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Investigation of Air Flow inside the Solar Air Heater and It's Temperature Variation: a Review

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Abstract:

Solar Air Heater is the device which heats the air flow and ultimately the air inside the heater. Collector plate mounted on the top of the box receives the sunrays and increases the temperature. This increased temperature is further convected to the air flow inside the heater through the ribs. Hence when air comes out through the solar air heater, its temperature is increased by 30-400C. The air flow inside the heater mainly causes the convective heat transfer. The nature of air flow and the convection pattern inside the heater is needed to study well to increase the efficiency of the solar air heater. There are several studies are available which focuses on the air flow pattern and convection takes place.

In this paper the various methods available to study the air flow pattern and the convection phenomenon inside the solar air heater are studied well. There are several methods are available to study air flow pattern inside the heater. Out of them CFD approach is the most reliable, cheaper and less time consuming method. It does not need any experimental setup. Also the pressure difference, velocity variation, turbulence and temperature variation can be founded very easily. Likewise the other methods are also studied and their conclusions are taken into consideration. Lacunas in available studies are also noted for avoiding further errors in study. Conclusion of this entire study is drawn on the basis of studied literature.

Keywords —**Solar Air Heater, Air Flow Pattern, CFD Approach**

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I. INTRODUCTION

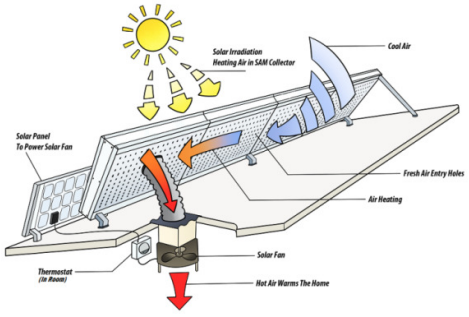

Fig. 1: Solar Air Heater used for domestic purpose

A solar air heater is similar to solar flat plate water heater, which uses the greenhouse concept to heat air or water through the accumulated heat in the absorber. Unlike solar water heater, where all 2m×2m panels are connected externally, the solar air heater modules are fitted together internally to facilitate air to pass through a long path to reach the desired temperature by creating a good heat transfer mechanism within the collector. In a solar water heater, water is re-circulated so that at the end of a day the given volume is heated from ambient temperature to say 60–80oC. But in an air heater, the ambient air by passing through the collector should reach 60–80oC in a few seconds. Using the

green house basic concept, solar air heaters are installed with integrating multiple modular systems which handles cold air and heats it to 60–80oC.

Solar Air Heater is the one the device which converts solar energy into thermal energy. This energy can be utilized in various applications like warming the room, dry heated air for industrial applications, removing moisture content in food industry etc. Hence it is important device and it consists of insulated box and collector plate which is placed on the top of the box. On the bottom plate and top plate v-shaped ribs were mounted for better convection of heat. This type of rib mounting is also called as increasing surface roughness.

Solar air heaters are being used for many applications at low and moderate temperatures. Some of these are crop drying, timber seasoning, space heating, cooking etc. The thermal efficiency of solar air heater has been found to be low due low thermal capacity of air and because of low convective heat transfer coefficient between absorber plate and flowing air in the duct. Attempts has been made to enhance the heat transfer rate by use of extending surface in form of fins but the heat transfer is accompanied by pressure drop penalty. In another approach use of artificial roughness is the most effective and economic way for improving performance of solar air heater. In this approach turbulence is created by roughened surface in viscous sub layer to obtain heat transfer enhancement. Several roughness geometry has been tested so far to enhance heat transfer with consumption of pumping power. [1]

Energy is the one of the most important need of mankind, be it proving light or be it to run machines. Energy in different forms and functions has portrayed a very important role in the extensive economic boom and industrialization. For coming generations, we need to depend on the source which can provide infinite energy. Solar energy can be said to be one of those forms which is freely available, and easily accessible and of course is non- polluting in nature. It is considered to be an indispensable source of energy to meet the growing demand for the sustainable development and to control the global climate change. The need to enhance the thermal performance of heat exchangers, consequently, effecting energy, material, and cost savings as well as a consequential mitigation of environmental degradation had led to the development and use of many heat transfer enhancement techniques. There are several devices like solar water heater and solar air heater are used to harness the solar energy. Many researchers have conducted numerical study of solar air heater. CFD is a vital tool to analyze thermal systems [7].

II. LITERATURE SURVEY

Suman Saurav1, M. M. Sahu2, “Heat transfer and thermal efficiency of solar air heater having artificial roughness: a review”: In their paper the artificial roughness in the form of ribs is discussed. Authors have given the experimental justification for the roughness which improves the thermal efficiency of solar air heater. It shows that making of specific designed patterns on surface (ribs) the efficiency will improve. Different patterns are considered to prove this. [1]

Naresh Prajapati*, Ajay Kumar Singh, Ashish Verma, “Comparison Of Performance of Double Pass Solar Air Heater Having Double Layer Glass”: In their study the discussion is held about the comparison of the thermal performance of double pass solar air heater of different types of absorber plates has been done in this paper. For this purpose, three different types/colors of metallic sheets are used. The absorber plates have- metallic color, black color and black color with mesh wire as auxiliary attachments. Experiment gives the result that the highest heat transfer is found out to be for black colored plate with wire mesh at all the exit wind velocity. Metallic colored plate is able to absorb least heat. Hence the black colored plate is efficient. [2]

Mr C Palaniappan, SUN BEST, Theni, Tamil Nadu, India, “Solar Air Heaters: Large Solar Thermal Air Systems for Industrial and Agro Applications”: Their article focuses on two existing solar air heater projects which are used in leather auto spray drying supported by a UNIDO project at Kanpur, State Uttar Pradesh, India and one for

chilies drying in Kerala, India run by a women self-help group. The results in both cases are much impressive and show the effectiveness of Solar Air Heater in industrial as well as agro-industrial field. The emerging solar air heating technology indicates a potential of 0.92 million m2 collectors and this is equivalent to savings in 3.52 Mtoe/y (million tonnes oil equivalent/year) in Indian industries and agro-processing sectors. [3]

M. Sivaganesh, 2Dr. R. Rathnasamy & 3Dr. R. Karthikeyan, "Performance Analysis on Improved Solar Air Heater": In their paper the incorporation of multiple v-ribs along with baffles on one side of absorber is placed to improve the heat transfer coefficient. Article also focuses on the reasons of poor thermal performance of solar air heater. Turbulent flow developed due to ribs and baffles improves thermal performance of heater. Experiment conducted under the different flow condition, shows the flow below the absorber gives better performs to increases efficiency by 11.18% at 10m/s and 22.88% at 15m/s compared with smooth side of absorber. [4]

Foued Chabane1,2,*, Noureddine Moummi1,2, Said Benramache3, Djamel Bensahal1, and Okba Belahssen3, "Collector Efficiency by Single Pass of Solar Air Heaters with and without Using Fins": In their paper single pass air heater with modified solar collector which improves the efficiency is discussed. Ribs are the main components which provide maximum area which comes in contact with air and hence the heat transfer rate is better. Two air mass flow rates of 0.012 and 0.016 kg/s were compared through the experimentation, the maximum efficiency obtained for the 0.012 and 0.016 kg/s with, and without fins were 40.02, 51.50% and 34.92, 43.94% respectively. This result proves the enhancement in the thermal efficiency. [5]

Santosh Vyas1 and Dr. Sunil Punjabi2, "Thermal Performance Testing of a Flat Plate Solar Air Heater Using Optical Measurement Technique". In their paper experimentation conducted for thermal performance testing of flat plate solar air heater with simulated solar radiation intensity; 600 W/m2 . Plane absorber, transverse V- porous ribs and inclined V-porous ribs of absorber are tested and their thermal efficiencies are found 14.91%, 17.24% and 20.04%. [6]

Sumit Kumar1 and Vijay Singh Bisht2, "CFD Analysis of Solar Air Heater Roughened with S-shape Ribs with Gap and S-shape Protrusion Roughness". For their study, the CFD tool ANSYS Fluent is used to carry out performance analysis of solar air heater in case of S shaped ribs, multiple broken arc shaped ribs combined with circular protrusion in arc shape on the back side of absorber plate. An improvement in Nusselt Number at high Reynolds number (Above 8000) is obtained. Improvement in Nusselt Number improves the life and it will be more economical. [7]

P. Velmurugan and P. Ramesh, "Evaluation of thermal performance of wire mesh solar air heater". Wire mesh on solar collector is installed to enhance the heat transfer. In their paper matrix solar air heater with wire mesh collector is discussed and its increased efficiency shows the effectiveness. Wire mesh solar air heater always gives better efficiency as compared with flat plate solar air heater. [8]

Rajendra Karwa and V. Srivastava, "Thermal Performance of Solar Air Heater Having Absorber Plate with V-Down Discrete Rib Roughness for Space-Heating Applications". Their paper focuses on v-down discrete rib with roughness on the air flow side of the observer plate for space heating application. [9]

Abhishek Saxena1 and Varun Goel2, "Solar Air Heaters with Thermal Heat Storages". In their paper the thermal storages are discussed where the rock bed type and phase changing material thermal storage is compared were the phase change material thermal storage found more effective. Few more thermal storages are discussed along with results. [10]

B. K. Maheshwari, Rajendra Karwa, and S. K. Gharai, "Performance Study of Solar Air Heater Having Absorber Plate with Half-Perforated Baffles". A mathematical model of smooth duct solar air heater is compared with experimental setup. Half-perforated baffles are attached with absorber plate on air flow side which improves the thermal efficiency by 28%–45% over that of the smooth duct solar air heater. Perforated baffles gives

180%–235% increment in thermal efficiency. Using the mathematical model, the performance plot for the baffled duct air heater presented, and the effect of the variation of ambient parameters on the predicted thermal efficiency published. [11]

Anamika, Dr. H.C. Thakur, Dr. Gopal Nandan, "A Review on Solar Air Heater Performance Using Different Artificial Roughened Rib". In their review paper various tool of improvement of thermal efficiency is discussed. Ribs, wired type of artificial roughness prevent laminar boundary layer formation and hence the efficiency improves. [12]

Sanda Budea, "Solar Air Collectors for Space Heating and Ventilation Applications-Performance and Case Studies under Romanian Climatic Conditions". The climatic conditions of the Southeastern Europe is considered to show experimental results. It was shown that after a maximum 50 min, solar air collectors, with baffles and double air passage can reach over 50% efficiency for solar irradiation of 900–1000 W/m2. The article also presents a mathematical model and the results of a computational program that allows sizing solar collectors for the transfer of air, with the purpose of improving the natural ventilation of buildings. [13]

In this regard, this article shows, on the one hand, the performance of solar air collectors used under the climatic conditions of Bucharest (Romania) during the cold season, to establish their performance in the heating process, and, on the other hand, during the warm season, to establish their efficiency in improving the ventilation process. [13]

Amod Kumar a, Rajiv Varshney b, " Experimental study on Heat Transfer Enhancement of a Solar Air Heater with Absorber Plate having Multi V-shaped Rib with Gap and Thermal Storage". Improvement in thermal efficiency is suggested by providing ribs and baffles in their paper. A solar air heater has been designed and fabricated with multi V-shaped rib with gap below the absorber plate. A thermal storage system with oil was used which releases heat at the time of low solar radiation. The performance of this modified solar air heater is investigated and compared with that of conventional solar air heater. It is found that 28% efficiency is improved by using thermal storage with oil. [14]

Madhav Durusoju1, Chetan Goyal2, Imran Sheik3, Akash Dongre4, Lalit Marbate5, Kumar Rohit6 and V.P.Katekar7, "Heat Transfer Enhancement Techniques for Solar Air Heater – A Review". Their review paper discussed the types of roughness can be provided on the absorber. Also the performance characteristics along with thermal efficiency testing are reviewed. [15]

Sanket Khamitkar 1*, Dr. O. D. Hebbal 2*, "Performance Analysis of Solar Air Heater Using CFD". In their paper, the thermal efficiency of a solar air collector called unglazed transpired collector (UTC) has been studied and validated using CFD. The study was done to calculate efficiency of solar air heater under hot climatic conditions with two different mass flow rates of air. It was found that temperature rise decreases with increasing air mass flow rate and the efficiency increases with increasing air mass flow rate. Increasing the irradiation level seems to have a very limited effect on the collector efficiency for both mass flow rates. Still, the results show a small increase in efficiency as the irradiation intensity decreases for both mass flow rates. [16]

Harish Kumar Patel; 2Saurabh Singh; 3Alfa Tigga ; 4Krishna Kumar Darpan, "Thermal Performance of Solar Air Heater by with artificial roughness-A Review". In their review paper also the artificial roughness is discussed to improve the efficiency of the solar air heater. Ribs and baffles of different size and shape gives improvement in thermal efficiency of Solar air heater. Same is discussed and concluded in this paper. [17]

Anand Patel1, Divyesh Patel2, Sadanand Namjoshi3, "Thermal Performance Evaluation of Spiral Solar Air Heater": In their paper spiral solar air heater is discussed in brief and its performance is checked using K type thermocouple. It is one more type of artificial roughness whose efficiency is much better than flat plate Solar Air Heater. [18]

III. CONCLUSIONS

- Most of the Authors have focused on artificial roughness on absorber plate to improve thermal efficiency.
- Effectiveness of rib can be improved in air heating process with curves.
- Performance analysis can be improved by improving free and force convection.
- Authors have focused on various issues of Solar Air Heater but fluctuation of solar energy is to be considered.
- Different types of artificial roughness methods are having different thermal efficiency improvements.

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