Energy Technology
Generation, Conversion, Storage, Distribution
www.entechnol.de

Enhanced Heat Transfer Efficiency through Formulation and Rheo-Thermal Analysis of Palm Oil-Based CNP/SiO_2 Binary Nanofluid

Sridhar Kulandaivel, Wai Keng Ngui, Mahendran Samykano, Reji Kumar Rajamony, Subbarama Kousik Suraparaju, Nurhanis Sofiah Abd Ghafar, and Muhamad Mat Noor*

The present work addresses the shortcomings of heat transfer fluid behavior by emphasizing solutions for improved stability, enhanced thermal properties, and environmental sustainability. The study introduces an innovative hybrid nanofluid combining silicon dioxide (SiO_2) and cellulose nanoparticles (CNP) into analytical-grade Palm oil, adopting a two-step methodology. This endeavor represents a significant advancement in exploring SiO_2–CNP-Palm oil hybrid nanofluids, positioning them as promising candidates for advanced heat transfer media. Physical characterization analysis confirms the successful integration of SiO_2 and CNP into analytical-grade Palm oil. The nanosuspensions of CNP-Palm oil, SiO_2-Palm oil, and SiO_2/CNP-Palm oil are prepared at varying volume concentrations. All nanosuspensions demonstrated good stability after ultrasonication, as evidenced by optical performance and sedimentation studies, which endure for up to 60 d. Fourier transform infrared (FT-IR) analysis further substantiates the chemical stability, revealing no emergence of peaks associated with the diffusion of nano-additives. The thermogravimetric analysis (TGA) also affirms superior thermal stability in all nanosuspensions compared to base fluids. Rheological studies indicate that Palm oil exhibits Newtonian behavior. The nanofluid containing 0.1 w/v% SiO_2/CNP nanoparticles exhibits a significant enhancement in thermal conductivity, showcasing an impressive 81.11% improvement. In addition, the nanofluid demonstrates an increase in viscosity with higher nanoparticle concentrations and decreased viscosity with rising temperatures.

1. Introduction

In the early decades, a growing focus has been on improving heat transfer performance. In response to this, researchers have developed a novel formulation known as nanofluids. This innovative formulation enhances the heat transport efficiency and flow characteristics for various applications.[1] A nanofluid is a stable mixture comprising mono or hybrid nanomaterials dispersed in a base liquid. Its extensive advancement is attributed to its capacity to boost the thermal conduction of diverse fluids, facilitating advanced applications in thermal instruments and cooling technologies.

A noteworthy trend in this scientific exploration is the consideration of using vegetable oil as a base transfer fluid.[2] Petroleum mineral oil from non-renewable energy resources and fossil fuel oil are of concern to nature due to their non-biodegradable behavior. As a result, scientists have shifted their focus to biodegradable and renewable substitutes. Because of its numerous benefits, plant-based oils are being explored as alternatives to mineral-based oils in various research endeavors.[3,4] Palm oil is acknowledged as the most widely used plant oil globally. It is a favourable replacement for mineral oils.[5] The possibility of producing biofuel from Palm oil has further improved production in the last 10 years.[6] Furthermore, in oil-based lubricants, combining various nanoparticles with Palm oil-based has shown a significant decrease in wear and coefficient of friction than are presently available due to enhanced thermal behavior of base fluids.[7–10]

S. Kulandaivel, W. K. Ngui, M. Samykano, S. K. Suraparaju, M. Mat Noor
Faculty of Mechanical & Automotive Engineering Technology
University Malaysia Pahang Al-Sultan Abdullah
Pekan 26600, Pahang, Malaysia
E-mail: wkngui@umpsa.edu.my

M. Samykano, S. K. Suraparaju
Centre for Research in Advanced Fluid and Process
University Malaysia Pahang Al-Sultan Abdullah
Lebuhraya Tun Razak, Gambang, Kuantan 26300, Pahang, Malaysia

R. K. Rajamony, N. S. Abd Ghafar
Institute of Sustainable Energy
Universiti Tenaga Nasional (National Energy University)
Jalan IKRAM-UNITEN, Kajang 43000, Selangor, Malaysia

R. K. Rajamony
Faculty of Engineering and Technology
Parul University
Waghodiya Road, Vadodara, Gujarat 391760, India

The ORCID identification number(s) for the author(s) of this article can be found under https://doi.org/10.1002/ente.202400314.

DOI: 10.1002/ente.202400314

