Effects of partial slip on rotating-disc boundary-layer flows

Sharon O. Stephen, School of Mathematics and Statistics, University of Sydney, Sydney NSW 2006, Australia

Long Abstract

Introduction

An asymptotic study is presented for the effects of partial slip on the linear stability of the flow due to a rotating disc. This is to take into account the effect of surface roughness. Of interest are the stationary crossflow vortices which arise in the transition process from a laminar to a turbulent flow. The numerical study of [1] has shown the effects of partial slip on the Type I and Type II instabilities. The effect on the Type II instabilities is of particular interest here as [1] show that it can be destabilising. The present study determines the important instability mechanisms at large Reynolds numbers when the no-slip boundary condition is replaced by a partial-slip condition. The effect of partial slip on the stability of non-Newtonian flows is also investigated, which has practical industrial applications for drag reduction.

1. Methods

We consider the effect of roughness on the stability of the flow due to a rotating disc by following the approach of [1]. This study considered a partial slip boundary condition at the wall. The partial-slip condition approximates the no-slip boundary condition for the case of small-scale roughness compared to the boundary layer thickness. Anisotropic and isotropic roughnesses are able to be modelled in this way.

The basic steady flow is obtained as an exact solution of the Navier–Stokes equations. The linear stability analysis for perturbations corresponding to stationary crossflow vortices is carried out. The inviscid Type I and viscous Type II instabilities are investigated by considering the appropriate asymptotic regimes. This is an extension of the study of [2] to consider the effect of roughness.

2. Results

The predictions for the neutral wavenumbers and orientations of the crossflow vortices will be compared with the numerical results of [1] for anisotropic and isotropic roughness. The results of the asymptotic study will further the knowledge of how roughness may be used for drag reduction in rotating flows.

3. Non-Newtonian flows

Non-Newtonian flows due to a rotating disc have many industrial applications. Previous studies have determined the numerical solutions for various fluids (see the review paper by [3] and the recent results of [4] for a power-law fluid). The first linear stability analyses of such flows has been given by [5], [6] and [7]. [8] considered the effects of partial slip on a non-Newtonian Reiner–Rivlin fluid.

Results will be presented for the effect of partial slip on the basic flows of several types of non-Newtonian rotating-disc flow. The first linear stability analyses of non-Newtonian flows with partial-slip boundary conditions will also be considered using asymptotic methods for large Reynolds numbers.

References

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