. Yadav AS, Agrawal A, Sharma A, Sharma S, Maithani R, Kumar A. Augmented artificially roughened solar air heaters. Materials Today: Proceedings. 2022;In press. [CrossRef]
15. Yadav AS, Agrawal A, Sharma A, Gupta A. Revisiting the effect of ribs on performance of solar air heater using CFD approach. Materials Today: Proceedings. 2022;In press. [CrossRef]
16. Shrivastava V, Yadav AS, Shrivastava N. Thermal performance assessment of greenhouse solar dryer. In: Kumar R, Pandey AK, Sharma RK, Norkey G, editors. Recent Trends in Thermal Engineering, Lecture Notes in Mechanical Engineering Singapore: Springer; 2022. p. 75-82. [CrossRef]
17. Kumar R, Verma SK, Mishra SK, Sharma A, Yadav AS, Sharma N. Performance Enhancement of SAH using Graphene/Cerium Oxide and Graphene -Black Paint Coating on Roughned Absorber Plate: A Comparative Study. Int J Vehicle Structures & Systems. 2022;14(2): 273-279. [CrossRef]
18. Alta D, Bilgili E, Ertekin C, Yaldiz O. Experimental investigation of three different solar air heaters: Energy and exergy analyses. Applied Energy. 2010;87(10):2953-73. [CrossRef]
19. Bhushan B, Singh R. A review on methodology of artificial roughness used in duct of solar air heaters. Energy. 2010;35(1):202-12. [CrossRef]
20. Hans VS, Saini RP, Saini JS. Heat transfer and friction factor correlations for a solar air heater duct roughened artificially with multiple v-ribs. Solar Energy. 2010;84(6):898-911. [CrossRef]
21. Karmare SV, Tikekar AN. Analysis of fluid flow and heat transfer in a rib grit roughened surface solar air heater using CFD. Solar Energy. 2010;84(3):409-17. [CrossRef]
22. Karwa R, Chauhan K. Performance evaluation of solar air heaters having v-down discrete rib roughness on the absorber plate. Energy. 2010;35(1):398-409. [CrossRef]
23. Promvonge P. Heat transfer and pressure drop in a channel with multiple 60° V-baffles. International Communications in Heat and Mass Transfer. 2010;37(7):835-40. [CrossRef]
24. Sun W, Ji J, He W. Influence of channel depth on the performance of solar air heaters. Energy. 2010;35(10):4201-7. [CrossRef]
25. Yadav AS, Shrivastava V, Sharma A, Sharma SK, Dwivedi MK, Shukla OP. CFD simulation on thermo-hydraulic characteristics of a circular tube having twisted tape inserts. Materials Today: Proceedings. 2021;47:2790-5. [CrossRef]
26. Yadav AS, Shrivastava V, Sharma A, Dwivedi MK. Numerical simulation and CFD-based correlations for artificially roughened solar air heater. Materials Today: Proceedings. 2021;47:2685-93. [CrossRef]
27. Yadav AS, Shrivastava V, Ravi Kiran T, Dwivedi MK. CFD-Based Correlation Development for Artificially Roughened Solar Air Heater. In: Kumar A, Pal A, Kachhwaha SS, Jain PK, editors. Recent Advances in Mechanical Engineering, Lecture Notes in Mechanical Engineering. Singapore: Springer; 2021. p. 217-26. [CrossRef]
28. Yadav AS, Shrivastava V, Dwivedi MK, Shukla OP. 3-dimensional CFD simulation and correlation development for circular tube equipped with twisted tape. Materials Today: Proceedings. 2021;47:2662-8. [CrossRef]
29. Yadav AS, Shrivastava V, Chouksey VK, Sharma A, Sharma SK, Dwivedi MK. Enhanced solar thermal air heater: A numerical investigation. Materials Today: Proceedings. 2021;47:2777-83. [CrossRef]
30. Yadav AS, Sharma SK. Numerical Simulation of Ribbed Solar Air Heater. In: Sikarwar BS, Sundén B, Wang Q, editors. Advances in Fluid and Thermal Engineering, Lecture Notes in Mechanical Engineering. Singapore: Springer; 2021. p. 549-58. [CrossRef]
31. Yadav AS, Gattani A. Solar thermal air heater for sustainable development. Materials Today: Proceedings. 2021;In press. [CrossRef]
32. Shrivastava V, Yadav AS, Shrivastava N. Comparative Study of the Performance of Double-Pass and Single-Pass Solar Air Heater with Thermal Storage. In: Kumar A, Pal A, Kachhwaha SS, Jain PK, editors. Recent Advances in Mechanical Engineering, Lecture Notes in Mechanical Engineering. Singapore: Springer; 2021. p. 227-37. [CrossRef]
33. Chouksey VK, Yadav AS, Raha S, Shrivastava V, Shrivas SP. A theoretical parametric analysis to optimize the bed depth of packed bed solar air collector. International Journal of Green Energy. 2021:1-11. [CrossRef]
34. Yadav AS, Singh DK, Soni G, Siddiqui DA. Artificial Roughness and Its Significance on Heat Transfer of Solar Air Heater: An Assessment. International Journal of Scientific Research and Engineering Development. 2020;3(2):1134-49.
35. Prasad R, Yadav AS, Singh NK, Johari D. Heat Transfer and Friction Characteristics of an Artificially Roughened Solar Air Heater. In: Saha P, Subbarao PMV, Sikarwar BS, editors. Advances in Fluid and Thermal Engineering, Lecture Notes in Mechanical Engineering. Singapore: Springer; 2019. p. 613-26. [CrossRef]
36. Yadav AS, Agrawal V. Renewable Energy Sources-An Application Guide. Republic of Moldova: LAMBERT Academic Publishing, 2018.
37. Qureshi TA, Yadav AS, Jain A. Recent alternative sources of energy-A brief review. RGI International Journal of Applied Science & Technology. 2017;12 & 13(01 & 02):70-1.
38. Dwivedi S, Yadav AS, Badoniya P. Study of Thin Walled Cone by Using of Finite Element Analysis in Deep Drawing. International Journal of Advanced Technology in Engineering and Science. 2017;5(5):587-91.
39. Yadav AS, Thapak MK. Artificially roughened solar air heater: A comparative study. International Journal of Green Energy. 2016;13(2):143-72. [CrossRef]
40. Yadav AS, Singh S. A CFD analysis of an artificially roughened solar air heater. RGI International Journal of Applied Science & Technology. 2016;10 & 11(01 & 02):1-6.
41. Yadav AS, Khan IA, Bhaisare AK. CFD Investigation of Circular and Square Sectioned Rib Fitted Solar Air Heater. International Journal of Advance Research in Science and Engineering (IJARSE). 2016;5(01):386-93.
42. Qureshi TA, Yadav AS. Heat transfer enhancement by swirl flow devices. International Journal of Current Engineering And Scientific Research. 2016;3(1):122-7.
43. Yadav AS, Bhagoria JL. Numerical investigation of flow through an artificially roughened solar air heater. International Journal of Ambient Energy. 2015;36(2):87-100. [CrossRef]
44. Yadav AS. CFD investigation of effect of relative roughness height on Nusselt number and friction factor in an artificially roughened solar air heater. Journal of the Chinese Institute of Engineers. 2015;38(4):494-502. [CrossRef]

45. Diani A, Mancin S, Zilio C, Rossetto L. An assessment on air forced convection on extended surfaces: Experimental results and numerical modeling. International Journal of Thermal Sciences. 2013;67:120-34. [CrossRef]
46. Chung HS, Lee GH, Nine MJ, Bae K, Jeong HM. Study on the Thermal and Flow Characteristics on the Periodically Arranged Semi-Circular Ribs in a Rectangular Channel. Experimental Heat Transfer. 2013;27(1):56-71. [CrossRef]
47. Choi EY, Choi YD, Lee WS, Chung JT, Kwak JS. Heat transfer augmentation using a rib–dimple compound cooling technique. Applied Thermal Engineering. 2013;51(1-2):435-41. [CrossRef]
48. Arslan K, Onur N. Experimental investigation of flow and heat transfer in rectangular cross-sectioned duct with baffles mounted on the bottom surface with different inclination angles. Heat and Mass Transfer. 2013;50(2):169-81. [CrossRef]
49. Ansari MR, Gheisari R, Azadi M. Flow pattern change in horizontal rectangular laterally ribbed ducts through alteration of the ribs thickness and pitch. International Journal of Multiphase Flow. 2013;54:11-21. [CrossRef]
50. Wongcharee K, Eiamsa-ard S. Heat transfer enhancement by using CuO/water nanofluid in corrugated tube equipped with twisted tape. International Communications in Heat and Mass Transfer. 2012;39(2):251-7. [CrossRef]
51. Tang X, Zhu D. Experimental and Numerical Study on Heat Transfer Enhancement of a Rectangular Channel with Discontinuous Crossed Ribs and Grooves. Chinese Journal of Chemical Engineering. 2012;20(2):220-30. [CrossRef]
52. Smith E-a, Koolnapadol N, Promvonge P. Heat Transfer Behavior in a Square Duct with Tandem Wire Coil Element Insert. Chinese Journal of Chemical Engineering. 2012;20(5):863-9. [CrossRef]
53. Yadav AS, Thapak MK. Evaluation of Turbulence Intensity in Rectangular Duct of A Solar Air Heater Attached with Repeated Ribs. In: Verma A, Kumar A, Pradhan MK, editors. Advancements And Current Trends In Industrial, Mechanical And Production Engineering. New Delhi India: Excellent Publishing House; 2014. p. 108-15.
54. Yadav AS, Thapak MK. Artificially roughened solar air heater: Experimental investigations. Renewable and Sustainable Energy Reviews. 2014;36:370-411. [CrossRef]
55. Yadav AS, Bhagoria JL. A Numerical Investigation of Turbulent Flows through an Artificially Roughened Solar Air Heater. Numerical Heat Transfer, Part A: Applications. 2014;65(7):679-98. [CrossRef]
56. Yadav AS, Bhagoria JL. Heat transfer and fluid flow analysis of an artificially roughened solar air heater: a CFD based investigation. Frontiers in Energy. 2014;8(2):201-11. [CrossRef]
57. Yadav AS, Bhagoria JL. A numerical investigation of square sectioned transverse rib roughened solar air heater. International Journal of Thermal Sciences. 2014;79:111-31. [CrossRef]
58. Yadav AS, Bhagoria JL. A CFD based thermo-hydraulic performance analysis of an artificially roughened solar air heater having equilateral triangular sectioned rib roughness on the absorber plate. International Journal of Heat and Mass Transfer. 2014;70:1016-39. [CrossRef]
59. Thapak MK, Yadav AS. Analysis approaches of an artificially roughened solar air heater. Corona Journal of Science and Technology. 2014;3(2):23-7.
60. Thapak MK, Yadav AS. A comparative study of artificially roughened solar air heater. Corona Journal of Science and Technology. 2014;3(2):19-22.
61. Yadav AS, Qureshi TA. A CFD analysis of an artificially roughened solar air heater. TIT International Journal of Science and Technology. 2013;2(2):70-3.
62. Yadav AS, Bhagoria JL. Modeling and Simulation of Turbulent Flows through a Solar Air Heater Having Square-Sectioned Transverse Rib Roughness on the Absorber Plate. The Scientific World Journal. 2013;2013:827131. [CrossRef]
63. Yadav AS, Bhagoria JL. Heat transfer and fluid flow analysis of solar air heater: A review of CFD approach. Renewable and Sustainable Energy Reviews. 2013;23:60-79. [CrossRef]
64. Yadav AS, Bhagoria JL. A CFD (computational fluid dynamics) based heat transfer and fluid flow analysis of a solar air heater provided with circular transverse wire rib roughness on the absorber plate. Energy. 2013;55:1127-42. [CrossRef]
65. Yadav AS, Bhagoria JL. A CFD analysis of a solar air heater having triangular rib roughness on the absorber plate. International Journal of ChemTech Research. 2013;5(2):964-71. [CrossRef]
66. Yadav AS, Bhagoria JL. A CFD based heat transfer and fluid flow analysis of a conventional solar air heater. Journal of Engineering Science and Management Education. 2013;6(2):137-46.
67. Yadav AS, Bhagoria JL. Renewable Energy Sources-An Application Guide: Energy for Future. International Journal of Energy Science. 2013;3(2):70-90.
68. Yadav AS, Bhagoria JL. An Economic Analysis of a Solar System. Corona Journal of Science and Technology. 2013;2(1):3-7.
69. Yadav AS. Effect of half length twisted-tape turbulators on heat transfer and pressure drop characteristics inside a double pipe u-bend heat exchanger. Jordan Journal of Mechanical and Industrial Engineering. 2009;3(1):17-22.
70. Yadav AS. Experimental investigation of heat transfer performance of double pipe U-bend heat exchanger using full length twisted tape. International Journal of Applied Engineering Research. 2008;3(3):399-407.
71. Yadav AS. Augmentation of heat transfer in double pipe heat exchanger using full & half-length twisted tape inserts. CSVTU Research Journal. 2008;1(1):67-73.
72. Sharma N, Dev Gupta R, Sharma RC, Dayal S, Yadav AS. Graphene: An overview of its characteristics and applications. Materials Today: Proceedings. 2021;47:2752-5. [CrossRef]
73. Modi VA, Kumar P, Malik R, Yadav AS, Pandey A. Analysis of optimized turning parameters of Hastelloy C-276 using PVD coated carbide inserts in CNC lathe under dry condition. Materials Today: Proceedings. 2021;47:2929-48. [CrossRef]
74. Kumar P, Darsigunta A, Chandra Mouli B, Sharma VK, Sharma N, Yadav AS. Analysis of intake swirl in a compression ignition engine at different intake valve lifts. Materials Today: Proceedings. 2021;47:2869-74. [CrossRef]
75. Khan IA, Yadav AS, Shakya AK. Prognosis and diagnosis of cracks of cantilever composite beam by vibration analysis and hybrid AI technique. International Journal of Advanced Technology in Engineering And Science. 2016;4(1):16-23.
76. Bhaskar B, Bhadoria RS, Yadav AS. Transportation system of coal distribution: a fuzzy logic approach using MATLAB. Corona Journal of Science and Technology. 2013;2(3):20-30.

AUTHORS PROFILE

Gyaneshwar Sanodiya pursuing M. Tech. (Thermal Engineering) in the Department of Mechanical Engineering at Oriental Institute of Science & Technology, Bhopal (MP). He received his Diploma in Production Engineering from S V Polytechnic College Bhopal (MP). He received his Bachelor's Degree in Mechanical Engineering from Trinity Institute of Technology & Research, Bhopal (MP).

Retrieval Number:100.1/ijae.C1507051322
DOI:10.54105/ijae.C1507.051322
Journal Website: www.ijae.latticescipub.com

Published By:
Lattice Science Publication