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Weakly nonlinear instability of viscoelastic planar sheets with initial varicose disturbances

Luo Xie, Li-Jun Yang*, Jun-jie Wang, Li-zi Qin

School of Astronautics, Beijing University of Aeronautics and Astronautics, Beijing 100191, China

Abstract

Viscoelastic sheets, moving in an inviscid gas with initial varicose disturbances, have been investigated by performing a second-order temporal weakly nonlinear instability analysis based on the perturbation technique. The Oldroyd-B equation is considered as the rheological model of viscoelastic fluid. The solutions of the second-order disturbances have been derived, including the second-order dispersion relation and the corresponding interface displacement. The results showed that the second-order interface displacement of the varicose mode was also varicose, which interacts with the fundamental varicose wave, causing disintegration of sheets at full-wavelength intervals and resulting in ligaments consisting of two connected swells. Much smaller satellite ligaments were also formed soon after breakup within such ligaments. Different breakup behaviors and mechanisms between sheets with initial varicose and sinuous disturbances are displayed and analyzed. It is found that the eventual shape of sheets depends mainly on three factors, the first-order and second-order temporal growth rates and the second-order disturbance amplitude. The breakup time has been calculated to assess the extent of nonlinear instability. The influence of dimensionless rheological parameters on instability, i.e. elasticity number and time constant ratio, are examined via comparison of the three key factors, breakup time and wave deformation at the shortest breakup time.

Key words: viscoelastic sheets; weakly nonlinear instability; linear varicose mode; breakup time

1. Introduction

The study of planar liquid sheets is of both practical and fundamental interest; it is encountered in various industrial processes and facilities, including spray combustion, gas turbines, diesel engines, ink-jet printing and agricultural spraying. With the development of advanced materials, viscoelastic fluids such as high

* Corresponding author. Tel.:+86 010 82339571; fax: +86 010 82339571.

E-mail address: yanglijun@buaa.edu.cn (L.-J. Yang).