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Developments and Future Insights of Using Nanofluids for Heat Transfer Enhancements in Geothermal Systems

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ABSTRACT

As we should encourage the uses of renewable sources of energy to make the world a better place and one of them is geothermal energy. It is the most suitable source of energy since it is possible to use it and generate sufficient power. There are various benefits to use geothermal energy among other renewable energy such as more availability factors, little maintenance, stable energy supply, and less pollution. And in order to continue to develop the technology, nanotechnology helps us to achieve that. From the literature reviews, we can say that nanofluids will play a crucial role in the advancement and the betterment of geothermal energy. The improvement relies on many factors together with the kind of nanofluid, concentration, and system specification. In keeping with the results of a study, the impact of mistreatment nanofluid on heat transfer rate became additional vital at higher flow rates. Nanofluids have a higher single-phase heat transfer coefficient, due to increased thermal conductivity. Thus nanofluids can be used to reduce the size of heat exchangers. And the effect is there will be a huge pressure drop.

1. INTRODUCTION

Geothermal energy is often defined because the thermal energy extracting from the crust that varies long between 5 and 10 km. At these high depths, the temperature is very high. Therefore, nanofluids can be used as a cooling fluid to cool the pipes which exposed to this high temperature. Nanofluids are liquid suspensions where nano-materials are dispersed into a base fluid. Nanofluids have received attention for applications in heat transfer process due to their promising performance as heating or cooling fluids. Traditional working fluids utilized in industrial heat transfer devices are for instance water, glycol, or engine oil. It is well-recognized that they need limited effect mainly thanks to low thermal conductivities, and are considered to get replaced by nanofluids with superior properties. Numerous theoretical and experimental studies have been conducted to investigate the thermophysical properties of nanofluids. It has been demonstrated that nanofluids significantly enhance the thermal conductivity and heat transfer capability compared with the traditional working fluids.

2. APPLICATION OF NANOFLUIDS AS AN HEAT TRANSFER MEDIUM IN GEOTHERMAL SYSTEM

Heat transfer processes play an important role in the efficiency of geothermal energy systems. The replacement of conventional heat transfer fluids by nanofluids in heat exchangers is remarkable. The advances in nanotechnology have helped to achieve higher efficiency and cost saving in heat transfer processes. Nanoparticles are considered to be new generation materials having very good potential applications in the heat transfer area.

2.1 Nanofluid in heat exchanger

Nanofluids can help in improving the heat transfer process more than twice with small volume fraction under 0.3%. The latest experimental work related to the utilization of nanofluids in heat exchangers claimed that the flow type within the heat exchanger is a crucial concern in the suitability of a nanofluid. The improvement in the Nusselt number was achieved by using alumina-water and Titania-water nanofluids in fluids where the flow was described as turbulent. The conductive heat transfer in turbulent flows using Cu/water nanofluid was investigated. K.V. Wong et al. 2010's study showed an improvement of more than 39% with a volume concentration of 1.5%. In another study found that, by adding 0.2% volume concentration of TiO_2 nanoparticles, an upgrade of 11% in the convective heat transfer coefficient is possible. W. Yu and H.Xie et al. 2012's study analyzed the use of nanofluid under laminar flow and reported a 41% improvement in heat transfer characteristics in the entry region. Similarly, graphite nanofluids were utilized in a horizontal circular tube to study the laminar convective heat transfer performance and were proven to be effective.

2.2 Geothermal Energy Extraction

Nanofluids using zinc oxide increases heat transfer ability of geothermal systems. using any nanofluid we can increase the efficiency of whole power generation cycle based on geothermal energy out of all renewable energy sources available geothermal energy is the one and only rarely used source. According to Y. Xuan and W. Roetzel et al. 2000, Only 1.5% of the available geothermal energy resource is extractable globally. nanofluids can help in extracting more geothermal energy and producing power in a Rankine cycle more efficiently. nanofluids behave as "fluid superconductors" and hence can be utilized as a working fluid to convert energy into useful form.

2.3 Borehole system in geothermal using Cu nanofluids

Digilio et al. 2018 has showed the study of the effect of using nanofluid as heat carrier instead of conventional fluid, mixture of water and ethylene glycol, on a borehole heat exchanger. In this study, various nano particles such as graphite, alumina and aluminum. were used in low concentrations. The volumetric concentrations of nanofluids were between 0.1% and 1%. It was observed that applying nanofluids can result in reduction in borehole thermal resistance. In addition, it was seen that using Ag nanofluids resulted in the highest convective heat transfer and pressure drop. By considering both heat transfer and pressure drop, it was finalized that using Cu-based nanofluids led to the most reduction in the length of borehole heat exchanger.

Borehole system in geothermal using $Al2O3$ /water and CuO/water nanofluids

Deneshipour et al. 2017 has showed the study of two nanofluids including $Al2O3$ /water and CuO/water were used in geothermal borehole heat exchanger as circuit fluids. Numerical simulation by applying Reynolds Averaged Navier-Stokes was performed to examine the effect of various factors. The volumetric concentration varied between 0% and 6% to evaluate the impact of concentration. Results of the study revealed that by using CuO/water nanofluid, higher heat extraction was achievable compared with $Al2O3$ /water nanofluid; the pressure loss was higher in the case of using CuO/water nanofluid. The results indicated higher local convective heat transfer coefficient by increasing the concentration of the nanofluids. In the study, $Al2O3$ nano particles were employed in volumetric concentrations between 0 and 0.5%. The obtained results showed that increase in the concentration resulted in improved heat flux. The utilized heat exchanger in this study was finned conical helical type. It was concluded that using nano particles with lower dimensions resulted in improvement in Brownian motion; and as a result, the heat transfer rate increased. The results of the research showed that, employing the nano particles in 0.5% vol concentration could lead to approximately 18% increase in obtained energy from the earth.

Mechanisms behind heat transfer enhancement

The mechanisms involving heat transfer enhancement as result of nanofluid application are summarized and presented below:

• The increase in flow rate of nanofluid enhanced heat transfer rate because: better mixing of particles in fluid, collision between wall and particles, collision between particles, elevation in forced convection and improvement in thermal transport properties.

• The increase in thermal conductivity, Brownian motion of nanoparticles and migration of particles associated with higher volume fraction of nanoparticles.

• The presence of nanoparticles caused reduction in thickness of boundary layer and particle clustering, which also played a part in improvement of heat transfer characteristics of system.

• The viscosity of fluid decreases with rise in temperature, this reduction in viscosity makes movement of particles easier and faster, which results in further improvement of thermal conductivity and thus in heat transfer rate.

• Nanofluids with smaller sized nanoparticles may have larger number of particles than big sized particles for same concentration. The smaller sized particles can attain high movement velocity, better interaction with base fluid and improved transport energy, which leads to enhancement in heat transfer rate.

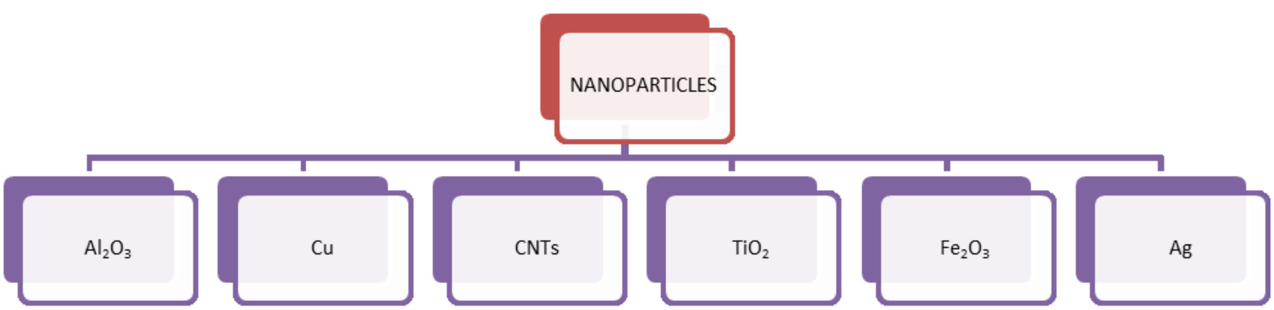

Figure 1: Distribution of nanofluids as an heat transfer medium in geothermal system.

3. CHALLENGES AND FUTURE SCOPE

Despite the promising heat transfer enhancement potential observed by many researchers, there are several barriers to widespread implementation in industrial settings. Most studies on nanofluids largely believe commercially available nanoparticles. Nanoparticles aren't cheap and there's no standard price for these particles as at the present (for example, at the time of writing, 100 g of the commonly studied alumina or copper oxide nanoparticles cost $492.00 and $80.00 US dollars, respectively). These proves that high cost, pumping power, pressure drop, erosion and corrosion of components makes commercially unsuitable. However, they concluded that the overall application of nanofluids remains in its infant stages and, therefore, future investigations will increase the potential applications of nanofluids.

Nanofluids experience a number of forces during and after suspension such as thermophoresis, drag, Van der Waals, Brownian, and electric double layer forces. This is a major challenge with no solution cited in the current literature, yet is one of the primary factors that many researchers think it contributes to aggregation and subsequent sedimentation.

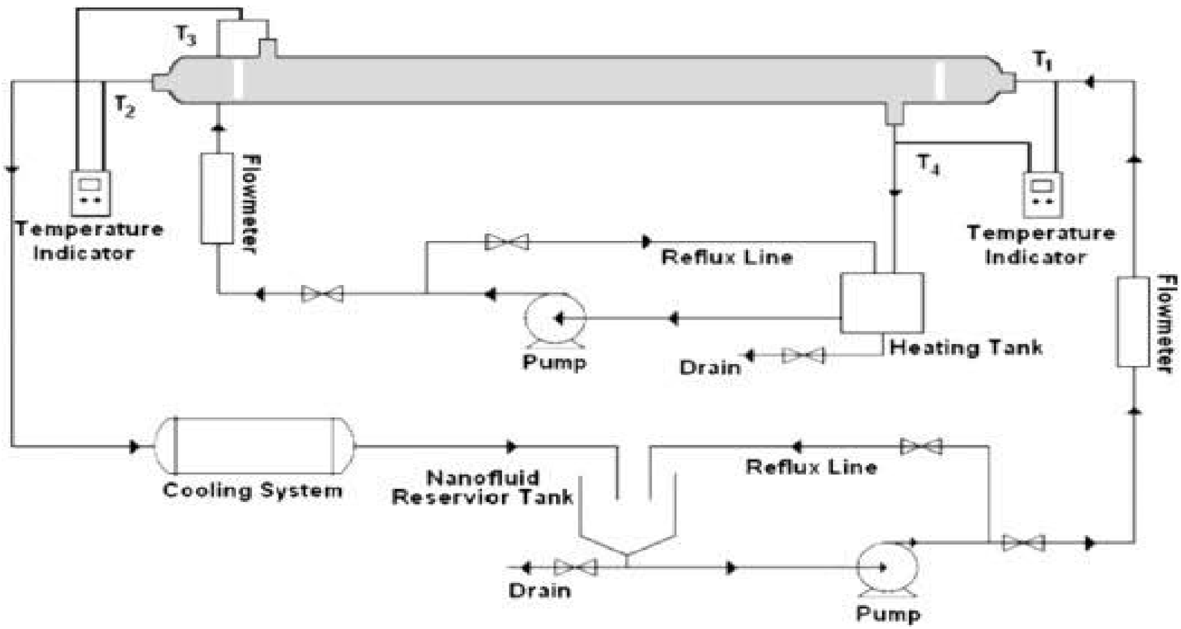

Figure 2: Application of Nanofluid in Heat Exchanger.

The sedimentation of nanoparticles over time remains a serious challenge that must be overcome before there are often widespread uptake of nanofluids. Simple methods have been proposed such as adding stabilizing agents (surfactants) to the base fluid before the suspension of nanoparticles to lower the interfacial forces between the fluid molecules and the nanoparticles. However, even with the addition of surfactants there is no guarantee of permanent stability.

In short, the use of nanofluids in a wide range of applications appears to be growing steadily. However, currently it appears that material scientists and chemists perform most investigations of nanofluids characterization, whereas thermal and engineering researchers carry the experiments on the appliance of nanofluids, and there's not always close collaboration or communication between the 2 groups, which can contribute to the agreements of results. Moreover, It was suggested that dispersing strategies of nanofluids in thermal applications is required to supply common guideline on the preparation as well as characterization of stably dispersed thermal nanofluids and also to help coonect the gap between researchers in different disciplines.

Despite the very fact that the sector of nanofluids remains within the infancy, the longer term of nanofluids seems promising. Apart from solar and refrigeration applications, industrial and research institutions have progressively gained interest in the usage of nanofluids in other applications including drug delivery for cancer treatment and surface and subsurface defect sensors. It is clear supported the review of the recent literature that significant efforts continue to be dedicated to theoretical and experimental studies to enhance the overall performance and potential applications of nanofluids. In addition, efforts are being made to reduce the production costs of nanofluids by developing large-scale production methods and to improve the stability of nanofluids.

4. CONCLUSION

Adsorption mechanisms analysis reveals that different kinds of interactions including chemical bonding, chemical interaction, precipitation, physical adsorption, ion-exchange, and electrostatic attraction are predominantly responsible for binding waste water pollutants and due to its high surface area, charged surface, and functional groups, influencing depth, Control density, Biochar is of great potential to adsorb heavy metal and organic contaminants. Addition of Biochar should decrease the Leachability, bioavailability, toxicity, and mobility of organic and inorganic pollutants. Biosorption using FPW is a new process that has shown good promise for the removal of different organic and inorganic contaminants from aqueous effluents. In this article, FPW as an adsorbent for different organic and inorganic contaminants has been reviewed. Three bio peels, avocado, hamimelon and dragon fruit peels, were investigated as potential bio adsorbents for the extraction of dissolved pollutants in water. Dragon fruit peels showed the highest extraction efficiency, close to 100%, toward alcian blue (71.85 mg/g) and methylene blue (62.58 mg/g) at neutral pH values. Hamimelon peels showed an extraction efficiency of Pb^{2+} (7.89 mg/g) and Ni^{2+} (9.45 mg/g) cations. The main advantages of the use of these materials are their availability (because they can be obtained relatively easy), their low cost and the fact that they do not require culture or synthesis for their production. Activated carbon is used in water filtering systems as it has excellent adsorption capacity. The pores of activated carbon trapped and locked water contaminants during the water filtering process. And from the experiment of purification of synthetic water containing fluoride it is proved that activated carbon removes the total hardness compared to fly ash and other ingredients used to purify it.

In these review paper, an overview is given about nanofluids as heat exchangers. There are wide ranges in heat transfer enhancement data provided by various research and studies. As results shows nanofluids are generally applied as heat transfer fluid in heat exchangers thanks to their ability in thermal enhancement. Nanofluids as heat exchangers and boreholes reduces the size and increases the efficiency. some studies were presented that compare heat transfer rates of nanofluids with water as base fluid in tube heat exchangers. The nanoparticles presented in this study are multi walled carbon nanotubes, graphene, alumina, titanium dioxide, silver, aluminum oxide, and copper oxide. It was observed from studies that heat transfer generally increases at low concentrations of all types of nano scale particles. Nanofluids have a wide range of potential applications for heat transfer improvement with solar thermal and refrigeration applications. More work is required in some areas like the steadiness of those nanofluids in various applications, the utilization of hybrid nanofluids, and effect of working conditions on the properties of those nanofluids

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