Non-Fourier Computations of Heat and Mass Transport in Nanoscale Solid-Fluid Interactions Using the Galerkin Finite Element Method

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This study investigates the enhancement of thermal performance in base fluids through the dispersion of three types of nanoparticles, utilizing a novel non-Fourier heat transfer theory. The focus is on comparing the thermal efficiencies of various nanoparticle and nanogyroids combinations to determine the optimal configuration for improved fluid thermal performance. Employing the Galerkin Finite Element Method (GFEM), the research delves into how the nanoparticles influence thermal dynamics, with models developed based on non-Fourier heat flux theory, computational fluid dynamics (CFD) conservation laws, and no-slip thermal boundary conditions. The numerical solutions, validated against published data, involve grid-sensitivity tests and assessments of solution accuracy, correction, and stability, examining critical parameters like wall shear stress, mass flow rate, and heat flux in relation to rheological variables and thermal relaxation time.

The findings highlight the significant role of thermal relaxation time—the duration a fluid takes to return to thermal equilibrium—in influencing fluid temperature. Simulations indicate that mono nanofluids exhibit the most pronounced impact on fluid temperature due to having the longest thermal relaxation times, whereas ternary nanofluids display the shortest. Moreover, ternary nanofluids show a greater thermal boundary thickness compared to mono and binary nanofluids, and the highest values of wall heat and mass flux are observed in non-Fourier scenarios of heat and mass diffusion, suggesting a superior thermal performance over traditional Fourier methods. These insights pave the way for optimized nanoparticle and nanogryroids enhanced thermal fluids, offering substantial improvements in thermal management technologies.

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