Three-dimensional modulations of solitary waves in a falling liquid film

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ABSTRACT

We consider a liquid film falling down an inclined plane when periodic forcing is applied at the inlet. For moderate Reynolds number, two-dimensional solitary waves are observed. If the forcing frequency is high, the waves are first nearly sinusoidal ; these γ_1 waves are unstable and evolve downstream into γ_2 solitary waves as a result of a secondary instability [1]. We study the transition to 3D waves when the flow rate is increased in order to better understand the transition to surface turbulence in liquid films.

The physical mechanism responsible for the 3D modulations of solitary waves is the Rayleigh-Plateau instability, as pointed out by Demekhin *et al.* [2]. By using a one-equation model (Nepomnyashchy equation), they decompose the 2D base state into normal modes and perform a series expansion at small transverse wavenumbers. We extend this analysis by using the three-equation Ruyer-Quil-Manneville model [1], and show that second order viscous terms can damp the instability.

We then compare this analysis with some experimental results. The experiment consists in a water film flowing down a 200 cm (length) $\times$ 40 cm (width) inclined glass plate. The inclination angle can vary up to $\beta = 20\,^\circ$. The forcing at the inlet is applied through harmonic vibration of a plate above the liquid surface in the range of frequencies : $2 \leq f \leq 20$ Hz. The Reynolds number is varied up to $R = 100$. We use a Schlieren method [3] to visualize the wave patterns and measure the film height (Fig. 1).

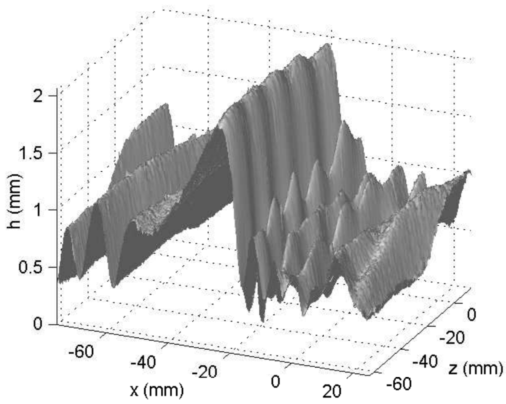

FIGURE 1 – Modulated solitary wave at $R = 59.6$, $f = 3.2$ Hz, $\beta = 7.2\,^\circ$

Références

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