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Numerical Simulation of the Perturbation Growth on Unstable Plane and Cylindrical Interfaces*

V. N. Motlokhov, V. A. Pavlovskii,
V. V. Rasskazova, V. G. Rogatchev, and
A. N. Shaporenko

Russian Federal Nuclear Center
Institute of Experimental Physics
Arzamas-16, Nizhegorodsky region,
Russia, 607200

Numerical simulations were done for evolution of hydrodynamic instabilities at plane and cylindrical surfaces under the jelly experiments conditions [1]. Simulations were carried out using DMK code [2] for 2-D gas dynamic flows calculations. Irregular polygonal grid was used such that to describe the perturbation evolution with high accuracy.

1 Local perturbation evolution on the interface of accelerated plane jelly layer

Numerical simulation of this experiment was performed using 2-D code in axisymmetrical geometry. The lateral boundary of the computational domain was a round-section cylinder with the radius R_b=2.3 cm. The domain $0 < Z < 40$ cm contained air at rest with the initial pressure 8 atm and ambient temperature. Equation of state for air corresponded to that for perfect gas with adiabatic index $\gamma = 1.4$. On the right from this domain a jelly layer ($40 < Z < 42.8$ cm) was at rest with its left unstable surface containing a cone cavity 0.6 cm high and 0.6 cm in diameter. The jelly density was 1 g/cm^3. Jelly was described by equation of state for water. The right stable surface of jelly contacted the rigid moving plate 0.3 cm thick with the density 0.6 g/cmvarying with time following the law determined by the leakage of compressed air from the right chamber to atmosphere after the membrane breaks. This relation corresponded to the results of similar experiment on unperturbed layer acceleration and had the form:

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$$\mathrm{P}(t) = 1 + 7 \cdot \left(1 + \frac{\mathrm{t}\,(\mu s)}{6000}\right)^{-8}, atm.$$

Lateral surface of the channel and the face (Z=0) were considered rigid walls with normal mass velocity component being zero. Normal velocity component of the jelly on the plate interface was the same for each surface point and equal to the plate velocity along Z axis. For the jelly layer with t=0, an irregular grid was generated composed of 3500 cells and that of air-filled domain $0 < Z < 40$ cm contained 1200 cells with their sizes monotonically decreasing to the air - jelly interface and symmetry axis. The cells were split in strong deformation domain with time and their total number reached 5600.

Fig. 1 compares contours of the perturbed layer obtained from calculation with the experimental pattern. At t=1090 μs the cavity closure occurs and the closed volume of the air bubble forms. Then a jet starts forming (t=1330 μs) on the symmetry axis and impacts the bubble surface at t=1570 μs resulting in the toroid formation. A good agreement is observed between the computational and experimental shapes of growing perturbation particularly at later times. Fig. 2 illustrates the grid at initial time and at time close to the computation completion.

The analysis of computational results shows the critical role of air motion from the volume into the growing cavity. At early times air pressure slightly decreases inside the cavity because of its expansion despite of air input from the volume. The resulting pressure distribution leads to that the material near cavity edge starts moving to the symmetry axis closing cavity entry. The decrease in the inlet hole surface area and further bubble expansion make closure process even faster. After material collapse a cumulation jet forms on the symmetry axis.

Evolution pattern of the localized perturbation on stable layer (Fig. 3) qualitatively differs from the previous case. The interface initially experiencing the localized perturbation becomes actually plane with time. The perturbations do not grow.

2 Harmonic perturbation evolution on the inner interface of converging cylindrical jelly shell

Experiment under discussion [1] imitates the experiment in which metal shell was driven by high explosive products [3].

At t=0 cylindrical jelly shell had the inner radius $\mathrm{R}_{in}(\varphi) = 7.2 + 0.2 \cdot \cos(26 \cdot \varphi)$ cm, the outer shell radius was R(t=0)=8.75 cm, and the inner rigid cylinder radius was $r = 3.5$ cm.

Equation of state for jelly and air were the same as in the previous computations.

Boundary condition was represented by the outer interface motion low determined from experiment involving the cylindrically symmetric jelly shell. The computational

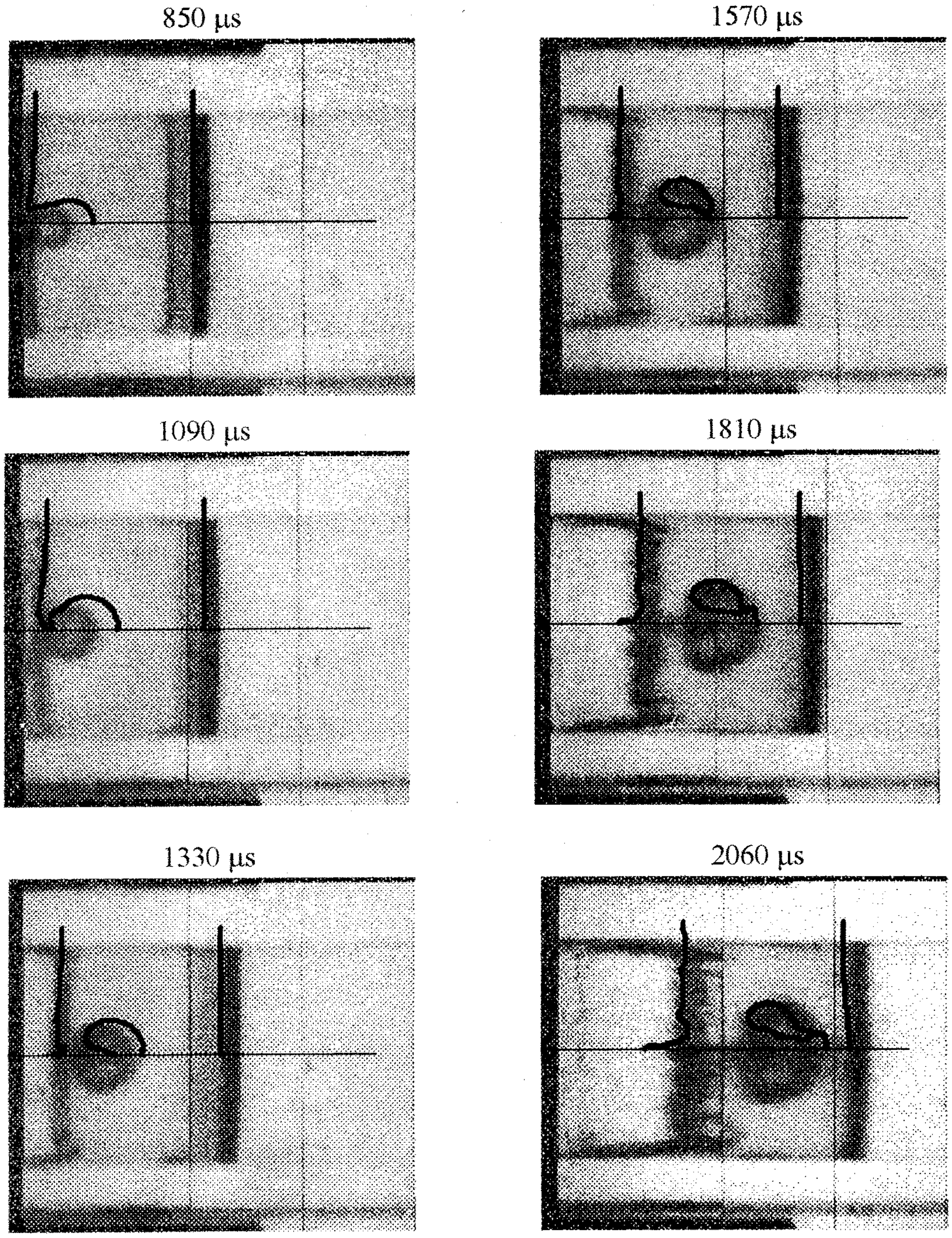

Figure 1: Comparison of the experimental results and DMK calculation of the conical perturbation growth at the unstable jelly layer interface.

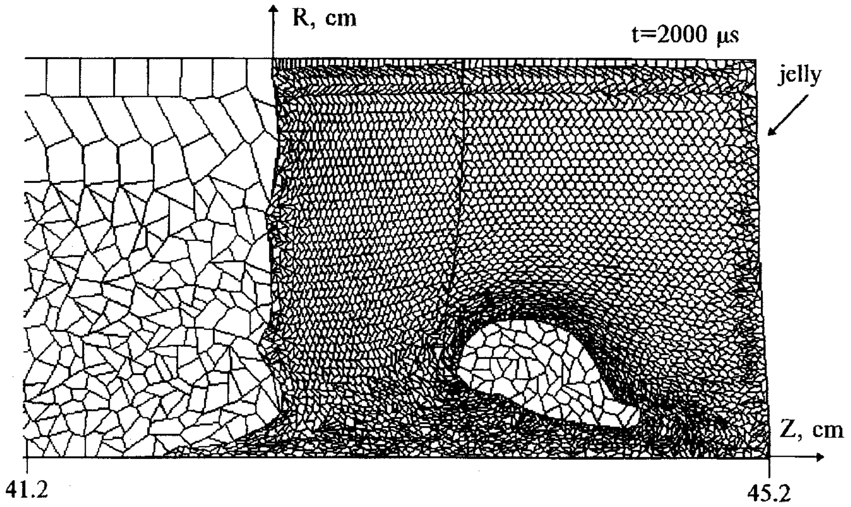

Figure 2: Fragments of the polygonal grid for conical perturbation growth at the unstable jelly layer interface. DMK calculation.

domain $0 < \varphi < 90^\circ$ was chosen from the symmetry condition. Jelly subdomain contained 8400 cells. Gas domain was covered by 850 cells.

Fig. 4 contains shell interfaces shape at different time moments. Inner interface shape spectral analysis results for the experiment and corresponding calculation presented in Fig. 5. Experimental and computational results are in good agreement.

3 Conclusions

Numerical simulations were carried out for jelly experiments using 2-D Lagrangian DMK code.

It was shown that the perturbation initially specified as cone at unstable plane layer interface converts to a compact gas toroid. It moves across the layer reaching its opposite interface. It was demonstrated that cavity closure and perturbation conversion to a toroid result from the pressure distribution change when air enters the cavity. Localized perturbation initially applied to the stable interface decays with time. A good agreement is obtained for the experimental and computational data.

2-D DMK calculations for jelly shell convergence where the inner interface initially experienced perturbation in the form of harmonic with N=26 are in good agreement with the jelly experiment imitating CEA/DAM experiment [3].

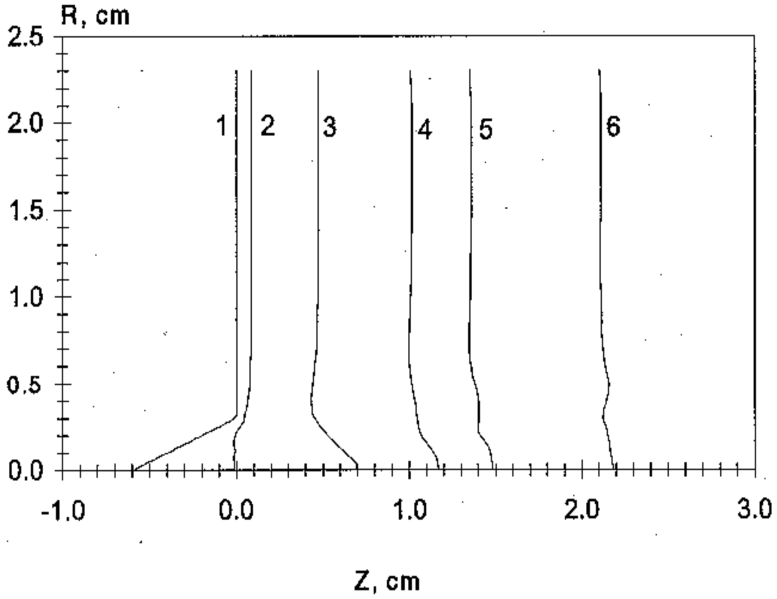

Figure 3: Conical local perturbation evolution at stable jelly interface. DMK calculation. 1-t=80 mks; 2-t=240 mks; 3-t=510 mks; 4-t=730 mks; 5-t=850 mks; 6-t=1050 mks.

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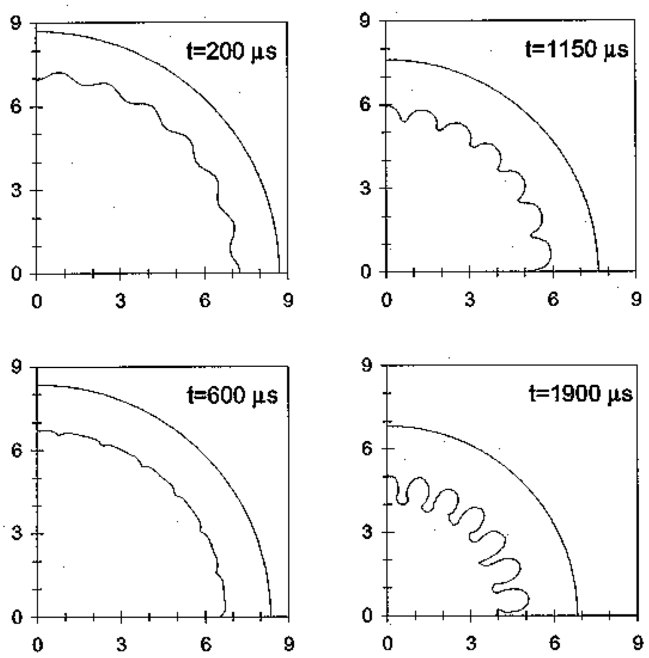

Figure 4: Convergence jelly shell interfaces. The inner surface in the DMK calculation had initial perturbation in the form of harmonics with N=26.

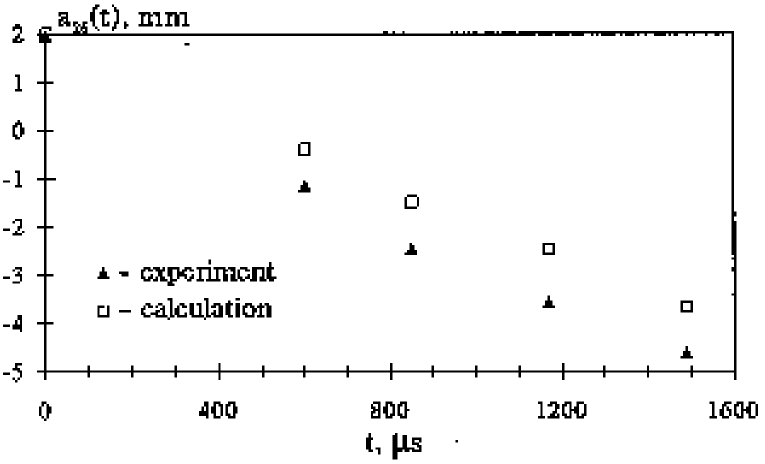

Figure 5: Inner jelly shell interface perturbation amplitude a_{26} time function.