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Investigation of thermophysical properties of Nanofluids for application in geothermal energy

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Abstract

Nanofluids are liquid suspensions where nano-materials are dispersed into a base fluid. The nano-scale additives generate superior thermophysical properties for the nanofluids than the base fluids. In particular, nanofluids have shown significantly enhanced heat transfer capacity compared to traditional working fluids. In some cases, nanofluids may increase the effective conductivity of 40 even at low particle volume fractions, making them promising for applications in more efficient and compact heat exchangers. Geothermal energy is a sustainable and renewable energy source that can be used to produce electricity, space heating/cooling, and other industrial applications. This paper investigated the potential of applying nanofluids as working fluids to extract more energy from reservoirs and to improve exploitation of the geothermal resources, by increasing the returning fluid temperature. Sensitivity analyses have been performed to demonstrate the importance of fluid viscosity and heat capacity in geothermal energy production, and nanofluids again have superior performance in heat transfer.

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Keywords: Nanofluids; Geothermal energy; Heat transfer

1. Introduction

Geothermal energy is a clean and sustainable energy resource with virtually unlimited supply. The potential geothermal energy is estimated to be equivalent to 42 million MW of power and expected to last for billions of years. Even though fossil fuel will continue to be the main energy source for the coming decades, the consumption of fossil fuel has resulted in significant emissions of greenhouse gas emissions and other pollution, which have caused concerns on their negative environmental impact and increasing interests on more sustainable renewable energy sources. Utilizing renewable energy sources are clean alternatives to the environmental damaging fossil fuel energy and hold great promises to mitigate climate changes according to the IEA technology roadmap. Among which, renewable energy production and utilization from geothermal resources are gaining increase interests. An abandoned oil well can be retrofitted to a

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closed loop heat exchanger system by installing a double pipe heat exchanger. One method of operating this system is to circulate the working fluid down from the annulus and up through the installed pipe. In [1], a good survey of geothermal energy applications [2, 3, 4] with the use of double-pipe heat exchangers and closed loop systems was conducted. Kujawa et al. investigated the theoretical possibility of acquiring geothermal energy from the Jachowka K-2 well [3], where the possible geothermal heat gained per year is estimated. David and Michaelides [4] used data from oil wells in Texas to simulate geothermal energy production from abandoned wells. Their results illustrated that these wells have the potential to produce a significant amount of power with a double-pipe heat exchanger installed. Bu et al. also demonstrated the feasibility of abandoned petroleum wells as geothermal systems, estimating a financial reward of electricity of 36833.26US dollars per year [2].

Nanotechnology is science, engineering and technology carried out on the nanometer scale. Nanoscale particles have significantly different properties compared to equivalent material at larger scale. The nanoscale additives influence significantly the properties of the base fluids, such as viscosity, density, specific heat capacity, and thermal conductivity etc. Consequently, nanofluids exhibit enhanced transfer of energy, momentum and mass compared to the conventional base fluids. In addition, nanofluids have the potential to give better stability, reduced erosion and pumping power and controlled reactions with other chemicals present in the system, for example in the oil reservoirs. The above-mentioned advantages together with the ability to manipulate the aspect ratio as well as the surface properties of the nanoparticles, and consequently properties of the nanofluids have given rise to a wide range of applications. Recently, nanofluids have received attention for applications in heat transfer process due to their promising performance as heating or cooling fluids. Traditional working fluids used in industrial heat transfer devices are for example water, ethylene glycol, or engine oil. It is well-recognized that they have limited effect mainly due to low thermal conductivities, and have been considered to be 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. For instance, it has been reported that by addition of carbon nanotubes, the thermal conductivity of the base fluid can be increased by as much as 160 percent.

In this study, we present a novel idea by utilizing nanofluids in geothermal energy applications. We have studied the potential to apply nanofluids as serve as working fluids in abandoned oil wells retrofitted into double pipe heat exchangers, by taking advantage of the reported significant heat transfer enhancement of the nanofluids [2, 3, 4]. An advanced geothermal energy simulator has been developed to estimate the heat extraction from the geothermal wellbores. Regarding the simulation results conducted by the simulator, nanofluids have superior performance of enhanced energy transfer. Using water as reference fluid, under the same circumstances, the heat energy could be increased by 112 percent at one particular particle volume fraction. Since viscosity, circulation rate and specific heat capacity are all dominate parameters to affect the heat energy extraction, the sensitivity analysis are also conducted to provide useful information to guide the nanofluids design. This innovative idea holds great promises for the utilization of geothermal resources by nanofluids application.

2. Properties of Nanofluids

2.1 Thermal conductivity

Nanofluids exhibit significant enhancement of thermal conductivity and heat transfer capability. Numerous studies on nanofluids have therefore focused on thermal conductivity, which unfortunately is the most complex parameter for the heat transfer process. Maxwell derived an equation that has been frequently utilized, where effective thermal conductivity for a solid-liquid mixture is defined [5] as: