Hydromagnetic instability of a power-law liquid film flowing down a vertical cylinder using numerical approximation approach techniques

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The long-wave perturbation method is employed to investigate the hydromagnetic stability of a thin electrically-conductive power-law liquid film flowing down the external surface of a vertical cylinder in a magnetic field. The validity of the numerical results is improved through the introduction of the flow index and the magnetic force into the governing equation. In contrast to most previous studies presented in the literature, the solution scheme employed in this study is based on a numerical approximation approach rather than an analytical method. The normal mode approach is used to analyze the stability of the film flow. The modeling results reveal that the stability of the film flow system is weakened as the radius of the cylinder is reduced. However, the flow stability can be enhanced by increasing the intensity of the magnetic field and the flow index, respectively. In general, the optimum conditions can be found through the use of a system to alter stability of the film flow by controlling the applied magnetic field.

1. Introduction

The hydrodynamic stability of fluid films flowing down a vertical cylindrical surface has attracted particular attention. Lin and Liu [1] compared their analytical solutions with existing experimental results for a falling flow film on a cylinder and a creeping annular flow thread in a viscous fluid, respectively. Krantz and Zollars [2] developed an asymptotic solution for the linear hydrodynamic stability of a film flowing on a vertical cylinder and indicated that the radius of curvature of the cylinder had a significant effect upon the stability of the thin-film system. Specifically, the authors demonstrated that the film flow became increasingly unstable as the radius of the cylinder was reduced. This phenomenon is not found in planar flow. Rosenau and Oron [3] derived an amplitude-based equation describing the evolution of a disturbed free film surface traveling down an infinite vertical cylindrical column. The modeling results indicated that both supercritical stability and subcritical instability states occurred within the film flow system given appropriate conditions. Furthermore, it was shown that the evolving waves broke at the instant that linearly unstable conditions were attained. Davalos-Orozco and Ruiz-Chavarria [4] investigated the linear stability of a fluid film flowing along both the internal and the external surfaces of a rotating vertical cylinder. They showed that the centrifugal force induced as the cylinder rotated counteracted the destabilizing effects of surface tension and created a more stable film system as a result. However, even in the absence of rotation, the authors showed that stability was still achieved at certain critical wave numbers. Hung et al. [5] conducted a weakly-nonlinear stability analysis of a condensation film flowing down a vertical cylinder and demonstrated the co-existence of supercritical stability in the linearly unstable region and subcritical instability in the linearly stable region. As in [2], the authors reported that lateral curvature of the cylinder exerted a destabilizing effect on the stability of the film flow. Furthermore, the numerous investigations of the hydrodynamic stability have been studied by the experimental observations [6,7].