A Critical Review of Renewable Solar Energy Applications

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***Abstract*: A critical review have been presented in this paper on renewable solar energy application on flat plate, evacuated tube, parabolic trough collectors with different flow conditions. Various authors have investigated using water, nano fluids in flat plate collector, evacuated tube heat exchangers for analyzing the heat transfer and available energy useful work in solar applications .**

***Keywords*: flat plate, evacuated tube and solar energy etc.**

Introduction:

Ehsan Shojaeizadeh, Farzad Veysi , Ahmad Kamandi [1] presented in their technical paper to investigate exergy efficiency of a Flat-plate solar collector containing Al_2O_3–water nano fluid as base fluid. The effect of various parameters like mass flow rate of fluid, nano particle volume concentration, collector inlet fluid temperature, solar radiation, and ambient temperature on the collector exergy efficiency is investigated. Also, the procedure to determine optimum values of nano particle volume concentration, mass flow rate of fluid, and collector inlet fluid temperature for maximum exergy efficiency delivery has been developed by means of interior-point method for constrained optimization under the given conditions. According to the results, each of these parameters can differently affect the collector exergy by changing the value of the other parameters. The optimization results indicate that under the actual constraints, in both pure water and nanofluid cases the optimized exergy efficiency is increased with increasing solar radiation value. By suspending Al_2O_3 nanoparticles in the base fluid (water) the maximum collector exergy efficiency is increased about 1% and also the corresponding optimum values of mass flow rate of fluid and collector inlet fluid temperature are decreased about 68% and 2%, respectively.
M. Mohanraj , S. Jayaraj, C. Muraleedharan [2] presented in their technical paper the applications of ANN for thermal analysis of heat exchangers are reviewed. The reported investigations on thermal analysis of heat exchangers are categorized into four major groups, namely (i) modeling of heat exchangers, (ii) estimation of heat exchanger parameters, (iii) estimation of phase change characteristics in heat exchangers and (iv) control of heat exchangers. Most of the papers related to the applications of ANN for thermal analysis of heat exchangers are discussed. The limitations of ANN for thermal analysis of heat exchangers and its further research needs in this field are highlighted. ANN is gaining popularity as a tool, which can be successfully used for the thermal analysis of heat exchangers with acceptable accuracy.
L.M. Ayompe , A. Duffy [3] presented in their technical paper the thermal performance of a solar water heating system with 4 m^2 flat plate collectors in Dublin, Ireland was presented in this paper. The experimental setup consisted of a commercially available forced circulation domestic scale system fitted with an automated sub-system that controlled hot water draw-offs and the operation of an auxiliary immersion heater. The system was tested over a year and the maximum recorded collector outlet fluid temperature was 70.4 °C while the maximum water temperature at the bottom of the hot water tank was 59.9 °C. The annual average daily energy collected was 19.6 MJ/d, energy delivered by the solar coil was 16.2 MJ/d, supply pipe loss was 3.2 MJ/d, solar fraction was 32.2%, collector efficiency was 45.6% and system efficiency was 37.8%. Supply pipe losses represented 16.4% of energy collected.
Ramkishore Singh , Ian J. Lazarus, Manolis Souliotis [4] presented in their technical paper Conversion of solar energy via thermal route was highly efficient, more environmental friendly and economically viable. Integrated Collector Storage Solar Water Heaters (ICSSWHs) convert the solar radiation directly into heat at an appreciable conversion rate and in many cases that happen under concentrated form. These systems are compact, aesthetically attractive and reasonable in construction. They have the potential to reduce environmental impact up to 40% and also have high collection efficiency factor. Despite many advantages, ICS solar water heaters suffer from high thermal losses in the night/overcast sky conditions. Performance of ICSSWH systems is influenced by various parameters such as reflector and absorber types, energy collection and storage arrangements and design parameters of the systems. In this article, various concentrating and non-concentrating ICSSWHs, systems with PCM (Phase Change Material) and heat retention strategies are reviewed. Recent development in the ICSSWHs indicates the potential of reliability of these systems for domestic hot water application at lower cost. The concentrating type ICSSWHs show better collection efficiency at reduced cost, but suffer high night time thermal losses. Further research is needed, especially in CPC-ICSSWHs, for minimizing night time thermal losses. Ehsan Ebrahimnia-Bajestan , Mohammad Charjouei Moghadam, Hamid Niazmand ,Weerapun Daungthongsuk, Somchai Wongwises [5] presented in their technical paper laminar convective heat transfer of water-based TiO_2 nanofluid flowing through a uniformly heated tube has been investigated via experiments and numerical modeling. The thermal conductivity and dynamic viscosity of the prepared nanofluids have also been measured and

modeled at different temperatures and nanoparticle concentrations. Based on the results, a maximum enhancement of 21% in average heat transfer coefficient has been obtained using TiO_2/water nanofluids. For the numerical section, the single-phase model was compared with the common two-phase numerical approaches. The numerical investigation indicated that the predicted heat transfer coefficients using single-phase and common two-phase approaches, even based on experimental thermophysical properties of nanofluids, underestimate and overestimate the experimental data, respectively. Therefore, some modifications are implemented to the common two-phase model in order to obtain more accurate predictions of the heat transfer characteristics of nanofluids. This modified model investigated the effects of particle concentration, particle diameter, and particle and base fluid material on the heat transfer rate at different Reynolds numbers. The results indicated that the convective heat transfer coefficient increases with an increase in nanoparticle concentration and flow Reynolds number, while particle size has an inverse effect. The obtained results can be very useful to the investigation of the potential application of nanofluid-based solar collectors.

Radim Rybár, Martin Beer' [6] presented in their technical paper an experimental thermal performance comparison of standard design heat pipe evacuated tube collector and collector with parallel flow manifold header with metal foam structural element which was developed by authors in their previous work. The used data were obtained during experimental simultaneous operation of two interconnected solar systems at the Centre of Renewable Energy Sources, Kosice, Slovakia during the months of April and May in various weather and climatic conditions. Manifold header with metal foam structural element partially eliminates deficiencies of standard design manifold headers by changing of heat transfer medium stream conducting to each condenser, reducing the internal fluid volume and introducing of new structural element to manifold header design – heat exchange chamber made of metal foam which increases the heat exchange surface of condenser. Presented data consist of a selection from all measurements taken during experimental operation, when solar collector with manifold header based on metal foam showed a performance increase around 25%, and reduced thermal inertia of the solar collector at operation with changing intensity of solar insolation, which leads to an overall improvement in function of the solar system.

Abhay Dinker, Madhu Agarwal, G.D. Agarwal [7] presented in their technical paper reviews various kinds of heat storage materials, their composites and applications investigated over the last two decades. It was found that sensible heat storage systems are bulkier in size as compared to the latent heat storage systems. Latent heat storage system using phase change materials (PCMs) stores energy at high density in isothermal way. Various geometries of PCM containers used for enhancement of heat transfer area, materials used for the construction of PCM containers and their interaction with heat storage materials are studied. The choice of storage material depends on the desired temperature range, application of thermal storage unit and size of thermal storage system. Low temperature heat storage system uses organic phase change materials while inorganic phase change materials are best suited for high temperature heat storage. Heat transfer within the PCM can be enhanced by preparing composite of high thermal conductivity as well as by altering the geometrical design like addition of fins, use of straight and helical tubes etc. Shell and tube configurations were mostly used for thermal storage systems. Heat transfer enhancement using PCM composite is a promising approach as it reduces cost and bulkiness to the system.

Abdul Waheed Badar', Reiner Buchholz, Felix Ziegler[8] presented in their technical paper, an analytical steady state model was developed to study the thermal performance of an individual vacuum tube solar collector with coaxial piping (direct flow type) incorporating both single and two-phase flows. A system of equations which describe the different heat transfer mechanisms and flow conditions was established, discretised, and solved in an iterative manner. For the case of good vacuum condition (10^{-5} mb) the calculated efficiency curve for single phase flow deviates significantly from the experiments with increasing collector temperature, but agrees well for the case of gas conduction inside the glass envelope at very low pressure ($\ll$1 mb) due to the corresponding increase in overall heat loss coefficient (*U*-value). For two-phase flow, the occurrence and propagation of flow boiling and condensation inside the collector piping under saturated condition is hypothesized. The modeling results indicate that for all-liquid-single-phase fluid flow, the collector efficiency decreases with decreasing mass flow rate. Once the fluid reaches the boiling point at a certain mass flow rate, no significant reduction in efficiency is observed anymore, which is in accordance with the experimental study.

Zhiyong Li', Chao Chen, Hailiang Luo, Ye Zhang, Yaning Xue[9] presented in their technical paper to establish the heat transfer model of all-glass vacuum tube collector used in forced-circulation solar water heating system. In this model, the simplified heat transfer of collector was composed of the natural convection in single glass tube and forced flow in manifold header. Thus the heat balance equation of water in single tube and the heat balance equation of water in manifold header have been established. The flow equation was also built by analyzing the friction and buoyancy in tube. Through solved these equations the relationship between the collector average temperature, the outlet temperature and natural convection flow rate have been obtained. From this relationship and energy balance equation of collector, the collector outlet temperature can be calculated. The validated experiments of this model were carried out in winter of Beijing. Indra Budihardjo, Graham L. Morrison', Masud Behnia [10] presented in their technical paper experimental and numerical investigations were undertaken to develop a correlation for natural circulation flow rate through single-ended water-in-glass evacuated tubes mounted over a diffuse reflector. The circulation flow rate was correlated in terms of solar input, tank temperature, collector inclination and tube aspect ratio. The sensitivity of the flow rate correlation to the variation in circumferential heat flux distribution was also investigated. Runsheng Tang', Yuqin Yang, Wenfeng Gao [11] presented in their technical paper performance comparative studies, two sets of water-in-glass evacuated tube solar water heater were constructed and tested. Both SWHs were identical in all aspects but had different collector tilt-angle from the horizon with the one inclined at 22° (SWH-22) and the other at 46° (SWH-46). Experimental results revealed that the collector tilt-angle of SWHs had no significant influence on the heat removal from solar tubes to the water storage tank, both systems had almost the same daily solar thermal conversion efficiency but different daily solar and heat gains, and climatic conditions had a negligible effect on the daily thermal efficiency of systems due to less heat loss of the collector to the ambient air. These findings indicated that, to maximize the annual heat gain of such solar water heaters, the collector should be inclined at a tilt-angle for maximizing its annual collection of solar radiation. Experiments also showed that, for the SWH-22, the cold water from the storage tank circulated down to the sealed end of tubes along the lower wall of tubes and then returned to the storage tank along the upper wall of solar tubes with a clear water circulation loop; whereas for the SWH-46, the situation in the morning was the same as the SWH-22, but in the afternoon, the cold water from the storage tank on the way to the sealed end was partially or fully mixed with the hot water returning to the storage tank without a clear water circulation loop, furthermore, such mixing became more intense with the increase in the inlet water temperature of solar tubes. This indicated that increasing the collector tilt-angle of SWHs had no positive effect on the thermosiphon circulation of the water inside tubes. No noticeable inactive region near the sealed end of solar tubes for both systems was observed in experiments.

References:

[1] Ehsan Shojaeizadeh, Farzad Veysi, Ahmad Kamandi Exergy efficiency investigation and optimization of an Al_2O_3–water nanofluid based Flat-plate solar collector Energy and Buildings (8), 2015, 12–23
[2] M. Mohanraj, S. Jayaraj, C. Muraleedharan Applications of artificial neural networks for thermal analysis of heat exchangers – A review International Journal of Thermal Sciences (4),l 2015, 150–172
[3] L.M. Ayompe, A. Duffy Analysis of the thermal performance of a solar water heating system with flat plate collectors in a temperate climate Applied Thermal Engineering 58(2), 2013, 447–454
[4] Ramkishore Singh, Ian J. Lazarus, Manolis Souliotis Recent developments in integrated collector storage solar water heaters: A review Renewable and Sustainable Energy Reviews (2) 54, 2016, 270–298
[5] Ehsan, Hamid Niazmand,Weerapun Daungthongsuk, Somchai Wongwises Experimental and numerical investigation of nanofluids heat transfer characteristics for application in solar heat exchangers International Journal of Heat Mass Transfer 92(1), 2016, 1041–1052
[6] Radim Rybár, Martin Beer The comparative field performance study of heat pipe evacuated tube collectors with standard design manifold header & parallel flow manifold header based on the metal foam structural element Solar Energy 122(12),2015, 359–367
[7] Abhay Dinker, Madhu Agarwal, G.D. Agarwal Journal of the Energy Institute 20 October 2015 Heat storage materials, geometry and applications: A review
[8] Abdul Waheed Badar, Reiner Buchholz, Felix Ziegler Single and two-phase flow modeling and analysis of a coaxial vacuum tube solar collector Solar Energy, 86(1),2012, 175-179
[9] Zhiyong Li, Chao Chen, Hailiang Luo, Ye Zhang, Yaning Xue All-glass vacuum tube collector heat transfer model used in forced-circulation solar water heating system Solar Energy 84(8),2010, 1413–1421
[10] Indra Budihardjo, Graham L. Morrison, Masud Behnia Natural circulation flow through water-in-glass evacuated tube solar collectors Solar Energy 81(12),2007, 1460–1472
[11] Runsheng Tang, Yuqin Yang, Wenfeng Gao Comparative studies on thermal performance of water-in-glass evacuated tube solar water heaters with different collector tilt-angles Solar Energy 85(7), 2011, 1381–1389