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Addressing Inconsistencies in Interferometric Nanofluid Heat Transfer Studies

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ABSTRACT *(USE STYLE: HEADING 1)*

This study employs Mach-Zehnder Interferometry (MZI) to measure the stability, thermal conductivity, and convective heat transfer of Al_2O_3-water nanofluids. Nanofluids have attracted considerable interest over the past two decades for their potential to enhance conduction and convection heat transfer. However, inconsistencies in reported findings have hindered their widespread adoption in industrial and medical applications. MZI provides a solid method for addressing these discrepancies by enabling temperature field visualization and local surface heat transfer measurements. Interferometry measures the interference fringe shift resulting from refractive index changes due to temperature and concentration. Using a highly stable nanofluid is essential in heat transfer studies to ensure that fringes are attributed to temperature variation rather than concentration. To assess the stability of the nanofluid, a 0.16 wt.% Al_2O_3-water nanofluid, prepared using standard methods, was monitored over a 3-hour period under isothermal conditions using MZI. It was demonstrated that the nanofluid is unstable, despite a favorable zeta potential of 43.7 mV, as concentration-induced fringes appeared after 15 minutes and evolved over time due to the gravitational settling of larger particles. Under a temperature difference, the unstable nanofluid produces fringes affected by both temperature and concentration, which cannot be distinguished. This results in errors in temperature gradient measurements. The temperature gradient measurement errors are evaluated under pure conduction conditions by applying a 10.4°C temperature difference from top to bottom to the 0.16 wt.% unstable nanofluid. Our results show that failure to detect concentration changes in the unstable nanofluid may result in a temperature gradient overestimation of up to 100%. To enhance the stability of the nanofluid and eliminate concentration-induced fringes, a 4 wt.% nanofluid is centrifuged at 1500 g for 90 minutes, and sodium dodecylbenzene sulfonate (SDBS) is added. This process results in a 0.23 wt.% Al_2O_3-water nanofluid with 0.23 wt.% SDBS, which remains stable for 90 minutes, providing sufficient time for most heat transfer studies. In another part of the study, the thermal conductivity of dilute Al_2O_3-water nanofluids (<0.11 wt.%) is measured using a steady comparative interferometric technique and transient hot wire method. Using both methods, the thermal conductivity of the nanofluid was found to be the same as water, in contrast to interferometric studies in literature. Since heat flux is the product of thermal conductivity and optically measured surface temperature gradient, the study will next investigate whether improvements in nanofluid heat transfer remains by utilizing a stable nanofluid and applying reliable thermal conductivity.