Indian Journal of Production and Thermal Engineering (IJPTE)
ISSN: 2582-8029 (Online), Volume-4 Issue-1, December 2023

An Investigation into The Enhancement of Heat Transfer in Roughened Ducts of Solar Air Heaters

Gyaneshwar, Shikha Bhatt

***Abstract:** One of the most crucial tools for the process of transforming solar energy into thermal energy is a solar air heater. Thanks to its low cost and ease of installation, solar air heaters have quickly become one of the most popular and widely used methods of harvesting solar energy. Low convective heat transfer coefficient values between the absorber plate and the air significantly reduce the solar air heater's thermal efficiency. This is because absorber plates are used in solar air heaters. As a consequence, the absorber plate heats up, releasing a great deal of thermal energy into the surrounding space. This article presents the findings of a study that used computational fluid dynamics to investigate how heat is transferred in a solar air heater. The work for this project was done by the author (CFD). Researchers are now investigating the impact of the Re on the Nu. Commercial software known as ANSYS FLUENT 20 may be used to analyse and visualise the flow that happens across the duct of a solar air heater. This programme falls under the category of finite volume software. Using the programme helps get the job done.*

***Keywords:** Energy, Air Heater, Heat, Pressure, CFD*

I. INTRODUCTION

Solar air heaters are an essential piece of technology for properly converting solar energy into thermal energy. Solar air heaters have rapidly become one of the most popular and extensively used techniques of gathering solar energy due to the fact that they can be installed with relative simplicity and at a reasonable cost. The most common applications for solar air heaters are the heating of indoor spaces, the drying and curing of manufactured goods, and the seasoning of lumber; however, these heaters can also be put to use for drying and curing the concrete and clay components that are used in the construction of buildings. The typical components of a traditional solar air heater are an air flow between the absorber plate and the rear plate, insulation below the rear plate, a transparent cover on the exposed side, and a solid rear plate. In addition, the rear plate must be solid. Solar air heaters are perfect for folks who want to cut down on the amount of work they have to put in around the home as a result of its uncomplicated design that needs no maintenance. The absorber plate and the surrounding air both have a heat transfer coefficient that is very low, which is one of the factors that contributes to the overall inefficiency of the device. As a result of this property, the surfaces that are facing in the direction of the air current have atendency to take on a textured appearance [1-13].

Manuscript received on 25 October 2023 | Revised Manuscript received on 07 November 2023 | Manuscript Accepted on 15 December 2023 | Manuscript published on 30 December 2023.
***Correspondence Author(s)**
Gyaneshwar*, Department of Mechanical Engineering, Oriental College of Technology, Bhopal (MP), India. E-mail: gyan.sanodiya1@gmail.com, ORCID ID: 0009-0007-1256-1058
Shikha Bhatt, Department of Mechanical Engineering, Oriental College of Technology, Bhopal (MP), India.

In the beginning, Joule [14] introduced the idea of artificial roughness with the intention of enhancing the heat transfer coefficients for steam condensation in tubes. Since that time, a number of laboratory investigations have been carried out in order to learn more about the advantages of utilising artificial roughness in a variety of applications. Some examples of these applications include the cooling of gas turbines, electronic equipment, nuclear reactors, and compact heat exchangers. The creation of the first flow model is credited to Nunner [15] according to the majority of sources. He contrasted the two in order to investigate the relationship between the Prandtl number and the temperature profile of the flow in a smooth tube. Because of this, Nunner's method was considered to be groundbreaking. According to the suggested flow model, roughness lowers the thermal resistance of the wall zone where turbulence predominates, but it has very little to no impact in the region where viscosity predominates. This result is something that the model anticipates will take place. In order to provide a quantitative explanation for the rationale, the Prandtl analogy was used, with (f/fs)Pr serving as a stand-in for Pr. According to this model's projections, the value of St/Sts will decrease whenever the Prandtl number increases. In addition, the suggested flow model is predicated on the idea that there is a consistent connection between St and Sts in all of the different forms of roughness. Nikuradse [16] was the first person to do the calculation that determined the friction correlation for flow over sand-grain roughness. Nikuradse was able to articulate their results on the pressure drop by using R, which stands for the roughness function, and e+, which is the roughness Re. This presentation was built using the idea of wall similarity, which served as its foundation. They were able to identify a stunning relationship between the two sets of data by creating a heat-momentum transfer analogy relation for flow in a sand-grain roughened tube. This allowed them to discover the connection. This helped to shed light on how the two different data sets were related to one another. Both Dipprey and Sabersky [17] who were close to one another, forged this connection. Any roughness may be accommodated by the approach suggested by Dipprey and Sabersky as long as the requirement of wall similarity is fulfilled. Prasad and Mullick [18] proposed the idea that the amount of water that could be dried using solar energy could be increased by adding artificial roughness to the bottom of an absorber panel in the form of wire with a very small diameter. This would allow for the drying of a greater quantity of water. Several experimental studies of solar air heaters have been carried out in order to locate the geometrical configuration of roughness element that yields the best results. In these investigations, several roughness components of diverse forms, sizes, and orientations with regard to flow direction have been considered. Researchers have used roughness components of varied sizes, geometries, and orientations with regard to flow direction in their studies [19-50]. The use of CFD was used by Chaube et al [51]. to explore the impact that roughening had on heat transfer and fluid flow inside a solar air heater.

Kumar and Saini [52] used computational fluid dynamics to study the fluid flow and heat transfer characteristics of a solar air heater with an arc-shaped artificial roughness. Their research was published in the journal Solar Energy. The absorber plate was then given the artificial roughness to finish it off. Karmare and Tikekar [10] used computational fluid dynamics in order to analyse the flow and heat transfer in a solar air heater duct with metal grit ribs as the roughness features on the absorber plate. This was done so that they could find out more about the system (CFD). Yadav and Bhagoria [39] performed a computational examination of the heat transfer behaviour of a rectangular duct in a solar air heater. The absorber plate had a roughness in the shape of a triangle rib, and the duct was rectangular. The purpose of this project was to simplify the process of analysing the impacts of heat transfer in a laboratory setting. Computational fluid dynamics was used by Yadav and Bhagoria [12] in order to model the fluid movement and heat transfer that occurs inside a conventional solar air heater (CFD). The end result was a numerical prediction that was accurate. We were able to analyse the flow along the duct of a standard solar air heater by making use of a finite volume tool called ANSYS FLUENT 12.1 that is available for purchase on the commercial market. The findings of a thorough literature review of artificially roughened solar air heaters that was carried out by Yadav and Bhagoria [53] and analysed the outcomes of several computational fluid dynamics (CFD) studies were made available to the general audience [54-60]. As part of this investigation, attempts will be made to improve the model that is now used to predict the flow of air inside solar air heaters. A near-wall function for TKE is presently being developed, and its incorporation into the computational fluid dynamics system Fluent is expected to take place within the next few weeks. In order to discretize the governing equations, both the second order upwind approach and the SIMPLE algorithm were used. The following set of mathematical equations, which regulate fluid flow, heat transfer, and related processes, may be solved with the help of the FLUENT programme, which can be used to get the appropriate answers.

II. CFD MODELING AND ANALYSIS

The primary objective of computational fluid dynamics is the numerical calculation of the flow field (CFD). This is accomplished, in the case of fluid flows, by first getting a numerical solution to the governing equation, and then propagating that solution either in time or space. This equation may be used to model non-ideal and reactive fluid behaviour, in addition to steady and unsteady flows, compressible and incompressible flows, viscous and incompressible flows, and so on and so forth. It is possible to use it to simulate flows that are either constant or variable. The specific format that is used will be different from one academic field or subject to another. Processing time, the difficulty of the flow mechanics, and the complexity of the geometry are now utilised as criteria to determine what constitutes the state of the art in a particular field of research. The computational domain that was used for the CFD investigation may be shown in Figure 1. This domain had dimensions of 461 millimetres in length, 100 millimetres in width, and 20 millimetres in height. The computational domain for this investigation is a two-dimensional model of a solar air heater that has been purposefully roughened in order to simulate real-world conditions.

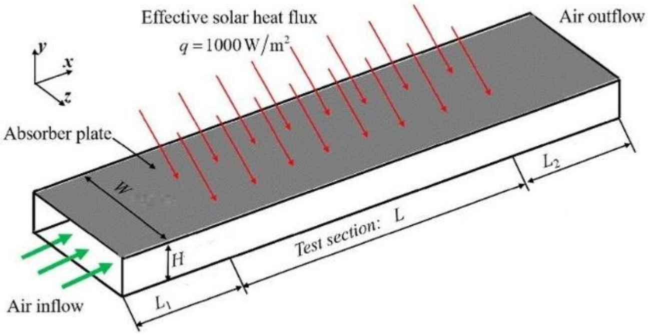

Figure: 1 2-D computational domain

After the computational domain has been selected, the construction of the non-uniform mesh may begin. In order to resolve the turbulent boundary layer, which is relatively thin in comparison to the height of the flow field, it is best to have more cells near the plate while designing this mesh. This is because the turbulent boundary layer is narrow. This is due to the fact that the plate is to blame for the generation of the turbulent boundary layer. The very turbulent boundary layer at such a low thickness is the cause of this phenomenon. After the mesh was produced, the boundary conditions were decided upon and stated. The first thing that has to be established is that the point of entrance will be located on the left side of the duct, and the point of exit will be located on the right side of the duct. The solar plate, the outflow length, and the intake length all act as restraints on the structure where they meet at the base. The peak is perilously situated on the very edge of the precipice. When speaking about a rectangular duct that only exists in two dimensions, the term "turbulator wall" is used to refer to all of the interior sides that comprise the duct as a whole. The application is helpful in bringing together the many components of the domain that were previously distinct. ICEM CFD 12.1, which was developed by ANSYS. In order for low-Reynolds-number turbulence models to be used, very fine grids will need to be constructed. Each cell in the original non-uniform quadrilateral mesh was 0.19 millimetres in size, and there were a total of 107,121 distinct quadrilateral cells in the mesh. It is not necessary to have a scale of this magnitude in order to resolve the laminar sublayer. During the course of the five steps that comprised the process of getting ready for the grid independence test, the total number of cells increased from 107,121 to 207,411. It has been shown that after the number of cells exceeds 161,568 cells, the value of either the Nu or the friction factor changes by less than one percent. The self-sufficiency of the grid may be measured in respect to these figures. In order to duplicate the results of a previous experiment, a large number of low Re turbulence models are used. The Standard k-model, the Renormalization-group k-model, the Realizable k-model, and the Shear stress transport k-model are some examples of these types of models. The results of the numerous experiments as well as the conclusions drawn from the various models are compared and contrasted here. As a consequence of the fact that the RNG k- model's predictions were more in line with the outcomes of the experiment when it was carried out in its intended manner, this option was chosen as the superior choice. Because of the limited space available for operation, it is likely that air, which is not subject to compression, is being used as the working fluid. The Re was used in the process of determining the flow's average entrance velocity so that we could compute it.

Retrieval Number: 100.1/ijpte.A2023124123
DOI: 10.54105/ijpte.A2023.124123
Journal Website: www.ijpte.latticescipub.com

Published By:
Lattice Science Publication (LSP)

Although the velocity boundary condition is compatible with the entry and might be used instead, the outflow boundary condition is the one that is preferred. In order to discretize the governing equations, both the second order upwind approach and the SIMPLE algorithm were used. The following set of mathematical equations, which regulate fluid flow, heat transfer, and related processes, may be solved with the help of the FLUENT programme, which can be used to get the appropriate answers.

III. RESULTS AND DISCUSSION

The relationship between the Re and the average Nu is seen in Figure 2. This effect is shown by varying amounts of relative roughness height (e/D), while maintaining the same roughness pitch (P). A higher average Nu, which is a measure of turbulence intensity, is the result of an increase in the kinetic energy of turbulence as well as the pace at which it dissipates. It's possible that the progression might be explained by the fact that the Nu rises with the Re.

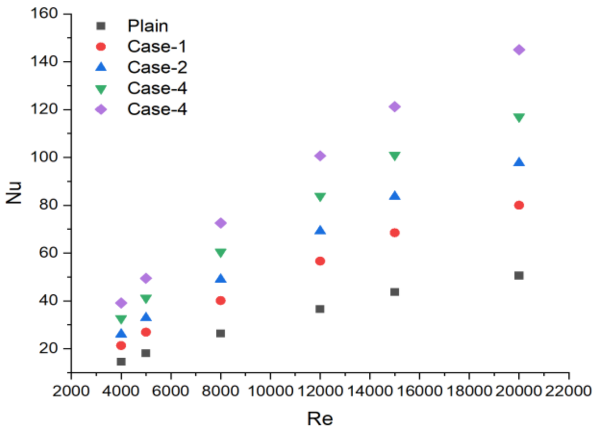

Figure: 2 Nu vs Re

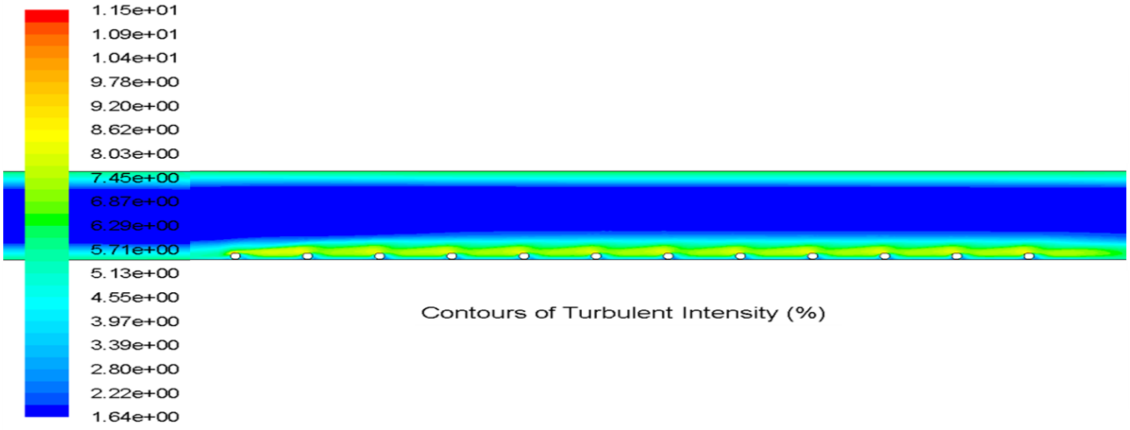

Figure: 3 Contour plot of Turbulence Intensity

There is a correlation between the Re and the difference in temperature that exists between the roughened and smooth ducts, and this temperature differential widens as the Re increases. If the roughness pitch is maintained fixed, then an increase in the ratio of the relative roughness height (e/d) will lead to a higher Nu. This is true even if the relative roughness height is decreased (P). This is due to the fact that the rib's heat transfer coefficient is highest at the following edge of a circular wire rib and lowest at the leading edge of the rib. When the relative roughness height was high, conditions that led to the formation of strong secondary flows included an increase in the frequency with which free shear layers reattached to one another. At a Re of 200000, a roughened duct with a relative roughness height of 0.06 may achieve a maximum Nu of 145. This is the greatest number that can be achieved. The roughened duct that has an e/d ratio of 0.021 generates the lowest Nu when the Re is 4000. It was demonstrated that with a relative roughness height of 0.06, the average Nu was amplified to its greatest extent at a Re 2.97 times greater than that of a smooth duct. This was the case because the Re is a measure of the resistance of the fluid moving through the duct. The evidence presented showed that this was really the situation.

Observing and analysing the contour plot of turbulence kinetic energy might help improve one's comprehension of the process that underlies the transfer of heat. A contour map displaying the observed turbulence may be seen in Figure 3, as is appropriate given the context of the figure. The flow field is rather turbulent between the rib and the wall, but between neighbouring ribs that are near to the main flow, there is a lot of turbulence. Therefore, there is a substantial association between the severity of the turbulence and an expanded ability to transmit heat.

IV. CONCLUSION

We examined the movement of fluid and the transmission of heat in a rectangular duct of a solar air heater that had a roughened wall composed of circular transverse wire ribs. This wall was designed to provide a textured surface. This objective was fulfilled with the assistance of a computational fluid dynamics (CFD) research that consisted of just two dimensions. Both the heat transfer coefficient and the friction factor have been the subject of research that investigates what happens when the Re and relative roughness pitch are changed. The predictions made by this numerical model were validated by comparing them to experimental data collected under flow circumstances that were comparable to those expected by the model. Computational fluid dynamics analyses were carried out on a flow with a Re ranging from 40000 to 20,000, and the results were discussed.

To begin, the CFD analysis that was utilised in this research may be believed since the findings that were predicted by the Renormalization-group (RNG) k- turbulence model are compatible with the data.

Retrieval Number: 100.1/ijpte.A2023124123
DOI: 10.54105/ijpte.A2023.124123
Journal Website: www.ijpte.latticescipub.com

Published By:
Lattice Science Publication (LSP)

This shows that the model is accurate. This result was highlighted in the most recent issue of the Journal of Computational and Fluid Dynamics (CFD). In addition to demonstrating that the RNG k- turbulence model is valid for usage in smooth ducts, we carried out a grid independence test in order to investigate the variance that was brought about by using a more extensive grid size. Second, when the Re increases, the average Nu increases as well. When the Re is larger than 200,000 and the relative roughness height is 0.06, the average Nu that may be determined is 145. When compared to a duct that is fully smooth, a rough duct results in an increase in the average Nu of 2.97 times for a roughness height of 0.06.

DECLARATION STATEMENT

Funding	No, I did not receive.
Conflicts of Interest	No conflicts of interest to the best of our knowledge.
Ethical Approval and Consent to Participate	No, the article does not require ethical approval and consent to participate with evidence.
Availability of Data and Material	Not relevant.
Authors Contributions	All authors have individual partnerships in this article.

REFERENCES

1. 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.
2. Qureshi TA, Yadav AS. Heat transfer enhancement by swirl flow devices. International Journal of Current Engineering And Scientific Research. 2016;3(1):122-7.
3. 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.
4. Thapak MK, Yadav AS. A comparative study of artificially roughened solar air heater. Corona Journal of Science and Technology. 2014;3(2):19-22.
5. Thapak MK, Yadav AS. Analysis approaches of an artificially roughened solar air heater. Corona Journal of Science and Technology. 2014;3(2):23-7.
6. 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.
7. Yadav AS, Bhagoria JL. Renewable Energy Sources-An Application Guide: Energy for Future. International Journal of Energy Science. 2013;3(2):70-90.
8. 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.
9. Yadav AS, Bhagoria JL. An Economic Analysis of a Solar System. Corona Journal of Science and Technology. 2013;2(1):3-7.
10. 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.
11. 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.
12. 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.
13. 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.
14. Joule JP. On the surface-condensation of steam. Philosophical Transactions of the Royal Society of London. 1861;151:133-60. https://doi.org/10.1098/rstl.1861.0009
15. Nunner W. Heat transfer and pressure drop in rough pipes. AERE Lib/Trans. 1958;786.
16. Nikuradse J. Laws of Flow in Rough Pipes, NACA TN 1292, 1950. English translation of VDI-Forschungsheft. 1933;361.
17. Dipprey DF, Sabersky RH. Heat and momentum transfer in smooth and rough tubes at various prandtl numbers. International Journal of Heat and Mass Transfer. 1963;6(5):329-53. https://doi.org/10.1016/0017-9310(63)90097-8
18. Prasad K, Mullick SC. Heat transfer characteristics of a solar air heater used for drying purposes. Applied Energy. 1983;13(2):83-93. https://doi.org/10.1016/0306-2619(83)90001-6
19. 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. Lecture Notes in Mechanical Engineering. Singapore: Springer; 2019. p. 613-26. https://doi.org/10.1007/978-981-13-6416-7_57
20. 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. Lecture Notes in Mechanical Engineering. Singapore: Springer; 2021. p. 227-37. https://doi.org/10.1007/978-981-15-9678-0_20
21. Shrivastava V, Yadav AS, Shrivastava N. Thermal performance assessment of greenhouse solar dryer. In: Kumar R, Pandey AK, Sharma RK, Norkey G, editors. Lecture Notes in Mechanical Engineering Singapore: Springer; 2022. p. 75-82. https://doi.org/10.1007/978-981-16-3132-0_8
22. Yadav AS, Agrawal A, Jain A, Saxena R, Kumar M, Sharma A, Singh S. Revisiting the Recent Advancements in the Design and Performance of Solar Greenhouse Dryers. In: Kumar A, Zunaid M, Subramanian KA, Lim H, editors. Lecture Notes in Mechanical Engineering. Singapore: Springer; 2023. p. 275-92. https://doi.org/10.1007/978-981-19-8517-1_20
23. 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. Lecture Notes in Mechanical Engineering. Singapore: Springer; 2021. p. 217-26. https://doi.org/10.1007/978-981-15-9678-0_19
24. 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.
25. Yadav AS, Alam T, Saxena R, Yadav RK, Kumar R, Sharma A, et al. Effect of Artificial Roughness on Heat Transfer and Friction Factor in a Solar Air Heater: A Review. In: Nayak RK, Pradhan MK, Mandal A, Davim JP, editors. Recent Advances in Materials and Manufacturing Technology. Singapore: Springer Nature Singapore; 2023. p. 355-64. https://doi.org/10.1007/978-981-99-2921-4_33
26. Absar Alam M, Kumar R, Yadav AS, Arya RK, Singh VP. Recent developments trends in HVAC (heating, ventilation, and air-conditioning) systems: A comprehensive review. Materials Today: Proceedings. 2023;In press. https://doi.org/10.1016/j.matpr.2023.01.357
27. Agrawal Y, Mishra A, Gautam A, Phaldessai G, Yadav AS, Vyas M. Performance analysis of photovoltaic thermal air collector having rectangular fins. Materials Today: Proceedings. 2023;84:6-15. https://doi.org/10.1016/j.matpr.2023.03.787
28. Agrawal Y, Yugbodh K, Ayachit B, Tenguria N, Kumar Nigam P, Gautam A, et al. Experimental investigation on thermal efficiency augmentation of solar air heater using copper wire for discrete roughened absorber plate. Materials Today: Proceedings. 2023;In press. https://doi.org/10.1016/j.matpr.2022.12.244
29. Alam MA, Kumar R, Banoriya D, Yadav AS, Goga G, Saxena KK, et al. Design and development of thermal comfort analysis for air-conditioned compartment. International Journal on Interactive Design and Manufacturing (IJIDeM). 2022;In press. https://doi.org/10.1007/s12008-022-01015-8
30. Goga G, Shahid Afridi M, Mewada C, Prasad J, Mohan R, Yadav AS, et al. Heat transfer enhancement in solar pond using nano fluids. Materials Today: Proceedings. 2023;In press. https://doi.org/10.1016/j.matpr.2022.12.238
31. Kumar A, Maithani R, Yadav AS, Sharma S. Effect of 450 protruded and dimpled rib height on the performance of triangular duct solar heat collector. Materials Today: Proceedings. 2022;63:253-8. https://doi.org/10.1016/j.matpr.2022.03.044
32. Kumar R, Anupam Rao Y, Yadav AS, Balu A, Prasad Panda B, Joshi M, et al. Application of phase change material in thermal energy storage systems. Materials Today:

Proceedings. 2022;63:798-804. https://doi.org/10.1016/j.matpr.2022.06.152
33. Kumar R, Verma SK, Mishra SK, Sharma A, Yadav AS, Sharma N. Performance Enhancement of Solar Air Heater using Graphene/Cerium Oxide and Graphene-Black Paint Coating on Roughened Absorber Plate. International Journal of Vehicle Structures and Systems. 2022;14(2):273-9. https://doi.org/10.4273/ijvss.14.2.23
34. Shrivastava V, Yadav AS, Sharma AK, Singh P, Alam T, Sharma A. Performance comparison of solar air heater with extended surfaces and iron filling. International Journal of Vehicle Structures and Systems. 2022;14(5):607-10. https://doi.org/10.4273/ijvss.14.5.10
35. 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.
36. 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;63:240-52. https://doi.org/10.1016/j.matpr.2022.02.549
37. Yadav AS, Agrawal A, Sharma A, Sharma S, Maithani R, Kumar A. Augmented artificially roughened solar air heaters. Materials Today: Proceedings. 2022;63:226-39. https://doi.org/10.1016/j.matpr.2022.02.548
38. Yadav AS, Alam T, Sharma A, Saxena R, Shrivastava V, Kumar R, et al. A revisit to recent development in enhancement of thermal and hydraulic performance of solar air heater. Materials Today: Proceedings. 2023;In press. https://doi.org/10.1016/j.matpr.2023.02.374
39. 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. https://doi.org/10.1080/01430750.2013.823107
40. Yadav AS, Dwivedi MK, Sharma A, Chouksey VK. CFD based heat transfer correlation for ribbed solar air heater. Materials Today: Proceedings. 2022;62:1402-7. https://doi.org/10.1016/j.matpr.2021.12.382
41. Yadav AS, Gattani A. Solar thermal air heater for sustainable development. Materials Today: Proceedings. 2022;60:80-6. https://doi.org/10.1016/j.matpr.2021.11.630
42. Yadav AS, Gattani A. Revisiting the influence of artificial roughness shapes on heat transfer enhancement. Materials Today: Proceedings. 2022;62:1383-91. https://doi.org/10.1016/j.matpr.2021.12.254
43. Yadav AS, Gupta S, Agrawal A, Saxena R, Agrawal N, Nashine S. Performance enhancement of solar air heater by attaching artificial rib roughness on the absorber Plate. Materials Today: Proceedings. 2022;63:706-17. https://doi.org/10.1016/j.matpr.2022.05.064
44. Yadav AS, Mishra A, Dwivedi K, Agrawal A, Galphat A, Sharma N. Investigation on performance enhancement due to rib roughened solar air heater. Materials Today: Proceedings. 2022;63:726-30. https://doi.org/10.1016/j.matpr.2022.05.071
45. Yadav AS, Prakash Shukla O, Singh Bhadoria R. Recent advances in modeling and simulation techniques used in analysis of solar air heater having ribs. Materials Today: Proceedings. 2022;62:1375-82. https://doi.org/10.1016/j.matpr.2021.12.242
46. 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. https://doi.org/10.1016/j.matpr.2021.03.385
47. 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. https://doi.org/10.1016/j.matpr.2021.02.549
48. 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. https://doi.org/10.1016/j.matpr.2021.02.759
49. 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. https://doi.org/10.1016/j.matpr.2021.03.396
50. Yadav AS, Shukla OP, Sharma A, Khan IA. CFD analysis of heat transfer performance of ribbed solar air heater. Materials Today: Proceedings. 2022;62:1413-9. https://doi.org/10.1016/j.matpr.2021.12.560
51. Chaube A, Gupta S, Verma P. Heat transfer and friction factor enhancement in a square channel having integral inclined discrete ribs on two opposite walls. Journal of Mechanical Science and Technology. 2014;28(5):1927-37. https://doi.org/10.1007/s12206-014-0143-1
52. Kumar S, Saini RP. CFD based performance analysis of a solar air heater duct provided with artificial roughness. Renewable Energy. 2009;34(5):1285-91. https://doi.org/10.1016/j.renene.2008.09.015
53. 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. https://doi.org/10.1007/s11708-014-0297-7
54. Agrawal Y, Bhagoria JL, Gautam A, Sharma A, Yadav AS, Alam T, et al. Investigation of thermal performance of a ribbed solar air heater for sustainable built environment. Sustainable Energy Technologies and Assessments. 2023;57:103288. https://doi.org/10.1016/j.seta.2023.103288
55. 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;19(07):775-85. https://doi.org/10.1080/15435075.2021.1961263
56. Dash AP, Alam T, Siddiqui MIH, Blecich P, Kumar M, Gupta NK, et al. Impact on Heat Transfer Rate Due to an Extended Surface on the Passage of Microchannel Using Cylindrical Ribs with Varying Sector Angle. Energies. 2022;15(21):8191. https://doi.org/10.3390/en15218191
57. Kumar A, Maithani R, Ali MA, Gupta NK, Sharma S, Alam T, et al. Enhancement of heat transfer utilizing small height twisted tape flat plate solar heat collector: A numerical study. Case Studies in Thermal Engineering. 2023;48:103123. https://doi.org/10.1016/j.csite.2023.103123
58. Kumari N, Alam T, Ali MA, Yadav AS, Gupta NK, Siddiqui MI, et al. A Numerical Investigation on Hydrothermal Performance of Micro Channel Heat Sink with Periodic Spatial Modification on Sidewalls. Micromachines. 2022;13(11):1986. https://doi.org/10.3390/mi13111986
59. Yadav AS, Alam T, Gupta G, Saxena R, Gupta NK, Allamraju KV, et al. A Numerical Investigation of an Artificially Roughened Solar Air Heater. Energies. 2022;15(21):8045. https://doi.org/10.3390/en15218045
60. Yadav AS, Sharma A. Experimental Investigation on Heat Transfer Enhancement of Artificially Roughened Solar Air Heater. Heat Transfer Engineering. 2022;44(7):624-37. https://doi.org/10.1080/01457632.2022.2079048

AUTHORS PROFILE

Gyaneshwar, pursuing M. Tech. (Thermal Engineering) in the Department of Mechanical Engineering at Oriental College of 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).

Shikha Bhatt done ME in Thermal engineering from Govt Engineering College Jabalpur and BE from Govt Engineering College Ujjain. She has three-year experience in teaching. Currently she is working as an Assistant Professor in Mechanical Engineering Department at Oriental College of Technology Bhopal (MP).