Introduction
We consider the problem of regular hydrodynamical refraction of a planar shock ($S$) at an inclined planar contact discontinuity ($CD$), separating two gases at rest. When the shock impinges on the inclined density discontinuity, it refracts and 3 signals arise. Regular refraction means that these signals meet at a single point, called the triple point. After reflection from the top wall, the contact discontinuity becomes unstable due to local Kelvin-Helmholtz instability, causing it to roll up and form a Richtmyer-Meshkov instability ($RM_1$). By solving for the conservative variables $\mathbf{u}(x, y, t)$ in the linear phase of the process, we can quantify the vorticity, $\omega_{CD}$, deposited on the $CD$. An exact numerical solution strategy is presented, and compared to simulations performed by AMRVAC [2, 3]. We predict possible wave pattern transitions, which agree with experiments [1] and von Neumann theory [4]. We investigate the effect of a perpendicular magnetic field $B$.

Solution Strategy

- Triple point moves aling $CD$
- Self-similar solution in frame of stationary triple point: $\mathbf{u} = \mathbf{u}(\phi)$
- Riemann problem around triple point
- Across expansion fans: numerical integration
- Across shocks: stationary Rankine-Hugoniot conditions
- $p$ and $\omega$ are invariant across the $CD$
- initial guess for $p^*$
- iteration on $\|\mathbf{u}\|^2$

Solution to the Riemann Problem

- Exact numerical solution for the Abd-El-Fattah experiment. Left: $\alpha_{CD} = 0.97$ and $\alpha_{Stmax} = 1.01$
- $\Phi(\alpha)$

Connectin slow/fast and fast/slow refraction

- Exact numerical solution for $\left(\alpha, \beta, \gamma, \eta, M\right) = \left(\frac{1}{4}, \frac{1}{2}, \frac{1}{2}, \frac{1}{2}, 4.5\right)$ and a varying range of $\eta$. Left: for $\eta < 1$, we have $p^* < p_{post} = 4.5$ and thus a reflected expansion fan. For $\eta > 1$, we have $p^* > p_{post} = 4.5$ and thus a reflected shock.

Effect of perpendicular $B$

- Jump in $\omega$ across the $CD$: strong perpendicular magnetic fields suppress the instability of the $CD$. Right: Strong perpendicular magnetic fields slightly broaden the angles of the wave configuration.

AMRVAC simulations

- Adaptive mesh refinement
- Hybrid block-based
- MPI support
- Up to 3D relativistic MHD
- Solving equations of fluid dynamics:

$\nabla \cdot \mathbf{U} + \mathbf{F}(\mathbf{U}) = 0 \quad \text{and} \quad \nabla \cdot \mathbf{B} = 0$

- Following an interface: $\mathbf{B} = \nabla \times (\rho \mathbf{v})$

Conclusion

We developed an exact Riemann solver-based solution strategy for regular hydrodynamical shock refraction. Our results fit with numerical simulations and experiments. We will generalise our strategy for arbitrary $B$, where $\gamma$ signals arise.

References


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