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Oblique Radiative Solar Nano-Polymer Gel Coating Heat Transfer and Slip Flow: Manufacturing Simulation

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Abstract : Nano-polymeric solar paints and sol-gels have emerged as a major new development in solar cell/collector coatings offering significant improvements in durability, anti-corrosion and thermal efficiency. They also exhibit substantial viscosity variation with temperature which can be exploited in solar collector designs. Modern manufacturing processes for such nano-rheological materials frequently employ stagnation flow dynamics under high temperature which invokes radiative heat transfer. Motivated by elaborating in further detail the nanoscale heat, mass and momentum characteristics of such sol gels, the present article presents a mathematical and computational study of the steady, two-dimensional, non-aligned thermo-fluid boundary layer transport of copper metal-doped water-based nano-polymeric sol gels under radiative heat flux. To simulate real nano-polymer boundary interface dynamics, thermal slip is analysed at the wall. A temperature-dependent viscosity is also considered. The Tiwari-Das nanofluid model is deployed which features a volume fraction for the nanoparticle concentration. This approach also features a Maxwell-Garnet model for the nanofluid thermal conductivity. The conservation equations for mass, normal and tangential momentum and energy (heat) are normalized via appropriate transformations to generate a multi-degree, ordinary differential, non-linear, coupled boundary value problem. Numerical solutions are obtained via the stable, efficient Runge-Kutta-Fehlberg scheme with shooting quadrature in MATLAB symbolic software. Validation of solutions is achieved with a Variational Iterative Method (VIM) utilizing Langrangian multipliers. The impact of key emerging dimensionless parameters i.e. obliqueness parameter, radiation-conduction Rosseland number (Rd), thermal slip parameter (α), viscosity parameter (m), nanoparticles volume fraction (ϕ) on non-dimensional normal and tangential velocity components, temperature, wall shear stress, local heat flux and streamline distributions is visualized graphically. Shear stress and temperature are boosted with increasing radiative effect whereas local heat flux is reduced. Increasing wall thermal slip parameter depletes temperatures. With greater volume fraction of copper nanoparticles temperature and thermal boundary layer thickness is elevated. Streamlines are found to be skewed markedly towards the left with positive obliqueness parameter.

Keywords : non-orthogonal stagnation-point heat transfer, solar nano-polymer coating, MATLAB numerical quadrature, Variational Iterative Method (VIM)
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