The Effect of Novel Similarity Transformations on the Stagnation Point Flow in a Different Nanofluid on a Nonlinear Stretching/Shrinking Interface

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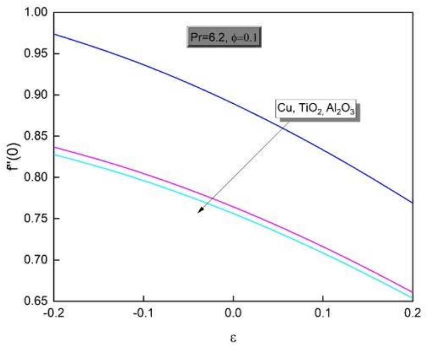
PAPER FOR THE YOUNG SCIENTIST AWARD

1. INTRODUCTION & OBJECTIVE

This article aims to address a prior limitation in research by introducing innovative similarity transformations. These transformations have shown promise in solving sets of partial differential equations. The study investigates a stable two-dimensional flow pattern involving a nanofluid flowing over a sheet that can either stretch or shrink within the same plane. It's important to note that both the sheet's movement and the surrounding fluid velocities vary linearly as one moves away from the stagnation point. Specifically, copper, alumina, and titanium nanoparticles are suspended in a Prandtl number of 6.2, taking into account the mass ratio to diameter. Prior studies, particularly those related to stretching sheets, primarily relied on nondimensional similarity variables tied to a single independent variable, which led to inaccuracies. In response, we have developed a fresh set of similarity transformations that encompass all independent variables in the analyzed equations. This innovative approach primarily aims to significantly enhance the accuracy of the results obtained. Our research includes a comprehensive comparative analysis, revealing inaccuracies in earlier investigations that used a similarity parameter derived from a single independent variable. To address these limitations, we introduced these new similarity transformations. For numerical computations, we smoothly integrated the Runge-Kutta Fehlberg 4th–5th method with the shooting technique.

Pakdemirli and Suhubi [1] introduced similarity solutions tailored to second-order fluids, while Pakdemirli and Yurusoy [2] emphasized the importance of similarity transformations for solving partial differential equations. In a study conducted by Cole and Bluman [3], they primarily focused on differential equations and showed a strong interest in solving them through similarity transformations. Some authors have developed similarity transformations for nonlinear stretching sheets, where the similarity variable may not necessarily be non-dimensional [4]-[5]. Previous studies often assumed a single independent variable for the nondimensional similarity variable "η," potentially leading to inaccuracies. To address this limitation, we independently formulated a new set of similarity transformations. Our current study focuses on analyzing the boundary flow of a nonlinear extended surface in two dimensions. By using these novel similarity transformations, we aim to obtain unique solutions and overcome the dual solution issue observed in prior research [6].



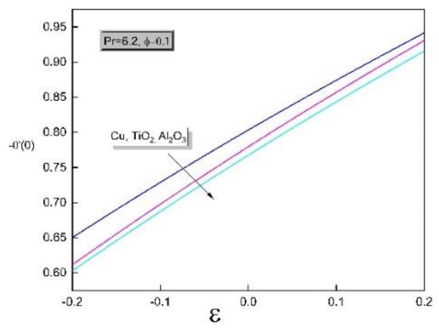


Figure 1: Variability of $f''(0)$ with ε for various nanoparticles with $\phi = 0.1$ and $Pr = 6.2$.

Figure 2: Variability of $-\theta'(0)$ with ε for various nanoparticles with $\phi = 0.1$ and $Pr = 6.2$.

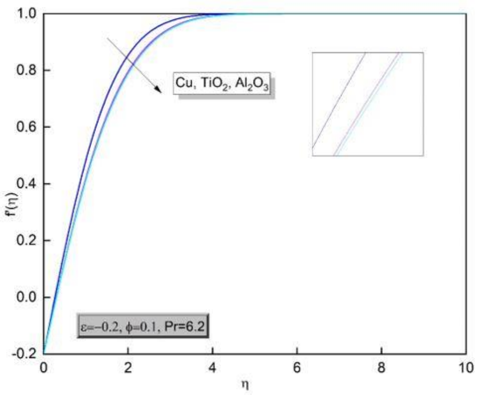


Figure 3: Velocity profile for a variety of nanoparticles with $\phi = 0.1$, $\varepsilon = -0.2$ and $Pr = 6.2$.

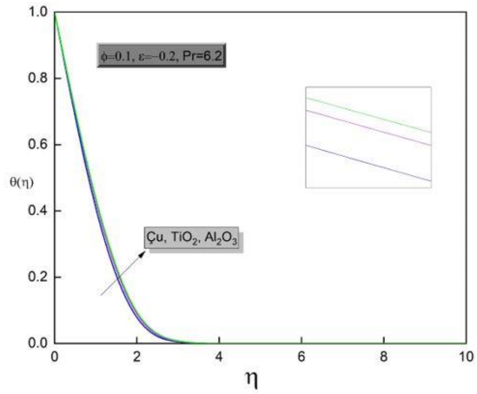


Figure 4: Temperature profile for a variety of nanoparticles with $\phi = 0.1$, $\varepsilon = -0.2$ and $Pr = 6.2$.

2. RESULTS AND HIGHLIGHTS OF IMPORTANT POINTS

This study explores nanofluids with Copper, Alumina, and Titanium Dioxide nanoparticles in water. Concentrations range from 0 to 0.2. Figures 1 and 2 depict variations in $f''(0)$ and $-\theta'(0)$ with changing ε. A previous study found unique solutions for $\varepsilon > -1$, dual solutions for $\varepsilon_c < \varepsilon \leq -1$, and no solutions for $\varepsilon < \varepsilon_c < 0$, with $\varepsilon_c = -1.2465$. New similarity transformations yield exclusive unique solutions for $\varepsilon > -1$, while Figures 3 and 4 illustrate how nanoparticle properties affect velocity and temperature profiles in nanofluids.

We have developed a novel set of similarity transformations that consider all relevant independent variables, eliminating dual solutions observed in the cited paper [25]. These transformations ensure proper dimensionality in the stretching velocity and reveal that increasing the Prandtl number leads to a temperature decrease and an expansion of the thermal boundary layer. Additionally, as the volume fraction of nanoparticles like Cu, Al_2O_3, and TiO_2 increases, fluid velocity decreases while temperature rises. These findings offer a fascinating insight into the behavior of nanofluid dynamics.

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