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Numerical simulation with MULTI code vs. analytical model in ablative Rayleigh Taylor mode generation

J.Ramírez[1], J.Sanz[1], R.Ramis[1]

[1]*E.T.S.I.Aeronáuticos, Universidad Politécnica, Madrid, Spain*

Introduction

The Rayleigh-Taylor instability (RTI) has great relevance in inertial confinement fusion (ICF) studies [1]. When the low density ablating plasma accelerates the imploding shell inward, the outer shell surface behaves unstably to the RTI. Mass ablation is generated by the heat front propagating through the shell and being driven by the laser energy absorbed at the critical surface (direct drive) or by X-Rays coming from the target walls (indirect drive). It has long been known that mass ablation reduces the RT instability rate. Consistent theories [2,3,5] have been developed to analyse the problem. Numerical simulation with appropriate codes (e.g. MULTI [4]) is also another useful tool.

In this contribution we present and comment a comparison between these two approaches in two examples (near to or far from the cut off wave number, at moderately high Froude number) particularly as far as mode generation is concerned.

The theoretical model

Following reference [2] we consider a planar foil of thickness ℓ, subject to acceleration g due to the ablation pressure P_a generated by the heat flux coming from the plasma corona. Attention is restricted to a region of characteristic thickness $\sim k^{-1}$ around the ablation front, being k a typical wave number of the interface modulation. We also assume that the unperturbed flow is stationary and one dimensional, and use one-fluid equations for an ideal gas with heat conduction: continuity, momentum, and an isobaric approximation (subsonic flow) for the energy. The model assumes that the ablation surface separates two semi-unbounded regions: a cold material with high density ρ_a on one side, and a blow off plasma with a very low density ρ_h (and very hot) on the other side. In the cold region, the heat flux is negligible, and we use a potential flow with constant density ρ_a, velocity $\vec{v}_c = \nabla\phi + V_a\vec{e}_y$ (V_a ablation velocity, with boundary condition $\vec{v}_c = V_a\vec{e}_y$ at $y = -\infty$) and temperature $T_a \equiv P_a/\rho_a$. On the hot region, the heat transport is very strong and we use, except close to the ablation front, an almost flat density (or temperature) profile, neglecting gradients except the one of temperature in the heat flux formula $(\sim \bar{K}T^n\nabla T \sim \bar{K}T\nabla T^n)$ with $n>>1$. Matching both regions with mass, momentun and energy conservation, and closing the model with an integral equation, we can recover the results of linear ablative RTI [5] in the linear case.

Non - linear single mode results (for an initially small single cosine - mode perturbation) are obtained solving numerically Laplace equation by means of a first kind Fredholm integral equation and using the panels method. For every fixed value of the Froude number, the limit $k/k_c \to 0$ corresponds to the classical RTI. Several Froude numbers and ratios k/k_c have been calculated.

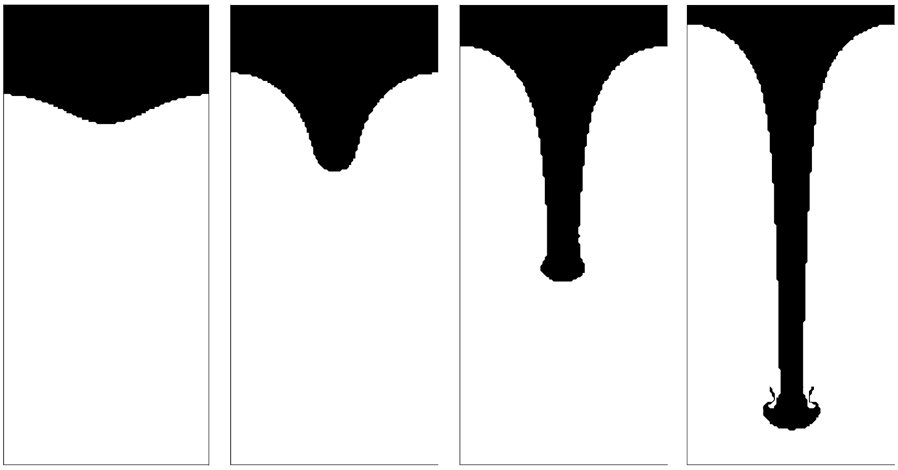

Fig.1a Ablation front interface at times $t\sqrt{kg} = 4, 6, 8, 9.5$; $k/k_c = 0.1$, and Froude = 5; (theoretical model)

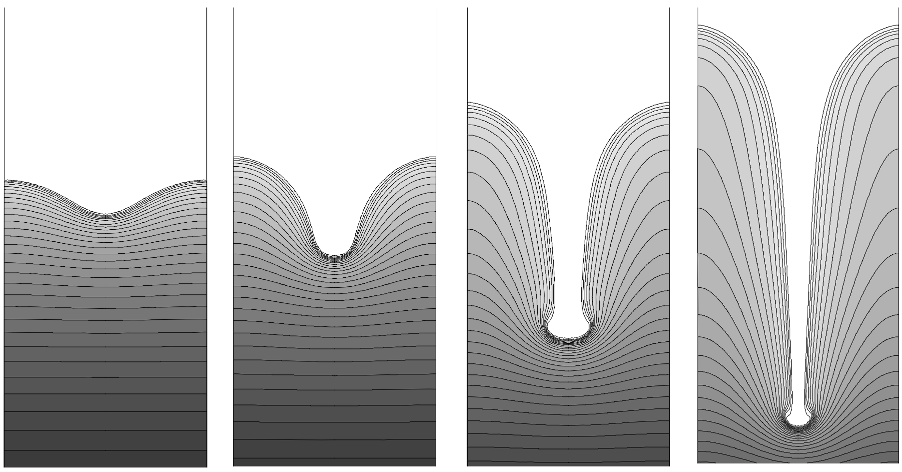

Fig.1b Isothermal contours from MULTI simulations corresponding to Fig 1a

In figures 1a - 2a we show some examples of a series of calculations; we can see the interface position at four time instants (1a) and the amplitudes of generated harmonics (2a) in selected cases, before the interface becomes multivalued. We have observed that the falling down spike widens and becomes thicker as the Froude number or k/k_c increase. This effect is also noticed looking at the time evolution of the high harmonics generated and observing the change of sign; the formation of mushrooms is evident, and gives an interface with a very rich and complicated structure.

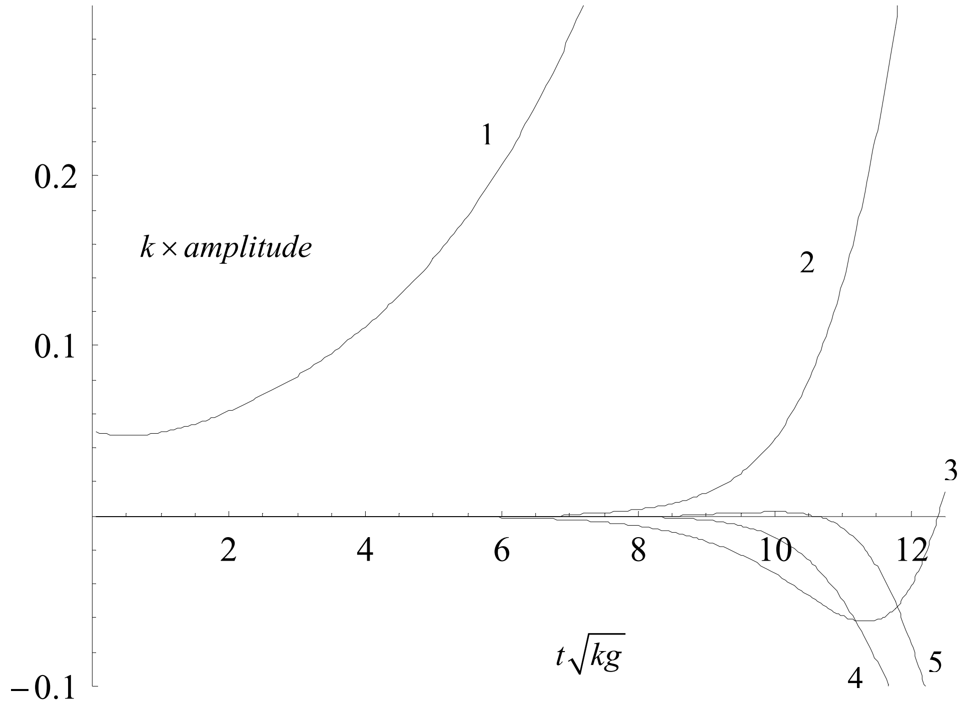

Fig.2a Normalized amplitudes of first five harmonics vs. normalized time;

$k/k_c = 0.5$, $F_r = 5$ (theoretical model)

The numerical model

Following reference [6] an indefinitely steady numerical solution was created with Multi-2D code on a steady Eulerian grid, where ablation material entering from one side was steadily ablated by a constant temperature energy source at the other side; after a small perturbation is introduced, a transient period is observed and then the Rayleigh-Taylor instability starts to evolve. Two types of studies have been done:

1) In Fig 1b we show temperature contour lines in a numerical case corresponding to the previosly analized with the theoretical model in Fig 1a. As it can be seen, the agreement is quite good.

2) In Fig. 2b, by identifying the ablation surface with the line where maximun thermal gradient appears, and through Fourier analysis of the ablation profile along the time, we study the creation of new modes and their amplitudes. Again, the agreement between theoretical model and numerical simulation is quite good.

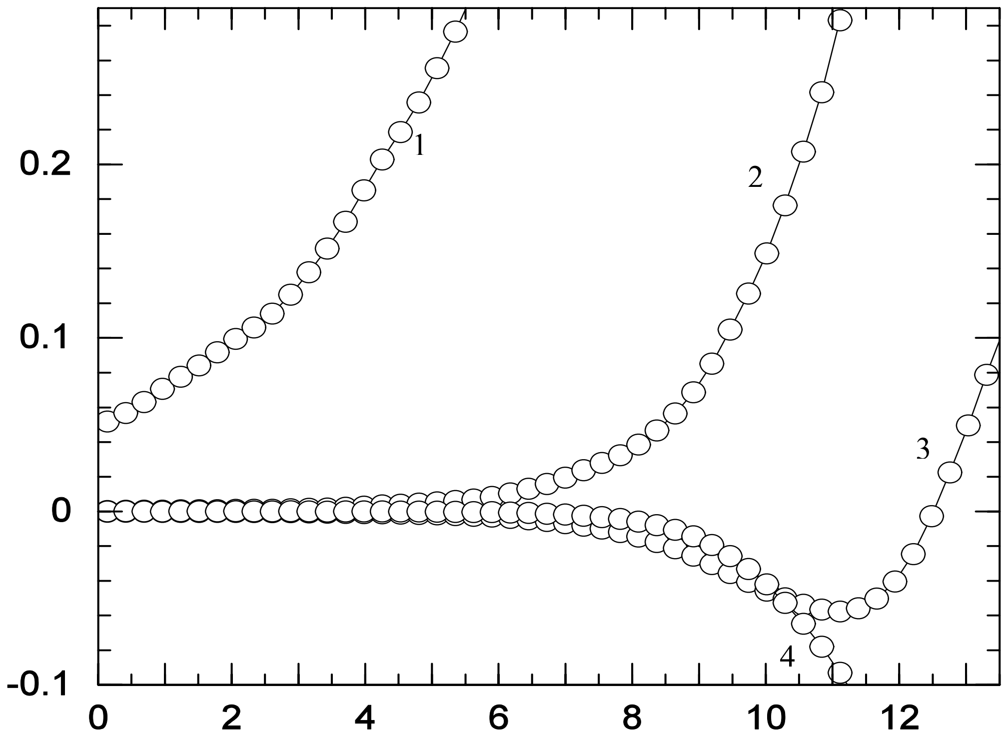

Fig.2b First four harmonics from MULTI simulation corresponding to Fig.2a

Acknowledgements

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References

[1] J.D. Lindl, *Inertial Confinement Fusion* (Springer, New York, 1998)

[2] J. Sanz, et al. *Phys. Rev. Lett.* 89 1 (2004)

[3] V.N. Goncharov et al., *Phys.Plasmas* 3, 1402 & 4665 (1996);

[4] MULTI Code, http://server.faia.upm.es/multi/

[5] H.J. Kull, *Phys. Rev.* A 33, 1957 (1986)

[6] J. Ramírez et al. *Laser & Particle Beams* 22 183-188 (2004)

[7] R. Ramis et al., *Nuclear Fusion* 44 720-730 (2004)