CHAPTER

6

THIN-FILM HYBRID NANOFLUID

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6.1 INTRODUCTION

The existence of nanoparticles in a fluid affects the fluid's ability to transport heat. Nanofluid is a combination of solid nanoparticles and a base liquid that was first described by Choi and Eastman (1995). The blends of nanoparticles known as "hybrid nanofluids" have prompted several industries to go deeper into their research because of its many technical, industrial, and scientific uses in medical manufacturing and microfluidics. An exceptional heat transmission coefficient augmentation with a low-pressure drop limit has been accomplished by the ideal fusion of numerous characteristics of nanoparticles (Ali, 2020). Maskeen et al. (2019), state that a little volume fraction of nanoparticles added to the fluid produces a stable and high thermal conductivity when the mixture of nanofluids is used.

Furthermore, it is thought that appropriate hybridisation of the nanocomposites will boost the fluid's heat transmission and mitigate the drawback of higher viscosity (Minea & Moldoveanu, 2018). There is more heat flux in the host fluid that contains hybrid nanoparticles. Izadi et al. (2018) looked into the study of a convection fluid flow that has hybrid nanoparticles implanted in it. The thermal conductivity, density, heat capacity, and viscosity of the nanoparticles are important elements that affect the heat transmission coefficients of the hybrid nanoparticles, according to Ravisankar and Chand (2013).

Several scholars have looked at several studies on the convective boundary layer flow in hybrid nanofluids that account for the altered model introduced by Tiwari and Das (2007). Compared to nanofluid, the research conducted by Devi and Devi (2017) as well as Waini et al. (2020) indicates that hybrid nanofluid has a greater rate of heat transmission. Maleki et al. (2019) reported on the numerical simulation for the various nanoparticles, specifically copper oxide, copper and titanium dioxide, distributed in carboxymethyl cellulose (CMC) plus water. They discovered that the heat transfer fluid's Nusselt number is increased by the volume fraction of nanoparticles in CMC-water, the base fluid.

The heat transmission of a hybrid nanofluid, $Cu\text{-}Al_2O_3$, which is quantified as the Nusselt number, was shown to be less than that of a single nanofluid by Venkateswarlu and Satya Narayana (2021). Sakkaravarthi and Reddy (2023) examined the hybrid Casson blood fluid of cobalt and tantalum on a porous curved stretched sheet under heat radiation. They found that the temperature profile is raised by magnetic factors and thermal radiation. In comparison to a single nanofluid, the addition of hybrid nanoparticles Al2O3-Cu in thin-film flow increases the heat transmission rate, according to Sulochana and Aparna (2019).

Thin-film flows are widespread in biology, geophysics, engineering, and other disciplines. Laminar thin-film flow between movable flat plates that are inclined, vertical, or horizontal is the main emphasis at the moment because it has a tremendous deal of potential for use in several design applications as a mechanical instrument. For instance, thin-film fluid flow is involved in coating, draining, biological, solar cell, and wetting processes (Girtan & Girtan, 2018). Without taking thermal performance into account, Wang, (1990) investigated the hydrodynamics of a thin Newtonian liquid layer over a stretched sheet. Heat transmission in fluid flow studies using a stretched sheet by Sakiadis (1961), Crane (1970), and Carragher and Crane (1982) served as an inspiration for Wang (1990).

The hydrodynamic heat transmission problem of Wang (1990) was then examined by Andersson et al. (2000). Applying the thermal similarity variable in the thin-film fluid resulted in an ordinary differential equation for energy equation. At low Prandtl numbers, the thin-film unsteadiness parameter incorporated in the fluid flow has a key impact on the behaviour of heat transmission. Wang (2006) then included the flow issue with heat transfer into the earlier study of. He utilised the Homotopy analysis method (HAM) approach to find the result for the parameters that were analysed.

By considering the existence of particles in nano size in a thin-film fluid, Xu et al. (2013) built on the work of Wang (2006). Tiwari and Das (2007) model was considered in this investigation. It was discovered that the temperature profile is more significantly impacted using nanoparticles in the thin-film liquid than by the fluid speed. In comparison to a single nanofluid, the inclusion of multi nanoparticles in thin-film fluid upsurges the heat transmission rate significantly, according to Sulochana and Aparna (2019). Studies on thin-film fluid flow with hybrid nanoparticles have recently been conducted by Khan et al. (2022) and Bilal et al. (2023).

The current work aims to analyse the thin-film hybrid nanofluid with water plus ethylene glycol as the base fluid over a stretched sheet with suction/injection. It is motivated by Sulochana and Aparna (2019), Devi and Devi (2017), and Wang, (2006). The hybrid nanofluid, a modified version of Tiwari and Das (2007) model, is used. A similarity transformation method is applied for converting the nonlinear partial governing equations (PDEs) into nonlinear ordinary differential equations (ODEs). The Keller-box technique, which is an implicit finite difference method, is then applied to numerically crack the nonlinear and dimensionless ODEs. Besides, the unknown thickness of the thin-film is calculated by using HAM.