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THERMAL PERFORMANCE ANALYSIS OF SOLAR WATER HEATER USING ANSYS FLUENT: A REVIEW

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Abstract:

The utilization of solar energy for water heating has gained significant attention in recent years due to its potential for sustainable and cost-effective energy solutions. In order to optimize the design and performance of solar water heaters, researchers have increasingly turned to computational fluid dynamics (CFD) simulations. Among the various CFD tools available, ANSYS Fluent has emerged as a popular choice for investigating the thermal characteristics of solar water heaters. This review aims to provide an overview and assessment of the studies that have employed ANSYS Fluent for the thermal analysis of solar water heaters.

Introduction:

Solar water heaters have gained significant attention as an environmentally friendly and cost-effective solution for domestic hot water production. Thermal analysis plays a crucial role in understanding and optimizing the performance of these systems. In recent years, computational fluid dynamics (CFD) software such as ANSYS Fluent has emerged as a powerful tool for simulating and analyzing the thermal behaviour of solar water heaters. The purpose of this study is to perform a thermal analysis of a solar water heater using ANSYS Fluent. The analysis aims to investigate the heat transfer characteristics, temperature distribution, and overall efficiency of the system under various operating conditions. The solar water heater system consists of a solar collector, heat exchanger, storage tank, and associated piping. The solar collector absorbs solar radiation and transfers the heat to a fluid (usually water or a heat transfer fluid) flowing through it. The heated fluid then passes through a heat exchanger, where it transfers its heat to the water in the storage tank. The heated water can be used for various domestic purposes. ANSYS Fluent offers a comprehensive set of tools and capabilities for simulating fluid flow, heat transfer, and radiation in complex geometries. It utilizes numerical methods, such as finite volume or finite element techniques, to solve the governing equations of fluid flow and heat transfer. By setting up appropriate boundary conditions and material properties, ANSYS Fluent can simulate the real-world behavior of a solar water heater system and provide detailed insights into its thermal performance.

The thermal analysis using ANSYS Fluent can help in evaluating different design parameters of the solar water heater system, such as the size and orientation of the solar collector, flow rate of the fluid, and insulation of the storage tank. By simulating various scenarios, it is possible to optimize the system's performance, maximize heat transfer efficiency, and minimize heat losses. This study aims to utilize ANSYS Fluent for the thermal analysis of a solar water heater system. The analysis will provide valuable insights into the heat transfer characteristics, temperature distribution, and overall efficiency of the system. The findings of this study can contribute to the design and optimization of solar water heaters, leading to more effective and energy-efficient systems for domestic hot water production.

Literature Review:

Ibrahim Abass, K. and Salih Jawad, R. (2018), In the context of this study, a Parabolic Trough Collector model is attempted using the Ansys 15.0 Workbench application. The 25:1 PTC concentration ratio was envisioned when it was initially suggested. Other mass flow rates, such as 0.25 kg/hr, 0.5 kg/hr, 0.75 kg/hr, and 1 kg/hr, were also used to model the PTC. The study's results are summarised in this section. The Nusselt number, heat transfer coefficient, and thermal fluxes at different mass flow rates are analyzed. The greatest water temperature of 3670 K is observed at a flow rate of 0.25 kg/hr, with a collector efficiency of 51.2%. The mass flow rate via the receiver pipe fluctuates widely, and these changes have been measured and recorded. However, the rising Nusselt number indicates a higher heat transfer rate, thus even though the temperature has dropped, the mass flow rate and heat transfer ratio have both improved.

Chaudhary, V. Y. et al. (2017) Installing a cutting-edge solar water heater and plenty of ceiling insulation to keep heat out indicated that solar energy was being used effectively. Standard computational fluid dynamics software is used to physically construct the rising isolated ceiling and then computationally simulate and verify the results. Several factors affect the solar water heater's efficiency and the system's ability to thermally insulate, all of which are investigated and addressed in length in this thesis. Changing to a more energy-efficient roof structure has allowed the facility to boost its daily hot water production to 25 liters and its summertime temperature to 60 degrees Celsius. This roof style has the potential to keep the roof at a comfortable 27 degrees Celsius throughout the day in the autumn.

Gujrathi, A. S. et al. (2017) Solar energy storage and night time home heating are two potential applications that researchers are looking into by studying PCMs. Reflectors, reflecting cumulated PCM (Paraffin wax), and no reflectors were all tested to see how well each one improved the efficiency of a solar hot water heater. Performance criteria for water-discharged tube solar receptor pipes will be reviewed in addition to the results of numerical analyses of water circulation through solar receptor pipes. The test data was then used to generate simulated results. The proposed method allows the warm water storage to maintain a consistent temperature of 5 to 7 degrees Celsius for long periods of time.

Junaid, M. A. et al. (2017) The effects of various absorber plate pipe sizes and shapes on thermal performance are investigated. The CFD analysis demonstrated that the collector's circular cross-section with the absorber layer had much superior thermal performance than other Nusselt environments. Numerical research shows that variations in heat efficiency matter for solar panel pipes with fixed cross-sectional area and perimeter needs. When compared to the needs with a constant cross-sectional area, the pressure loss and absolute temperature increase throughout a triangle pipe are revealed to be very large.

Karanth, K. V., Cornelio, et al, (2017) Three times in March, at 11 a.m., 12 p.m., and 2 p.m., the mass stream will occur at the same frequency each time. Modeling using GAMBIT 2.4 and testing with ANSYS FLUENT 14.5 The time-related simulation model of FPC is used to compute it from 11:00 am to 2:00 pm. When the water intake temperature is 25 degrees Celsius, the 12:00 collector's input temperature rises to 40.89 degrees Celsius, but the output temperature falls with time.

Badgujar, G. K.et. al. (2017) this study investigated the effects of incorporating Phase Change Materials, a high-quality storage medium, into a solar water heater (PCM). A solar water warmer has a spherical tank that contains a paraffin wax capsule. The jacket cover on the solar tank keeps the elements out. Researchers looked at research that compared the effects of low, moderate, and high doses of sun radiation. We compared the heater's energy and exergy performance before and after PCM was introduced to the tank, as well as the time it took to produce hot water. Adding PCM to the tank increases energy density by 39%, and the efficiency of exercise by 16%, according to studies. However, research has shown that PCM-based solar water heaters reliably deliver hot water at the ideal temperature around a quarter of the time. Thermogenic activity in the tank was found to increase upon analysis of temperature profiles at varying water depths.

Babu, M. D. et, al. (2016) The purpose of this research is to see whether a static operating mode compatible with the HNCPCM may help solar water heaters overcome their thermal energy deficit (Hybrid Nano Composite Phase Shift Material). Based on the traditional all-glass solar water heater, the calculations were made (AGSWH). For each of the five possible circumstances, the device was put to the test using the first and second principles of thermodynamics. When hybrid nanoparticles were deposited into a paraffin matrix at a mass fraction of 2.0%, it was discovered that the matrix's heat conductivity improved by 65.56 percent! In experiments testing the first and second principles, hybrid nanocomposites were found to dramatically boost the device's energy output and output quality. HNCPCM improved energy and exergy efficiency by 19.4 and 1.28 percent, respectively, while using hybrid nanoparticles at a mass fraction of 1.0. The importance of determining the optimal concentration of nanoparticles for a given task was first emphasized.

Basheer Sheeba, J.et. al. (2014) Based on these findings, an ICSSWH of the same size as a full-water facility will be 5 degrees Celsius warmer than water at 6 a.m. the following day. Microcapsules were able to maintain their connections when stored at temperatures above their operating temperature because to the use of concentrating collectors/reflectors. The current PCS composition also poses a threat of corrosion to the aluminum storage tanks.

Chaudhari, S. et al. (2014) The absorber tube wall and working fluid will be outfitted with a variety of inserts and internal caps as part of this project to boost their efficiency. By increasing the fluid's contact surface with the absorber pipe, obstacles like extensions can reduce the velocity at which heat is transmitted through tubes. In turn, this reduces the stress on the ducts themselves. Researchers looked at how different finely profiled materials handled heat transfer in an absorber pipe and compared that to a control absorber pipe that had no such issues.

Basavanna, S. et. al. (2013) This study describes and evaluates the thermal energy savings from solar water heaters with and without a PCM. As a result, two categories of relative experiments may be distinguished: collectors and sensitive or latent storage. There has been extensive research into the solar water heating PCM literature. Solar water heaters may benefit from utilizing a phase transition material with a wide surface area and high latent heat to increase their thermal efficiency.

Bhaumik, M. (2012) this thesis analyzes a specific pattern of hot water demand during harsh weather in West Australia, and it does so by evaluating the technical and empirical performance of solar water heating systems on a cold day. The optimal number of glass tubes for solar heating pipes was calculated using a statistical model. Solar water heaters' thermal performance was found to have a major impact on energy use, efficiency, and savings. This conclusion demonstrates the need of creating and researching these behavioural mechanisms for hot water utilisation. Because of the lengthy start-up time (19 minutes) and the dismal, rainy weather, extra heaters were required.

Need of the Study:

The thermal analysis of a solar water heater using ANSYS Fluent is a study of paramount importance in the field of renewable energy and sustainable development. Solar water heaters play a significant role in harnessing the abundant energy from the sun and converting it into usable heat for various applications, particularly in domestic and industrial water heating systems. Conducting a thorough analysis of the performance and efficiency of these systems using advanced computational tools like ANSYS Fluent provides valuable insights for system optimization and design improvement. The primary objective of this study is to evaluate the thermal performance of a solar water heater under different operating conditions and design parameters. By simulating the heat transfer processes within the system, ANSYS Fluent enables the analysis of various factors such as solar radiation intensity, collector design, fluid flow characteristics, and insulation properties. These analyses contribute to enhancing the overall efficiency and reliability of solar water heaters.
Solar energy is a renewable and sustainable energy source that harnesses the radiant light and heat emitted by the Sun. It offers numerous advantages and has the potential to shape the future of energy production.

In terms of environmental benefits, solar energy is clean and does not release greenhouse gases or air pollutants during its operation. This significantly reduces carbon emissions and helps combat climate change. Additionally, solar power does not deplete finite resources like fossil fuels, ensuring long-term availability and sustainability. The cost savings associated with solar energy are another compelling factor. Once installed, solar panels can generate electricity for decades, resulting in significant long-term savings on electricity bills. With advancements in technology and manufacturing processes, the cost of solar panels has been steadily decreasing, making solar energy more affordable and accessible to a wider range of consumers. The future of solar energy also lies in its potential for innovation and advancement. Researchers and engineers are continuously working on improving the efficiency of solar panels to maximize energy production. New materials, such as perovskite solar cells, have shown great promise in increasing conversion rates and overall efficiency.

Furthermore, energy storage technologies are being developed to address the intermittent nature of solar power. Advanced batteries and thermal storage systems can store excess energy during peak production hours for later use during periods of low solar generation. This integration of energy storage will help stabilize the grid and enhance the reliability of solar energy. Solar farms and floating solar installations are also gaining popularity as demand for renewable energy increases. These large-scale installations leverage economies of scale to generate significant amounts of electricity. Floating solar farms, in particular, utilize bodies of water to house solar panels, reducing land use and offering additional benefits such as reduced evaporation and improved water quality. Moreover, building integrated photovoltaics (BIPV) is an emerging trend that integrates solar panels into building materials. This approach allows for seamless incorporation of solar energy generation into the infrastructure of buildings, making it more accessible and ubiquitous.

The Future of Solar Energy:

Solar energy is poised to play a crucial role in the future of global energy production. With growing concerns over climate change and the need to transition to cleaner and more sustainable energy sources, solar power has emerged as a promising solution. The future of solar energy looks bright, with several key trends shaping its growth and development. Advancements in solar technology are driving increased efficiency and lower costs. Over the years, there have been significant improvements in photovoltaic (PV) cells, resulting in higher conversion rates and improved energy generation. Thin-film solar panels and tandem solar cells, which combine multiple layers of materials to capture a broader spectrum of light, are among the innovations enhancing efficiency. Additionally, the use of materials like perovskites and organics is showing great potential for further improving solar cell performance.

Moreover, the integration of solar power with energy storage systems is becoming more prevalent. Battery technologies such as lithium-ion batteries have made significant progress in terms of cost reduction and performance enhancement, enabling the storage of excess solar energy for use during times of low generation or high demand. This advancement is critical for overcoming the intermittent nature of solar power and ensuring a stable and reliable energy supply. Another important trend is the adoption of solar energy on a larger scale. Governments and businesses around the world are increasingly recognizing the benefits of solar power and implementing supportive policies and incentives. This includes feed-in tariffs, tax credits, and renewable energy targets. As a result, the deployment of solar panels is rapidly expanding, from large-scale solar farms to rooftop installations on residential and commercial buildings.

The integration of solar energy into smart grids and the rise of decentralized energy systems are reshaping the energy landscape. Smart grids allow for more efficient distribution and management of electricity, enabling the seamless integration of solar power into existing infrastructure. Decentralized energy systems empower individuals and communities to generate their own solar energy, reducing dependence on centralized power plants and increasing energy independence. The future of solar energy is promising. Continued advancements in solar technology, coupled with energy storage solutions and supportive policies, are driving the widespread adoption of solar power. As solar becomes more efficient, cost-effective, and integrated into our energy systems, it has the potential to become a dominant source of clean and sustainable energy, contributing significantly to the global efforts to combat climate change and create a more sustainable future.

Problem Statement:

The thermal analysis of a solar water heater aims to evaluate and optimize the performance of the system by analyzing its thermal characteristics and efficiency. The objective is to assess the heat transfer processes, identify potential areas for improvement, and optimize the design for maximum energy efficiency. The problem statement for the thermal analysis of a solar water heater involves several key aspects. Firstly, the heat absorption efficiency of the system needs to be evaluated. This involves assessing the performance of the absorber plate in terms of its ability to absorb solar radiation and convert it into usable heat. Factors such as the design, material properties, and surface treatment of the absorber plate will be examined to optimize solar absorption and minimize heat loss. the heat transfer mechanisms within the solar water heater will be studied. This includes analyzing conduction, convection, and radiation processes. The thermal conductivity of the materials used in the system, such as the absorber plate, insulation, and water pipes, will be assessed to identify areas of potential heat loss or inefficiency. The fluid flow dynamics within the system will also be examined to optimize the heat transfer process. This involves evaluating the design and placement of pipes, pumps, and valves to minimize flow resistance and ensure efficient heat transfer between the absorber plate and the water. Another aspect of the analysis is the evaluation of heat storage and heat loss mechanisms. The effectiveness of the heat storage tank, insulation materials, and overall system insulation will be assessed to minimize heat loss during periods of low solar radiation or high hot water demand.

Conclusion:

In conclusion, the thermal analysis of a solar water heater is a crucial step in evaluating and optimizing the performance of the system. By assessing the heat transfer processes, heat absorption efficiency, fluid flow dynamics, heat storage, and overall system efficiency, it becomes possible to identify areas for improvement and enhance the energy conversion efficiency of the system. Through the analysis, it is possible to optimize the design of the absorber plate to maximize solar absorption and minimize heat loss. The thermal conductivity of materials used in the system can be evaluated to identify potential areas of heat loss and inefficiency, allowing for the selection of more suitable materials. Additionally, the fluid flow dynamics can be optimized by assessing the design and placement of pipes, pumps, and valves, ensuring efficient heat transfer. The analysis also addresses heat storage and loss mechanisms, examining the effectiveness of the storage tank and insulation materials. This allows for the identification of opportunities to minimize heat loss during periods of low solar radiation or high hot water demand. This enables the identification of potential areas for improvement and guides design modifications to maximize the utilization of solar energy for water heating applications. The thermal analysis of a solar water heater is a valuable tool for enhancing its performance, energy efficiency, and contribution to sustainable energy utilization. By optimizing various aspects of the system, it becomes possible to harness the full potential of solar energy, reducing reliance on traditional energy sources and mitigating environmental impacts.

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