Dissertation abstract

Dissertation title: Impact of ferromagnetic nanoparticles on heat transfer process in nanofluids

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Conventional heat transfer liquids in thermal systems has reached its operational limits, necessitating the search for high-efficiency alternatives. Developing thermal systems and convective heat exchangers requires identifying high-efficiency working liquids. One such liquid is a ferronanofluid, a nanofluid containing ferromagnetic nanoparticles. Ferronanofluids are a promising solution due to their enhanced thermal properties and magnetic responsiveness. This property influences mass and heat transfer but complicates flow analysis. Research on ferronanofluids in convective heat transfer remains inconclusive, particularly concerning their application in inclined flows, which are common in real-world scenarios. This dissertation aims to address these challenges.

Chapter One introduces heat transfer principles, focusing on convective heat transfer and methods to enhance heat exchanger performance. It outlines the potential benefits of nanofluids in thermal systems. Chapter two discusses nanofluids and their components and explains the mechanisms behind their above-expected heat transfer performance. A comprehensive literature review highlights current advancements and challenges hindering nanofluid adoption.

Chapter three reviews the use of ferronanofluids in convective heat transfer, examining laminar and turbulent flows under static and alternating magnetic fields. It discusses mixed convection in horizontal and inclined nanofluid flows. The chapter concludes by identifying knowledge gaps. Chapter four establishes the dissertation objectives and research hypotheses based on this review.

Chapters 5–7 detail experimental studies addressing these objectives. Chapter Five characterizes the ferronanofluid used in the experiments. This includes thermophysical properties such as viscosity, specific heat capacity, thermal conductivity, and density. Additionally, it investigates the influence of a magnetic field on the dynamics of ferronanofluid droplets and the behavior of ferronanoparticles. Two regimes dependent on the magnetic field strength were identified: a pinning-fixed regime, where the contact angle increased without contact line movement, and a de-pinning regime, characterized by a reduced contact angle and droplet elongation toward the magnets. The experiments were followed by an analysis of deposits of droplets dried under a magnetic field. The interaction effect was visible in the final crack pattern. In magnet-free environments, cracks form due to elastic stresses. The application of an external magnetic field generated additional magnetic stresses. The latter ordered the magnetite particles and therefore aligned cracks according to the magnetic field lines. These findings confirm the potential to manipulate ferronanoparticles in heat transfer experiments.

Chapter six evaluates heat transfer performance in horizontal laminar ferronanofluid flow under a magnetic field. The effect of the magnetic field orientation in relation to secondary motions in the fluid defined the change in heat transfer. Placing a magnet under the test tube increased the Nusselt number, whereas placing it above led to a decrease. This was attributed to magnetic forces amplifying or counteracting secondary motions induced by the temperature gradient. Based on the introduced similarity numbers, the critical values below which the effect on heat transfer is negligible were identified. These values depend on the magnetic field orientation and its interaction mechanism with the ferronanofluid.

Chapter seven investigates ferronanofluid upward flow inclined at 30°, 60°, and 90°, exploring the influence of a static magnet on heat transfer. The findings indicated that the flow inclination for Reynolds numbers of Re = 106 and Re = 185 led to a deterioration of heat transfer in ferronanofluid flow. This resulted from the weakening of the secondary motions, which reached a minimum in the vertical position. As the inertia forces in the flow increased, the negative effect of inclination on heat transfer diminished and became marginal from Re = 264. It was found that the possibility of improving heat transfer in inclined flow by a permanent magnet is limited. Additionally, selecting the magnetic configuration is challenging due to the orientation of the fluid flow and gravity and resulting mixed convection conditions. The effect of a magnetic field on heat transfer must be determined in relation to the mass transfer within the fluid. Strategic manipulation of the magnetic force acting on ferronanoparticles offers the potential to either amplify or mitigate the secondary flow effects, like in horizontal flow. To achieve this, the mass transfer in inclined mixed convection flow must be analyzed.

Chapter eight concludes the dissertation, summarizing the findings and providing an outline for future experiments.

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