Morgan, Scott; Davies, Christopher

Linear stability eigenmodal analysis for steady and temporally periodic boundary-layer flow configurations using a velocity-vorticity formulation. (English) Zbl 1435.76023


Summary: A novel solution procedure is presented for undertaking the linear stability eigenmodal analysis of two and three dimensional steady and time-periodic boundary-layer flow configurations. A velocity-vorticity formulation of the governing equations is deployed, together with a numerical discretisation that utilises a version of the Chebyshev-tau method. The required linear operators are applied in an integrated form to the Chebyshev series representations, instead of the more commonly used differential form. No-slip conditions are imposed in a fully consistent manner using integral constraints on the vorticity. The chosen numerical methods culminate in matrix equations which can be constructed in a relatively simple manner. These are then solved using the eigenvalue routines available in standard software libraries for linear algebra. Validation is provided against previously published results for two distinct cases. Firstly, for the steady boundary layer formed above a disk of infinite extent that rotates with a constant angular velocity. Secondly, for the semi-infinite time-periodic Stokes layer that is driven by the oscillatory motion of a flat plate. New results are then presented for the oscillatory boundary layer that forms above a disk that rotates with a rate that is periodically modulated. This configuration can be construed as providing a canonical example of a three-dimensional temporally periodic boundary layer. Its stability is examined here for the first time, with a Floquet analysis conducted by combining the solution methods that were developed for the other two cases.

MSC:
76D10 Boundary-layer theory, separation and reattachment, higher-order effects
76E99 Hydrodynamic stability

Keywords:
hydrodynamic stability; boundary layer; vorticity method; normal mode; Floquet mode; numerical solution

Full Text: DOI

References:
[27] Ramage, A., Linear disturbance evolution in the semi-infinite Stokes layer and related flows (2017), Cardiff University, PhD thesis
[38] Womersley, J. R., Method for the calculation of velocity, rate of flow and viscous drag in arteries when the pressure gradient is known, J. Physiol., 127, 3, 553-563 (1955)

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