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SIMULATING SOLITARY WAVES ON A FLOWING DOWN LIQUID FILM ENTRAINED BY A GAS STREAM

We consider nonlinear waves on the liquid film, flowing down over a vertical plane in the field of gravity and entrained by a concurrent gas flow. The long-wave modes of such a flow are studied for the case of small flow rates. The problem is reduced to studying the solutions of a nonlinear evolution equation for the film thickness perturbation. Soliton solutions of this model equation have been built numerically. It is shown that, similar to the case of the freely falling film, this model equation has solutions in the form of multi-hump solitons-elevations.

1. Introduction

The joint flow of liquid and gas is a well-known problem of hydrodynamics and practice. Flows of thin, wave-coated liquid films occurring in the presence of a counterflow or a cocurrent gas flow are often used in various technological applications. Such systems are widely used in power engineering, chemical, metallurgic and other industries.

Various aspects of the problem of wave regimes of film flows have been considered in numerous works [1-11]. To date, the free flowing down liquid films have become the subject of a number of full reviews, which has already become classical monographs (see, e.g. [12-14]). However, there are yet no monographs, devoted to the study of combined flows of viscous liquid film and gas. Rather detailed reviews devoted to this problem are presented, for example, in [8, 10, 11]. Its consideration in a fully conjugated statement is associated with substantial computing difficulties. So in the solution of this problem, two stages of modeling are often distinguished: determining gas stresses on the film surface and subsequent calculation of the evolution of waves in the liquid. The possibility of separating the problem into these stages, in particular, is substantiated in [8].

It becomes possible, since the fluid velocity is usually much smaller than the characteristic gas velocity, so the interface can be considered rigid and fixed. In addition, because of the smallness of the film thickness, the impact of the boundary perturbation on gas velocities may be considered linear. Because of this, the problem of calculation of normal and shear stresses of gas on the surface is reduced to considering the impact of individual spatial harmonics. It is taken into account here that any perturbation of the interface is a sum of the Fourier series. The interaction between a gas and a liquid is thus determined by the value of the stress tensor at the media interface. This formulation of the problem was used by many authors (see for example [2, 5, 8, 10, 15]).

At the second phase of the joint flow study, the dynamics of nonlinear waves on the liquid film surface is investigated.

From the academic point of view, wave flows of thin films are interesting, in particular, because the initial gas-hydrodynamic problem can be often reduced to relatively simple models in the form of equations for the thickness of a liquid film or for the perturbation of its thickness. Such models allow identifying and understanding the role of different physical processes and effects responsible for the formation of different characteristic wave flow regimes, since the terms included in these model equations have, as a rule, a clear physical meaning. In addition, it is possible to obtain and analyze solutions of such models by simpler numerical and analytical methods than in the case of the initial problem statement, formulated in the form of Navier-Stokes equations with appropriate boundary conditions.

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