A Review: Solar Thermal Fluids

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ABSTRACT

This explores the fundamental characteristics and applications of thermic fluids. It delves into the key properties that make them suitable for heat transfer, such as high thermal conductivity and stability at elevated temperatures. It is also highlighting their role in maintaining temperature uniformity and preventing overheating or freezing in diverse systems. Thermic fluids, also known as heat transfer fluids or thermal fluids, play a crucial role in various industrial processes and systems. These specialized liquids are engineered to efficiently transfer heat from one point to another, making them essential in applications ranging from manufacturing and power generation to HVAC systems.

KEYWORDS: Solar thermal fluids types, Heat transfer fluids, G.O. sheets.

INTRODUCTION

Solar-thermal technology stands out as one of the most effective and eco-friendly methods to harness the power of the sun. It plays a crucial role in various applications related to heat. Achieving high efficiency in solar-thermal energy capture is essential for the success of these applications. In conventional solar-thermal systems, a solar receiver is used to transform sunlight into thermal energy, which is then slowly diffused into a storage medium. However, this separation of energy conversion and storage lead to heat buildup at the solar receiver due to the poor thermal conductivity of the storage material. Consequently, a portion of the converted thermal energy is lost to the environment, particularly in high temperature conversion processes. To address this issue, a solution has been proposed in the form of direct absorption solar collectors, where solar-thermal conversion and storage happen simultaneously using optical nanofluids, aiming to boost energy harvesting efficiency. The performance of direct solar-thermal energy harvesting is greatly influenced by the thermophysical properties of nanofluids. Researchers have explored various materials, including plasmonic noble metals like Au nanoparticles (NPs), Fe_3O_4 NPs, carbon nanotubes, graphene, graphene oxide (GO), and its derivatives, as potential solar-thermal converters. Among these, graphene-based materials have emerged as highly promising candidates due to their broad and efficient solar absorption. Notably, graphene requires relatively low loading in the fluid to fully absorb incident sunlight. Furthermore, graphene-based fluids exhibit good physical and chemical stability and can be easily manufactured through cost effective wet chemical processes. However, it's worth noting that the strong van der Waals attraction between graphene nanosheets can lead to stacking and aggregation issues, diminishing volumetric solar absorption and potentially causing clogging and abrasion problems. Up to this point, most researched graphene fluids have been water-based, which have a relatively narrow operating temperature range due to water's freezing and evaporation limits. In contrast, silicone oil can function efficiently in a broader temperature range from -50 to 200 °C and remains stable at medium-to-high temperatures, making it suitable for driving technologically significant industrial processes.

TYPES OF SOLAR THERMIC FLUIDS

- **Synthetic Oils**: These are organic fluids with high thermal stability used in medium-temperature solar collectors.
- **Molten Salts**: Typically, a mixture of sodium nitrate and potassium nitrate, they are used in high temperature concentrating solar power systems.
- **Water/Steam**: Used in low-temperature systems, where water is directly heated by sunlight or converted to steam for power generation.
- **Propylene Glycol**: Commonly used as an antifreeze in low-temperature applications to prevent freezing in the solar collector.
- **Dowtherm**: A heat transfer fluid with good thermal stability, often used in medium to high-temperature solar thermal systems.
- **Therminol**: A synthetic heat transfer fluid suitable for medium to high-temperature applications in solar collectors.
- **Silicon Oil**: Used in some medium-temperature solar thermal systems due to its stability and heat transfer capabilities.

HEAT TRANSFER FLUIDS

The Heat transfer fluid (HTF) is a key component of solar thermal power plant because it significantly impacts the receiver efficiency, determines the type of thermodynamic cycle and the performance it can achieve, and determines the thermal energy storage technology that must be used. This paper reviews current and future liquid, gas, supercritical, two-phase, and particulate HTFs. (1) Supervising thermal fluids transfer systems applied in solar parabolic through fields deals with a typical nonlinear process which suffers from lack of detectability when analytic model-based techniques are applied on fault detection, isolation and reconfiguration tasks. (2) Using simple friction factor and heat transfer correlations, equations for diameter ratio, heat transfer coefficient ratio, area ratio, length ratio, fluid pumping power ratio and fluid inventory cost ratio are obtained for various fluids, taking supercritical CO2 as the reference fluid. Figure of merit (FOM) ratio is also calculated using available equations. It is observed that liquid heat transfer fluids and molten salts offer better performance in the intermediate temperature range of around 150–550 °C. However, currently gaseous fluids (e.g. CO2 or He) are the only alternatives for temperatures beyond 550 °C. Supercritical CO2 offers the best performance in terms of cost of fluid. (3) Apart from directly generating electric power (using solar photovoltaic cells), more and more attention is being paid to the use of solar thermal collectors for heating various fluids for applications ranging from space heating/cooling, process heating, steam generation etc. Such solar thermal collectors are generally of conventional type, having a 'black' surface-based absorption of solar irradiation. (4) Thermophysical properties of base ionic liquids (ILs) and nanoparticle enhanced ionic liquids (NEILs) were measured experimentally. NEILs are formed by dispersing different wt% (0.5, 1.0, and 2.5) of Al 2 O 3 nanoparticles in four base ILs. NEILs show enhanced thermal conductivity, viscosity, and heat capacity compared to the base ILs. (5) The key feature which delineates nanofluid-based direct absorption volumetric systems from their surface absorption counterparts is that here the working fluid actively (directly) interacts with the solar irradiation and hence enhances the overall heat transfer of the system. In this work, a host of nanoparticle materials have been evaluated for their solar-weighted absorptivity and heat transfer enhancements relative to the base fluid. (6) The increase in energy demands and depletion of fossil fuel for power generation are the major concern nowadays. Utilization of renewable energy sources can be regarded as one of the options to tackle these issues. Renewable energy such as solar powered energy can be harnessed by using solar thermal collector. (7) The global demand for energy is increasing and the detrimental consequences of rising greenhouse gas emissions, global warming and environmental degradation present major challenges. Solar energy offers a clean and viable renewable energy source with the potential to alleviate the detrimental consequences normally associated with fossil fuel-based energy generation. (8) Thermal conductivity and viscosity measurement were done using heated discs and Anton Paar viscometers. Using oxidized MWCNTs to disperse, the base fluids increased thermal conductivity by 15% to 24%. Surfactant-assisted MWCNTs in nanofluids perform worse than oxidized MWCNTs. The dynamic viscosity of nanofluids is higher than that of basic fluids between 50 and 70°C. During a mathematical computation, all of the MWCNT weight fractions and ethylene glycol volume percentages are included. (9) Thermo-physical property evaluation is very vital to evaluate the performance of solar thermal systems. Ethylene glycol and a commercially reachable thermic fluid therminol 62 are preferred as based fluids. Nanofluids are prepared by dispersing 0.1%, 0.25%, 0.5% and 0.1% weight fraction of surface modified multi-walled carbon nanotubes. (10) Milk is a perishable commodity and needs immediate processing to prevent the growth of microorganisms. Milk processing mainly involves heating and cooling operations, and it is found that for most of the milk processing operations, temperature up to 90 o C is required (Jaglan et al., 2018). On the other hand, mainly conventional or non-renewable energy sources are used for milk processing. (11) study to extract the heat from solar concentrated power (CSP) systems. This system will heat the thermic fluid due to thermal energy in solar rays. This hot fluid is then passed through a guided passages formed between two plates and is used for heating top and bottom surfaces of two metallic plates. These hot surfaces then can be used as source of energy for home and industrial purposes. However, in the present experimentation work, the scope of work is limited to thermal heat handling through the plate surfaces. Hence the supply of thermal energy from CSP is equivalently replaced by electric heater/ gas burners. (12)

GRAPHENE OXIDE SHEETS

Large energy storage capacity and high thermal charging/discharging rate are crucial for microencapsulated phase change materials (MEPCM) in thermal energy storage application. The microcapsules with dodecanal core and melamine-formaldehyde (MF) resin shell modified by graphene oxide (GO) and carbon nanotube (CNT) hybrid filler were prepared via in-situ polymerization. The effect of the combination of GO and CNT on morphology and thermal properties of the microcapsules was investigated, and the mechanism for heat transfer enhancement was further studied from both macroscopic and microscopic views. (13) the optical absorption properties and photo-thermal conversion characteristics of GO-water nanofluids were experimentally studied and compared. With the increase of GO mass fraction or the decrease of GO sheet size, the optical absorption capacity of nanofluids can be enhanced, and a thin layer of nanofluid can absorb most of the solar irradiation. As for a direct absorption solar collector (DASC), the temperature rise increased with the irradiation angle at the reverse-irradiation mode because of the natural convection induced temperature uniformity improvement. (14) Solar-driven water desalination technologies are rapidly developing with various links to other renewable sources. However, the efficiency of such systems severely depends on the design parameters. The present study focused on using graphene oxide (GO) with the $\Phi = 0.2$, 0.4 and 0.6 wt.% dispersed in paraffin, as phase-change materials (PCMs), to improve the productivity of a solar still for desalination applications. The outcomes showed that by adding more graphene oxide to paraffin, the melting temperature got reduced. Solar still with GO/paraffin showed 25% productivity improvement in comparison with the solar still with only PCM. (15) Nanofluids have attracted significant attention over the past decade due to the anomalous thermal conductivity in thermal management exhibited by nanofluids containing a low proportion of transition metal nanoparticles. In this work, a hybrid nanofluid graphene oxide (GO)–copper oxide (CuO) composite blended in silicone oil is prepared as a prospective alternative for heat transfer investigation. A simple and low-cost hydrothermal technique is used to fabricate the GO and GO-CuO nanocomposites. (16) Graphene Oxide (GO) is a new carbon material with a two-dimensional sheet structure, which has high thermal conductivity and strong hydrophilicity. In this study, influence of GO nanofluid and filling ratio on the start-up performance of a water-based PHP was investigated. The PHP was fabricated with a long copper tube, which was bent into 3 turns, with the inner and outer diameters were 2 mm and 4 mm respectively. The nanofluid was prepared by dissolving GO nanoparticles into the deionized water, with different mass fraction range (ω = 0.02–0.1 wt%), and filling ratios (FR = 20%, 50%, 80%). The evaporation section was electrically heated, with a heating power ranged from 10 W to 30 W, while the condensation section was cooled by the forced convective wind. (17)

FUTURE PROSPECTS

Solar thermic fluid systems' future possibilities may include a number of advances and trends:

Ongoing research and development may lead to increases in the efficiency and cost-effectiveness of solar thermal fluid systems. Material, design, and manufacturing process innovations may help to improve the reliability and scalability of these systems.

Improvements in the efficiency of solar collectors, heat transfer fluids, and overall system design may improve the overall performance of solar thermal fluid systems. This may increase their competitiveness against other renewable energy sources.

With a growing focus on sustainable energy, solar thermic fluid systems may gain popularity, especially in areas with high sunshine levels. Government incentives, programs, and regulations promoting renewable energy have the potential to accelerate industry expansion.

Using improved batteries or thermal storage can solve the intermittent nature of solar energy. This integration could boost the dependability and dispatchability of solar thermal systems.

Solar thermic fluid systems have multiple applications, including energy generation, industrial processes, and district heating. Exploring new and diverse uses could help to expand their use in various industries.
Solar thermic fluid systems can dramatically lower greenhouse gas emissions compared to standard fossil fuel-based energy sources. As environmental concerns develop, solar thermal systems may become more widely adopted.

The global market for solar thermal technologies, including solar thermic fluid systems, is predicted to expand as demand for sustainable and clean energy solutions rises worldwide.

CONCLUSION

Finally, the study of thermic fluids' fundamental properties and applications emphasizes their importance in a variety of industrial processes and systems. The review delves into crucial features, emphasizing the fluids' remarkable thermal conductivity and stability at high temperatures, making them suitable for efficient heat transmission. The ability of thermic fluids to maintain temperature homogeneity and avoid extremes, such as overheating or freezing, emphasizes their importance in guaranteeing the smooth operation of many applications.

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