Computational Fluid Dynamics Analysis of Shock Wave Interactions on MgO/Epoxy Interface

ENGINEERING HONORS PROGRAM
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Background

MgO, a fundamental constituent of Earth's mantle and similar planetary structures, plays a pivotal role in understanding the dynamics of planetary interiors. Despite its significance, experimental measurements of MgO's viscosity under extreme pressures remain scarce. To address this, computational fluid dynamics tools and numerical methods offer a promising avenue for comparing experimental findings with simulation data.

Project Objective

- Compare the effects of different simulation setups and initial conditions on final results
- Compare simulation data with experimental data

Project Setup

In this project, Rayleigh–Taylor instability and Richtmyer–Meshkov instability is used to help quantify and compare data by experiments and by simulations.
The simulation setup is a sinusoidal interface of MgO and Epoxy. By exerting shock wave onto the interface, the interface will move like the following diagram.

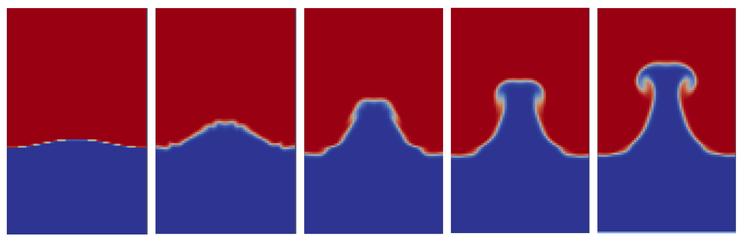


Figure 1. Example of simulation result of RM instability after shock wave is exerted to a sinusoidal interface of two different media with respect to time.

Different mesh resolutions for the simulation were also conducted to find the convergence of the solution as well as used to compare with experimental data.

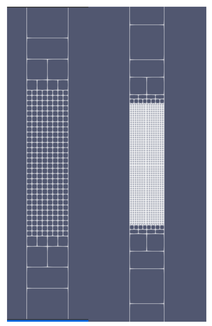


Figure 2. Examples of different mesh resolutions

Methods

Two sets of simulations were performed:

1. Varied the initial condition of the shock wave with different input Mach numbers from 1.5 to 5.5.
2. Varied the setup of mesh resolutions and focused more on the period right after the shock. Resolutions vary from 32 cells/wavelength to 1024 cells/wavelength.

After running each simulation set, data is processed by:

1. Measure the location of the interface throughout time and record relevant parameters including Pressure, Density, Volumetric Gradient
2. Amplitude and Amplitude Velocity were computed
3. Compare the plots with theoretical and experimental data

Results Part 1

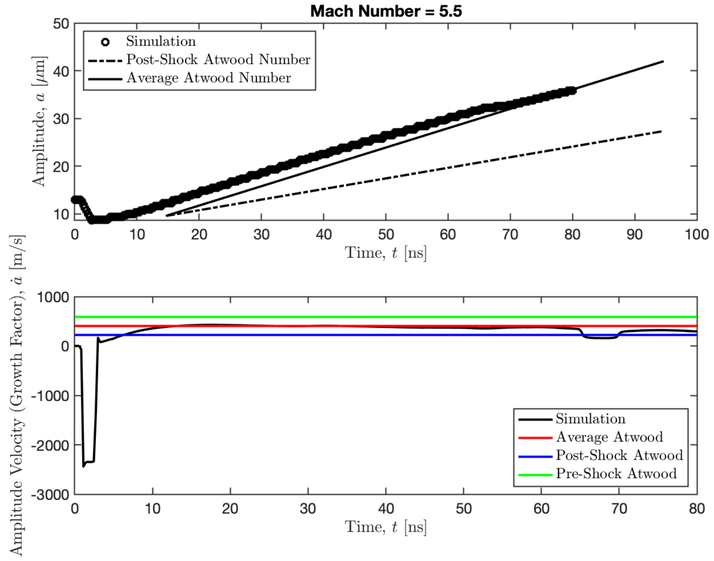


Figure 3. Plots of the interface amplitude and amplitude velocity with respect to time when the shock wave is exerted at a Mach number of 5.5 comparing to the theoretical values.

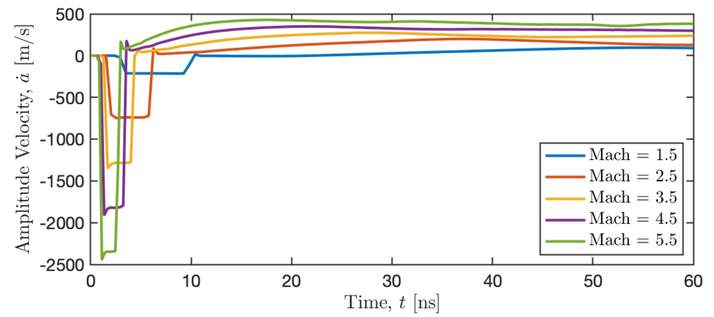
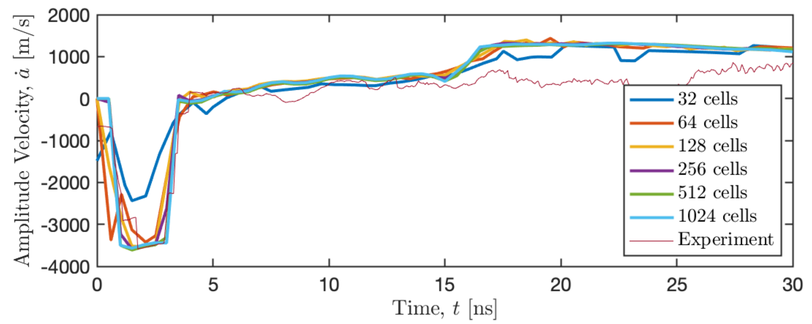
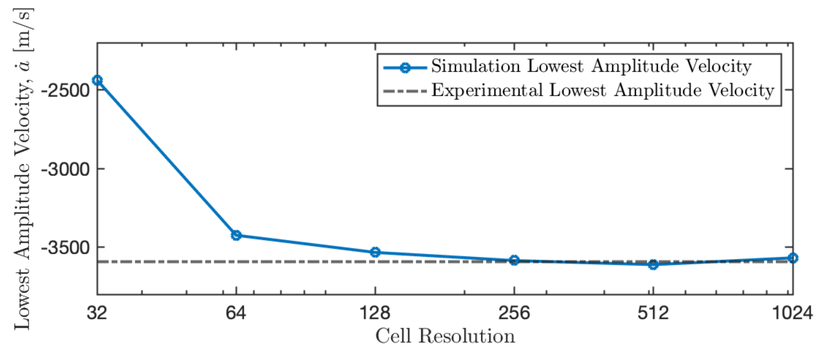
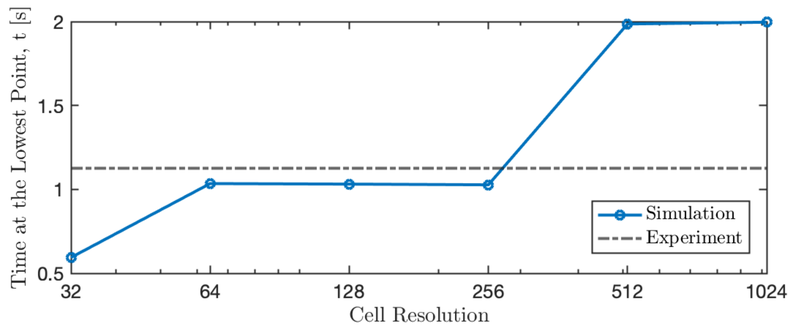


Figure 4. Plot of interface amplitude velocity with respect to time when the shock wave is exerted at a series of Mach number of 1.5 to 5.5.

Results Part 2







Conclusion and Future Work

- The varying Mach number simulations fit well with theoretical data and a clear trend that increasing Mach number would result in shorter time reaching the maximum amplitude velocity.
- The comparison of simulations with various mesh quality to the experiment showed great convergence of the simulation data at 512 cells with AMR level of 0.
- Test with the simulation setup of other AMR levels to find the best convergence point
- Use viscous setup to better study the later section after the response of the shock wave