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自己相似球収縮衝撃波における流体不安定性の時間発展
Instability analysis of spherical converging shock wave

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The shock wave is a most basic and important hydrodynamic phenomenon in many different branches of high energy density physics. In converging geometries such as cylinders and spheres, a shock wave is cumulatively strengthened towards the center and exhibits asymptotically self-similar behavior. The self-similar solution of a spherical converging shock wave was first reported by Guderley [1]

Following Gurderley[1] and using the notations of Ref.[2], we introduce the self-similar coordinate, $\xi=r/R=r/A|t|^{\alpha}$, and the self-similar fluid variables, $v=\frac{r}{t}V_0(\xi)$, $\rho=\rho_0 G_0(\xi)$,and $\gamma\frac{p}{\rho}=(\frac{r}{t})^2 G_0(\xi)$, where V_0, G_0, and Z_0, denote the dimensionless velocity, density, and squared sound speed, respectively, with being the initial density.

The perturbation quantities are postulated to be expanded in terms of spherical harmonics $Y_l^m(\theta,\psi)$. We then introduce such a 1-st order variable as the total perturbation amplitude of the shock surface is given by $R(t)[1+\Sigma(-t/\tau)^{\sigma}\eta_1^{\,l}Y_l^m]$ with normalized l^{th}–mode amplitude $\eta_1^{\,l}$, where is unkown growth rate. Moreover we formulate the other variables such as the radial velocity $v=(r/t)[V_0+\Sigma(-t/\tau)^{\sigma}V_1^{\,l}Y_l^m]$, the density $\rho=\rho_0\,[G_0+\Sigma(-t/\tau)^{\sigma}G_1^{\,l}Y_l^m]$, and the squared sound speed $c_s^2=(r/t)^2[Z_0+\Sigma(-t/\tau)^{\sigma}Z_1^{\,l}Y_l^m]$. The σ is to be found as an eigenvalue by solving the first-order system, derived by linearizing the one dimensional hydrodynamic system. Meanwhile the transverse velocity $v_\perp$ is not used below in its explicit form. Instead, its divergence is used as a tractable form, $r\nabla_\perp\cdot v_\perp=(r/t)\Sigma(-t/\tau)^{\sigma}D_1^{\,l}Y_l^m$, where $\nabla_\perp$ denote the transverse divergence operator with respect to the polar/azimuthal angles (θ,ψ).

Then the one dimensional hydrodynamic system, the conservation of mass, momentum, and entropy, is reduced to the perturbed system, which is numerically integrated. The integration is terminated at the singular point, such all the integrated corves for the perturbed quantities smoothly pass the singular point, $\xi=\xi_0$, as observed for the background quantities. The fluid velocity relative to the line with $\xi=\xi_0$ become sonic,where ξ_0 is a specific constant of the system. Only an appropriate complex value σ of satisfies this condition as the eigenvalue.

A novel compression scheme is proposed, in which hollow targets with specifically curved structures initially filled with uniform matter, are driven by converging shock wave. A linear stability analysis for a spherical geometry reveals a new dispersion relation with cut-off mode numbers as a function of the specific heat ratio, above which eigenmode perturbations are smeared.

We have presented the rigorous linear perturbation theory, for spherical converging shock. Concerning the stability, it has been revealed that a cut-off mode number depending on γ exists, over which eigenmode perturbations diminish.

[1] G. Guderley, Luftfahrforschung 19, 302 (1942)
[2] Zeldvich, Ya. B., & Raizer, Yu. P. 1960, Physics of Shock Waves and High Temperature Hydrodynamic Phenomena(New York: Academic)
[3] M. Murakami, Nagatomo H.,Nucl. Instrum. Methods Phys. Plasmas, **7** (2000) 2978

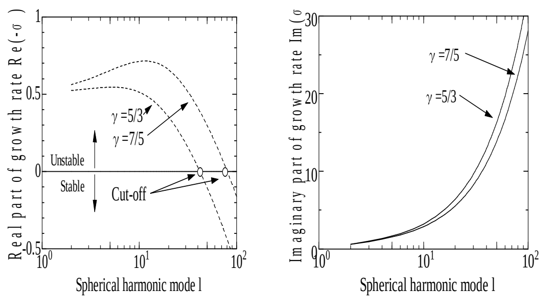

Fig. 1: Growth rate of perturbations in a spherical converging shock: (a) Re(-σ) (b) Im(σ)