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A Comprehensive Review on Solar Air Heater Heat-Transfer and Friction Characteristics

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Abstract

Creating artificial turbulence by roughening the surface of a fully formed turbulent flow is an efficient method to enhance the rate of heat transfer. The roughness geometries on the artificially roughened solar air heater duct were found to have an effect on heat transmission and friction properties. In this paper, roughness arrangements and geometries are investigated in order to enhance the heat transmission capacity of the solar air heater duct. This study investigates how to make the absorber plate of solar air heaters artificially rough by adding repeated ribs, or just rib roughness (SAHs). When it comes to rib surface roughness, there are many different types to choose from. These ribs are put through their paces to determine whether their design has improved and, as a result, if the results have changed. This article has covered many of the potential determinants of SAH efficacy. HT mechanics and smooth movement throughout the rib cage is the subject of this study. Numerous recent developments in the roughness of the SAH repeating ribs have been made.

Keywords: Sustainability; Heat Transfer; Solar air heater; Environment; Nussel number; Ribs; Reynolds number; Efficiency

Introduction

To put it simply, energy is the capacity to do labor. In the cosmos or on our earth, it is the most powerful force. Mechanical energy, electrical energy, chemical energy, radiation energy, and a slew of other types exist [1]. This kind of radiant energy is emitted by the sun and is referred to as solar energy. Solar energy is the process of using heat or radiant energy from the sun to generate electricity. Natural gas provides an endless supply of cheap and clean energy. Many advantages come with using solar energy, including the fact that it is a renewable resource and requires no upkeep. Solar energy is utilized in a wide range of products, from solar water heaters to solar thermal power plants to solar cookers to solar pumps to solar power plants. SAH devices are used in the construction industry for heating interior rooms, heating of building walls, and so on. They may also be used in the home to pre-heat furnaces and dryers [2].The world seems to be on the brink of an energy crisis due to rapid population growth and rising living standards. In order to fulfill the needs of the next years, traditional energy sources like coal, petroleum, and natural gas are being phased out at an alarming rate. As a consequence, finding new sources of alternative energy is becoming more important. One of them is solar energy, which is both cheap and plentiful. Among the many ways that solar energy has been put to use, there are the following thermal ones. Turning solar energy into thermal energy for heating applications such as agricultural drying, wood seasoning, household heating, and industrial curing is the simplest and most efficient way to utilize solar energy [3]. Figure 1 A solar-powered air heater's duct harnesses incoming solar energy to generate heat, which is then transferred to a fluid running through the collector (usually air or water). Because of the absorber plate's low heat transfer coefficient, the solar air heater's biggest drawback is its poor thermal efficiency. In order to enhance the rate of heat transfer, increase the absorber plate's surface area or convective heat transfer coefficient by adding artificial roughness to the bottom.

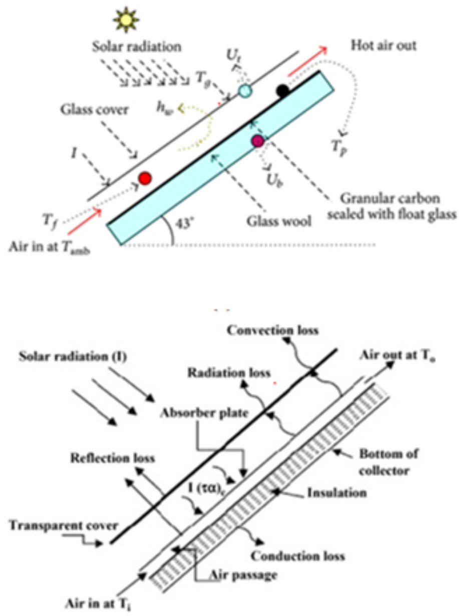

Figure 1: Typical solar air heater.

Because of its simple and low-cost construction, the Solar Air Heater (SAH) is widely used Figure 1. A solar air warmer utilizes solar power to warm the air. These heaters utilize absorbent surfaces or plates to gather solar energy from the sun's surface and use it to warm the air flowing over them. In addition to heating interior areas, solar air heaters may also be used to season wood or heat industrial operations [4]. Solar air heaters have poor heat or thermal energy transportation between the absorber layer and fluid flow because of low thermal efficiency and a low convective heat transfer coefficient produced by the development of a very thin laminar viscous sub-layer on the absorber surface. Thus, the solar air heater's overall efficiency is poor, but it may be improved by generating or altering the boundary layer formed on the absorber surface. Fluid, surface, and chemical enhancement methods are well-known theoretical or practical approaches for altering boundary layers. The use of fins or roughening the absorber surface has been studied extensively, and it is one of the most common methods. Smooth absorber plates and surfaces perform poorly thermally. Surface roughening methods such as creating ribs and grooves over the surface of the air heater help enhance thermal performance and efficiency by dividing and breaking up the laminar viscous layer formed at the boundary layer. Gas turbines and nuclear reactors, for example, both employ artificial roughness. Artificial roughness increases efficiency and heat transfer rate by inducing flow dissociation and reattachment between consecutive ribs or grooves. An air heater's ability to transmit heat is improved, but at the cost of increased friction and a lower heat transfer coefficient (*i.e*., power penalty). This has led to many experiments and research on different rib types, sizes, and configurations, all with the aim of improving the overall efficiency of air heaters by reducing friction value and power penalty, with positive results. A layer's artificial boundary roughness can be achieved by sandblasting the surface, creating grooves, ribs, or wire geometry in the surface, and fixing ribs of various shapes, sizes and orientations in accordance with the flow direction, such as circular, rectangular, square, V-shaped ribs, and so on. Scientists are doing a number of CFD research on roughness in solar air heaters in order to find the best arrangement for roughness element geometry. The purpose of this article is to look at several CFD studies done to enhance solar air heater heat transmission [5].

Literature Review

Solar energy may be turned to thermal energy using a variety of devices, including a solar air heater. As well as room heating, solar air heaters may be used for curing/drying concrete/clay construction components, as well as seasoning wood and other industrial goods. Simple in construction, solar air heaters are very low maintenance. However, the absorber plate-to-air heat transfer coefficient is poor, resulting in reduced efficiency. An artificially roughened heat transfer surface may help break up a laminar sub-layer, which is why the heat transfer coefficient is so low. A solar-powered air heater warms the air by harnessing the power of the sun's rays [6]. The efficiency of the solar air heater determines how quickly solar energy is converted to heat, and this efficiency may be improved by roughening the absorber plate's surface artificially. The impact of varied roughness geometries on heat transmission and friction factor characteristics was studied in several researches. Effectiveness, thermo hydraulic performance parameter, and energy efficiency are all ways to measure the thermo-hydraulic performance of a solar air heater [7]. Geometries for artificial roughness and improving the performance of solar air heaters were investigated in this research. It was. To find out how much rib roughness affects solar air heater performance, scientists have conducted a slew of experiments on heat transmission and flow properties. In order to enhance the thermal performance of the solar air heater for drying, [8] used tiny diameter wire connected to the bottom of the absorber plate. Roughness pitch and roughness height were tested for their impact on heat transmission and friction, respectively. It has been examined the transverse rib roughness using tiny diameter wires in a solar air heater duct. For optimum heat transfer rates, the free shear layer between successive ribs, researchers found that the roughness pitch and height should be carefully chosen to have maximum numbers of reattachment sites. The impact of transverse and inclined wire roughness on the fluid flow parameters of a solar air heater duct was studied. Researchers found that when air passes over an inclined rib, it creates secondary flow cells that speed up the main flow [9]. This produces more wall turbulence, which enhances heat transmission. Novel V-shaped ribs affixed to the duct's bottom as an artificial roughness. Higher Nusselt numbers and friction factors were found when rough absorber plates were compared to those with smooth absorber plates due to flow separations, reattachments, and secondary flow production. Reynolds number was observed to increase the Nusselt number by 1.14 times over roughened plate with inclined ribs and 2.30 times over a smooth plate at a relative roughness height of 0.034 and an attack angle of 60 degrees [10].

(CFD) is the use of computer-based simulation to analyze systems, including fluid movement, heat transport, and other phenomena like chemical reactions. There are many industrial and non-industrial uses for this technology. Many specialists are doing CFD study on roughness for solar air heaters in order to get the optimal arrangement of roughness element geometry. According to the fluid flow and heat transfer of a typical solar air heater may be calculated using Computational Fluid Dynamics (CFD) [11]. The effects of Reynolds number on heat transmission and friction factor were investigated. The friction factor decreases when the Nusselt number increases in response to an increase in Reynolds number. Investigated the heat transmission and flow friction characteristics of a rectangular solar air heater duct with triangular rib roughness on the absorber plate using numerical modeling [12]. The highest Nusselt number was discovered to have a relative roughness pitch of 10. New research has utilized a 2-dimensional CFD simulation to investigate heat transfer and fluid flow behavior in a solar air heater rectangular duct with one roughened wall and circular transverse wire rib roughness. The effects of roughness eight, Reynolds number, relative roughness pitch, roughness pitch, and relative roughness height on heat transfer coefficient and friction factor were investigated Figure 2 [13].

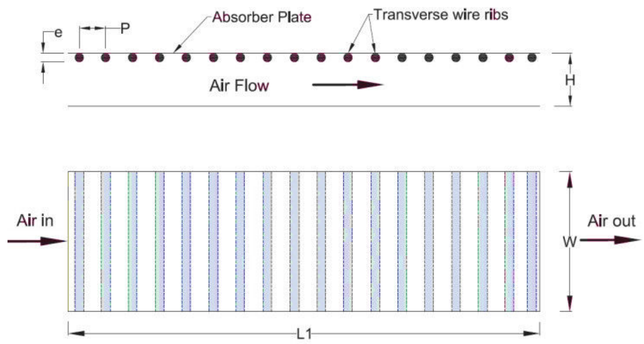

Figure 2: Circular transverse wire rib roughness.

In their study of the literature, it has been found that CFD was widely utilized in the development of solar air heaters. The optimum turbulence model for use in the construction of a solar air heater was determined via a Computational Fluid Dynamics (CFD) examination in this study utilized CFD to investigate fluid flow and heat transmission in a rectangular solar air heater pipe [14]. CFD As a roughness characteristic, a circular rib was utilized. In connection to rib pitch and Reynolds number, the heat transfer coefficient and friction factor were studied. It used two-dimensional CFD to investigate four distinct rib roughness configurations and six different Reynolds numbers spanning from 3800 to 18,000 for a solar air heater with square-sectioned transverse rib roughness on the absorber plate. For further details, see Figure 3.

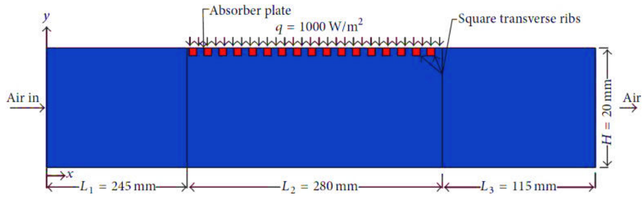

Figure 3: Computational domain.

Diagrams of turbulent kinetic energy, turbulent intensity, and pressure contours were shown in a solar air heater with deliberately roughed surfaces. Scholars utilized computational fluid dynamics to better understand fluid flow and heat transmission in the rectangular duct of a solar air heater (CFD). Both of the heat transfer coefficient and the friction factor were found to be significantly affected by the Reynolds number focused on three approaches or tactics for resolving the fluid flow and heat transfer issue in a deliberately roughened solar air heater [15]. The goal of this study was to evaluate several methods to dealing with fluid flow and heat transfer issues in a solar air heater with artificially uneven surfaces used the intentionally roughened solar air heater to calculate two-dimensional incompressible Navier–Stokes flows across important Reynolds number ranges of 3800 to 18,000. As roughness elements, twelve alternative equilateral triangular sectioned rib configurations (P/e=7.14–35.71 and e/d=0.021–0.042) were utilized. The optimum ruggedness element design for a synthetically roughed solar air heater was investigated in Figure 4.

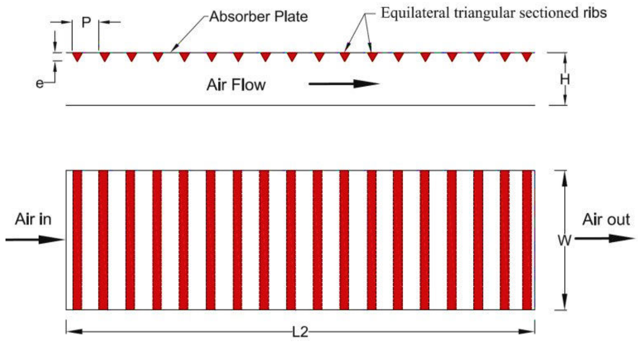

Figure 4: Equilateral triangular sectioned rib.

Researchers performed study to better understand the heat transmission and fluid flow behavior of fully developed turbulent flow in a rectangular duct with repeated transverse square-sectioned rib roughness on the absorber plate. The ansys fluent (version 12.1) commercialized finite-volume CFD code was used to model turbulent airflow via a purposefully roughed Solar Air Heater (SAH). The optimum thermo-hydraulic performance parameter for the square-sectioned transverse rib roughened duct was determined to be P/e=10.71 and e/D=0.042 for the studied range of parameters. Researchers used a roughened solar air heater (duct aspect ratio, AR=5) to examine the impact of rib (circular sectioned) spacing on average Nusselt number and friction factor. Transverse ribs with round portions were installed on the bottom of the duct's top, i.e., the absorber plate. At a Reynolds number of 15000, the thermo-hydraulic performance parameter P/e=10.71 was determined to be optimum for the studied range of values. The thermo-hydraulic performance of solar air heaters with deliberately roughened surfaces was investigated by a team headed. A variety of factors influence the roughness components. The repeating rib kind of roughness geometry, on the other hand, was the most preferred for solar air heaters. Turbulent flow was discovered to be produced by semicircular sectioned transverse rib roughness on the surface of a solar air heater. We can solve the transport equations using a set of governing equations thanks to the finite element technique (Figure 5). For a relative roughness height of 0.042, the thermo hydraulic performance measure gets the highest value [16].

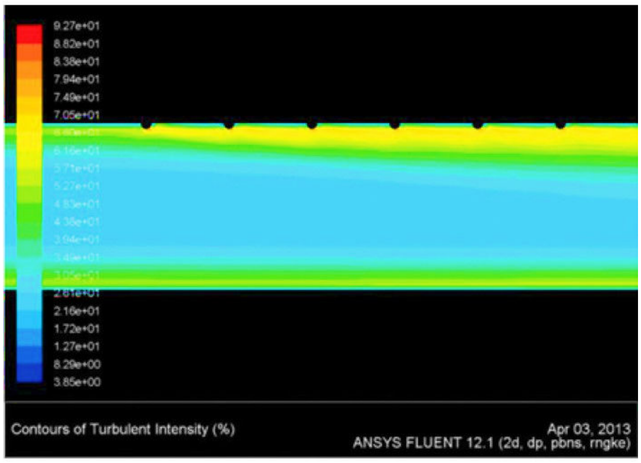

Figure 5: Contour plot of turbulent intensity.

According to research, solar air heaters may benefit from artificial roughness to improve performance via experimental methods. In 38 experimental experiments, researchers studied solar air heaters roughened using various types of roughness geometry. In the rectangular solar air heater duct investigated, the roughness components supplied on the moistened side of the bottom wall had the largest impact on the turbulence intensity. The impact of roughness on turbulence intensity was studied for Reynolds numbers ranging from 3000 to 18000. It was discovered that a rib-roughened rectangular duct surface generates more turbulence than a smooth one used numerical analysis to evaluate the heat transmission and flow friction characteristics of an artificially rough surfaces solar air heater with square-sectioned transverse ribs installed on the bottom of the top wall. Researchers found the relative roughness pitch when they compared the average Nusselt number, average friction factor, and the Thermo Hydraulic Performance Parameter (THPP) with the average Nusselt number, average friction factor, and the Thermo Hydraulic Performance Parameter (THPP) (Figure 6). Using P/e 10.71 ribs with a THPP of 1.82 resulted in the highest THPP [17].

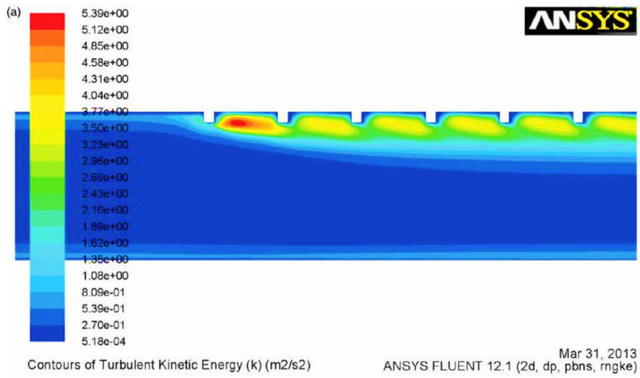

Figure 6: The contour plot of turbulent kinetic energy.

A solar air heater having circular-sectioned transverse rib roughness (AR=5:1) was artificially roughened using Computational Fluid Dynamics (CFD) to study the impact of comparative roughness height on Nusselt number and friction factor. The finest thermal enhancement factor was found for e/D=0.042, and it's about 1.635 for the conditions investigated (Figure 7).

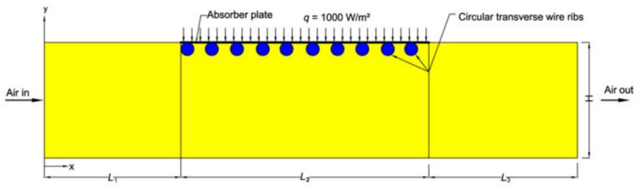

Figure 7: Schematic of 2D computational domain.

Researchers utilized two dimensional CFD simulations with rough surfaces walls and circular and square rib roughness to investigate thermal performance and fluid flow behavior in a rectangle duct of solar air heaters. The impacts of Reynolds number and relative roughness pitch on heat transfer coefficient and friction factor were investigated. Circular ribs had thermal enhancement values ranging from 1.42 to 1.74, whereas square ribs had thermal enhancement factors ranging from 1.51 to 1.762 examined the roughness geometries used to improve heat transmission in solar air heaters in detail. In terms of thermo-hydraulic performance characteristics, the authors compared the thermo-hydraulic performance of 21 distinct artificial roughness geometries connected to a solar air heater's absorber plate used Computational Fluid Dynamics (CFD) to examine a simple rectangular duct with simulated irregularity on the absorber plate. Both the heat transfer coefficient and the friction factor were found to be significantly affected by the Reynolds number. The air flow via the solar air heater ducts was evaluated and shown using a limited-edition commercial bundle of ansys fluent. The friction factor decreases when the Nusselt number increases in response to an increase in Reynolds number investigated changes made to the absorber plate of solar air heaters to increase turbulence and heat transfer rate, and therefore efficiency. Despite the fact that the majority of these absorber plate changes improved efficiency by losing pumping power owing to a higher friction factor, they were nevertheless utilized because of the higher efficiency they offered for example, demonstrated how enhanced thermo-hydraulic performance on absorber plates influences chamfer rib roughness on plate performance. This study utilized roughness pitches ranging from 7.143 to 17.857, roughness heights ranging from 0.042 to 0.047, and Reynolds numbers ranging from 3800 to 18000. The impact of relative roughness pitch and Reynolds number on the heat transfer enhancement and friction properties of the chamfered rib was investigated and recorded [18].

In a solar-powered air warmer, found that roughening the bottom of the observer surface increased the rate at which heat was transmitted. In a SAH pipe with a symmetrical triangular shaped transverse rib, CFD is utilized to assess the warm course through convection and the grinding factor. The CFD programmer ansys fluent was used to compute the findings. Extreme Nu and f values of 2.94 and 3.27 were found in this investigation. An equilateral triangular transverse ribbed surface Solar Air Heater (SAH) is numerically modeled [19].

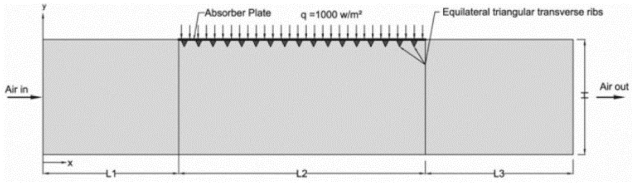

Figure 8: 2D computational domain.

Thermal and flow parameters are studied using ansys fluent 12.1. To connect pressure and speed, a straightforward technique was used. The model was simulated using a second-order upwind discretization technique and a Re Normalization-Group (RNG) k-e (Figure 8). A THF of 1.99 was determined to be the optimal value for thermal performance improvement. For rib roughened solar air heaters, provide a new CFD-based correlation. Pitch, which ranged from 10 to 25 mm, and Reynolds number, Re, which ranged from 3800 to 18,000, were used in the research. To create correlations, we utilized a linear stepwise regression technique. There is a 95% confidence interval around the proven relationships for all of the Nur and fr data. New CFD-based correlations for ribbed roughened solar air heaters were established. A SAH absorber panel with round ribs was investigated as a solar air heater. Artificially roughened solar air heater equations correctly predict all friction factor and Nusselt number data to within 5% of relative absolute variations [20].

A study found that adding ribs to the SAH's smooth plates improved the heat-transfer coefficient. As part of the numerical analysis, semi-circular rib shapes were scrutinised. A semi-circular rib with a pitch distance of P=15 mm exhibited the best Nusselt number and the greatest gradual reduction in friction factor, according to the findings of this study [21-22].

Conclusion

In the present study, several solar air heater duct scientists offered various types of roughness geometries of various sizes. A solar air heater duct with artificial unevenness enhances performance and reduces size while increasing heat transfer rate. As a consequence, future generations of artificially roughened solar air heaters will definitely increase their efficiency. To improve the heat transfer rate and thermal efficiency of a Solar Air Heater (SAH), many studies have been performed numerically. These studies include adding or generating artificial roughness to the absorber's border or absorber plate. A number of studies on the artificial roughness of absorber plates have concluded that many researchers and scientists have developed ribs or grooves of various shapes, sizes and orientations such as rectangle or square rib, triangular or triangular groove, etc. with various patterns of arrangement like longitudinal, radial or etc. on the artificial roughness of absorber plates. As high a heat convective coefficient as possible to a study of an article on solar air heater roughness led to the following conclusion: Air heaters with artificially roughened surfaces have better heat transfer and overall thermal efficiency than those with smooth surfaces. Experiments have shown that artificial roughness geometry may be used to enhance performance in a range of shapes, sizes, and alignments. The use of artificial roughness has been shown to increase pumping power requirements as a result of a higher frictional value. Because of this, it's better to construct a solar air heater with greater thermal efficiency while using less pumping power. Based on our research, solar air heaters have undergone a lot of development utilizing an experimental approach. In addition, a few pieces of study on solar air heater CFD analysis are revealed in this review. Thermo-hydraulic efficiency of solar air heaters with a roughened surface has been predicted or quantified by many researchers who have developed connections and formulae. By creating vortices in both the upstream and downstream streams (i.e., upstream and downstream) of the rib and reconnecting them in the inter-rib gaps, the traverse rib form enhances heat transfer. Using a common solar air heater and the renormalization-group k model, the calculations show that the best results are obtained for two-dimensional flows.

References

1. Xia CL (2012) Permanent magnet brushless dc drives and controls. Max WELL from Hoboken, New Jersey, USA.
2. Morris (2006) Use of ultra-power and neural networks in electrical hybrid vehicle power management systems. IEEE Trans Ind Electron.
3. Chen YT, Chiu CL, Jhang YR, Tang ZH, Liang RH (2013) The brushless DC fan brushless single-phase winding structure. IEEE Trans Ind Electron 60: 4369-4375.
4. Toliyat HA , Campbell SG (2003) DSP-based electromechanical motion control. CRC Press, (1st edn), Boca Raton FL USA. p: 361.
5. Pillay P, Krishnan R (1998) Modeling of permanent magnet motor drives. IEEE Trans Ind Electron 35: 537-541.
6. Singh S, Sanjeev, Bhim (2012) A voltage driven PFC Cuk converter dependent PMBLDCM for air conditioners. IEEE Trans Ind Appl 48: 832-838.
7. Pandey B, Singh, Kothari p (2003) Enhancement of single-stage power-efficiency AC-DC converters. IEEE Trans Ind Electron 50: 962-981.
8. Singh, In-depth high frequency isolation rectified single-stage single phase power factor converters. IEEE Trans Informati 7: 456-540.
9. SL (1992) Sepecic and cuk conversion converters as non-continuous drive power factor pre-regulators and others in proc. Int Electron Motion Control Conf 1: 283-288.
10. Das TK, Banik A, Chattopadhyay S, Das A (2019) Sub-harmonics based string fault assessment in solar PV arrays. In: Chattopadhyay S, Roy T, Sengupta S, Berger-Vachon C (eds) Modelling and simulation in science technology and engineering mathematics. advances in intelligent systems and computing 749: 293-301.
11. Das TK, Banik A, Chattopadhyay S, Das A (2019) FFT based classification of solar photo voltaic microgrid system. Second International Conference on Advanced Computational and Communication Paradigms (ICACCP) pp: 1-5.
12. Banik A, Sengupta A (2021) Scope challenges opportunities and future goal assessment of floating solar park. Innovations in Energy Management and Renewable Resources pp: 1-5.
13. Banik A, Shrivastava A, Manohar Potdar R Design modelling and analysis of novel solar PV System using MATLAB. Materials today: proceedings.
14. Das TK, Banik A, Chattopadhyay S, Das A (2021) Energy-efficient cooling scheme of power transformer: An innovative approach using solar and waste heat energy technology. In: Ghosh SK, Ghosh K, Das S, Dan PK, Kundu A (eds) Advances in thermal engineering manufacturing and production management. ICTEMA 2020. Mechanical engineering Springer, Singapore.
15. Shrivastava A, Sharma SK (2016) Various arbitration algorithm for on-chip (AMBA) shared bus multi-processor SOC. IEEE Int Stud Conf Electr pp: 1-7.
16. Shrivastava A, Sharma SK (2015) AMBA AXI bus verification technique. Int J Appl Eng Res 10: 44178-44182.
17. Shrivastava A, Sharma SK (2015) A reliable routing architecture and algorithm for network-on chip. Journal of Electronic Design Technology (JOEDT) 6: 40-48.
18. Shrivastava A, Pandit AK (2012) Design and performance evaluation of a NOC based router architecture for MPSOC. IEEE Fourth International conference on computational intelligence and communication networks pp: 468-472.
19. Shrivastava A, Singh AK, Tomar GS (2011) Performance comparison of amba bus-based system on-chip communication protocol. IEEE International conference on communication systems and network technologies pp: 449-454.
20. Singh AK, Shrivastava A, Tomar GS (2011) Design and implementation of high performance AHB reconfigurable arbiter for on chip bus architecture. IEEE International conference on communication systems and network technologies pp: 455- 458.
21. Shrivastava A, Tomar GS, Kalra KK (2010) Efficient design and performance analysis for amba bus architecture based system-on-chip. IEEE International conference on computational intelligence and communication networks pp: 656-660.
22. Shrivastava A, Sharma SK (2016) Efficient buss based router for NOC architecture. World J Eng 13: 370-375.