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A Review on the Applications of Various Aqua Based Nanofluids in the Field of Parabolic Trough Collector

Papil M. Gautam[1], M. K. Chudasama[2]
[1, 2]Assistant professor, Mechanical Engineering Dept., Government Engineering College, Dahod.

***Abstract:** Nanofluids were created as a result of researchers' efforts to improve the thermal efficiency of solar collectors by improving the thermal properties. Various nanomaterials, such as copper oxide, alumina, silica, Titania, and others, have been highlighted in numerous studies for dispersion in working fluid and subsequent use in parabolic trough collectors. Carbon nanomaterials, on the other hand, have been deemed the most promising for the preparation of water-based nanofluids and heat transfer applications. This is due to the extraordinary thermophysical properties of carbon nanomaterials. These properties lead to a significant improvement in the thermophysical properties of the working fluid, which improves solar collector efficiency. The efficiency of parabolic trough collectors using various nanofluids is examined in this review. The findings of this study revealed that low-concentration carbon-based nanofluids increased the collector performance of a parabolic trough. Because of their high energy content, carbon nanotubes had the greatest effect on heat transfer rate. The research also showed that commercialising carbon-based nanofluid has a lot of potential. The advantages, obstacles, and opportunities for future research have all been established.*

***Keywords:** Nanoparticles, MWCNT, Surfactant, Triton X 100, Parabolic trough collector.*

Nomenclature

A	Area, m^2
C	Concentration ratio, -
C_p	Specific heat of the heat transfer fluid, J/kg K
D	Diameter of the receiver, mm
G_b	Direct solar radiation W/m^2
h	Heat Transfer coefficient, W/m^2K
h_{out}	Convection coefficient between cover and ambient, W/m^2K
k	Thermal Conductivity, W/mK
L	Tube length, mm
m	Mass flow rate, kg/s
Nu	Mean Nusselt Number
Pr	Prandlt Number, -
Q_s	Heat Flux, W
Re	Reynolds Number, -
T	Temperature, °C
V	Volumetric flow rate, m^3/h

Subscripts and Superscript

am	*ambient*
bf	base fluid
c	cover
ci	inner cover
co	outer cover
fm	mean fluid
in	inlet
loss	losses
nf	nanofluid
np	nanoparticles
opt	optical
out	outlet
r	receiver
ri	inner receiver
ro	outer receiver
s	solar
th	thermal

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Greek symbols

ε	Emittance, -
η	Efficiency, -
μ	Dynamic viscosity, Pa s
ρ	Density, kg/m^3
σ	Stefan-Boltzmann constant [= $5.67 \times 10^{-8}\ W/m^2\ K^4$]
φ	Volumetric fraction of nanoparticles, %

th, exp	thermal experimental
u	usefull

Abbreviations

CFD	Computational fluid dyna
PTC	Parabolic trough collecto

I. INTRODUCTION

Solar energy is currently one of the most significant sources of clean, free, inexhaustible, renewable energy with low environmental impact. The amount of solar energy intercepted by the earth is about 1.8 x 10^{11} MW.[1]. Just about 30% of solar energy enters the planet, and the sun generates enough energy to fulfil the world's needs for an entire year every 20 minutes. [2]. Solar energy is described as energy derived from the sun that can be converted into electricity and heat. Solar energy and the technologies of its materials have gotten a lot of attention in the last ten years since it has been producing energy for billions of years. [3,4]. For example, some studies have shown that solar energy can meet around 1000 times the world's energy needs; however, only 0.02 % of this energy is actually used. [5]. The rising demand for electricity, the limited supply of fossil fuels, and the environmental issues associated with them, such as carbon dioxide emissions, are the key reasons for this intense interest in solar energy applications. Furthermore, the exponential growth in the human population can be considered a serious concern, as the global population has grown by nearly 2 billion, mainly due to developing countries' contributions. [6]. Furthermore, it has been established that humans consume fossil fuels at a much faster pace than geologic processes can replace them. In reality, the sun emits an immense amount of energy every day, and the hourly solar flux incident on the earth's surface is greater than the entire human energy intake in a year. [7]. Despite the vast amount of solar energy available, nearly 80% of the energy consumed worldwide still comes from fossil fuels such as coal, petroleum, and natural gas. [8].

The current work offers a detailed review of recent developments in nanotechnology's application in parabolic trough solar collectors. Theoretical, numerical, and experimental up-to-date works related to nanofluid applications in parabolic trough solar collectors were reviewed. A large amount of literature is reviewed and summarised in order to provide the reader with a detailed overview of the role of nanofluid in improving solar collector efficiency.

A. Concept of Nanofluid and Surfactant.

The term "nanofluid" or "nanoparticle suspensions in liquids" refers to a mixture of a normal fluid (water, oil, ethylene glycol, and molten salts) and a very small amount of solid metallic or metallic oxide nanoparticles or nanotubes, as proposed by Choi.[9] in 1995. Due to its excellent performance, it was regarded as a new generation of advanced heat transfer fluids or a two-phase device that could be used in a variety of engineering and industrial applications. Nuclear reactors, transportation, transformer oil cooling, electrical energy, electronic, magnetic, microchip cooling, solar absorption, and biomedical fields are only a few examples of these applications [10]. Metals have higher thermal conductivities than fluids, which is common knowledge. Copper, for example, has a thermal conductivity about 700 times greater than water and 3000 times greater than engine oil at room temperature. [11]. The first decade of nanofluid research focused on determining the thermo-physical properties of these fluids, such as thermal conductivity, density, viscosity, and heat transfer coefficient. [12]. Nanofluid has strong radiation absorption properties and a high thermal conductivity. Specific multi-walled carbon nanotubes (MWCNTs) have been found to have thermal conductivity values greater than 3000 W/m K at room temperature. [13]. Assael et al. [14] indicated, a 1% volumetric fraction of MWCNT increased the thermal conductivity of water by around 40%.The preparation of nanofluids by dispersing nanoparticles in a base fluid necessitates careful particle mixing and stabilisation. Nanoparticles are extremely thin, measuring in the range of 1–100 nm[15], or one-thousandth the diameter of a human hair. It is strongly advised against using broad solids.

According to Sh. Ebrazeh et al.[16], the use of nanofluids improves thermal efficiency due to their high energy content. Al_2O_3 nanoparticles have been used in a variety of studies due to their lower cost. The thermal efficiency of the collector can also be increased by increasing the working fluid inlet temperature. Figure 1 depicts the contribution of various forms of nanofluids to the research field.

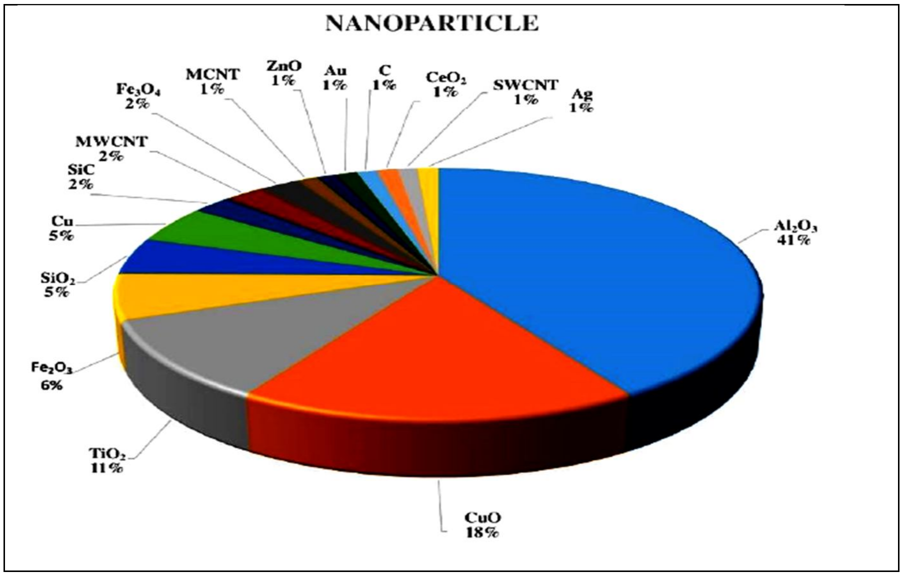


Figure. 1. The rate at which different nanofluids are used in PTC [16].

Surfactant, also known as a surface-active agent, is a material like a detergent that decreases the surface tension of a liquid, enhancing its spreading and wetting properties. The surfactant used to delay the deposition of suspended nanoparticles in the emulsion determines the stability of nanofluid. The time it takes for nanoparticles to be suspended in an emulsion is largely determined by the form of surfactant used and the duration of ultra sonication.T. Yousefi et al.[17] found that raising the weight fraction from 0.2% to 0.4 % improved performance. The addition of the surfactant improves performance as well. The best sonication time was found to be 30 minutes. Triton X-100 is the best dispersing agent for suspending MWCNTs as a non-ionic surfactant. According to R. Rastogi et al.[18]. Among several surfactants such as Tween 80, Tween 20, and sodium dodecyl sulphate(SDS), Triton X-100 offers the strongest dispersion This is due to the structure's Triton X-100 benzene ring. Molecules with the benzene ring structure are said to absorb more strongly into the graphitic surface due to p-p stacking type interaction. In the case of Triton X-100, the optimal amount of surfactant required is also less than that of other surfactants. The ideal Triton X-100-to-CNT ratio was determined to be 1:350. MWCNT nanofluid 0.02 wt % with 160 lph showed better results for overall thermal performance. The use of surfactant Triton X-100 with MWCNT nanofluid was also used to increase the amount of base fluid heat absorption capacity, according to R.S. Mishra et al.[19].

II. MATHEMATICAL MODELING.

The basic mathematical equations that describe the established mathematical models are given in this paragraph. The energy balances in the collector, the heat transfer analysis, and the properties formulas for nanofluids are all explained by these equations. Parabolic trough collectors are high-concentration concentrating collectors that rely solely on solar beam irradiation [20]. The product of the concentration ratio (C), the outer absorber region (A_{ro}), and the solar beam irradiation (G_b) yields the available solar energy

$$Q_s = C \cdot A_{ro\cdot} G_b \tag{1}$$

Using the outer absorber diameter (D_{ro}) and the length (L) of the evacuated tube, the outer absorber area is measured using Eq. (2). Similar formulas can be used to measure the inner absorber area as well as the cover area.

$$A_{ro\cdot} = \pi \cdot D_{ro} \cdot L \tag{2}$$

As shown in Eq. (3), the useful energy gained by the heat transfer fluid can be determined using the energy balance of its volume.

$$Q_u = m \cdot c_p \cdot \left(T_{out} - T_{in}\right) \tag{3}$$

It's helpful to remember that the mass flow rate (m) is equal to the product of the fluid density (ρ) and the volumetric flow rate (V), as shown in Eq. (4).

$$m = \rho \cdot V \tag{4}$$

The thermal efficiency (η_{th}) of solar collectors is the most important term for evaluating. As shown in Eq. (5), this parameter is measured as the ratio of usable energy to available solar energy.

$$\eta_{th} = \frac{Q_u}{Q_s} \tag{5}$$

Eq. (6) indicates that the absorber's thermal losses (Q_{loss}) are radiation losses [20]. It is important to remember that due to the vacuum between the absorber and the cover, heat convection losses are ignored in evacuated tube collectors.

$$Q_{loss=} \frac{A_{ro\cdot} \cdot \sigma\left(T_r^{\ 4} - T_c^{\ 4}\right)}{\frac{1}{\varepsilon_r} + \frac{1-\varepsilon_c}{\varepsilon_c} \cdot \left(\frac{A_{ro}}{A_{ci}}\right)} \tag{6}$$

The absorber's emissivity (ε_r) is determined as a function of its mean temperature [21].

$$\varepsilon_r = 0.000327 \cdot T_r - 0.065971 \tag{7}$$

Furthermore, in steady-state conditions, the absorber's thermal losses to the cover are equal to the cover's thermal losses to the ambient. As shown in Eq. (8), thermal energy losses due to radiation and convection are covered:

$$Q_{loss} = A_{co} \cdot h_{out} \cdot (T_c - T_{am}) + A_{co} \cdot \sigma \cdot \varepsilon_c \cdot (T_c^{\ 4} - T_{am}^4) \tag{8}$$

The energy balance on the absorber is a fundamental equation in the study since, as Eq. (9) shows, it correlates usable energy and thermal losses. This equation explicitly illustrates how absorbed solar energy ($Q_s \cdot \eta_{opt}$)is divided into usable heat and thermal losses.

$$Q_s \cdot \eta_{opt} = Q_u + Q_{loss} \tag{9}$$

The heat transfer analysis within the absorber tube must be studied in order to compare the temperature level on the absorber with the fluid operating temperature level. The heat transfer from the absorber to the working fluid is defined by Eq. (10).

$$Q_u = h \cdot A_{ri} \cdot (T_r - T_{fm}) \tag{10}$$

Eq. (11) is used to measure the mean temperature of the working fluid:

$$T_{fm} = \frac{T_{in} + T_{out}}{2} \tag{11}$$

The heat transfer coefficient (h) between the absorber tube and the fluid is a crucial parameter in this modelling. Many factors affect this parameter, including tube geometry, flow rate, and fluid properties, with thermal conductivity playing a significant role. The dimensionless Nusselt number is used to calculate this parameter, as shown in Eq. (12):

$$h = \frac{N_{u\cdot}k}{D_{ri}} \tag{12}$$

As in the current analysis, the Nusselt number can be determined using the Dittus- Boelter equation for turbulent flow (Re > 2300) [22].

$$N_{u\cdot} = 0.023 \cdot \mathrm{Re}^{0.8} \cdot \mathrm{Pr}^{0.4} \tag{13}$$

A modified correlation is used for activity with nanofluids, as suggested by Pak and Cho [23]:

$$N_{u\cdot} = 0.021 \cdot \mathrm{Re}^{0.8} \cdot \mathrm{Pr}^{0.5} \tag{14}$$

The calculation formula for Reynolds number in circular tubes is shown in Eq. (15):

$$\mathrm{Re} = \frac{4 \cdot m}{\pi \cdot D_{ri} \cdot \mu} \tag{15}$$

The Prandtl number can be calculated according to Eq. (160)

$$\mathrm{Pr} = \frac{\mu \cdot C_p}{k} \tag{16}$$

Eqs. (17)–(20) can be used to measure the properties of nanofluids using the properties of the base fluid (bf) and nanoparticles (np). Eq. (17) [24] gives the mixture's density, while Eq. (18) [25] gives the specific heat power.

$$\rho_{nf} = \rho_{bf} \cdot (1-\phi) + \rho_{np} \cdot \phi \tag{17}$$

$$C_{p,nf} = \frac{\rho_{bf} \cdot (1-\phi)}{\rho_{nf}} \cdot C_{p,bf} + \frac{\rho_{np} \cdot \phi}{\rho_{nf}} \cdot C_{p,np} \tag{18}$$

The Maxwell equation [26,27] is used to measure the thermal conductivity of the nanofluid:

$$k_{nf} = \frac{k_{np} + 2 \cdot k_{bf} - 2 \cdot \phi \cdot (k_{bf} - k_{np})}{\frac{k_{np}}{k_{bf}} + 2 + \phi \cdot \frac{k_{bf} - k_{np}}{k_{bf}}} \tag{19}$$

Eq. (20) [28] is used to measure the viscosity of the mixture:

$$\mu_{nf} = \mu_{bf} \cdot (1 + 2.5 \cdot \phi + 6.5 \cdot \phi^2) \tag{20}$$

III. APPLICATION OF NANOFLUID IN THE PTC.

When comparing Al_2O_3 and Fe_2O_3 nanofluids at 2 lpm to water under the same operating conditions, M.A. Rehan et al.[29] found that the maximum efficiencies obtained with Al_2O_3 and Fe_2O_3 nanofluids are 13 % and 11 % higher, respectively. Al_2O_3 nanofluids appeared to be more effective than Fe_2O_3 in improving PTC efficiency for domestic applications. According to K.S. Chaudhari et al.[30], AL_2O_3 nanofluid can increase solar thermal efficiency by 7% and the heat transfer coefficient by 32%. Kumar Sunil et al.[31] looked into whether a SiO_2-H_2O-based nanofluid is more effective at higher volume flow rates and concentrations. Nanofluids, according to Sh. Ebrazeh et al.[16], improve thermal efficiency due to their high energy content. Al_2O_3 nanoparticles have been used in a variety of studies due to their lower cost. The thermal efficiency of the collector can also be increased by increasing the working fluid inlet temperature. The use of MWCNTs has the best thermal efficiency of any kind of nanofluid. S.Verma et al.[32] studied multiwalled carbon nanotube/water and found that it has the highest energy efficiency improvement of 23.47 %, followed by 16.97 %, 12.64 %, 8.28 %, 5.09 %, and 4.08 % for graphene/water, Copper oxide/water, Aluminium oxide/water, Titanium oxide/water, and Silicon oxide/water, respectively, as compared to water as the baseline. In graphene, copper, aluminium, titanium, and silicon oxide-based nanofluids, the percentage decrease in area observed was given as 19.01 % in MWCNTs/water, followed by 14.66 %, 10.66 %, 8.78 %, 4.83 %, and 3.99 %, respectively. As compared to water as the working fluid, S. Verma et al.[33] found that using MgO nanofluid increases solar collector performance by 9.34 % for 0.75 % particle volume fraction and volume flow rate of 1.5 lpm. S.S. Bernard et al.[34] found that the heat energy obtained by the MWCNT fluid increased by 5.2 %, 7.3 %, and 7.2 % as compared to water at mass flow rates of 0.0069 kg/s, 0.0138 kg/s, and 0.0207 kg/s, respectively.

When A.A. Hachicha et al.[35] tested MWCNT nanoparticles in water, they found that concentrations of 0.05 %, 0.1 %, and 0.3 % increased the Nusselt amount by 12 %, 16 %, and 21 %, respectively. At flow rates below 0.2 lps, using low concentrations of nanofluid could boost thermo-hydraulic efficiency. For improved heat transfer at higher flow rates, the concentration of nanoparticles should be increased. K. Khanafer et al.[36] reviewed the literature on solar systems and concluded that improved thermal conductivity of nanofluid is a critical factor in increasing nanofluid performance. Higher nanoparticle volume fractions do not consistently improve efficiency. Second, the increase in nanofluid viscosity caused by the addition of nanoparticles is a major disadvantage since it is linked to increased pumping power. As a result, nanofluids with low viscosity and high thermal conductivity are advantageous. Carbon nanomaterials, according to A. Borode et al.[37], are the most promising for the preparation of nanofluids and the application of heat transfer. Carbon nanomaterials have an exceptional thermophysical property. These characteristics result in a significant improvement in the thermophysical properties of the working fluid, increasing solar collector performance. With a low concentration of about 0.3 vol. %, carbon-based nanofluids enhanced the collector efficiency of flat-plate, evacuated-tube, parabolic trough, and hybrid photovoltaic thermal solar collectors by up to 95.12 %, 93.43 %, 74.7 %, and 97.3 %, respectively. M.S.B.de Los Rios et al.[38] investigated the nanofluid with a 3% volume fraction and found that it had a maximum efficiency of 52.4 % for an incident angle interval of 20° to 30°, compared to 40.8 % for water. For an incident angle of 10°, the nanofluid with 1% volume concentration had a maximum efficiency of 57.7%, while the water had a maximum efficiency of 46.5 %. Even though the collector received lower solar radiation values, the temperatures of the nanofluids at the PTC's outlet were higher than those of the water. The output of the nanofluids was discovered to be highly dependent on the angle at which the event occurred.

IV. BENEfiTS OF USING NANOflUID IN THE SOLAR COLLECTORS.

Nanofluids have a range of advantages over conventional fluids, making them very efficient in solar collectors[39].

A. Nanoparticles are very effective at maximising solar energy absorption due to their ease of changing form, material, scale, and solid volume fraction.
B. Because of their small particle size, solid nanoparticles increase the surface area and heat power of the fluid.
C. Nanofluids can be optically selective, with high absorption in the solar spectrum and low emittance in the infrared spectrum. As a result, using the nanofluid improves the optical characteristics (light absorption and emission behaviour) of a base liquid, such as the extinction coefficient.
D. Strong nanoparticles greatly improve the thermal conductivity of the base fluid, improving the performance of solar collectors. Since the thermal conductivity of the nanofluid increases as the concentration and temperature of the nanofluid rises.
E. In relation to the base fluid, nanofluid has a high absorption coefficient. It also has strong stability under moderate temperature gradients, making it one of the best absorbing fluids available.
F. Nanofluids significantly boost the radiative properties of simple fluids, resulting in higher solar collector performance.
G. Nanofluid can be used to minimise surface temperature by improving fluid properties rather than pumping water at a higher flow rate, which is inefficient since the solar collector's overall performance is decreased.
H. Due to its extremely small scale, nanofluid can prevent sedimentation, fouling, and clogging of pumps and pipes.
I. Nanofluid was successfully used to minimise the necessary heat transfer area of tubes and heat exchangers used in parabolic trough collectors, lowering the total cost of these collectors
J. As incident radiation passes through nanofluids, it scatters and absorbs more efficiently. It's also been discovered that applying nanoparticles to pure water improves its optical properties significantly.
K. Using nanofluid in the solar collector increases the system's desired output temperature, which is needed to boost collector performance. While in a traditional solar collector, raising the output temperature necessitates increasing the heat transfer region, which increases the collector's size and expense.
L. The nanofluid can be effectively used to reduce the size and expense of solar collector systems. This is because the complicated manufacturing methods used to create surface-absorbing plates have been eliminated.
M. Because of its high density, low specific heat of nanoparticles, and high convective heat transfer coefficient, the nanofluid improves collector performance.
N. The nanofluid can be used to significantly minimise convection and emissive heat loss in traditional collectors.

V. CHALLENGES AND DIFFICULTIES.

A. It takes a long time for the nanofluid to become soluble in base fluids.
B. In contrast to the base fluid, the nanofluid has a low specific heat. Many studies have shown that the best heat transfer method necessitates a high specific heat in the working fluid in order to exchange more heat.
C. Since the nanofluid has a high toxicity, it must be handled with caution during its preparation.
D. Nanofluid preparation and testing are both expensive.
E. The nanofluid has low boiling characteristics. As a result, as the concentration of nanoparticles grows, the surface temperature of the nanofluid rises, causing extreme overheating.
F. Since the nanofluid has a high viscosity, it has a higher pressure drop, which increases the pumping power required.
G. The presence of nanoparticles in the nanofluid can cause solar collector corrosion and erosion over time.
H. There are several technological issues with using nanofluids, such as nanoparticle sedimentation.
I. The cost of the nanofluid is high due to difficulties in its manufacture, and it may pollute the atmosphere when drained after use.

VI. CONCLUSION.

This study observed at the thermal efficiency of PTC that used nanofluids as heat transfer fluids. The findings show that using nanofluids improves thermal efficiency due to their high energy content. Because of its low cost, Al_2O_3 nanoparticles have been used in a wide range of studies. Furthermore, increasing the inlet temperature of working fluids will increase the collector's thermal efficiency. However, because of the need to cool down the device at high temperatures, it is recommended that nanofluid be substituted in low-temperature ranges.

To improve the efficiency of the nanofluid collector, the volume fraction of nanoparticles must be carefully selected. This is because; the large volume fractions of nanoparticles increase the viscous force of nanofluids and reduce the heat transfer. Because of its small size, the nanofluid is unable to absorb all of the incident solar radiation. It has been discovered that the size of the nanoparticles has a significant impact on the efficiency of various types of solar collectors. Future research should concentrate on developing non-toxic, low-cost nanoparticles in order to further reduce the cost of nanofluid-based solar collectors and meet consumer demands quickly.

Because of their high energy content, carbon nanotubes had the greatest effect on heat transfer rate. The use of carbon-based nanofluids in solar collectors results in an increase in the collectors' thermal performance. As a result, carbon-based nanofluids have a tremendous potential to increase not only energy efficiency but also minimise collector size, lowering production costs.

REFERENCES

[1] Sukhatme S, Nayak K. Solar energy principles of thermal collection and storage, Tata McGraw Hill Education Private Limited; 2009.
[2] Duffie J, Beckman W. Solar engineering of thermal processes. New York: John Wiley and Sons; 1991.
[3] Kandasamy R, Muhaimin I, Rosmila A. The performance evaluation of unsteady MHD non-Darcy nanofluid flow over a porous wedge due to renewable (solar) energy. Renew Energy 2014;64:1–9.
[4] Shan F, Tang F, Cao L, Fang G. Comparative simulation analyses on dynamic performances of photovoltaic- thermal solar collectors with different con- figurations. Energy Convers Manag 2014;87:778–86.
[5] Xia X, Xia J, Virkar A. Evaluation of potential for developing renewable sources of energy to facilitate development in developing countries. In: Proceedings of the Asia-Pacific power and energy engineering conference, Chengdu, China; 2010: p. 1–3.
[6] Allamraju K. Materials used for renewable energy resources. Adv Mater Manuf Charact 2013;3:243–8.
[7] Hussein A. Applications of nanotechnology in renewable energies – a com- prehensive overview and understanding. Renew Sustain Energy Rev 2015;42:460–76.
[8] Thirugnanasambandam M, Iniyan S, Goic R. A review of solar thermal technologies. Renew Sustain Energy Rev 2010;14:312–22.
[9] Choi S. Enhancing thermal conductivity of fluids with nanoparticles. Devel- opments and applications of non-Newtonian flows. ASME FED 1995;Vol. 231/MD-66:99–105.
[10] Rao N, Gahane L, Ranganayakulu S. Synthesis, applications and challenges of nanofluids – review. IOSR J Appl Phys 2014:21–8.
[11] Bejan A, Karaus A. Heat transfer handbook. John Wiley and Sons; 2003.
[12] Faiz F, Zahir E. A comparative study of nanofluids for tuneable filter opera- tion. Int J Eng Res 2014;3:9–12.
[13] Hone J. Carbon nanotubes: thermal properties. In:Dekker encyclopedia of nanoscience and nanotechnology; 2004.
[14] Assael M, Chen C, Metaxa N, Wakeham W. Thermal conductivity of sus- pensions of carbon nanotubes in water. Int J Thermophys 2004;25:971–85.
[15] Yadav D, Agrawal G, Bhargava R. The onset of convection in a binary nano- fluid saturated porous layer. Int J Theor Appl Multiscale Mech 2012;2:198– 224.
[16] S. Ebrazeh, M. Sheikholeslami, Applications of nanomaterial for parabolic trough collector, Powder Technol. 375 (2020) 472–492. https://doi.org/10.1016/j.powtec.2020.08.005.

[17] T. Yousefi, F. Veisy, E. Shojaeizadeh, S. Zinadini, An experimental investigation on the effect of MWCNT-H 2O nanofluid on the efficiency of flat-plate solar collectors, Exp. Therm. Fluid Sci. 39 (2012) 207–212. https://doi.org/10.1016/j.expthermflusci.2012.01.025.

[18] R. Rastogi, R. Kaushal, S.K. Tripathi, A.L. Sharma, I. Kaur, L.M. Bharadwaj, Comparative study of carbon nanotube dispersion using surfactants, J. Colloid Interface Sci. 328 (2008) 421–428. https://doi.org/10.1016/j.jcis.2008.09.015.

[19] R.S. Mishra, H. Singh, International Journal of Research in Engineering and Innovation Comparative study of parabolic trough collector through MWCNT / H_2O nanofluid and water, (2017) 64–70.

[20] C. Tzivanidis, E. Bellos, D. Korres, K.A. Antonopoulos, G. Mitsopoulos, Thermal and optical efficiency investigation of a parabolic trough collector, Case Studies Thermal Eng. 6 (2015) 226–237.

[21] Z.-D. Cheng, Y.-L. He, Y. Qiu, A detailed nonuniform thermal model of a parabolic trough solar receiver with two halves and two inactive ends, Renewable Energy 74 (2015) 139–147.

[22] J. Leinhard IV, J. Leinhard V, A Heat Transfer Textbook, fourth ed., Philogiston Press, USA, 2012, pp. 354–360.

[23] B.C. Pak, Y.I. Cho, Hydrodynamic and heat transfer study of dispersed fluids with submicron metallic oxide particles, Exp. Heat Transfer 11 (1998) 151– 170.

[24] M. Ayatollahi, S.H. Nasiri, A.B. Kasaeian, Convection heat transfer modeling of Ag nanofluid using different viscosity theories, IIUM Eng. J. 13 (1) (2012).

[25] K. Khanafer, K. Vafai, A critical synthesis of thermophysical characteristics of nanofluids, Int. J. Heat Mass Transf. 54 (2011) 4410–4428.

[26] W. Yu, S.U.S. Choi, The role of interfacial layers in the enhanced thermal conductivity of nanofluids: a renovated Hamilton-Crosser model, J. Nanoparticle Res. 6 (4) (2004) 355–361.

[27] J.C. Maxwell, A Treatise on Electricity and Magnetism, second ed., Clarendon Press, Oxford, UK, 1881.

[28] G.K. Batchelor, The effect of Brownian motion on the bulk stress in a suspension of spherical particles, J. Fluid Mech. 83 (1977) 97–117.

[29] M.A. Rehan, M. Ali, N.A. Sheikh, M.S. Khalil, G.Q. Chaudhary, T. ur Rashid, M. Shehryar, Experimental performance analysis of low concentration ratio solar parabolic trough collectors with nanofluids in winter conditions, Renew. Energy. 118 (2018) 742–751. https://doi.org/10.1016/j.renene.2017.11.062.

[30] K. Chaudhari, P. Walke, U. Wankhede, R. Shelke, An Experimental Investigation of a Nanofluid (Al2O3+H2O) Based Parabolic Trough Solar Collectors, Br. J. Appl. Sci. Technol. 9 (2015) 551–557. https://doi.org/10.9734/bjast/2015/11946.

[31] K. Sunil, L.A.L. Kundan, S. Sumeet, Performance Evaluation of a Nanofluid Based Parabolic Solar Collector – an Experimental Study, Proc. Twelveth IRF Int. Conf. 31st August 2014, Chennai, India, ISBN 978-93-84209-48-3. (2014) 29–35.

[32] S.K. Verma, A.K. Tiwari, D.S. Chauhan, Experimental evaluation of flat plate solar collector using nanofluids, Energy Convers. Manag. 134 (2017) 103–115. https://doi.org/10.1016/j.enconman.2016.12.037.

[33] S.K. Verma, A.K. Tiwari, D.S. Chauhan, Performance augmentation in flat plate solar collector using MgO/water nanofluid, Energy Convers. Manag. 124 (2016) 607–617. https://doi.org/10.1016/j.enconman.2016.07.007.

[34] S.S. Bernard, G. Suresh, M.D.J. Ahmed, G. Mageshwaran, V. Madanagopal, J. Karthikeyan, Performance analysis of MWCNT fluid parabolic trough collector for whole year, Mater. Today Proc. (2020) 3–6. https://doi.org/10.1016/j.matpr.2020.05.289.

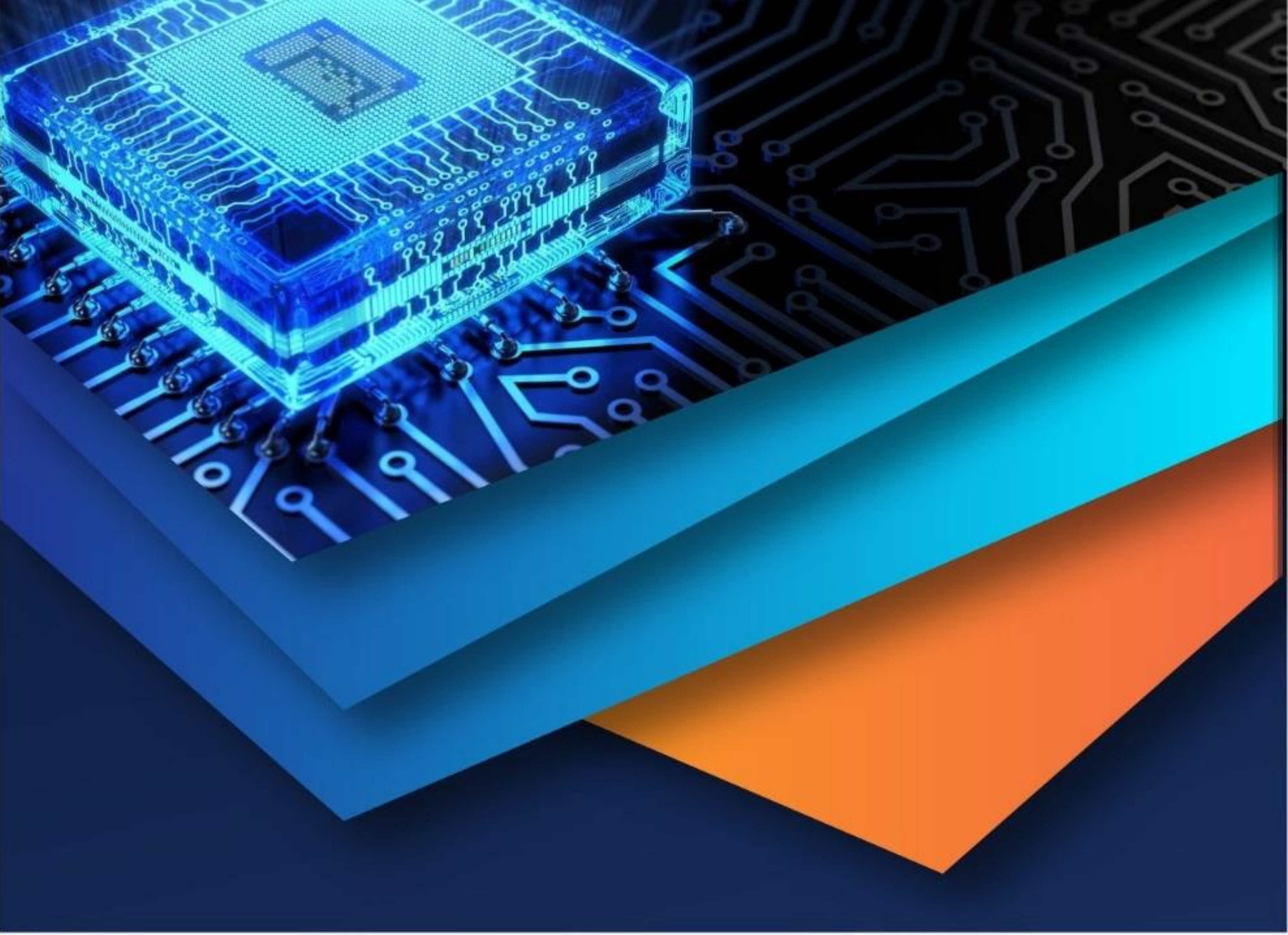
[35] A.A. Hachicha, Z. Said, S.M.A. Rahman, E. Al-Sarairah, On the thermal and thermodynamic analysis of parabolic trough collector technology using industrial-grade MWCNT based nanofluid, Renew. Energy. 161 (2020) 1303–1317. https://doi.org/10.1016/j.renene.2020.07.096.

[36] K. Khanafer, K. Vafai, A review on the applications of nanofluids in solar energy field, Renew. Energy. 123 (2018) 398–406. https://doi.org/10.1016/j.renene.2018.01.097.

[37] A. Borode, N. Ahmed, P. Olubambi, A review of solar collectors using carbon-based nanofluids, J. Clean. Prod. 241 (2019) 118311. https://doi.org/10.1016/j.jclepro.2019.118311.

[38] M.S. Bretado de los Rios, C.I. Rivera-Solorio, A.J. García-Cuéllar, Thermal performance of a parabolic trough linear collector using Al2O3/H2O nanofluids, Renew. Energy. 122 (2018) 665–673. https://doi.org/10.1016/j.renene.2018.01.094.

[39] A.K. Hussein, Applications of nanotechnology to improve the performance of solar collectors –Recent advances and overview, Renew. Sustain. Energy Rev. 62 (2016) 767–792.https://doi.org/10.1016/j.rser.2016.04.050.



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