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Thermal-Hydraulic Analysis of a Parabolic Trough Solar Collector with Serpentine Absorber having Varying Pitch

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Abstract*—Many technologies have been developed in order to harness the maximum solar energy received from sun on earth surface. Many researchers have carried out their research work to improve the efficiency of solar parabolic trough collector by changing the design of solar collector and absorber tube. The parabolic trough reflector is a solar thermal energy collector designed to capture the sun's direct solar radiation over a large surface area and focus, or more generally "concentrate it" onto a small focal point area increasing the intensity of solar energy received at the focal point. The aim of present research work is to improve the heat gain capacity of absorber tube by changing its shape. The present research deals with performance evaluation of parabolic through collector with conventional straight absorber tube and serpentine absorber tube under identical input conditions. For evaluation, serpentine absorber tubes with different pitch were used. The material used for both straight as well as serpentine absorber tube is aluminum. The objective of this research is to find the effect of serpentine tube pitch on pressure drop and heat transfer rate to the fluid flowing through the absorber tube. The experimental testing of parabolic through collector were conducted with water as working fluid for all three absorber tubes and readings are taken for same flow rate. In the first phase, experiments were conducted on solar parabolic trough collector with conventional straight absorber tube. In second phase, experiments were conducted with serpentine absorber tubes with varying pitch. For experimentation serpentine absorber tubes having two different pitch of 397.42 mm & 393.92 mm respectively were used. Also, CFD, Ansys fluent v 19.1 module was used in present research work to analyze the flow behavior of fluid flowing through the straight and serpentine absorber of parabolic trough collector. It is observed that solar parabolic trough collector with serpentine absorber gives better efficiency compared with solar parabolic trough collector with conventional straight absorber.

***Index Terms*— Parabolic trough collector, Serpentine absorber, Collector efficiency, pressure drop.**

I. INTRODUCTION

The solar energy which is a renewable form of energy has been the primary interests of many engineers and researchers for the last two centuries due to its wide applications such electricity generation and domestic water heating systems.

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Since the energy getting from the solar is totally free of value so the utilization of sun strength may be very useful as a result there has been extensive improvement within the area of sun electricity. A parabolic trough is a kind of sun thermal collector this is straight in one measurement and curved as a parabola inside the different two, covered with a elegant metallic reflect. The sunlight which enters the replicate parallel to its plane of symmetry is cantered along the focal line, in which items are placed that is intended to be heated. The sunlight is focused on the tube and the fluid flowing through the tube is heated to a high temperature by way of the power of the sunlight. the hot fluid can be piped to a warmth engine, which makes use of the warmth strength to pressure equipment, or to generate electricity. Many researchers have carried the studies within the discipline of sun trough parabolic collectors with a purpose to enhance the sun power utilization. Sumair Faisal Ahmed et.al [1] has over-viewed the maximum generally used solar water heating technology. They severely analysed and summarized the latest advancements inside the generation, consisting of storage tank/incorporated collector storage solar water heater, sun water warmers (active and passive), sun thermal collectors, including focused and non-focused collectors and distinct guidelines. Nabil shukri et al. [2] evaluated three varieties of sun water warmers and studied the effect of wind and dust that collect constantly at the glass floor of those solar heaters. The paintings additionally present guidelines to pick out the simple and clean manner of producing considering the least poor villagers with their neighbourhood competencies and materials. Three different forms of sun heaters specifically Flat Plate, Serpentine and Zigzag heaters with different forms were designed, considering retaining similar dimensions and the identical zones exposed for the sun rays, and tested them within the equal climatic situations. A. V. Ramayya et al [3] performed numerical simulation and experimental trying out on solar collector with striped absorber plate of the serpentine sun collector.

The various modes were designed in ANSYS 14.5 launch FLUENT and simulated using computational fluid dynamics. The impact of the configuration parameters of striped serpentine sun collector was investigated and good outcomes were acquired. Auch Venkata Ramayya et al. [4] determined to improve the thermal overall performance of striped passive serpentine flat plate solar collectors. Striped mechanism was used at the absorber plate to lessen thermal fusion and to research enhancing the education of power conversion from collector units to working fluid. Experimental trying out turned into used to conduct or perform the study. domestic hot water demand has largely been met through conventional flat plate solar creditors. conventional solar collectors are appropriate for excessive drift prices with high operational prices. due to the high pumping requirements at higher go with the flow rates, serpentine solar creditors had been previously unnoticed. Serpentine creditors, then again, are more cost-effective and efficient at low drift rates. As a result, the serpentine absorber plate is lined. Mohamed A. Hamada et al. [5] studied the numerous parameters influencing the parabolic trough creditors (%) thermal performance and the improvements to improve the design change, optical, and thermal homes utilized in %. R. F. Ahmed et. al. [6] experimentally investigated a parabolic trough sun collector (P.C.), with two-gate helical screw-tape inserted into an evacuated tube (ET) receiver.

The experiments had been accomplished at waft prices of 10, 12, 16, 20, and 25 L/h. results confirmed that the maximum each day efficiency is sixty-nine% at water glide charge of 20 L/h at the same time as the minimum each day efficiency is fifty-nine. Five% at water glide rate of 16 L/h. the warmth removal issue and the general warmth loss coefficient of the device are 0.843 and nine. Sixty-four W/m² °C, respectively. it's also determined that the helical screw centre enhances the solar collector overall performance throughout cloudy durations by way of compensating the impact of the big instant version of the incident solar radiation where it works as a thermal garage detail.

Present research aimed to analyse the thermal performance of parabolic trough collectors (PTCs) by changing the design of absorber tube. In this study, experiments were conducted on parabolic trough collectors with conventional straight absorber tube to a serpentine tube having varying pitch of 397.42 mm & 393.92 mm respectively.

II. EXPERIMENTATION

The Experimental Setup of sun parabolic collector is demonstrated in Fig.1. The solar collector was sited north–south. The parabolic solar collector having a concentration factor of 20, representing the amount of solar radiation concentrated on the absorber tube, with a reflectivity of 85 % and an absorptivity of 95 %. The parameters such as reflectivity, absorptivity and concentration factor are responsible to increase the rate of heat transfer to the working fluid resulting in increase in temperature.

Several Experiments were conducted on parabolic collector with three different types of absorber tubes under identical conditions.

For experimentation following specifications were used

Dimension of collector:
Length = 800 mm, Breadth = 770 mm
Dimension of absorber tube:
OD = 15 mm, ID = 12.5mm, Length = 1100mm
Dimension of focal point = 6 Inches
Longitudinal of collector = 33
Rim Angle = 90

Fig.1. Experimental setup of parabolic trough collector with serpentine absorber tube

Fig.2. Serpentine Tube with Pitch 393.92 mm

Fig.3. Serpentine Tube with Pitch 397.42 mm

III. CFD ANALYSIS

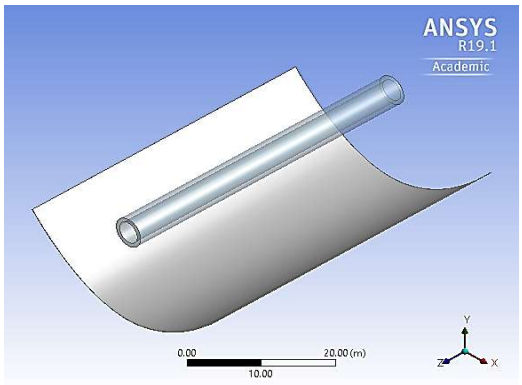

Fig.4. CAD model with Straight absorber

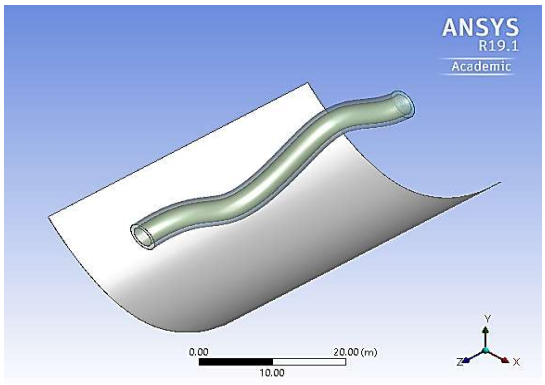

Fig.5. CAD model with Serpentine absorber

CFD Ansys Fluent v19.1 was used in the proposed work to analyze the performance of parabolic trough collector with straight and serpentine absorber tube.

IV. DATA REDUCTION

Solar Intensity (I) = 720 W/m^2
Area of Collector (Ac) = 0.619 m^2
Total Radiation incident on collector in Watt = I*Ac
Intensity of radiations reflected by collector = I*Ac*ρ
ρ – Reflectivity of collector
η collector = (I*Ac*ρ)/(I*Ac)
α – Absorptivity of Absorber
Intensity of radiations absorbed by absorber = I*Ac*ρ*α
Useful heat gain: The amount of heat gained by fluid flowing through the receiver tube.
Heat gained by water in Watt = ṁ*Cp*(To -Ti)
The thermal efficiency of collector is defined as the ratio of the instantaneous useful heat gained by the fluid and solar radiation incident on absorber tube from parabolic collector
η collector = ṁ*Cp*(To -Ti) / I*Ac*ρ*α * 100

IV. RESULT AND DISCUSSION

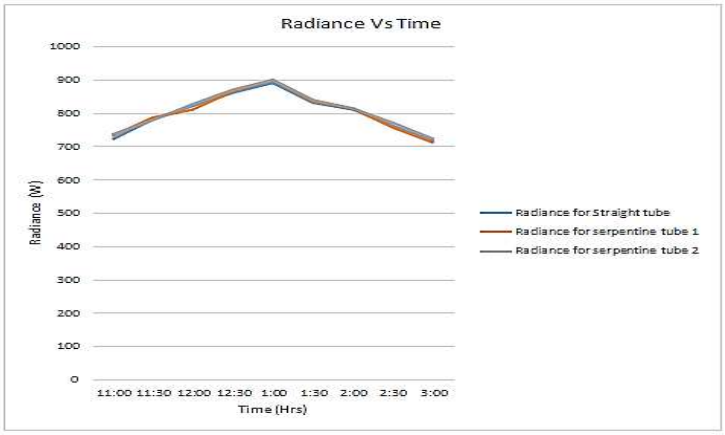

Fig.6. Radiance Vs Time

Fig. 6 depicts the variation of solar radiance with time. It is found that the intensity of solar radiations increases in early hours of day and reaches its ultimate value between 12:30 PM and 1:30 PM then again decreases in the sundown hours. Along with solar intensity, reflectivity of surface, absorber tube geometry, fluid flow properties is also responsible to increase or decrease the efficiency of parabolic trough collector.

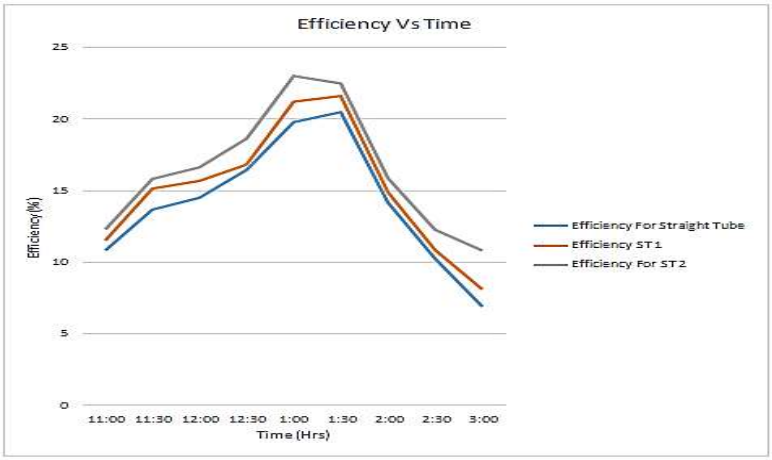

Fig.7. Efficiency Vs Time

It is observed that for same flow rate, the parabolic trough collector with serpentine absorber tube gives more surges in outlet temperature of water when it is associated to parabolic trough collector with straight absorber tube. The increase in heat transfer takes place due to swirling initiated by serpentine shape of absorber tube which in turn increases the contact between the fluid flowing through the tube and the surface of the tube.

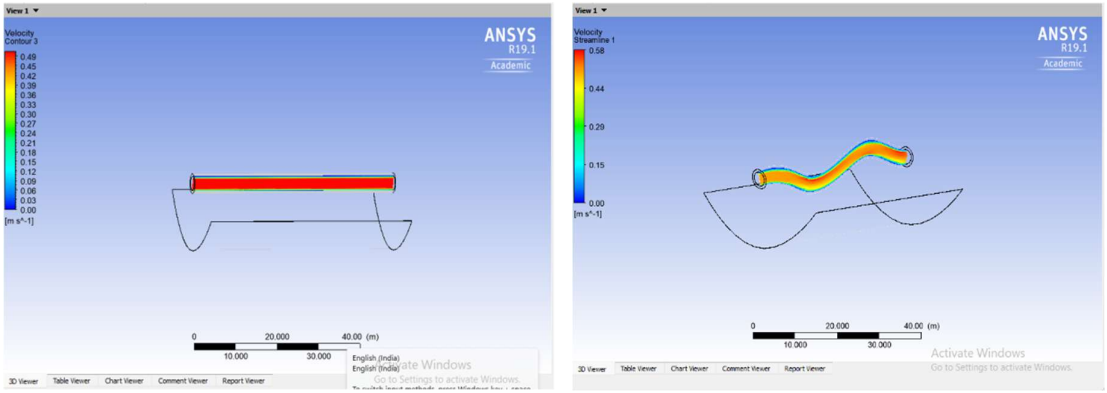

Fig.8. Velocity contour for Straight and Serpentine absorber respectively

It is observed that serpentine absorber tube generates higher turbulence for the fluid flowing through it as compared to straight absorber of parabolic trough collector. This increase in turbulence due to serpentine shape resulted in increase in velocity for the fluid flowing through serpentine absorber compared with straight absorber of parabolic trough collector. Increase in turbulence resulted in more heat gain for the fluid flowing through serpentine absorber.

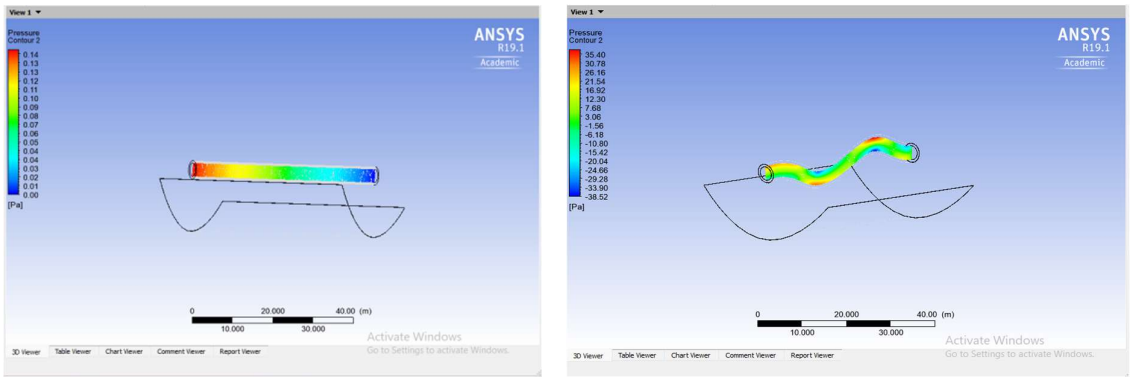

Fig.9. Pressure contour for Straight and Serpentine absorber respectively

It is observed that serpentine absorber gives more pressure drop for the fluid flowing through it as compared to straight absorber of parabolic trough collector. There is increase in pressure drop for fluid flowing through serpentine absorber tube due to obstacle produce by serpentine shape. The increase in pressure drop resulted in increase in pumping power for the fluid flowing through the serpentine absorber.

V. CONCLUSION

Experiments were carried out on a conventional straight single tube absorber and a improved absorber where a serpentine absorber tube of varying pitch was used to extract the heat received from parabolic trough collector. Experimental evaluation conducted on conventional instantly single tube absorber showed a lesser solar energy recovery than the modified absorber tube of serpentine form.

The solar strength restoration is stepped forward with the modified absorber layout, inside the shape of improved water temperature, consequently growing the efficiency of the absorber. From the experimental data, it was found that the parabolic trough collector with serpentine absorber tube having pitch of 397.42 mm gives increase in efficiency by 3% and serpentine absorber tube having pitch of 393.92 mm gives increases the efficiency by 4.02% as compared to parabolic trough collector with straight absorber tube.

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