STUDY OF GROWTH OF LOCAL PERTURBATION AND ITS INTERACTION WITH ZONE OF TURBULENT MIXING AT GAS-JELLY INTERFACE

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ABSTRACT

The authors present results of experimental study of growth of local perturbation and its interaction with zone of turbulent mixing occurred at Rayleigh-Taylor instability at interface of low-strength layer of jelly accelerated by compressed helium.

Local perturbation was a cavity of hemispherical shape with radius varied from R=0.5 mm to R=3 mm. On the free surface of the layer without local perturbations, background perturbations were specified as small cavities of square section having sizes of 2×2×0.2mm.They were located in the coincidental order.

Pressure of compressed helium was 13±0,1 atm. Acceleration of the layer was equal in all experiments and it was $g\sim 3*10^4$ m/s^2.

It was obtained that:

a) with increase of LP initial radius from 1mm to 3 mm, velocity of its growth into jelly layer is growing twice;

b) local perturbation having an initial amplitude close to background perturbation amplitude actually coincides with the zone of turbulent mixing.

Introduction

Instability such as *Rayleigh-Taylor* (RT) [1, 2] occurs, if the interface of heterogeneous media (media with different density) accelerates and the acceleration goes from light media to heavy one.

Instability of the interface will develop, if there are initial perturbations at the interface. Generally, initial perturbations are perturbations of the interface form, perturbations of media density, and perturbations of pressure at the interface or their combination.

In practice there are often occasions when perturbations of instable boundary surface of heterogeneous media (media with different density) occupy a small area of this surface (scratches, dimples, thin supports holding a laser target and so on). Such perturbations have come to be known as *local* or *localized* (LP) [3-5]. Computational and theoretical studies of growth of such perturbation are known without any influence of the zone of turbulent mixing on perturbations [6,7].

The problem on the interaction of the local perturbation with the zone of turbulent mixing (TM) is often discussed in recent years. Its experimental investigation is of chief interest.

This report presents the results of the experimental investigation of growth and interaction of LP with the zone of turbulent mixing.

Techniques of Experiments

The experiments have been performed on the experimental setup shown in Fig. 1.

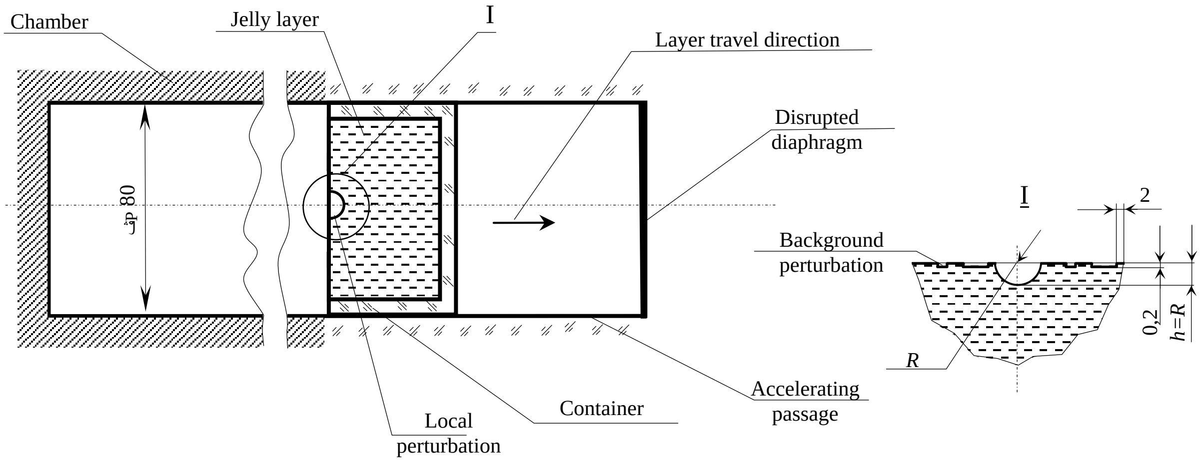

Figure 1 – Diagram of Experimental Setup

The experimental setup has consisted of an accelerating passage made of clear organic glass and a metallic chamber joined together. A free end face of the accelerating passage was closed by lavsan diaphragm. Internal cross-section was 80×80 mm.

In experiments jelly of gelatin aqueous solution [8] (with minimally possible strength) was used as a model of «heavy» layer (σ<<0,005 MPa, solution concentration C=3.2%). A container was filled with the jelly layer. The container was made of clear organic glass.

There were background perturbation at a free (instable) surface of the layer during the process of filling by the help of a specific form (background perturbations were specified as small cavities of square section having sizes of 2×2×0.2mm, located in the coincidental order) and hemispherical 3D local perturbation (Fig. 1). Radius of local perturbation was 3; 2; 1; 0.5 mm. The layer of jelly was 35 mm thick.

The container with the layer was installed in the accelerating passage. The chamber and the passage were filled with compressed helium at a pressure of P_0=13±0,1 atm. Then a diaphragm was destructed by electroblast of a nichrome wire glued to the diaphragm; in that case gas went from the passage into the atmosphere. The container was accelerated vertically downwards under the influence of pressure of compressed gas in the chamber. The acceleration of the container was $3{\cdot}10^4$ m/s^2. The process of accelerating the layer was recorded by the use of a rapid movie camera.

The Results of the Experiments and their Study

Figure 2 demonstrates some film frames of the experiments with 3D perturbations with the same displacement of the layer.

Figure 3 presents dependencies of depth of penetration of bubble pole 3D LP $h_{b(bubble)}$ and of gas front in $h_{LH(\text{light into heavy})}$ into the jelly layer upon the displacement of the layer 2S.

From moving image frames and dependencies we notice that:

1) At the instable interface of jelly layer without LP, the growth of background perturbations leads to the formation of the turbulent mixing zone growing across the width with time. At dependency in h_{LH} $(2S)$ at a liner range/linear section the amount of tilt $\Delta h_{LH}/\Delta 2S$ comes to $\approx 0.1 - 0.12$ (Fig. 3).

2) Velocity of LP growth into jelly layer having initial sizes approaching the sizes of background perturbation (R_{LP}=0.5mm) becomes close to velocity of growth of a gas front into jelly when displacing $20 \leq 2S < 100$ mm (Fig. 3).

3) The velocity of local perturbation growth into the layer has the aspect of linear dependence with a knee (jog) (Fig. 3); as this takes place, the velocity of LP growth into jelly layer depends upon its initial amplitude: when increasing LP initial radius from 0.5 mm up to 3 mm at section $2S \leq 20$ mm the amount of tilt $\Delta h_b/\Delta 2S$ increases practically by a factor of two (from 0.25 to 0.45). When displacing $20 \leq 2S < 100$ mm the amount of tilt $\Delta h_b/\Delta 2S$ decreases from ≈ 0.2 to ≈ 0.12 in all the experiments conducted with reduction in R_{LP} from 3 mm to 1 mm, namely velocity of growth of LP into the layer noticeably decreases. Reduction in $\Delta h_b/\Delta 2S$ at the second area of the specified dependence may be associated with «suppression» of local perturbation by TM zone.

Conclusions

The results of this work are as follows:

a) with increase in initial radius of local perturbation from 1 mm up to 3 mm the velocity of its growth into jelly layer is increasing approximately twice;

б) local perturbation having an initial amplitude close to a background perturbation amplitude actually coincides with the zone of turbulent mixing.

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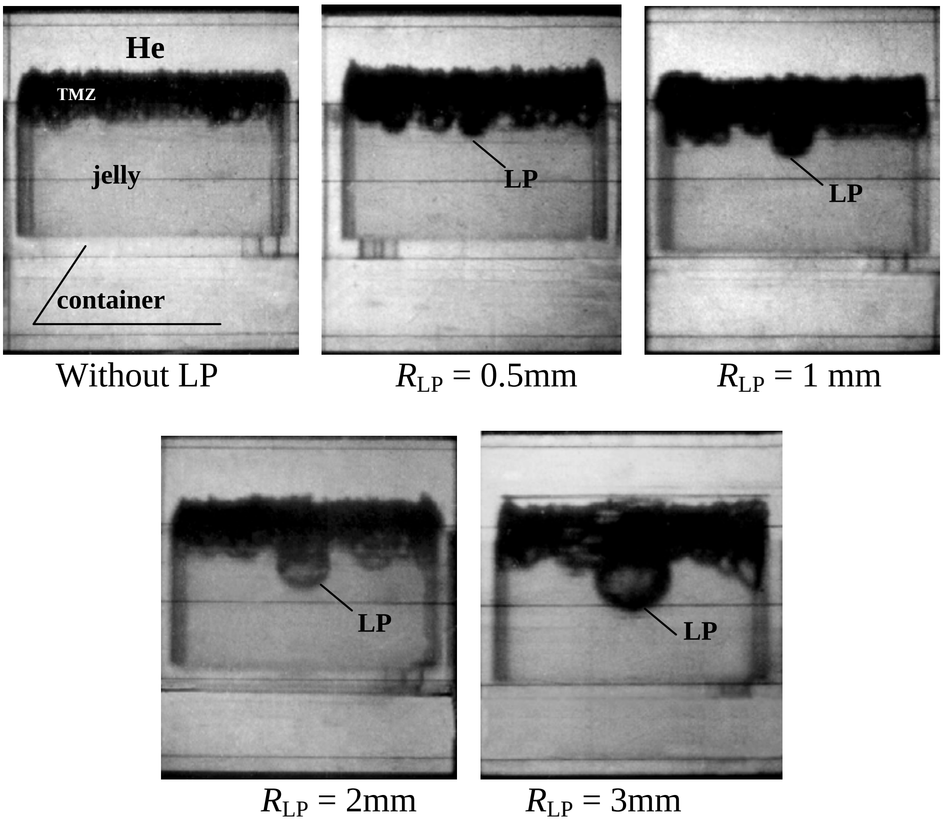

Figure 2 - Film frames showing growth of hemispherical 3D local perturbation

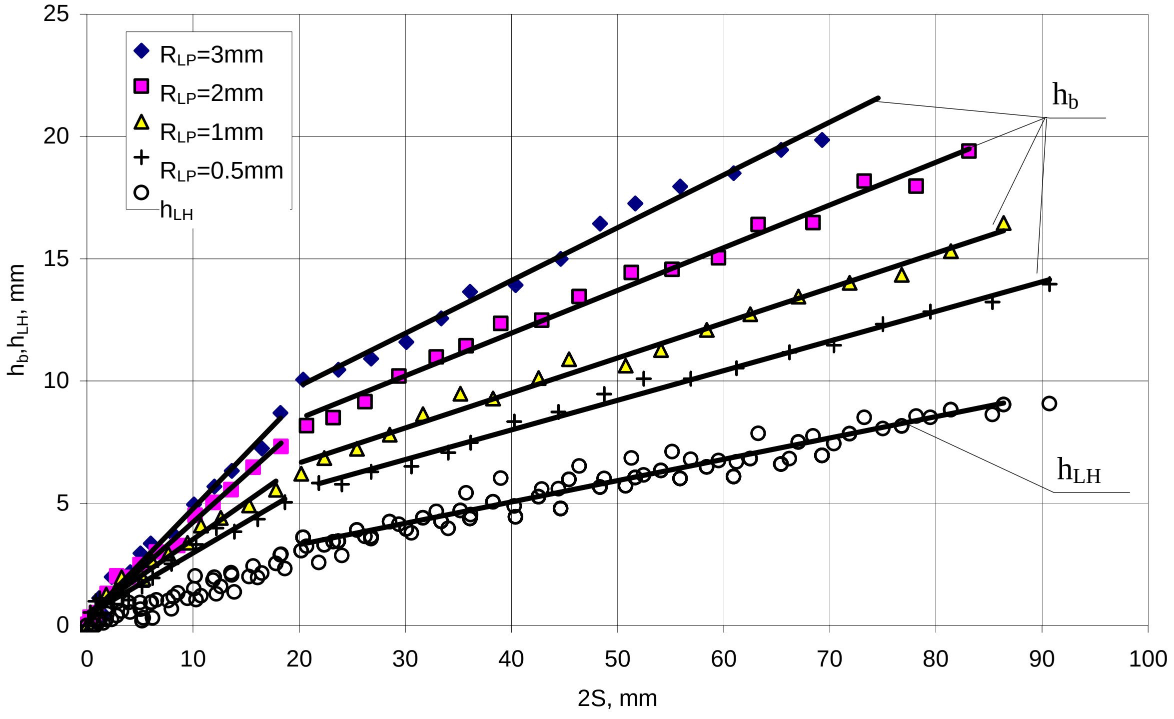

Figure 3 – Dependence of depth of penetration of 3D LP (h_b) bubble pole and dependence of depth of penetration of gas front (h_{LH}) into jelly layer upon displacement of layer $2S$

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