Accepted Manuscript

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PII: S0997-7546(16)30080-2
DOI: https://doi.org/10.1016/j.euromechflu.2018.03.001
Reference: EJMFLU 3266

To appear in: *European Journal of Mechanics / B Fluids*

Received date : 6 March 2016
Accepted date : 1 March 2018

Please cite this article as: S. Dholey, On the fluid dynamics of unsteady separated stagnation-point flow of a power-law fluid on the surface of a moving flat plate, *European Journal of Mechanics / B Fluids* (2018), https://doi.org/10.1016/j.euromechflu.2018.03.001

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Abstract

The transformation group theoretic approach is applied to perform an analysis of the unsteady separated stagnation-point (USSP) flow over a moving flat plate immersed in a non-Newtonian power-law fluid. This unsteady two-dimensional laminar boundary layer flow of a power-law fluid is governed by the classical Ostwald-de Waele power-law model. The system of governing partial differential equations reduces to an autonomous third order nonlinear ordinary differential equation via two-parameter group theoretic method. By using an efficient shooting method, we have established the existence of two different kinds of solutions, namely : (i) attached flow solution (AFS) and (ii) reverse flow solution (RFS) of this USSP flow problem under a definite negative value of the unsteadiness parameter β with a given value of the acceleration parameter a and for all values of the power-law index n considered in the present study. We have also found a unique AFS solution that is irrespective of n when $\beta \geq 0$. Dual solutions of the governing boundary layer equation are found for all kinds of fluids with the fixed values of $a = 1$ and $\beta =$ - 1. The role of the rheological index n on the displacement thickness, skin-friction coefficient and velocity boundary layer are explored numerically. The results of this analysis reveal that the wall shear stress is always positive for AFS flow and negative for RFS flow for the above values of a and β with any given value of n. A novel result that emerges from this analysis is that the magnitude of the wall shear stress decreases and finally it approaches asymptotically to a constant value with the increase in the non-Newtonian behavior ($n > 1$) of the fluids for both the cases of AFS and RFS.

Keywords: Unsteady flow, Power-law fluids, Similarity solution, Pressure gradient, Dual solutions, Stagnation-point.