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Mitigation of the Richtmyer-Meshkov instability in Plasmas

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Turbulent mixing excited by the RMI often plays a crucial role associated with plasma explosions in astrophysical objects and the implosion in inertial confinement fusion. Interaction of supernova shocks and inhomogeneous interstellar matters is one of the promising sites of the RMI, which could contribute to the origin of the interstellar turbulence as well as the amplification of magnetic fields. The RMI is recognized as one of the severe obstacles to prevent the ideal implosion in laser fusion plasmas. Drastic symmetry reduction results in inadequate energy gain at the end of the process. Therefore, the mitigation mechanisms of the RMI are paid attention intensely in this field.

We investigate several effects proposed to stabilize the RMI by numerical simulations. A strong magnetic field can suppress the growth of the RMI when the Alfven number, which is the ratio of the linear growth velocity to the Alfven speed, is less than unity [1,2]. The vorticity deposited at the interface right after the incident shock refraction is the driving source of the RMI growth, while the vorticity left in the bulk of the fluids has been proved to be a physical agent that decreases the growth of the contact surface ripple [3]. We also focus on the effect of a density transition layer on the suppression of the RMI. When the transition layer becomes broader than the modulation wavelength, the perturbed velocity associated with the RMI is reduced considerably [4].

We have investigated the role of the density transition layer on the growth of the RMI using two-dimensional hydrodynamic simulations. Although three-dimensional evolutions of hydrodynamic instabilities are essential in many cases, two-dimensional study is still important to understand the physics behind it. A universal condition for the suppression of RMI due to the transition layer has been obtained successfully through a systematic parameter study. If the transition layer is narrower than the wavelength of the surface modulation, the effect on the RMI can be ignored. However, the RMI growth is severely reduced when the thickness of the transition layer exceeds the modulation wavelength. The obtained threshold condition, L > λ, can be explained by the comparison be- tween the shock-transit time through the transition layer and the stabilizing time of the pressure fluctuations by sound waves. This simple criterion will be useful to evaluate the importance of the RMI in various situations, such as interstellar shock waves in astrophysical phenomena and laser-driven shocks in inertial confinement fusion experiments. An exhaustive analytic study on the transition-layer effects should be carried out. Nonetheless, the inclusion of compressibility effects and double reflection of reflected waves makes the calculations extremely cumbersome, and it is proposed as future work.

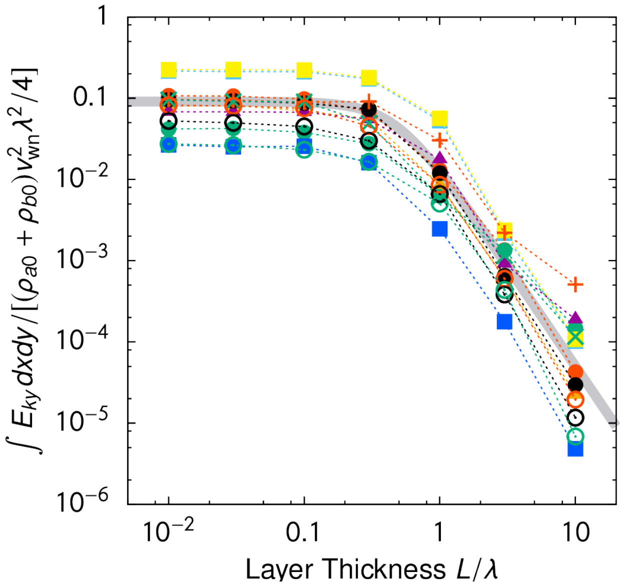

Figure 1. Dependence of the integrated kinetic energy measured at the nonlinear regime on the thickness of the transition layer L. Various parameter runs listed in Table I are plotted with different marks. The gray thick curve is the fitted function of all the data, which are proportional to $[1 + (qL/\lambda)^{p}]-1$ with q = 2.11 and p = 2.46.

References

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