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THERMAL AND PHYSICAL PROPERTIES OF CU: AL_2O_3 - WATER: EG HYBRID NANOFLUID (0.05%, 0.1% & 0.2%) FOR HEAT TRANSFER APPLICATION

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ABSTRACT:
This study presents an experimental evaluation of the thermic behavior of Al_2O_3/ H_2O, Cu/ H_2O, and Al_2O_3–Cu/ H_2O hybrid nanofluids. The hybrid nanofluid samples were prepared using a single-step method to ensure proper dispersion and stability. Three different nanoparticle volume fractions—0.05percent, 0.1percent, and 0.2percent—were used, where Al_2O_3 and CuO nanoparticles were uniformly mixed into H_2O.The thermal conductivity and other thermal and physical properties were measured across a temperature range of 20°C to 60°C. Results showed that thermal conductivity rises with rising temperature and higher nanoparticle concentration. Specifically, the highest observed boost in thermal conductivity was 9.8percent at 0.2percent volume concentration.Experimental data were compared with theoretical models to evaluate prediction accuracy. Further, nanofluids containing copper (Cu) and aluminum oxide (Al_2O_3) nanoparticles mixed in H_2O –ethylene glycol base fluid demonstrated notable improvements in thermal performance, highlighting their potential for use in heat transfer systems. Key properties such as thermal conductivity, specific heat, and density were examined, as they directly impact heat transfer efficiency. While the nanoparticles significantly increased thermal conductivity, changes in specific heat capacity and density were relatively small. Additionally, the study considered rheological properties like shear rate sensitivity and thixotropic behavior, which are crucial for understanding flow performance. These findings, emphasize the importance of analyzing both thermal and rheological characteristics for the effective application of hybrid nanofluids in cooling technologies, heat exchangers, and other thermal management solutions.

KEYWORDS:- Copper Oxide Nanofluid,Aluminium Oxide, Nanofluids, Ethylene Glycol (EG),Themophysical Properties, Heat Transfer Applications.

Aim:-The main aim is to inspect how the addition of copper (Cu) and aluminum oxide (Al_2O_3) nanoparticles to a water-ethylene glycol (EG) hybrid fluid influences its thermophysical properties and rheological behavior.

Objectives:-

1. To categorize thermophysical properties.
2. To analyze rheological characteristics.
3. To evaluate thermal conductivity of the nanofluid.

INTRODUCTION:

Nanofluids—suspensions of nanoparticles dispersed within a base fluid—have attracted significant attention in recent years because of their potential to improve heat transfer performance across a wide range of industrial, engineering, and energy

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systems has been studied by Rezaei, N. and Rashidi, M., (2016). By introducing nanoparticles that possess high thermal conductivity and suitable specific heat capacity into conventional heat transfer fluids, nanofluids hold the potential to significantly boost heat transfer efficiency while maintaining fluid stability and compatibility with existing systems. The application of nanofluids has emerged as a promising approach to improve thermal performance across various industrial and commercial sectors. Thanks to their unique thermophysical properties, nanofluids offer valuable opportunities to enhance the effectiveness of traditional heat transfer fluids is explained by Oztop, H. F., Abu-Nada, E., and Al-Salem, A. S., (2010) Among the various types of nanoparticles and base fluids studied, the blend of copper (Cu) and aluminum oxide (Al_2O_3) nanoparticles suspended in a H_2O –ethylene glycol (EG) mixture has attracted considerable attention because of its promising ability to improve heat transfer performance.

A notable example of an advanced nanofluid that has gained significant attention is the Cu:Al_2O_3– H_2O:EG hybrid nanofluid. This formulation combines copper (Cu) and aluminum oxide (Al_2O_3) nanoparticles dispersed within a H_2O –ethylene glycol (EG) base fluid. The aim is to utilize the complementary thermal properties of both types of nanoparticles, together with the hybrid fluid, to achieve enhanced heat transfer performance in various applications is explored in the work of Jagtap, S. N., Raut, V. B., and Patil, M. A., (2019). Copper (Cu) nanoparticles are well known for their excellent thermal conductivity and relatively high specific heat capacity, making them highly effective in conducting heat. In contrast, aluminum oxide (Al_2O_3) nanoparticles offer superior thermal stability and good dispersion characteristics, which enhance the overall stability and performance of the nanofluid. By blending these nanoparticles into a H_2O –ethylene glycol (EG) base fluid, it becomes possible to develop a nanofluid with optimized thermal properties and stability, making it well suited for demanding heat transfer applications.

Gaining insight into the thermophysical properties and flow behavior of Cu:Al_2O_3–H_2O:EG hybrid nanofluids is crucial for evaluating their suitability and effectiveness as heat transfer media is cleared by Lee, S., Choi, S. U. S., Li, S., and Eastman, J. A., (1999). Sajjadi, A. R., Hamidi, A. A., and Akhavan-Behabadi, M. A., (2011) classified that Thermophysical properties—including thermal conductivity, specific heat capacity, and density—are critical factors that directly affect the heat transfer performance and efficiency of nanofluids. Introducing nanoparticles into the base fluid modifies these properties, often resulting in notable improvements in thermal performance. Additionally, the rheological characteristics of nanofluids—such as viscosity and their dependence on shear rate—play an important role in determining flow behavior and ensuring stability when applied in real-world heat transfer systems.

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Wang, Y., Xie, Z., Han, X., Liu, Y., and Wang, Y., (2012) in their study focused on examining the thermophysical and rheological properties of Cu:Al_2O_3–H_2O:EG hybrid nanofluids intended for heat transfer applications. Experimental tests will be conducted to measure key parameters such as thermal conductivity, specific heat capacity, and density across different temperatures and varying nanoparticle concentrations. Haghighi, A. K. and Javadi, M. Y., (2015) in addition gave idea of numerical simulations could be utilized alongside experimental results to provide deeper insights into the mechanisms responsible for the observed heat transfer enhancement in these hybrid nanofluids.

By thoroughly examining the thermophysical and rheological properties of Cu:Al_2O_3– H_2O:EG hybrid nanofluids, this study aims to offer valuable insights into their potential applications in diverse heat transfer systems, such as heat exchangers, cooling technologies, and thermal energy storage devices. In the results of Nagasaka, Y., Nagashima, A., (1981) this research are expected to contribute to the advancement of more efficient and sustainable heat transfer technologies, with potential benefits for improving energy efficiency and reducing environmental impact across various industrial applications.

Table 1:- Thermal & Physical properties of CuO and Al_2O_3 Nanoparticles:-

Sr No	Nanoparticle/Fluid	Mean Diameter (nm)	Specific Surface $(m^2 g)$	Density (Kg/(m^3))	Thermal Conductivity (W/mK)
1	Cu	27	29	6310	32.9
2	Al_2O_3	50	15-20	3890	30

METHODS:-

This study employs the Transient Hot Wire (THW) method to determine the thermal conductivity of the nanofluids, using a battery-powered KD2 Pro thermal property analyzer (Decagon Devices Inc., USA). In this study, the transient hot wire method will be utilized for measuring thermal conductivity. The measurement setup includes a KS-1 sensor, which is 60 mm in length and 1.3 mm in Diameter, and constructed from stainless steel. The thermal property analyzer itself comprises a 16-bit microcontroller, an analog-to-digital converter, and a power control unit. During the experiment, the sensor is inserted vertically into the nanofluid sample. The sensor records temperature variations in the nanofluid at 5-second intervals. Based on the temperature change over time, the microcontroller calculates the thermal conductivity using the appropriate equation, and the data are stored in real time for analysis.

$$K = [\frac{q}{4\pi(\Delta T_2 - T_1 \Delta)}] * \ln [\frac{T_2}{T_1}] \text{......... (Equation 1)}$$

The Schematic Diagram of the experimental setup is proven in Diag.1.

Before beginning the experimental study, the accuracy of the sensor used to be calibrated by way of measuring the thermal conductivity of pure H_2O. The evaluation of investigative thermal conductivity data points and the current publication information is proven in Diag.2. The

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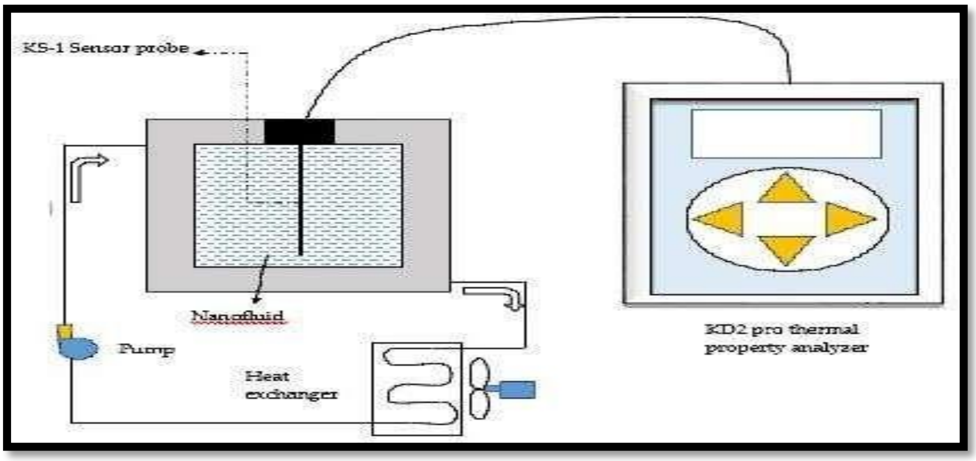
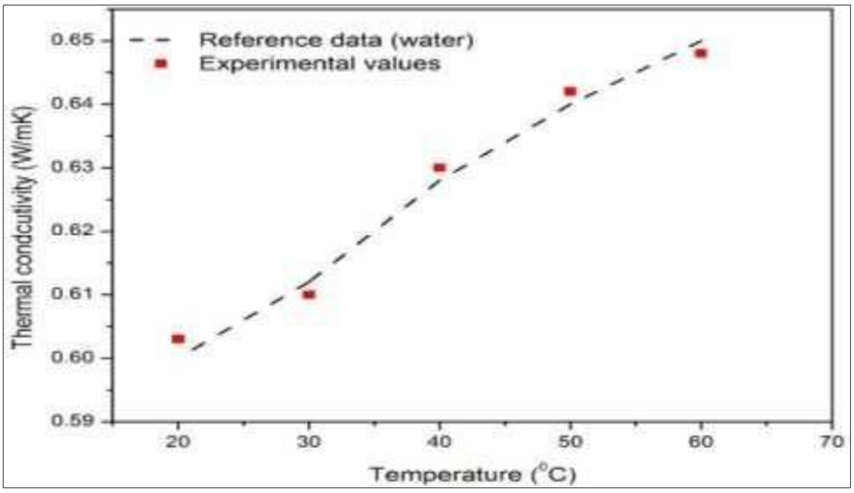
unpredictability of the measured data points and the current data points has been estimated as ± 5percent.



Diag. 1:- Illustrative Diagram of Investigative set up used to measure thermal conductivity and rheological characteristics of nanofluids



Diag 2:- Thermal conductivity comparison with measure and reference data

RESULTS AND FINDINGS: -

The variations of thermal conductivity enhancements with time and temperatures have been introduced in detail. The experiments have been carried out to measure the thermal conductivity enhancements and rheological behavior of Al_2O_3/ H_2O, Cu/ H_2O, and Al_2O_3- Cu/ H_2O nanofluids with distinct extent concentrations (0.05percent, 0.1percent, and 0.2percent). The **Eq. (2)** is used to calculate the thermal conductivity enhancements of nanofluids.

$$\text{Percent } K_{enhanement} = \left[\frac{K_{nf} - K_{bf}}{K_{bf}} \right] * 100$$

……………………**(Equation 2)**

From **Diag.3** can be concluded that the Al_2O_3 - Cu/ H_2O hybrid nanofluids have greater Augmentation of thermal conductivity than different nanofluids .The least heat conduction is to be found in Al_2O_3/ nanofluids at 0.05 vol percent. The thermal conductivity enhancements of Al_2O_3- Cu/ H_2O hybrid nanofluids are 2.7 percent, 6.7 percent, and 9.8 percent for 0.05 percent, 0.1 percent, and 0.2 percent

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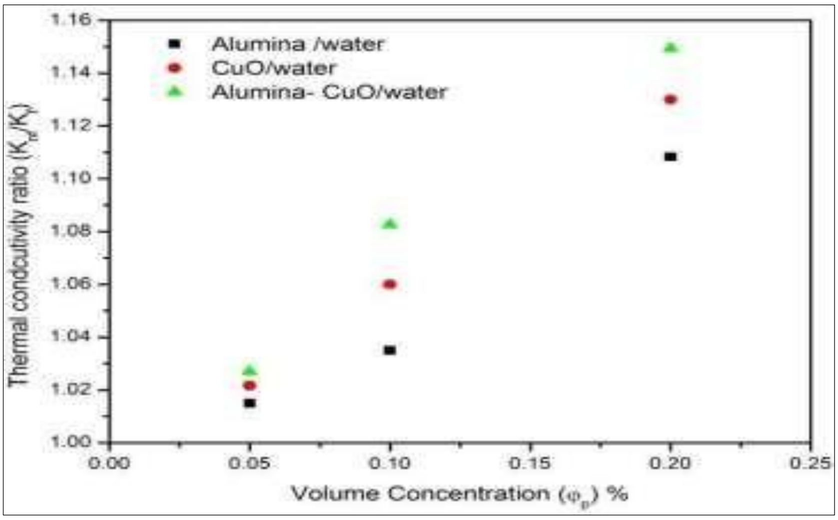
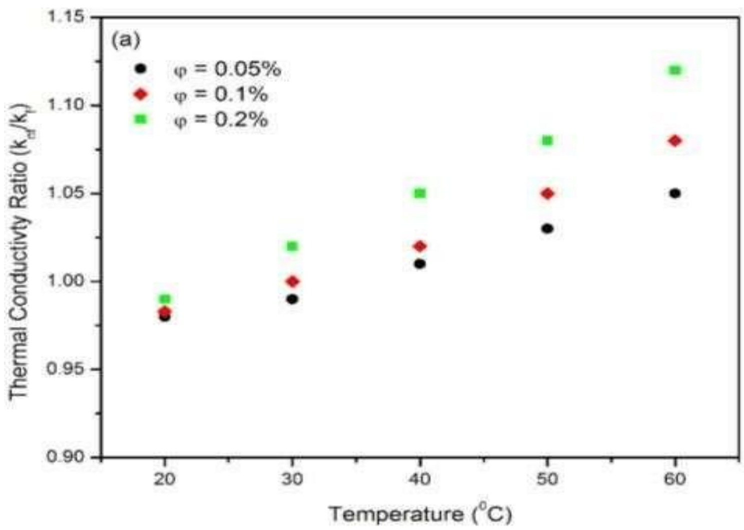


respectively in contrast with the H_2O. The enhancement of thermal conductivity for Al_2O_3/ H_2O nanofluids are 1.5 percent, 2.2 percent, and 6.1 percent, and in the case of Cu/H_2O nanofluids are 2.4 percent, 4.8 percent, and 8 percent respectively.

Diag 3:- Thermal conductivity ratio of different nanofluids as a function of percent Volume concentration

The outcomes of temperature on the thermal conductivity enhancement of distinct nanofluids and the base fluids have been measured inside the range of 20 °C – 60°C the variations of thermal conductivity enhancements of Al_2O_3/ H_2O, Cu/ H_2O, and Al_2O_3- Cu/ H_2O nanofluids with different volume concentrations regarding temperature are illustrated in Diag.4. For all nanofluids, the most thermal conductivity enhancement used to be acquired for 0.2 vol percent at 60°C. The thermal conductivity used to be stronger from 2.48percent to 3.5percent, 1.26percent to 4.9percent, and 1.81percent to 5.52 for Al_2O_3/ H_2O, Cu/ H_2O, and Al_2O_3- Cu/ H_2O nanofluids respectively at 0.2 Vol.percent with every 100C.



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Diag 4:- Thermal conductivity of nanofluid as a function of temperature and nanoparticle volume concentration

CONCLUSIONS: -

The incorporation of copper (Cu) and alumina (Al_2O_3) nanoparticles into the base fluid comprising a combination of H_2O and ethylene glycol (EG) resulted in a sizable enhancement in thermal conductivity. This enhancement is integral for facilitating environment-friendly heat transfer in several engineering applications, such as heat exchangers and cooling systems. The hybrid nanofluid exhibited non-Newtonian behavior, characterized by way of shear-thinning properties. The thermal conductivity of nanofluid is measured using a KD2 pro thermal property analyzer. Thermal conductivity of all nanofluids is increased with the increase of particle volume concentrations and temperature. Among all types of nanofluids Al_2O_3, Cu - H_2O hybrid nanofluids showed higher thermal conductivity enhancement over the base fluids.The rheological characteristics of the nanofluid have been determined to be influenced by elements such as nanoparticle concentration and the ratio of H_2O to EG in the base fluid. Adjusting these parameters can enable fine-tuning of the nanofluid's flow behavior to suit specific application requirements. The study underscores the significance of optimizing the composition of the hybrid nanofluid to maximize heat transfer efficiency while making sure of favorable rheological properties. By systematically varying nanoparticle concentration and base fluid composition, the most efficient formulation can be recognized to acquire the favored stability between thermal conductivity enhancement and flow behavior. The findings of this study have practical implications for the design and development of nanofluid-based heat transfer systems. By leveraging the enhanced thermophysical properties and tailored rheological characteristics of the hybrid nanofluid, engineers and researchers can design more efficient and sustainable heat transfer options throughout several industries.

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