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RESEARCH PAPER

Precipitation phenomenon of nanoparticles in power-law fluids over a rotating disk

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Abstract The steady flow and mass transfer of nanofluids with power-law type base fluids over a free-rotating disk are investigated. Previously, we have modeled the volume fraction of nanoparticles and verified the experimental conclusion through the numerical simulation of particle distribution in nanofluid in a Petri dish under the influence of movement using a power-law model of mass diffusivity. We further this study by a similar model of the mass diffusivity following a power-law type to consider the laminar non-Newtonian power-law flow in a rotating infinite disk with angular velocity about the z-axis. The coupled governing equations are transformed into ODEs. Homotopy analysis method (HAM) is applied to solve the ODEs while special attention is paid to deal with the nonlinear items in the ODEs. In the last section, we provide images of nanoparticles suspended in power-law fluids in a rotating disk as obtained using the laser speckle method. When they are compared with the analytical results gained by the HAM, they qualitatively matched the solutions of the concentration equation of nanofluids.

Keywords Nanofluids · Power-law fluids · Mass diffusivity · Nanoparticle precipitation · HAM

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1 Introduction

Precipitation and mass transfer of nanoparticles in fluids are common phenomena in scientific and industrial applications, such as the monitoring and controlling of product manufacturing processes and their quality. In medical and biological fields, homogeneous PLA/insulin solutions containing different amounts of Da PEG (0–75 wt% PEG) were processed by semi-continuous, compressed CO_2 antisolvent precipitation to fabricate protein-loaded polymeric nanoparticles (Caliceti et al. 2004). Polymeric scaffolds were fabricated with micro- and nanoscale porosity by developing a new technique that couples two conventional scaffold production methods: solvent casting-salt leaching and gas antisolvent precipitation to avoid the mass transport through biocompatible and biodegradable polymeric 3D porous scaffolds depleted by nonporous impermeable internal walls (Flaibani and Elvassore 2012). Engineers also investigated nanoparticle precipitation in a confined impinging jet reactor (CIJR) (Gavi et al. 2007). With the aim of obtaining controlled size and particle size distributions of these superconductor precursors, semi-continuous supercritical antisolvent (SAS) precipitation has been used to produce europium (EuAc) and gadolinium (GdAc) acetate nano- and microparticles (Reverchon et al. 2002). Most of the base fluids of nanosolutions in industrial and scientific fields are non-Newtonian fluids (i.e., fluids that do not satisfy the linear relationship between the shear stress and the shear rate of deformation). Non-Newtonian fluids cover a wide range of fluids including, but not limited to: colloidal emulsoid, cosmetics, UV protection gel, lubricants, corrosion resistant coatings, pigments, oils, paints, milk, toothpaste, mud, vivo blood, intra-articular synovial fluid, lymph fluid, cells fluid, cerebrospinal fluid and bronchial endocrine liquid (Bird et al. 1960). Shear thinning, stress relaxation,

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