The Rayleigh-Taylor Instability at a Water/Magnetorheological Fluid Interface

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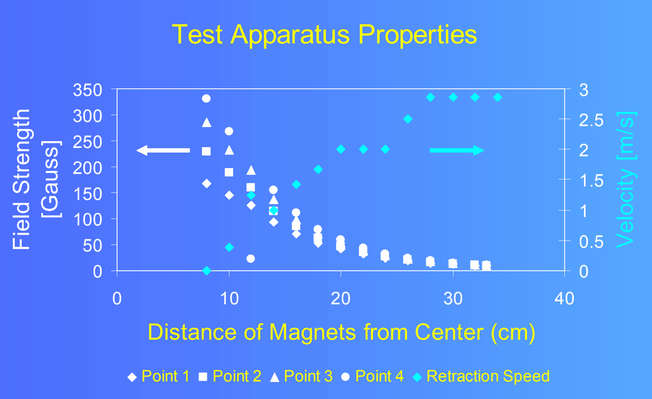
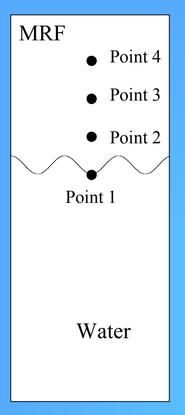
Experimental Procedure

Figure 1: Experiment Setup without Imaging Hardware

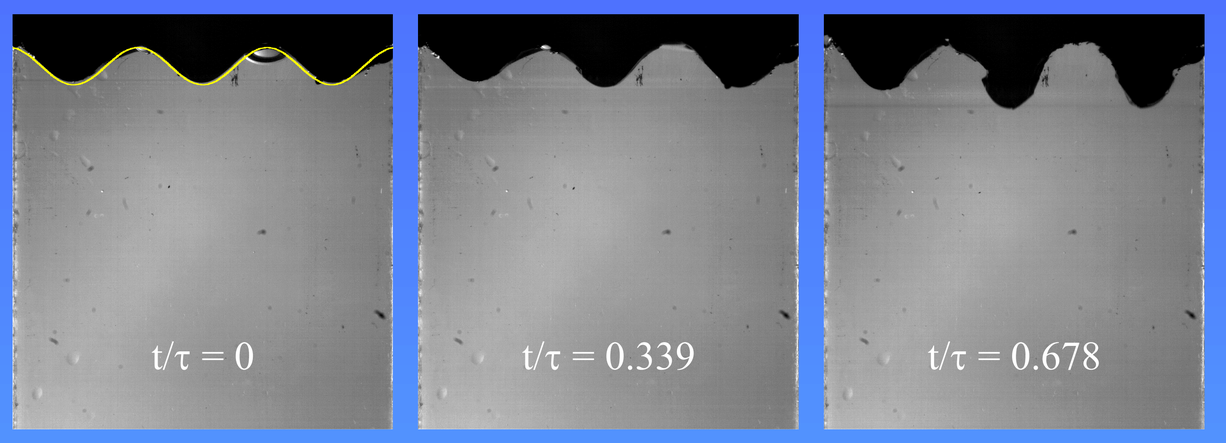
1) Insert shaped plunger in test section and partially fill with water (fig 2); freeze test section
2) Remove shaped plunger; fill test section with MR fluid over ice; attach magnet to MR filled side of test section to prevent settling of iron particles and seal that end.
3) Flip over test section; fill water over ice and seal that end.
4) Flip the test section so that MR fluid is above water; remove magnet from test section and place test section between magnet magazines to keep interface frozen while melting ice (fig 1). Test section submerged in water bath to speed melting and prevent condensation from obstructing view
5) Turn on backlight.
6) Pressurize gas lines for pneumatic pistons.
7) Start acquiring images and activate pistons to initiate magnet bank retraction.

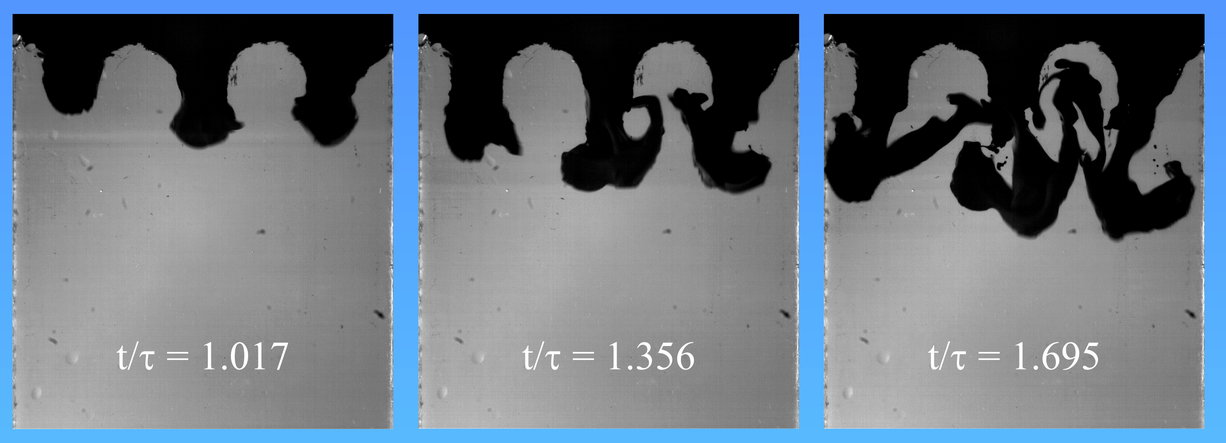
Figure 2: Test Section Before With Plunger Before Freezing





Results





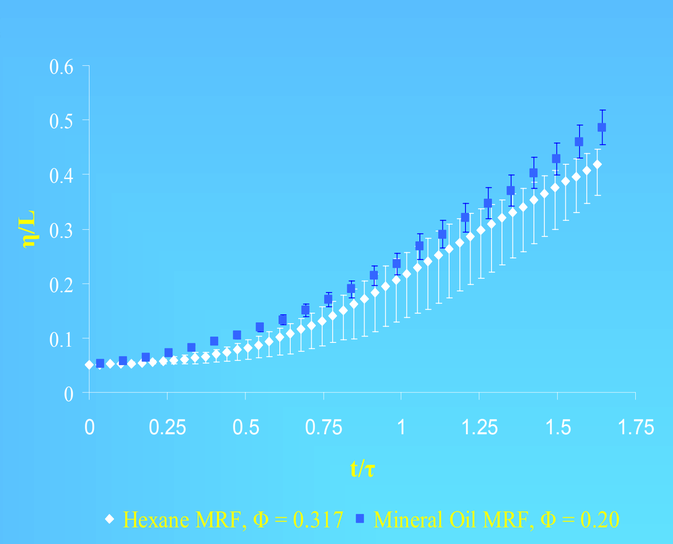


Figure 3: Normalized Amplitudes

The following figures show growth rate data for tests run with each of the three MR fluid mixtures. Figure 3 shows the growth data for several tests in dimensional form, comparing this new hexane based fluid with the previously used mineral oil based fluids. The amplitude is normalized with respect to the width of the interface (L=6.35 cm), while the time is normalized by $\tau = \sqrt{L/Ag}$.

Interface Shape

Single Mode

$$\eta_3 = (0.3175\ cm)\cos\left(\frac{2\pi}{\lambda_3}x\right)$$

$$\lambda_3 = 2.12\ cm$$

Imaging

Resolution: 1024x1024 pixels

Frame Rate: 250 fps

Magnetorheological Fluid

- Mixture contains hexane, oleic acid, carbonyl iron powder
  - Oleic acid stabilizes fluid by preventing agglomeration of iron particles
- Mixture studied contained 31.7 % by volume of iron powder (Φ)
- Ratio of oleic acid to mass of iron arrived chosen by iteratively increasing amount of oleic acid to reduce agglomeration
- **A** represents the Atwood number for MR fluid over water

Table 1: Hexane MR fluid properties

Φ	ρ (kg/m^3)	μ (Pa-s)	A
0.317	2735	Est. ~0.005	0.465

Table 2: Mineral Oil MR fluid properties

Φ	ρ (kg/m^3)	μ (Pa-s)	A
0.15	1782.2	0.0229	0.28206
0.2	2050	0.100	0.34514
0.3	2772.3	0.643	0.47059

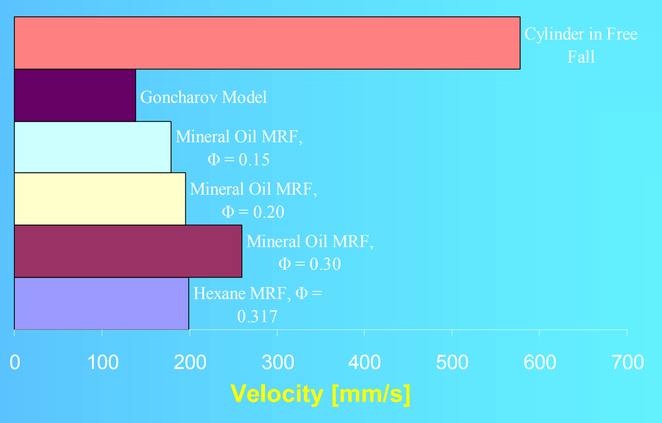


Figure 4: Growth Rates

Growth rates were measured for each fluid case using a curve fit to the amplitude data and taking the derivative for velocity. Figure 4 shows average data for four different MRF's and compares those to a cylinder in free fall and the prediction from the Goncharov model for a 2-D Rayleigh-Taylor spike. The cylinder is modeled as having a diameter one half the wavelength of the interfacial waveform. The Goncharov model does not agree well with experiments due to it's inviscid nature. Better agreements are achieved with lower viscosity fluids as expected.

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