Richtmyer-Meshkov Instability in Magnetized Plasmas

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Interfacial instabilities are of great importance in various plasma phenomena in the universe and laboratory experiments. The Richtmyer-Meshkov instability (RMI) is one of such instabilities that occurs when a planar shock hits a corrugated surface of the contact discontinuity. 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.

There are several effects proposed to stabilize the RMI. A strong magnetic field can suppress the growth of the RMI when the Alfven (Mach) number, which is the ratio of the linear growth velocity to the Alfven speed, is less than unity [1,2]. However, if the direction of the magnetic field is parallel to the interface but perpendicular to the wavevector of the surface modulation, the Lorentz force hardly works on the RMI. Then, the suppression by the magnetic field in three-dimensional geometry would be difficult so as in the case of the Rayleigh-Taylor instability. The vorticity deposited at the interface just 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. However, the effect of the bulk vorticity becomes significant only when the shock is sufficiently strong, or the compression is high enough.

It is well known that the smooth density structure of the interface affects the unstable growth of surface fluctuations. For example, the density stratification at the shear layer of the velocity stabilizes the Kelvin-Helmholtz instability. The stability condition is given by the Richardson number, which is a function of the density gradient. The Rayleigh-Taylor instability is also affected by the density stratification. The growth rate of the instability decreases dramatically if the scale length of the density structure is longer than the wavelength of the Rayleigh-Taylor mode. As for the RMI, the transition-layer effects have not been much investigated because of the difficulty of the analytical approach.

We have investigated the effects of a smooth transition layer at the contact discontinuity on the growth of the RMI by hydrodynamic numerical simulations (see Fig. 1), and we derived an empirical condition for the suppression of the instability [3]. The transition layer has little influence on the RMI when the thickness L is narrower than the wavelength of an interface modulation. However, if the transition layer becomes broader than the wavelength, the perturbed velocity associated with the RMI is reduced considerably. The suppression condition is interpreted as the cases in which the shock transit time through the transition layer is longer than the sound crossing time of the modulation wavelength. This feature is found to be quite universal and appeared in a wide range of shock-interface interactions.

References

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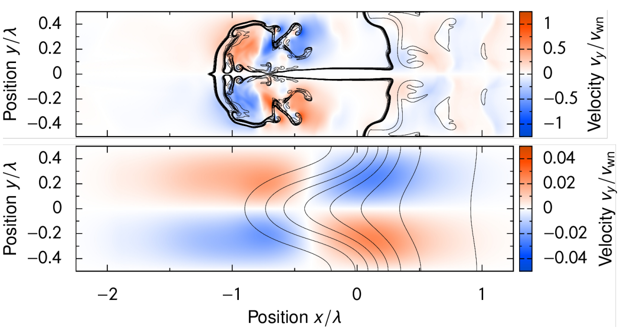

Figure 1: Spacial distribution of the density (contour lines) and the tangential velocity (color) at the nonlinear regime of the RMI growth for the cases of (a) sharp and (b) shallow density gradient.